Consideration of ecosystem services in urban resilience in South African cities

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Abstract

In 2011 South Africa published the 3rd State of Cities Report (SoCR) for its nine largest municipalities. This report, titled: ''Towards Resilient Cities, a Reflection on the first decade of a democratic and transformed local government, 2001 – 2011'', sets out to view the various economic, environmental, social and governance issues of the cities from a resilience perspective. The purpose of this paper is to critically examine the use of resilience thinking as an analytical framework for State of Cities Reporting, by using the Resilience Assessment Framework (developed by the international Resilience Alliance for assessing resilience in social-ecological systems) as a measure against which to interrogate the 2011 State of Cities Report (SoCR). For reasons of economy, the focus was on how the SoCR considered resilience in terms of ecosystem services provided to cities, and specifically the ecosystem service of fresh water. The objective of this paper is to critically examine how the resilience of urban ecosystem services was considered in the South African SoCR. It was found that while the 2011 SoCR opened the door to using a resilience approach in discussing the sustainability of cities, it does not really allow the user to gain an understanding of the resilience of the ecosystem services in South Africa's main cities and the reporting methodologies needs to be adapted in future reports. The paper concludes with recommendations for future reports.

Keywords: Urban resilience, urban ecosystem services, State of Cities, South Africa

1. Introduction

According to the UN-HABITAT (2010) in 2009, Africa's total population for the first time exceeded one billion, of which 395 million (or almost 40 per cent) lived in urban areas. Africa should prepare for a total population increase of about 60 per cent between 2010 and 2050, with the urban population tripling to 1.23 billion during this period. ''With a projected 61.7 per cent of its population living in urban areas, Southern Africa remains the most urbanised sub region on the continent'' (UN-HABITAT, 2010, p14). Furthermore, 62% of South Africa's population currently live in urban areas, mostly concentrated in the large metropolitan areas of Cape Town, the Gauteng Urban Region and eThekwini (Population Reference Bureau,

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2011). These statistics paint a picture of great challenges to a global social-ecological system which is already under huge strain.

The State of Cities Report (SoCR) is acknowledged as a global tool to understand these challenges at an urban level and monitor progress towards set development goals, informing policies which allows for improved and more innovative public management and governance (Cities Alliance 2013). Since 2001 several State of the World's Cities Reports have been published by UN HABITAT and most members of the global Cities Alliance have published regular country reports of their own. In 2011 South Africa published the 3rd State of Cities Report (SoCR) for its nine largest municipalities. This report, titled: ''Towards Resilient Cities, a Reflection on the first decade of a democratic and transformed local government, 2001 – 2011'', sets out to view the various economic, environmental, social and governance issues of the cities from a resilience perspective. This is the first time that resilience has been introduced as an analytical framework for State of Cites Reporting. Previous reports have used concepts of productivity, inclusivity, sustainability and governance as an analytical framework.

The purpose of this paper is to critically examine the use of resilience thinking as an analytical framework for State of Cities Reporting, by using the Resilience Assessment Framework developed by the international Resilience Alliance as a measure against which to interrogate the 2011 State of Cities Report (SoCR). For reasons of economy, we will focus on how the SoCR considered resilience in terms of ecosystem services provided to cities, and specifically the ecosystem service of fresh water.

The first half of the paper introduces the theoretical frameworks used to frame the study, namely resilience theory (especially in the context of social-ecological systems) and the Resilience Assessment Framework developed by the Resilience Alliance, as well as the notion of ecosystem services. In the second half of the paper the State of Cities Report and its approach to resilience and ecosystem services is introduced. The paper will then proceed with assessing how three steps of the Resilience Assessment Framework can be used to understand how the SoCR considered resilience in terms of ecosystems services, before concluding with recommendations for future reports.

2. The Resilience Assessment Framework

2.1 What is resilience?

There are a number of definitions and interpretations of resilience (Holling and Gunderson, 2002; Walker and Salt, 2006; Pendall et al. 2010). The Resilience Alliance (2010, p5) describes the resilience of social-ecological systems as: ''Resilience is fundamentally a system property. It refers to the magnitude of change or disturbance that a system can experience without shifting into an alternate state that has different structural and functional properties and supplies different bundles of the ecosystem services that benefit people''. However, it should be noted that the definition of resilience in an urban context is still under contestation, with the definition by the Resilience Alliance (see above) being criticised as

equilibrist and not suitable for cities which are characterised by constant evolutionary change and multiple desirable states (Simmie and Martin, 2010).

The city can be described as a special category of social-ecological system, reflecting an ecosystem which consists of a community of plants and animals and the physical environment of that community (Rowe, 1961). In the city the physical environment would include the built environment and the community of animals would include humans and the individual and collective normative and functional institutions they contribute (Du Plessis 2012). The resilience of a social-ecological system is determined by the presence of certain values and characteristics within both the tangible and intangible components of the city. These include adaptive capacity, (determined by factors such as diversity, modularity, degree of connectedness and tightness of feedback loops); the potential available in the system, whether social capital or system reserves and variability in critical ecosystems services; and an acknowledgement of slow variables (Holling and Gunderson 2002; Walker and Salt 2006, pp145-148).

2.2 The Resilience Alliance Framework for assessment

The Resilience Alliance (2010) proposes an iterative and reflexive process for assessing resilience in social-ecological systems that follows five main stages (described in Figure 1).

The first step is to develop a description of the system including the key components of the system and, in order to focus and direct the assessment, the main issues (or disturbances) that should be considered. (Resilience Alliance 2010, p13) These are identified by asking resilience of what to what, and by investigating the dynamics in the system. This requires that the history of the system be considered to identify changes across multiple scales of time and space and the social and ecological dimensions that interact with the focal system. (Resilience Alliance, 2010, p18). This is followed by **step two** where the Resilience Alliance (2010) further proposes that different thresholds and system states can be identified that create a panarchy of adaptive change cycles that leads to the **third step**. In this step, the interaction between the different systems are assessed through investigating the influence of and the interaction between the larger-scale systems in which the social-ecological systems are entrenched as well as with the smaller scale systems which it consists of (Resilience Alliance 2010, p29). By identifying the present phases of the connected systems, potential vulnerabilities and opportunities in the focal system is revealed (Resilience Alliance 2010, p29). This step therefore assesses how the system variables might be expected to interact. This is valuable information and important for management decisions (Resilience Alliance 2010, p32) This

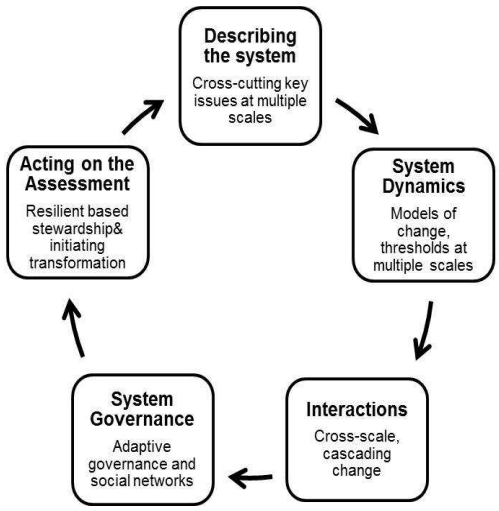

Figure 1: Framework for Assessment (Resilience Alliance, 2010, p5)

leads to the **fourth step**, which deals with evaluation of the governance in terms of its adaptive governance capacity and the strength of the social networks that exists (Resilience Alliance 2010, p41); and then the final step, **step five**, in the Resilience Assessment Framework, is to evaluate how to best act on the assessment through synthesising the assessment findings, identifying the thresholds interactions, the development of stewardship strategies, timing the transformation and finally implementing the resilience assessment. (Resilience Alliance 2010, pp43-50)

According to the Resilience Alliance (2010), the resilience of the urban system is compromised when it's supporting ecosystems services are threatened and degraded as a result of ineffective and inflexible institutions, loss of biodiversity, pollution and a focus on production and increased efficiencies, which in turn leads to a loss of functional and response diversity and redundancy. Ecosystem services are more often than not recognised only after they have been lost. Planning for resilience would include ecosystem services in development strategies and proposals in contrast to purely market driven economies where ecosystem services are ignored. (Walker and Salt, 2006; Resilience Alliance, 2002)

Ecosystem services can be summarised into four groups, as described in UNEP's Millennium Ecosystem Assessment (MEA 2005, p7):

- Provisioning of services: food, water, timber, and fiber, natural medicines, pharmaceuticals, genetic resources and biochemicals;
- Regulating services: climate regulation, air quality regulation, water regulation, erosion regulation, water purification and waste treatment, disease regulation and pest regulation, pollination, natural hazard regulation;
- Cultural services: spiritual and religious values, aesthetic values, ecotourism and recreation; and
- Supporting services: soil formation, photosynthesis, and nutrient cycling.

3. Resilience and ecosystem services in the SoCR

3.1 Resilience as defined in the South African SOCR

Opposed to the approach to urban resilience which implies ''..coping with or ameliorating the effects of the problem and restoring the position that existed beforehand. (SACN 2011, p12), the SoCR supports an approach to resilience which implies "transforming local conditions for the better, based on experimentation, creativity and innovation, therefore using a more dynamic approach of resilience" (SACN 2011, p12). The SoCR defines the concept of resilience as, *"*the capacity of a place to anticipate, respond and adapt successfully to challenging conditions, such as global recession, environmental threats or pressures of population growth*.''* (ibid). The resilience theme in the SoCR recognises that ''change is necessary to avoid being locked into inefficient urban structures, outmoded environmental technologies, obsolete industries, conflicting social patterns and inflexible institutions" (SACN 2011, p12). The SoCR also establishes the link with ecosystems in the context of

resilience and describes the cities' dependence on healthy supporting ecosystems to cope with global crisis such as food crises and riots and natural disasters (SACN 2011, p88). The SoCR also emphasises that the current patterns in which cities conduct their business, have the potential to destroy the very ecosystems on which cities' livelihood depend, unless significant change are made in the way settlements are managed.(SACN 2011, p88). In considering resilience the SoCR looked at four aspects of the city: the economy and the financial state of the city, city governance, social resilience as supported by the built environment, and cities as life supporting systems (including ecosystem services). The SoCR discusses a number of critical concerns which can be considered as press disturbances on the city system. These include economic transformation, social division, natural resource depletion and climate change, and the spatial and institutional structures of South African cities.

3.2 What ecosystem services were included in the SoCR?

The SoCR deals with the natural resources in the city under the topic: 'Cities as Life Supporting Systems''. This is done in three sections, the first deals with 'Improving Resource Productivity'' which include issues of water, electricity and transport fuel, although the latter two is not regarded as ecosystem services as such. The second section addresses ''Enhancing Local Capacity'', which deals with the issues of food supply, sustainable energy and ecosystem goods and services. The ecosystem goods and services covers the valuing of ecosystem services in general, it also refers to biodiversity initiatives in the city, conservation and wetland rehabilitation and forestation. The third and final section, describes 'Closing the Waste Loops'' and include issues on solid waste recycling, waste to energy and water re-use, these are not addressing ecosystem services as such, but rather how city infrastructure is replacing regulating ecosystem services such as water purification and waste management.

It can therefore be concluded that the ecosystem services addressed in the SoCR, include food and freshwater as *provisioning services* for the city; forestation(climate/air quality regulation) and wetlands(water regulation/purification) under *regulating services*; and biodiversity as part of *supporting services*. To discover how resilience was approached in the way the SoCR's considered ecosystem services, this paper will focus on the ecosystem service provided by freshwater.

3.3 What characteristics of resilience did the SoCR consider?

Although the SoCR did not explicitly address the characteristics of resilience, in the discussion on ecosystem services the following characteristics of resilient systems were revealed. Diversity was addressed in terms of biodiversity. Social capital, modularity and tightness of feedback were briefly revealed in illustrating biodiversity initiatives in communities. Emerging policies in support of urban food production initiatives entering the system hints at openness. System reserves were discussed in terms of the expected shortage of freshwater reserves by 2025; ecosystem services were discussed but not ecological variability; and innovation was indirectly addressed as a solution to extend the

freshwater resources by reclaiming waste water through a waste water recycling facility to provide water for industrial use, therefore saving potable water supply

4. Using the Resilience Assessment Framework to describe the State of Cities from an ecosystem services perspective

Although the SoCR aims to use a resilience lens to engage with the state of cities it did not explicitly include a framework for resilience assessment. In this section the process suggested in the Resilience Alliance Workbook (2010) is used to test the usefulness of the current SoCR in assessing resilience with the intention to develop suggestions for how this aspect of the report can be improved. This will be done in three steps, firstly by looking if a focal system/s was identified, followed by considering if system dynamics was considered and thirdly assessing if, and how the cross scale interactions were taken into account.

4.1 STEP 1: Describing the focal system - setting soft boundaries

As suggested by the Resilience Alliance (2010), the first step includes the setting of the system boundaries and defining the focal system. This is done by identifying the main issues; determining the key components off the systems (and asking resilience of what?); identifying the key disturbances, disruptions and uncertainties in the systems (and asking resilient to what?); and lastly, understanding the multiple space and time scale of the system.

There are two issues which emerged in terms of freshwater in the SoCR. They are the adequate supply of freshwater and the quality of freshwater. Based on the SACN (2011, p91), South Africa is a semi-arid country with a shortage of water supply for beneficial water and sanitation services. ‘’Few cities are currently self-sufficient in terms of their water supply...’’(SACN 2011, p91), with a projection that by 2025 the supply of water in 58% of South Africa’s water management areas will be outweighed by demand (SACN 2011, p92). The SoCR also briefly highlighted issues on water quality, as the quality of ecosystems and water bodies are affected by the polluted water coming from ineffective waste water treatment works and acid mine drainage. The following drivers of the focal system in terms of fresh water were identified: badly maintained water supply systems and unsustainable consumer consumption patterns and ineffective functioning of water purification plants.

Resilience assessment requires also that a time frame of relevance to the issues be determined. Although the SoCR speaks of the progress of the last 10 years, the data generally only covers a five year historical period, while future projections of fresh water availability is limited to 13 years.

The SoCR did not explicitly highlight what aspects of this ecosystem service the city requires to be resilient. However, these aspects can be inferred as healthy freshwater systems (ecological components) and supply of clean freshwater systems (social components). These two interdependent systems (the natural freshwater systems and the technical infrastructure to supply and purify water) can be seen as focal systems of the SoCR.

The following disturbances affecting freshwater supply could be identified from the SoCR: unpredictable weather patterns (droughts and floods), unsustainable per person water consumption, wastage of water due to poorly maintained water supply systems and the uncertainty of city level data on resource stocks and flows which cities require in order to be accountable for their resource.

The SoCR has not addressed any historical disturbances or their effects on the focal systems. Except for the demand of freshwater, which poses a potential future uncertainty in terms of the shortage of water supply, there is also no interpretation of the current disturbances presenting a concern. Neither ‘“pulse” disturbances that occur as singular events’’, or ‘“press” disturbances that occur continually’’ and over a longer period of time, were considered in the discussions of the two focal systems. (Resilience Alliance 2010, p16) The SoCR does list management strategies relating to minimising the effect of disturbances of freshwater. These include Water Conservation and Demand Side Management (WC/WDM) strategies and projects to ensure improved water resource management. The SoCR also suggests the improvement of government resource management through innovative strategies that encourage more efficient use of resources and minimise waste and input cost (SACN 2011, p91). A further uncertainty highlighted is the undervaluing or in cases ignoring the economic value of the benefits and potential contributions to disaster mitigation and management provided by features of the freshwater ecosystem such as wetlands (SACN, 2011, p107).

As suggested by the concept of the panarchy, the focal system is part of a hierarchy of nested systems that function at multiple space and time scales (Resilience Alliance 2010, p18). Although some issues originating in larger or smaller scale systems that pressurise the focal systems can be identified in the SoCR, there has been no attempt to structure these in a more comprehensive understanding of the interactions between these two focal systems or their larger or smaller scale manifestations as these relate to the city. Neither of these focal systems was considered against a historical timeline that included social and ecological dimensions of these systems at larger and smaller scales.

4.2 STEP 2: System dynamics

As suggested in the Resilience Alliance Workbook (2010), the next step is to investigate the dynamics in the system. This requires that the history of the system be considered to identify changes across multiple scales of time and space and the social and ecological dimensions that interact with the focal system. From this, different thresholds and system states can be identified that create a panarchy of adaptive change cycles that leads to the third step.

Although this is not highlighted by the SoCR, it can be assumed that the freshwater system in the SoCR can be described as moving from a rapid growth phase into a conservation phase. The SoCR did not explicitly draw on the context of the adaptive cycle or identified the phases of the adaptive cycle through which the system has moved over time. As there was no historical timeline done in the SoCR, it is difficult to infer the key variables that would allow the tracking of changes over the history of the system. Locating the key variables over

time can provide knowledge regarding the timing and nature of the changes in the system (Resilience Alliance, 2010, p24). The SoCR did not describe its ecosystem services in terms of the alternate states or historical state(s) of the systems, as seen in the phases of the adaptive cycle. It furthermore did not describe the transition phases between alternate states of the system and the key variables that determine a transition between alternate states (Resilience Alliance, 2010, p24). Except for the freshwater system where a future prediction of a clear tipping point and transition is predicted by 2025, the SoCR did not identify any possible thresholds or tipping points.

4.3 STEP 3: Cross scale interactions

As suggested by the Resilience Alliance (2010, p29), the third and final step addressed in this paper will assess the cross scale interaction found in the panarchy of the system, as well as the interacting thresholds and cascading of change. This will lead to a discussion of the general and specific resilience of the system.

The SoCR does not address the desirable and undesirable influences from larger-scale systems or describe any system vulnerabilities at the focal scale identified by considering cross-scale interactions. It also did not "characterize the balance (or tradeoffs) between flexibility and efficiency in the focal system", as suggested by the Resilience Alliance (2010, p31).The SoCR also did not list "the main thresholds associated with key slow variables", nor did it indicate any effects arising through the interactions which includes factors that influence the crossing of one threshold to another either by increasing or decreasing the effect (Resilience Alliance, 2010, p34).

The Resilience Alliance (2010, p35) considers the elements of general resilience to include diversity, openness, tightness of feedback, system reserves and modularity. When these concepts are applied to the discussion of the freshwater ecosystem services by the SoCR it can be seen that the following elements of general resilience were considered in the SoCR in terms of fresh water supply and quality. The element of system reserves was highlighted in terms of the freshwater supply, which is depreciating as demand grows. The element of diversity was also indirectly addressed in discussing the expansion of the city's water resources through reclaiming waste water, which requires innovation and openness in the system.

5. Findings

The SoCR supported a transformative resilience approach. This places emphasis on change and renewal, and considers the building of adaptive capacity and potential in the system, enabling the system to adapt to the challenging conditions of global pressures, environmental threats and the dynamics of population growth, which cities need to deal with (SACN 2011, p12).

The discussion of the freshwater system does not reveal sufficient information to obtain a view on the resilience and the actual vulnerability of the current system. This is due to the

fact that it fails to acknowledge the slow variables associated with critical thresholds. The SoCR does not reveal a historical profile of the focal systems (freshwater systems in this case), depicting what where the ‘’driving forces that contributed to or triggered major change’’ (Resilience Alliance, 2010, p21). By extracting the information of the various driving forces through time and understanding the patterns of past disturbances which shaped the current system, this knowledge increases the capacity of managing these effects better in the future, therefore increasing the resilience of the system (Resilience Alliance, 2010, p18).

Fresh water systems also need to be considered in a wider context to include their interdependence with the other systems to which they are connected. The issue of freshwater stretches far beyond the supply of water to the city, it also needs to be considered as part of a bigger ecosystem which spans regional, national and even international boundaries. As Folke et al suggest (2002, p10) ‘’freshwater is required to sustain the capacity of, for example, forests, wetlands, agricultural land, and savannahs to uphold the flow of ecosystem goods and services to humans.’’ Future reports need to recognise that the resilience of the ecosystem service provided by freshwater cannot just be determined by considering the quantity of water. It is also necessary to acknowledge the human related challenges such as industrial pollution, untreated effluent, use of fertilisers, unmanaged water-thirsty alien vegetation and development in floodplains, which decreases the functioning of the freshwater systems and increases its vulnerability.

It would be valuable for future reports to include a more detailed investigation into the resilience aspects of a system, to pinpoint the real problems which could then be addressed to enhance resilience. Future reports should:

1. Clearly identify focal systems and the focal scale that serves as point of departure. This will allow the construction of a panarchy model for each focal system that will illustrate the systemic interactions between higher/larger scales of the system (e.g. national or regional water systems), the focal scale of the system (e.g. a watershed) and the lower/smaller scales of the system (e.g. wetlands) that are usually the subject of illustrative case studies.

2. Develop a systems perspective that can improve understanding regarding the interactions between different systems and the changes/disturbances that result from these interactions (e.g. the industrial system and its resultant demands for freshwater and pollution of water sources). To do this it is necessary to identify the key variables that describe the system, the potential thresholds in these variables that separate one system regime/ state from another and the pressures on these variables as a result of disturbances introduced by other systems.

3. Describe the changes in the focal systems along timeframes that can adequately capture change at larger system scales. This will necessitate the development of historical timelines that span at least 50 to 100 years in the case of ecosystem services.

4. Use the above information to establish the adaptive cycle phases exhibited by the focal system and its current position in this cycle. By monitoring this in successive State of City Reports, city managers will be able to identify possible threats and opportunities in the system that are opened up by the specific phase of the adaptive cycle the system is experiencing.

5. Gather and organise data on changes in the system that will allow the identification of attributes of resilience such as diversity, adaptive capacity and connectedness, exhibited by the system being studied.

6. Conclusions

The objective of this paper was to critically examine the use of resilience thinking as an analytical framework for State of Cities Reporting, as expressed in the 2011 South African State of Cities Report, with specific reference to the resilience of urban ecosystem services. This was done using a comparison with the Assessment Framework suggested in the Resilience Alliance Assessment Workbook. It was found that the resilience of ecosystem services was not adequately addressed in the SoCR. This can be remedied in future reports by incorporating wider and more integrated historical information of the various systems and the changes in the systems over time, including information on the drivers of those changes. There is also no discussion around critical aspects of resilience such as cross-scale interactions, thresholds and methods for monitoring these thresholds. Future reports could address fewer ecosystem services but those that are addressed should be assessed in more detail to determine their adaptive capacity and to reveal the thresholds of change, in order to enable improved management of these systems. Overall, while the 2011 SoCR opened the door to using a resilience approach in discussing the sustainability of cities, it does not really allow the user to gain an understanding of the resilience of the ecosystem services in South Africa's main cities.

7. Acknowledgements

The authors are grateful to the National Research Foundation (NRF) who supported the production of this essay through NRF Grant no 78649.

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Critical Factors for Successful Housing Reconstruction Projects Following a Major Disaster

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Abstract

Post–disaster reconstruction projects are often considered ineffectual or unproductive because on many occasions in the past they have performed extremely poorly during post-contract occupation, or have failed altogether to deliver acceptable outcomes. In some cases, these projects have already failed even before their completion, leading many sponsor aid organisations to hold these projects up as examples of how not to deliver housing reconstruction. Research into some previous unsuccessful projects has revealed that often the lack of adequate knowledge regarding the context and complexity involved in the implementation of these projects is generally responsible for their failure. Post-disaster reconstruction projects are certainly very complex in nature, often very context-specific and they can vary widely in magnitude. Despite such complexity, reconstruction projects can still have a high likelihood of success if adequate consideration is given to the importance of factors which are known to positively influence reconstruction efforts. Good outcomes can be achieved when planners and practitioners ensure best practices are embedded in the design of reconstruction projects at the time reconstruction projects they are first instigated. This paper outlines and discusses factors that significantly contribute to the successful delivery of post-disaster housing reconstruction projects.

Keywords: Post-disaster housing reconstruction, success factors, project outcomes

1. Introduction

The reconstruction of domestic dwellings in large quantities after a significant disaster presents many challenges and is a daunting task (Blanco et al. 2009). Reconstruction projects are constantly threatened by such challenges right from their initiation through to their closure. Even though post-disaster reconstruction management and planning as a whole still remain quite under-researched, sporadic attempts have been made by both professional bodies and academic researchers to determine the most common factors contributing to the poor performance and reasons for failure of some of the least successful projects. For examples, Pyles (2007) in her study of "Community Organizing for Social Development" argues that poor consideration of community organising is a challenge for

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social development of affected communities after a disaster. Williams (2006) undertook a study of community participation in post-apartheid South Africa and revealed that the lack of existence of any community organisations was the main impediment to effective community participation in reconstruction. Hayles (2010) explored some of the main challenges for non-government organisations (NGOs) involved in post-disaster reconstruction. In another instance, Fayazi (2011) compared the outcome of two different methods used in the reconstruction of permanent houses after the Manjil earthquake in 1990. The author (ibid. 2011) identified that the absence of an appropriate reconstruction program, neglect of the main principles of traditional architecture and failure to consider environmental effects on buildings were some of the main problems encountered during the rebuilding of permanent houses. This paper, which forms part of a larger ongoing PhD research project, examines briefly the nature of post-disaster housing reconstruction projects and underlines some of the important factors that determine the outcomes of such projects. A comprehensive review of the extant literature was conducted to explore desirable practices in reconstruction projects that have already been successfully implemented. Case studies of past projects from around the world are examined and factors which positively support and influence post-disaster reconstruction outcomes are identified. QSR International's NVivo 9 qualitative data analysis software was used to organise and analyse the information.

2. Post-disaster housing reconstruction projects – success factors

2.1 Community participation

Although those people and communities directly affected by a disaster are the first to engage with the emergency, they are often perceived as being mere victims rather than the potential critical driving force behind reconstruction (Jha et al. 2010; Pius Mulwanda 1992). Local communities and the survivors of disasters play a crucial role in post-disaster reconstruction and their participation ultimately determines project success (Lawther 2009; Lyons 2009; IFRC and ICRC1994; Lemanski 2008). Post-disaster reconstruction is a complex and highly demanding process that involves a number of different and well coordinated courses of action. Therefore, it is vital that these complex activities are well planned (Roseberry 2008) and subject to thorough consultation, and effective collaboration with a wide range of community members (John 2008; Pius Mulwanda 1992). Since community members have the most knowledge about their own communities and specific building requirements, often possessing a good technical knowledge of appropriate building techniques, it is critical to involve them when conducting community needs assessments and planning reconstruction projects (Lawther 2009). Communities must also be encouraged and supported to use their own reconstruction techniques when rebuilding their houses (Pomeroy et al. 2006; Jha et al. 2010; Gaillard and Texier 2010; Kaklauskas, Amaratunga and Haigh 2009; Geis 2000; Ganapati and Ganapati 2009).

Communities play a vital role in rescuing human lives during the immediate post-disaster emergency and humanitarian relief phases (Shaw 2006; Dikmen 2005) and in planning and developing the subsequent medium recovery and long-term reconstruction. One study of community participation in the aftermath of the 2004 Indian Ocean tsunami revealed the significant role that the Aceh-Indonesia community played in disseminating information about

the scale and effect of the disaster to relief agencies, when many government units did not function and could not provide this critical information. The information provided by local communities in Aceh-Indonesia, expedited relief efforts and established the way forward for planning of post-disaster reconstruction (Steinberg 2007). Affected communities in Aceh-Indonesia also played a key role in establishing the identities of those individuals and families affected by the Tsunami, and their eligibility for assistance (Da Silva and Batchelor 2010). An analysis of the factors contributing to success, failures and processes of two housing reconstruction policies adopted in the aftermath of the 2004 Indian Ocean Tsunami concluded that owner-driven programmes in Sri Lanka had higher success rates than donor-assisted programmes. While the number of dwellings produced by owner-driven programmes reached 48,981 (73% of all houses) by December 2006 (two years after the tsunami), the number of houses produced through donor-assisted programmes remained at only 12,207 (19% of all houses) (Lyons 2009).

Thus, it is clear that community participation is important at all stages of post-disaster reconstruction, and since a community is composed of different groups of people, suitable methods to include these groups proactively in the process of reconstruction need to be devised (Lloyd-Jones 2006). Attention must be paid to ensure that disadvantaged members of the affected communities, such as vulnerable women, children, the elderly and persons with disabilities (El-Masri and Tipple 2002; Pyles 2007; Lankatilleke 2010; Leon et al. 2009; Lloyd-Jones 2006) are properly included in the reconstruction process, and that the design of post-disaster reconstruction projects responds to their fundamental requirements (Barakat 2003; Snider and Takeda 2008; Krishnadas 2007). Effective participation must begin with, and be promoted by, effective community empowerment (El-Masri and Tipple 2002).

2.2 Community empowerment

Empowering communities to participate in reconstruction can provide an opportunity for community members to contribute their knowledge and skills to the process that will in turn most deeply affect their future lives. Empowerment is made possible when affected communities are effectively involved in all stages of the post-disaster reconstruction (Jha et al. 2010). Davidson (2010) highlights the existing complex relationships between the multiple stakeholders and the significance of this in post-disaster reconstruction and argues that the selection of procurement strategies must best suit the requirements of the reconstruction programme. In the context of post-disaster reconstruction and disaster management, empowering local communities should not be perceived as merely a technical capacity-building exercise. Rather, it should be seriously accepted as a holistic approach towards utilising local knowledge and involving affected communities and local institutions in the process of reconstruction (Allen 2006).

Community empowerment in a post-disaster project must include improving community access to information and services, and thus enabling community participation in decision-making (Maier 2001; Bosher and Dainty 2011; Maginn 2007) and increasing control over the procurement and consumption of local and natural resources (Pomeroy et al. 2006; Alireza 2008). Building local capacity is vital for effective participation during reconstruction as well as for producing a more sustainable built environment (Pyles 2007; Allen 2006; Pomeroy et

al. 2006; Hayles 2010). After the 2006 Jogjakarta earthquake in Indonesia, a cash grant for construction materials and a skills exchange reconstruction project facilitated the building of 12,250 shelters in 10 months; and in Kenya after the 2008 election violence, the affected community was successful in building 255 transitional shelters. The Kenyan pilot shelter project was successful mainly because the community received technical training and also construction materials prior to project implementation (Leon et al. 2009). Case studies relating to the transitional settlement and shelter processes in Afghanistan, Democratic Republic of Congo, Eritrea, Honduras, India, Indonesia, Kenya, Liberia, Mozambique, Pakistan, Peru, Russia, Rwanda, Somalia, Sri Lanka and Sudan, which were compiled and analysed by these authors (ibid. 2009), revealed that empowerment enabled affected communities to participate more productively in a transitional settlement and building of sustainable houses. The work and involvement of Denise Thornton, a resident of New Orleans, provides a prominent example of community participation in reconstruction. In the aftermath of Hurricane Katrina in 2005, Thornton's dedication and motivation to rebuild her destroyed house inspired the entire community to return to their devastated homes and demonstrated to them that rebuilding was indeed possible (Maret and Amdal 2010). As part of the integrated approach to successful post-disaster reconstruction management, community participation and empowerment require a strong line of communication and information dissemination (Lawther 2009).

2.3 Communication and information dissemination

In post-disaster situations, it is imperative to establish a strong and reliable line of communication and an information dissemination system. People's awareness of the existing opportunities for participation and their relevant importance for immediate recovery and long term housing reconstruction is crucial (Lawther 2009; Galtung and Tisné 2009). In May 2000, Roombeek, a city of Enshede in the Netherlands, was destroyed by the explosion of fireworks stock being stored in a warehouse (Denters and Klok 2010). A case study of the post-disaster reconstruction conducted by these authors (ibid. 2010) revealed that in the aftermath of the explosion, the established information rules had been successful in stimulating wider public participation in rebuilding Roombeek. These rules ensured that the rebuilding process was transparent and that residents were well informed of the participatory process and the available opportunities for participation. Chang et al. (2011), based on their investigation of reconstruction resourcing after the 2008 Wenchuan earthquake in China, concluded that post-disaster environments are complex and dynamic, necessitating a great degree of resources coordination and communication among stakeholders. These authors suggest that well established and successful resource coordination requires systematic data collection, information systems, and communication and coordination mechanisms. In relation to the significance of communication and information dissemination in post-disaster reconstruction, El-Masri and Tipple (2002) argue that local authorities should promote dissemination of knowledge about the cultural and social condition of the affected communities amongst stakeholders.

2.4 Community culture and beliefs

An understanding of the community involved in reconstruction is of the utmost importance in establishing a constraint for delivering successful projects and managing community participation (Allen 2006). Housing design must meet both the socio-economic and cultural requirements of the affected communities and should also allow for future expansion of such accommodation based on people's changing needs (Diacon 1997; El-Masri and Tipple 2002). The role of religious groups can be vital in mobilising and persuading affected communities to return to the affected area and actively participate in rebuilding their houses (Denhart 2009). As a direct result of Hurricane Katrina, 1,300 people died and 1,000,000 were evacuated (Colten, Kates and Laska 2008). In order to rebuild New Orleans, the affected communities had to make the difficult decision to return to the devastated area, which largely depended on whether their displaced neighbours also returned. In this uncertain and difficult time, members of the Mary Queen of Vietnam (MQVN) Catholic Church in New Orleans East played a key role in organising and mobilising a wider displaced population through working with its lay leadership, facilitating a great level of social coordination and providing emergency assistance to returnees (Chamlee-Wright and Storr 2009). Alexander (2004) suggests that giving consideration to the affected communities' emotional and economic attachment to their home areas increases the chances of success as compared to adopting a more radical solution that has a propensity to remove past attachments. El-Masri and Kellett (2001) in their study of post-war reconstruction in the village of al Burjain in Lebanon, highlighted that even though the displaced members of the affected community had total control over the reconstruction of their new houses in the host village, most of them expressed strong positive attachment towards their original villages and dwellings and had a strong desire to return. The authors (ibid 2001) concluded that it is imperative to consider both the socio-economic and cultural aspects when planning reconstruction.

2.5 Support from local government

Following large scale disasters, the rebuilding of houses requires a more contributive community capacity that may not be immediately available locally. So, the affected members may not be able to reconstruct their houses without substantial external support (Alam 2010). Local government plays a vital role in establishing budget priorities and is able to establish effective lines of information dissemination that can help other stakeholders make more informed and logical decisions (Olshansky et al. 2008). Therefore, incorporating the initiatives from local governments in disaster management is another important contributor to effective post-disaster response (Ye and Okada 2002). As mentioned previously, communities often possess great intellectual and physical resources; however, these resources may be obliterated by the existing event. While a community may still be able to transform itself without external aid, effective interaction with governments and non-governmental organisations through a well defined framework can substantially expedite the reconstruction process (Gauthamadas, Negi and Shyamprasad 2005). In the aftermath of the May 2000 fireworks store explosion, the role of the Roombeek-Netherlands local government in providing opportunities for participation in rebuilding the city was critical (Denters and Klok 2010). During the Indian Ocean Tsunami in 2004, the water that severely

devastated Tamil Nadu (India) penetrated almost 1.5 kms inland. An estimated 984,564 people were affected and 126,182 houses damaged or completely wiped out. In an effort to bring life back to normality, a massive reconstruction effort had to be undertaken. To effectively coordinate and strengthen the recovery mechanism, the state government selected personnel from different departments across the state. These personnel were placed at different managerial levels and were delegated considerable decision making and financial authorities. This level of administrative authority and the lack of political and bureaucratic influence over the recovery process led to a more effective response compared to other states and even countries (Srinivasan and Nagaraj 2006). Whilst it is true that local community participation is possible even without the commitment from local governments or non governmental agencies, often more successful participation is assured by such commitment from, and effective cooperation of, the external agencies (Lawther 2009). The role of local government is crucial in enhancing the resultant human settlements and developing resilient communities. Local authorities are responsible for the implementation of development projects and application of central government policies (El-Masri and Tipple 2002). Pyles (2007) advocates that community based reconstruction efforts must involve participation from the most vulnerable members in order to further strengthen the capacity of local community and government.

3. Conclusion

The extant literature suggests that an absolute knowledge of the complexity of reconstruction, a detailed understanding of the factors contributing to failure, as well as those supporting reconstruction, are crucial for rebuilding domestic dwellings successfully after a major disaster. This paper touches upon five common factors that are believed to impact positively on the outcomes of post-disaster housing reconstruction projects. The findings reveal that reconstruction projects can be delivered satisfactorily when among others, factors such as community participation and community empowerment, effective communication among the stakeholders (in particular with members of the affected communities), community cultures and beliefs and support from the local government, are considered. Community participation that ensures the inclusion of beneficiaries from all sectors of the affected community and at all stages of post-disaster reconstruction is important and should be enhanced by effective community empowerment. Successful post-disaster reconstruction projects require a strong and reliable line of communication and an information dissemination system, which can be established with the support of the local government. Housing designs that are considerate of the socio-cultural and economic requirements of the affected communities are more acceptable and therefore stand a better chance of success. The uniqueness of post-disaster reconstruction projects and their contextual requirements mean that the sponsors and practitioners involved in these projects must adapt their practices to respond to the complexity inherent in these projects and so achieve more desirable outcomes.

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Improving Self-Help Housing in Texas Colonias Using Spatial Agents and Building Information Modeling (BIM)

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Abstract

By equipping field agents with knowledge of spatial design and advanced information technology, it may be possible to improve the affordability and sustainability of self-help housing in informal settlements. This paper presents a research design to investigate this proposition through qualitative research methods, model-based reasoning and a quasi-experiment. Informal settlements are comprised of low-cost self-built houses with deficiencies such as: substandard construction, higher energy costs per unit area due to poor construction methods, and inattention to best practices for sustainable community development due to low knowledge of residents. The introduction of increased knowledge of sustainable design practices may enable residents to make better decisions with respect to sustainability when undertaking self-help construction projects. The concept for delivering information about sustainability to residents is to equip 'spatial agents' with advanced information technology for architectural design. Spatial agency refers to providing professional services including design ideas and knowledge to people who do not have access to them. The agents can be facilitated by equipping them with Building Information Modelling (BIM) tools that aid designers in providing high performance design, visualization and analysis capabilities.

This study is a part of an on-going Ph.D dissertation. This paper proposes a mixed method research to devise a new model for aiding the residents to achieve greater sustainability in self-help housing through a test case of an informal settlement near Laredo, Texas, US, known as "*colonias*". We propose three steps: (1) collect information through interviews on two topics: best practices for sustainable home design and construction, and existing patterns of home design and construction, (2) incorporate the rules and patterns for home design revealed from the first step into BIM software to produce a tool kit for designing sustainable homes and additions, and (3) test the software using a quasi-experiment for spatial agents. The expectation is that the new model using trained spatial agents assisted with a BIM toolkit can produce home designs that are more affordable, more sustainable, and more quickly.

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Keywords: Colonias, self-help housing, spatial agents, Building Information Modelling (BIM), sustainable and affordable housing

1. Introduction

The aim of this paper is to explore a strategy to improve affordability and sustainability of self-help housing in informal settlements by fusing the concepts of spatial agency and Building Information Model (BIM). Spatial agents can assist residents in sustainable design and construction with advanced technology which may results in energy efficient and cost effective houses in informal settlements. Thus, the quality of housing and quality of life may be improved.

Informal settlements serve to provide shelter to low- and very-low income people who cannot afford to live in a formal house. These settlements are one of the major challenges for most cities owing to their lack of access to basic services and their unpredictable growth (UN-Habitat 2008). Global growth of population in informal settlements has an increasing impact on consumption of resources. Therefore, achieving sustainability and energy efficiency in these settlements is becoming an acute challenge.

This study focuses on informal settlement development north of the United States (U.S.)/Mexico border called ‘colonias’. The common practice in the colonias is self-help housing in which residents construct their houses incrementally with help of family members and friends to accommodate their changing needs and based on availability of money. Houses in colonias often have deficiencies such as substandard construction (Ward, Olmedo, et al. 2010), higher energy cost (Gharaibeh et al. 2009), and lack of sustainable community development due to low knowledge and awareness on the part of the residents (Rohe et al. 2002). The introduction of increased knowledge of sustainable design practices may enable residents to make better decisions with respect to sustainability when undertaking self-help construction projects.

We envisioned a new process of delivering design and construction knowledge on sustainable and cost-effective self-help housing in colonias from experts to residents. This process includes agency in architecture via spatial agents, assisted BIM tool. Spatial agency refers to providing/bringing professional services including design ideas and knowledge to people and communities who do not have access to them. The notions of agency and advocacy in architecture apply the concept to provide underserved populations with architectural knowledge. The spatial agents can be facilitated by equipping them with BIM tools that aid designers in providing high performance design, visualization and analysis capabilities.

This paper is structured in three sections: (1) background information on informal settlements and colonias in U.S., (2) conceptual framework of this study: Spatial agency and BIM, and (3) assisting residents with advanced technology.

2. Background

This section serves to define the universe of informal settlements and to identify where colonias fit in this framework.

2.1 Informal Settlements: A Global Challenge

Informal settlements are unplanned residential areas in which houses are built by people who are unable to pay for legal houses. Unauthorized occupation of land usually with no land use and building regulations initiates the informal settlement formation process. These houses are mostly constructed without building codes and regulations. UN-Habitat (2003) defines informal settlements as the areas comprised of houses with one or two of the following universal features: (1) inadequate access to basic services such as clean water and sanitation, (2) substandard housing or illegal and inadequate building structure, (3) overcrowding and high density settlements, (4) unhealthy living conditions and locating hazardous locations, (5) insecure residents, (6) irregularly developed settlements, (7) poverty and social exclusion, and (8) minimum settlement size. Therefore, not only do they often provide deplorable living conditions with inadequate living space and poor access to basic facilities and services, but growth is unpredictable and often at a rate that overwhelms resources (UN-Habitat 2003).

2.2 Type of Informal Settlements

Informal settlements are found not only in developing countries but also in developed ones: Brazil, South Africa, Turkey, China, India, Nigeria, Pakistan, Bangladesh, Indonesia, Iran, Philippines, Mexico, South Korea, Peru, USA, Egypt, Argentina, Tanzania, Ethiopia, Sudan, and Vietnam (UN-Habitat 2003). No matter social, economic and political dynamics of the nations, 'pirate urbanism' and 'traditional squatting' are the two formation processes observed all over the world (Davis 2006). 'Pirate urbanism' refers to the abandoned inner city residential structures accommodated by low income families such as; *inquilinatos* in Buenos Aires, *chawls* in Mumbai, and *Callejones* in Lima. On the other hand, the second type, 'traditional squatting' includes a self-help process of construction by invasion of land illegally. This process often ends up with a formation of widespread communities such as *barrios, tugurios*, *favelas, bidonvilles, gecekondus, kampongs, and* ***colonias. Colonias*** is the focus of this study.

2.3 Colonias: An example of informal settlements in U.S.

Colonias are examples of informal settlements development north of the U.S.-Mexico border in the states of Texas (1,800 *colonias*), New Mexico (142 *colonias*), Arizona (86 *colonias*), and California (15 *colonias*) (HUD 2003). *Colonias* share many of the same features of the informal settlements in other parts of the world such as: (1) being developed on mostly unincorporated towns and cities, (2) being built by using improper materials and construction methods, (3) with inadequate regulation, (4) with lack of access to services such as running water, sewage system, public safety, and a proper electricity installation, (5) with attached water tanks on many units, (6) being composed of mixture of trailer and self-built houses and

(7) inattention on the part of economy and political authority (Ward 1999). However, the major differences are (1) being mostly constructed on legal lands, and (2) being multiple housing located on larger lots which leads to lower density than the other informal settlements (Arizmendi et al. 2010).

When considering colonias in U.S. context, the characteristics of colonia residents differ from the rest of U.S. in terms of (a) having mostly Hispanic population, (b) having larger family size than the average in U.S., and (c) having median household income$14,458 less than the U.S. average (Martinez 2010) (Table 1). In terms of population, 7 million people live in the 24 border counties with a 67.1% of Hispanic population. Texas and California have higher population than Arizona and New Mexico; Texas has the highest Hispanic population ratio. On the other hand, Texas and New Mexico house the counties that have lower median household income. In terms of poverty, the highest percentage belongs to Texas (24%). However, it is mostly observed in border counties (Martinez 2010).

Table 1: Socio-Economic Conditions in U.S.-Mexico Border States (Adopted from Martinez 2010)

State	# counties (having colonias)	Total Population (2007)	% Hispanic Population (2006)	Median Household Income (2004)	% Population in poverty (2004)	Percent Annual Unemployment Rate (2007)
Arizona	4	1,328,357	50.2	35,601	17.6	7.2
California	2	3,136,726	52.9	42,807	14.7	10.5
New Mexico	3	230,732	60.6	25,777	22.8	5.3
Texas*	15	2,269,778	74.9	27,446*	24.0	6.0
TOTAL/AVE	24	6,965,593	67.1	29,876	22.0	6.5
USA		301,621,157	14.8	44,334	12.7	4.6

The economic patterns on the north of U.S.-Mexico border has transformed from a basic agriculture related production system to a more diversified commercial, industrial and service related system providing low-cost labour (Martinez 2010). Today, counties on the border region offer low-paying jobs, usually temporary, in agriculture, construction, and manufacturing.

Poverty causes most colonia developments. In Texas, residents with wages from $12 to $14 can afford at most a $60,000 to $70,000 house constructed by homebuilders (TDCHA 2011). However, considering the additional land acquisition and development costs, it is difficult to build low price homes. Since Colonia residents mostly work seasonal and low-wage jobs, lending/financial institutions do not regard them as credit worthy. Therefore, they do not have access to credit or financing methods (Giusti and Estevez 2011). They tend to purchase small lots and build their houses incrementally with help of family members and friends to accommodate their changing needs and based on availability of money (Giusti and Estevez 2011). This situation causes Contract for Deed arrangements which mean that lots and dwellings are sold to residents through non formal financial arrangements and the title is transformed to the purchaser after he/she finishes all the payments. Considering the income

level of residents in Texas Border counties, colonia type housing is the only feasible way of home ownership (Ward et al. 2011).

Houses in the colonias often have substandard construction that does not meet building standards for safety (Ward, Olmedo, et al. 2010). The major house types in colonias on the U.S./Mexico border are (a) classic self-help border houses with additions added over an extended period of time, (b) manufactured homes (single or double wide trailers), and (c) modular housing structures (Sullivan and Ward 2012). Although there are only three types of houses, they demonstrate a great variety in terms of form, materials and construction. They vary from $500 dilapidated trailers, to half constructed houses, to middle class houses that are seen in urban areas (Coronado 2003). This variety is based on incremental self-building process according to individual needs and availability of their money (Figure 1).

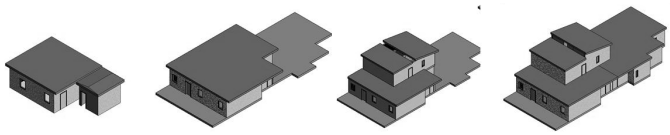
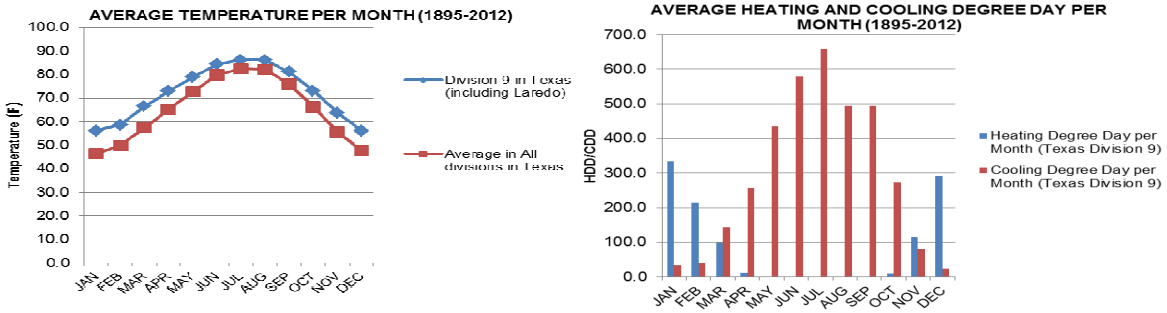


Figure 1: An example of an Incremental Growth/Improvements of colonia self-help house (Adopted from Reimers, 2009, modelled in BIM by author)

As colonias have a growing population, there is an increasing demand for cost-effective housing. Due to poor construction methods and inadequate access to infrastructure systems, the colonia residents pay higher energy costs per unit area (Gharaibeh et al. 2009). Electricity, natural gas, and bottled, tank or liquid propane or butane are the energy sources used by colonia residents for lighting, heating, cooling, and cooking (Machado 2006). According to the results of the study performed in El Paso county colonias in Texas (climate division 5), the average electricity bill in colonias (82.5 $/mo) is 40% more than the average in El Paso (59.7 $/mo) (Machado 2006). As illustrated in Table 2, Laredo in Texas has (climate division 9) more cooling degree days (3509.6) than heating degree days (1076). Therefore, the electricity for cooling is one of the major expenses for colonia residents in Laredo.

Table 2: Climate data for Texas Climate division 9 including Laredo, TX.



Data Source: http://www.ncdc.noaa.gov

Another deficiency in the colonias is lack of sustainable community development due to low knowledge and awareness on the part of the residents (Rohe et al. 2002). The growing population in the colonias has an escalating impact on consumption of resources. Therefore,

delivering sustainable and energy efficient solutions becomes a serious challenge. However, in order to eliminate the barrier of acceptability of proposed strategies in housing by colonia residents, it is crucial to comprehend and document the existing housing design and construction patterns.

This study was built on three existing studies: (a) Reimers's (2009) study on colonia houses and their expansion patterns according to residents' satisfaction over time, (b) Ward, and others' study (2010) on investigation of self-help housing conditions, and construction techniques in Central Texas colonias, and (c) Sullivan and Ward (2012) on sustainable housing applications and policies for low-income and self-built housing rehab. However, the significance of this study is making use of technology and methods from advanced architectural practice to assist in data collection of housing forms, materials, construction techniques, energy consumption and cost analyses, and resident profile.

3. A New Conceptual Framework for Improving Informal Settlements / Colonias

We propose a new model for delivering sustainable cost-effective architecture and construction knowledge from experts to residents in self-help housing in colonias Texas through fusing the concepts of spatial agency and BIM technology (Figure 2).

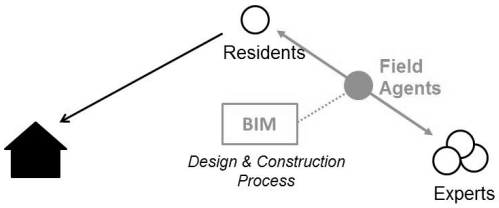


Figure 2: Conceptual Model for Spatial Agents and BIM in the colonias

3.1 Agency in Architecture via Field Agents: Two Models of Agency

The concept of agency in architecture relies on the notion of "advocacy" in architecture. In literature, the term "advocacy" was first referred in the context of urban planning which means empowering poor and unrepresentative population; scholars assert that planners must behave as an advocate for poor and unrepresented group (Heskin 1980). Similarly, 'advocacy' in architecture has been established as a new approach on spatial production that is different from the traditional concerns in architecture. Hence, the role of architects has been questioned. Architecture for Humanity (AFH) (2006) defines the essence of advocacy in architecture as architects delivering service to underrepresented and disadvantaged populations through using information technology and tools and empower people to participate in the design process.

Awan, Schneider and Till (2011) use the term *'Spatial Agency'* which means architects sharing their knowledge and design ideas with non-professional and self-builders to guide them. They ground on the term 'spatial" from Henri Lefebvre's book entitled *The Production of Space* (1974) and 'agency' and 'agent' from Anthony Giddens's *Theory of Structuration*

(1984). In other words, they use ‘spatial’ to extend the term architecture by encompassing social, economic, environmental and political notions. Therefore, spatial agency triggers self-help architecture process through empowering residents and encouraging residents to participate in the process of spatial design and production. To sum up, field agency refers to providing/bringing professional services including design ideas and knowledge to people and communities who do not have access to them.

Informal settlements are the product of bottom-up process of designing, building and managing the houses proceeded by residents. Agents are not only individual advocacy architects, but also organizations, advocacy groups, which act with and on behalf of self-builders. American agriculture has long used governmental representatives in the role of “field agents” to provide knowledge of best practices to farmers and the general public. United States Agency for International Development (USAID) and World Bank have developed and funded Farming System Research and Extension projects (FSR/E) (Kerry J. Byrnes 1989). The main idea of FSR/E is based on a training and field experience to deliver knowledge from researchers to cultivators in developing countries from 1970s to 1980s. These are funded by Federal Government, State Government and World Bank (Ugwu 2007).

In colonias, community organization has been established to overcome the challenges in housing and living conditions. These organizations set up a platform for collaboration between residents and authorities, which is advocated under the concept of spatial agency. Colonias Self-Help Center (SHC) program developed by Texas Department of Housing and Community Affairs (TDHCA) is a prominent on-going example established in several counties of Texas such as Cameron/Willacy, Hidalgo, Starr, Webb and El Paso. The aim of this program is to offer technical assistance to residents in housing improvements, new construction, infrastructure access, and capital access for mortgages (THDCA 2012).Texas A&M University Colonias Program, which was funded by counties and federal government, private sector and Texas Legislature, has developed Promotoras Program to link between the residents and the authorities in health care area. Promotoras are indigenous mostly women colonia residents who are specially trained by experts in Department of State Health Services to serve as agents in community organizations (Arizmendi and Ortiz 2004).

This paper suggests a similar model of spatial agents for sustainable architectural service delivery model from experts to residents that can be established under Texas A&M University Colonias Program***.*** By following a similar path with both promotoras and field agents in agriculture, spatial agents can be trained by undergraduate interns from Department of Architecture at Texas A&M University. The equipment and the funding can be provided by counties and federal government, private sector. In sustainable design and construction, there are several experts whose knowledge can be very useful to *colonias* residents. Therefore, this study is to employ ‘spatial agency’ in architecture by extending the concept of the self-help centers to share knowledge of experts with residents.

3.2 Methods for Sustainable and Affordable Housing Design

The introduction of increased knowledge of sustainable design practices may enable residents to make better decisions with respect to sustainability when undertaking self-help

construction projects. Even though the existing literature on sustainable construction and design practices often focuses on middle and high income houses, the studies focused on low-income houses are related to rehabilitation of existing houses for low-income settlements and infrastructure systems of informal settlements.

Several studies have identified the sustainable and cost-effective housing interventions to colonias according to ease of application and maintenance, cost savings, initial cost and human capital (Ward, Olmedo, et al. 2010; Ward, Sullivan, et al. 2010). There are very limited number of studies focuses on quantitative documentation of cost and energy savings of different applications that can be used by low-income residents (Bradshaw et al. 2005).

3.3 BIM Technology

This study suggests applying advanced digital tools for architectural design to architectural service delivery model of spatial agents to guide residents on sustainable and affordable housing design and construction in informal settlements. BIM is a recent advanced technology in the Architecture, Engineering and Construction Industry (AEC) that is enabling designers to produce high performance buildings more quickly and at a lower cost. Being an object-oriented modeling tool is the major feature of BIM that makes it distinguished from other conventional design tools such as; Computer Aided Design (CAD). The object-oriented modeling feature of BIM enables designers to determine geometric and non-geometric features through setting up parameters and rules for objects (Eastman et al. 2008).

In the context of modeling informal settlements, Geographic Information Systems (GIS) software is currently used for integrating spatial and non-spatial data. In colonias, it has been utilized in several researches to manage, monitor and predict health of dwellers, the growth of communities and resources. GIS is a tool to visualize the data. To allow quick visualization, there are several design software developed to support visualization and design process such as Project Galileo and Autodesk Civil by Autodesk, Bentley Map by Bentley Systems, CityCad by Holistic City Software and CommunityViz® by Placeways LLC (Gil et al. 2010). However, these tools lack in parametric modeling and integrating comprehensive information on design patterns, materials, construction and parameters of individual buildings.

Application of BIM holds significant capabilities in the informal settlement context *(Figure 3).* (1) BIM technology supports *3-dimensional modeling of a building*, parametric form generation and object-oriented modeling that represents real-time design changes of it (Eastman et al. 2008). (2) BIM allows *documenting and collecting large amounts of data* (design, construction and operation) on both existing and newly designed individual houses such as (a) designer data, (b) legal data, (c) geospatial data, (d) financial data, (e) specifier data, (e) environmentalist data, (f) sustainers data, and (g) owner/occupier data (Bazjanac 2008). (3) BIM design tools have an *embedded library of components* that are frequently used for conventional buildings (Eastman et al. 2008) which enable users to develop new library that *supports modeling buildings in the colonias* with additional parameters. (4) The idea of *parametric modeling* refers to creating models which are clearly defined by parameters mainly to establish variation of geometrical components of objects (Woodbury

2010). (5) To examine the risk of a proposed building, a number of *simulation tools* may be used. However, one of the major challenges of these tools is that they are mainly dependent on user input of building components, loads and so on (Hand et al. 2008). In literature, several researches have been focused on linking the 3D rich visual BIMs of buildings and the computational tools. This integration enables designers in earlier stages of design to test the proposed building by changing the form or material (Clayton, Warden, and Parker 2002).



Figure 3: BIMs of houses in Larga Vista colonias (Yenerim, and Clayton 2011)

To sum up, BIM can aid spatial agents to design, visualize and analyse the houses in 3-dimensions, and to create affordable high performance buildings that meet building standards*.*

4. Assisting Residents with Advanced Technology

This study is a part of an on-going Ph.D dissertation at Texas A&M University. This section shows the research development stage which employs a mixed-method research to devise a new model for aiding residents of informal settlements to achieve greater sustainability in self-help housing.

4.1 Study Area in Texas Colonias

The study area of this research is Texas since it has the largest number of colonia residents in U.S. The criteria of sample selection are (1) having varied ages and types of self-help houses, (2) accessibility and field work support, (3) data richness, and (4) manageable size. The city of Laredo in Webb County is the sample population; Laredo has Webb County Self-help Center, Texas A&M University Colonias Program and Promotoras Program Center which makes it convenient in terms of accessibility and field work support. In order to represent the varied characteristics of houses and households, we pick Larga Vista, San Carlos 1 and 2. Larga Vista is the smallest colonia with higher population located within the city limits, whereas San Carlos 1 & 2 are also denser colonias than the rest and are located outside the city limits.

4.2 Research Plan

This research relies upon both qualitative and quantitative research methods to explore the relationship between human beings and technology. This study involves three phases after the literature review.

4.2.1 Data Collection

Data collection includes interviews, focus groups and field survey. Data collection is required in two subjects: (1) best practices for sustainable cost effective home design and construction (completed), and (2) preferences and patterns of construction and lifestyle of colonia residents. First, we convened a focus group between eight experts who are experienced in sustainable and affordable home construction and design from government agencies, private practice, non-profit research centers, and academic research centers. The participants were selected from either Texas or Louisiana, since regional climate and industrial patterns are important determinants of construction practice. The outcome was a report that recommends specific sustainable design and construction practices for the colonia residents. Second, the interviews with residents and the field survey will serve to document size/volume/aspect ratio, orientation, form complexity, ratio of fenestration on façade, construction materials and methods, and shading of houses and characteristics of household. The Colonias Program and Promotoras Program of Texas A&M University are the gatekeepers of this study.

4.2.2 BIM Toolkit: Creating BIM Library and Parametric Models

The next stage will be to incorporate the rules and patterns for home design revealed from the first step into BIM software to produce a tool kit for designing sustainable homes, and home additions in the colonias. Autodesk Revit 2013 will be utilized as a BIM tool. First, based on the input from the first step, we will create two libraries including parametric families of building components and system families; one for existing houses, and other for sustainable cost effective solutions. We will add several parameters such as parameters such as cost, size and materials to be incorporated into a framework of simulation and analysis tools. The outcome will be two BIM libraries and a prototypical house that can be easily composed and manipulated to represent a variety of designs and rapidly analysed with respect to sustainability performance.

4.2.3 Usability Test of the Toolkit

The third step will be to test the software using a quasi-experiment with architecture design students who are stand-ins for spatial agents. The quasi-experiment will determine the ease of use, rapidity of design, satisfaction of the users, and sustainability of resulting designs in comparison to benchmark designs produced with more conventional methods.

5. Conclusion

Colonias are example of informal settlements in U.S. that provide shelter for low- and very-low income people who cannot afford formal ones. In colonias, residents often build their houses by themselves with help of families and friends based on their needs and availability of money. Due to lack of knowledge in sustainable cost-effective strategies in design and construction, people live in substandard houses, and pay more for energy. To overcome these challenges, it is important to first understand their culture and pattern of construction and then deliver these residents knowledge of sustainable architecture from experts.

This study proposed a new model for sustainable and affordable interventions to informal settlement through aiding trained spatial agents with BIM tool. Thus, Colonias Program of Texas A&M University can act as spatial agents after a training process with BIM toolkit. By utilizing BIM toolkit, they can empower residents and can guide residents to produce home designs that are more affordable, more sustainable, and more quickly. Since colonias share many of the same characteristics of “traditional squatting” formation typology, this model can be applied to other informal settlements.

The possible difficulties can be the training process which might be longer than other agency models. The tools can be expensive to purchase whereas the software is free for students and faculty in the university. The IT tools, experts and agents can be funded by federal government, county government and private agencies like the Colonias Program.

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Wood in the urban context: Infill development using prefabricated timber construction systems

Steffen Lehmann[1]

Abstract

Wood is an important contemporary building resource due to its low embodied energy, rapid natural regrowth and unique attributes. The potential of prefabricated engineered solid wood panel systems, such as cross-laminated timber (CLT), as a sustainable building system, is only just being realized by the construction sector. Since timber is one of the few materials that has the capacity to store carbon in large quantities over a long period of time, solid wood panel construction offers the opportunity of carbon engineering, e.g. to turn buildings and districts into 'carbon sinks'. Thus, some of the historically negative environmental impact of urban development and construction could be avoided. Given the many benefits of lightweight CLT construction, its introduction to the Australian construction sector is timely and relevant. The purpose of the study is to identify the barriers preventing a fast uptake and strategies for removing these barriers.

The author introduces a series of case studies of recently constructed inner-city residential timber buildings using CLT systems, exploring their levels of acceptance (post-occupancy evaluation). These precedents are in London, Vienna and Trondheim; while Australia's first timber high-rise has recently been completed in Melbourne. First conclusions are discussed at the end of the paper, but further research will be necessary, based on in-depth post-occupancy evaluations that involve collecting information from owners, residents, neighbours, architects, real estate experts, construction managers and developers to better assess residential life in CLT multi-storey timber buildings.

Keywords: Engineered timber, **digital prefabrication**, **solid wood panels**, **low carbon construction**, **social acceptance**.

1. Introduction and problem definition

Expanding cities and the current rate of loss of agricultural land make a strong argument for urban infill and the need for consolidation and more sustainable urban development. Cities are the centre of consumption; they require an enormous concentration of energy, construction materials, water, food and land, which nature cannot provide (Mumford, 1961; Lyle, 1994; Brown, 2009). Brown (2009) notes that collecting masses of materials and later

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dispersing them in the form of garbage, sewage and pollutants in air, water and landfill is challenging municipalities worldwide.

Most of Australia's larger cities have recently developed master plans for the next 20 years, to cater for predicted population growth (Australia is currently predicted to grow from 23 million people in 2012 to 36 million by 2045: COAG, 2011), and to achieve this growth by increasing the proportion of urban infill from a current rate of around 35 per cent in Sydney, Melbourne and Adelaide to a nominated target of 60 to 70 per cent (with similar figures in Brisbane and Perth). These cities have identified transit-oriented development (TOD) sites and allow for higher density along transit corridors: thus, the master plans of all large Australian cities are strikingly similar in their aims and strategies. All this has urban design implications for housing typologies and densification strategies.

The renewed planning focus has led to the Australian government – through the Council of Australian Governments (COAG) and the federal government's Major City Unit – taking a much greater interest in the mechanisms whereby affordable and sustainable inner-city housing can be provided. However, the production of conventional apartment buildings using concrete and steel are one-way energy-intensive processes that release large amounts of greenhouse gases into the atmosphere. One strategy to achieve more sustainable inner-city housing is to design and manufacture 'green' assemblies for mass customization of buildings using modular prefabricated low-carbon construction systems with engineered timber. It is a way to get closer to ensuring the vision of 'making buildings without creating waste' finally becomes a reality (COAG, 2011). Mid-rise density infill projects, insertions within the existing urban fabric (not high-density or high-rise, but mid-rise, with 4 to 10 storey blocks), are gaining in popularity. The inner-city residential buildings of tomorrow will focus on construction speed, reduced carbon emissions and weight reduction by using low-carbon lightweight construction and cladding; these prefabricated systems will use high-performance timber panels such as cross-laminated (CLT) panels, as these can be easily handled on-site.

Behaviour change has frequently been listed as the number one barrier to reducing consumption towards pro-environmental behaviour and a more energy and material-efficient, low-carbon future (McKenzie-Mohr et al., 1995; Newton, 2011; Lehmann and Crocker, 2012). Tackling the carbon intensity of development and urban sprawl concurrently requires finding low-carbon alternatives for better urban infill development. Technology is always most effective if it is embedded into a societal framework. However, residents' motivation and commitment to aspire to sustainable living are still not well understood, i.e., how to best overcome social barriers to inner-city living in prefabricated timber towers.

The purpose of this study is to identify the barriers preventing a fast uptake of cross-laminated timber (CLT) in building construction and strategies for removing these barriers. The author introduces a series of case studies of recently constructed inner-city residential timber buildings using CLT systems; these precedents are in London, Vienna and Trondheim; while Australia's first timber high-rise has recently been built in Melbourne (the Forté apartment building in Docklands, see following case 5).

The research methodology includes an analysis of cases, structured around four inter-related themes: mapping of key low carbon timber construction concepts, providing an evidence base for policy and decision makers; investigating design standards for lightweight prefabricated timber buildings and their disassembly; describing how engineered wood construction systems could best be applied to Australian urban infill; synthesising the above to develop pathways to a construction system suitable for Australian conditions, e.g. its particular climate and supply chain. The availability and comparability of data will be assessed, gaps in the data identified. At a later stage, design-testing will be done for three Australian sites, including lifecycle analysis focusing on CO_2-equivalent global warming potential.

The paper is therefore structured in 3 parts: firstly, the benefits of solid wood construction are discussed; then the case studies presented; and, a concluding discussion considers what might have to happen for Australians to swap their backyard for a balcony.

2. Forests, trees, wood panels and carbon sinks

Timber has been described as materialized solar energy and an efficient CO_2 accumulator (Wegener, Pahler and Tratzmiller, 2010). Residential building construction with wood is now changing, focusing on green materials, local supply chains and resource-optimized engineered systems. Wood is to be sourced in a sustainable way from well-managed forests. Timber construction is an efficient method of CO_2 storage, as long as the material is obtained using responsible methods of forest cultivation (plantations) and from a certified source that is not too far away (to avoid transport-generated greenhouse gases).

The aim is to evolve systems and designs in engineered timber that tackle the significant negative environmental impact of buildings and offer new ways of constructing efficient and affordable structures that demand fewer resources and can be easily re-used/recycled. One cubic metre of timber can store up to one ton of CO_2. No doubt, steel and concrete are great building materials, until you consider their ecological footprint: over 5 per cent of all GhG emissions worldwide come from concrete, while each ton of solid wood panels has sequestered up to -1.6 tons of CO_2. New engineered timber panels can outperform both concrete and steel: during manufacture, a ton of steel emits up to 1,5 tons of carbon; and the production of a ton of cement emits over 1,1 tons (FP Innovations, 2011). Hence, fast growing softwoods will be the future, planted for laminating into large solid structural panels.

Contemporary technology has changed both the way in which timber buildings are converted and assembled (Vessby et al., 2009), and how these can be protected against fire, insects and decay (Frangi et al., 2009; Gereke et al., 2011). Given its carbon sequestration capacity, wood might well be *the* construction material of the twenty-first century.

> *The energy budgets of products and buildings made of wood show that they may use less energy over their total life cycle (manufacture, use, maintenance and disposal) than can be recovered from the waste products of their production and from their recycling potential at the end of their life cycle: they are energy-positive. No other construction material is so comprehensively*

energy-efficient and therefore climate effective as wood. (Wegener, Pahler and Tratzmiller, 2010, p.4)

2.1 What exactly are the advantages of solid wood panel construction?

According to the Timber Development Association of New South Wales (TDA, 2011), a CLT construction system is a structural wood panel system fabricated by bonding together large timber boards with structural adhesives, alternating the grain directions of each layer, to produce a solid, load-bearing timber panel with each layer of the panel alternating between longitudinal and transverse lamellae. It's not a 'product', it's a recognised construction system increasingly used in Europe as an alternative to steel and concrete. Large-format solid timber panels are engineered wood products used as massive load-bearing walls, roofs and floor slabs. CLT panels are an extension of the technology that began with plywood and may be best described as 'jumbo plywood', where layers of timber are glued together with the grain alternating at 90 degree angles for each layer (thus different from LVL or glue-lam). Cross-laminating layers of wood veneer improve the structural properties by distributing the along-the-grain strength of wood in both directions. The advantages this offers are quite exciting – timber panels are much lighter than concrete, more easily worked and safer to erect (Sathre and Gustavsson, 2009; WoodWisdom-Net, 2009; Lehmann, 2011).

Two recent scoping studies identified the research needed and existing capacity to deliver solid wood panel buildings for infill development in Australia using CLT construction systems (Lehmann and Hamilton, 2011; Lehmann, 2012a). Key stakeholders were interviewed for their perspectives about CLT, including the perceived barriers to and/or opportunities for using CLT construction systems in Australia. However, there is still some confusion between acceptance and skepticism (consumer resistance) about the introduction of CLT apartment buildings in Australia**.** There are a number of clear benefits to solid wood panel buildings. The following list is drawn from the author's review of such buildings, a review of research papers, of wood product industry strategies and from discussions with architects, engineers and industry stakeholders in the supply chain:

- the speed with which the structure of CLT constructed buildings can be assembled on-site (built at least 30 per cent faster, because much of it is prefabricated and lighter);

- the acoustic and thermal performance of massive CLT panels, which reduce the level of additional insulation needed for energy efficiency and sound deadening;

- the higher fire performance of CLT compared to timber-framed buildings (high-density massive wood panels char rather than ignite, and the charring creates a fire barrier, as the charred layers protect the panels' load-bearing capacity);

- storage of carbon in the timber of each CLT building (CO_2 sequestration); and a reduced carbon footprint for timber buildings from responsibly sourced wood (reduced embodied energy);

- lighter: resource-reduced construction with only a quarter of the weight compared with a concrete building, and significantly reduced waste;

- the ease and affordability of heating and cooling a CLT dwelling, providing a healthy indoor climate (resulting in reduced operational energy and smaller energy bills for residents).

3. CLT-constructed buildings in an urban context: some European cases and a first application in Australia

How can consumers be influenced to accept inner-city apartment buildings constructed entirely of timber? The use of post-occupancy evaluation (POE) of new CLT housing projects is a promising approach for analysing occupant comfort, user behaviour and energy consumption. It will enable researchers to develop and validate an 'ideal' model for CLT infill housing for Australian cities. In Europe, construction of solid wood panel multi-storey apartment buildings has increased recently, with several projects in European cities built or under way (including large projects in Austria, Switzerland, Germany, Italy, Norway, Finland and the UK). In Australia, only a few CLT buildings have been designed and submitted for development approval so far (proposals have been developed in Sydney, Melbourne and Adelaide). Construction costs for apartment buildings are still significantly higher than costs for suburban houses; however, increasing the scale of CLT construction would change this situation. There is still a lack of knowledge within the architectural design community about CLT buildings' design and the impact of various design features on infill developments' carbon footprints–as compared to other construction systems.
Figures 1 to 5 show some of the residential buildings recently constructed with CLT systems. These multi-storey apartment buildings were selected as case studies to provide an insight into the diversity of design possibilities using the wood panel system (for a more detailed analysis of them, see: Lehmann, 2012).

3.1 CLT case study 1: Bridport House, Hackney, London

The eight-storey Bridport House is, with 'Stadthaus' (also in Hackney), the tallest all cross-laminated timber building in the UK. It has pushed the boundaries of CLT construction up to eight storeys. Bridport House replaces an original 1950s block with 41 new apartments in two joined blocks, one eight storeys and the other five storeys high. All elements from the ground floor upwards are of cross-laminated timber, manufactured in and supplied from Austria – including the lift shaft. Below ground level the raft, foundations and lift pit are of reinforced concrete. In the design phase, reinforced concrete and structural steel was compared in detail with the use of a CLT system (Eurban ran a detailed comparative analysis). There are several reasons why CLT was selected: one was weight. CLT is considerably lighter than the alternative structural materials, and a large Victorian sewer runs beneath the site and point loads had to be avoided. Speed of construction was another benefit, it can take as little as half the time to construct using CLT as a conventional reinforced concrete frame. In addition, the construction process is far less likely to be interrupted in bad weather conditions. Stephen Powney notes that, despite the transport, carbon saving over steel and concrete was 2,113 tons; the amount of sequestered carbon is

a saving equivalent to providing 20 per cent of the building's operational energy requirement for 139 years (Powney, 2011).




Figure 1 a and b: Bridport House, Hackney, London, was completed in August 2012. (Source: Lehmann/architects, 2012)

3.2 CLT case study 2: Svartlamoen multi-apartment building in Trondheim, Norway

This development (architects: Brendeland and Kristoffersen, Trondheim, 2005) consists of two buildings with an overall area of around 1000 sqm. The main five-storey building also contains rooms that can be used commercially, and the four upper floors contain units of 120 sqm designed to accommodate 5 persons each. The entire construction was made out of solid CLT boards and clad with Norwegian larch (see Figures 2a, 2b). The building was controversial and one of the architects (Brendeland) commented that ‘the day the Svartlamoen housing block was opened, concrete companies took out a full-page advert in the city newspaper showing a blazing timber building, a scare tactic focusing on timber’s fire risks’ (Lattke and Lehmann, 2007). A post-occupancy evaluation for the building is currently underway. In April 2012, the author met with residents to discuss their lifestyle choices. He learnt that there is now a long waiting list to move into this building; it has become very popular to be associated with this green building. The occupants mentioned that they like the idea that the building materials are recyclable and all tenants are conscious of the building’s sustainability, appreciating its particular ‘timber qualities’, for example, the healthy indoor climate.



Figure 2 a and b: Svartlamoen project, Trondheim, Norway – exterior view with resident. (Source: S. Lehmann, 2012)

3.3 CLT case study 3: the Am Muehlweg complex, Vienna-Floridsdorf, Austria

The Am Muehlweg project was designed by Hubert Riess, Dietrich & Untertrifaller, and the construction cooperative Hermann & Johannes Kaufmann Architects. One hundred public-sector apartments were built on each of three interconnecting plots, with the emphasis on the optimum exploitation of the ecological and economic benefits of timber and mixed constructions. Terraced houses and an L-shaped building surround an internal courtyard, creating a communal area. In total, the project provides 6,750 sqm in 70 dwellings in 13 buildings (a detailed description of the project is in Kaufmann and Nerdinger, 2011). The three-storey structures made from prefabricated CLT panels built on top of a concrete base were constructed in 15 months (see Figure 3). The entire four storeys of the building are clad in larch. The author interviewed residents to discuss their lifestyle choices and reasons for deciding to live in the building and the findings are similar to the Norwegian case.



Figure 3 a and b: Resident Barbara of the Am Muehlweg project in Vienna, Austria. (Source: S. Lehmann, 2012)

3.4 CLT case study 4: Wagramerstrasse public housing, Vienna

This is Austria's highest residential building constructed using CLT systems: 101 apartments in a 7-storey slab along Wagramerstrasse and three 3-storey fingers forming courtyards. Six storeys of CLT sit on top of a concrete podium (Brinkmann, 2012). The solution is the outcome of a 2009 design competition organized by the City of Vienna. The build is a composite structure of concrete cores with a CLT system; engineer Wolfgang Winter predicts that 'most large-scale multistorey timber buildings in future will be hybrid structures,

where sound insulation is typically added via the use of concrete or screed' (personal communication, April 2012). The 2,400 cubic metre timber structure stores around 2,400 tons of CO_2, which equals the annual emissions of 1,600 cars. The project was completed in February 2013. The apartments are 2, 3 and 4 bedroom units of 60 to 105 sqm in size; some are maisonettes.



Figure 4 a and b: The Wagramerstrasse apartment complex, part of Vienna's 'Wood in the City' initiative, which now allows timber buildings up to 32 metres in height. Cores and ground floor podium are concrete. (Source: S. Lehmann, 2012).

3.5 CLT case study 5: the Forté apartment tower in Melbourne, Australia

Forté, the 10-storey timber residential building in Melbourne's Docklands, is Australia's first large CLT building and a landmark project for the timber industry in Australasia. 9 storeys in CLT sit on top of a concrete podium. The ground floor is used for retail space. The advantages of CLT were particularly relevant to the Docklands location, as its reduced weight generated substantial below-ground savings and the fast build suited the compact site. According to the developers, by using CLT, Forté reduces carbon emissions by more than 1,400 tons of CO_2, compared with building in concrete and steel. The advantages are likely to continue for residents too: the 23 apartments require 25 per cent less energy to heat and cool than a similar apartment built in reinforced concrete; they note that the building will be carbon neutral for at least 10 years. Construction of the building only took from February to October 2012 (see Figure 5). The tower is constructed from 760 CLT panels, which were shipped from Austria to Australia in 25 containers (panel length was limited to 12 metres due to container size). In the assembly process, around 20 panels per day were put in place. However, only a few timber surfaces are exposed internally, reduced to one 'feature wall' per unit. An earlier design option proposed that the entire building be wood clad, but 'it was then decided to reduce the timber aesthetic, to avoid marketing risks' (Hopkins, 2012). The developer decided on 'a more ordinary façade to have a building not completely out of the ordinary', and also decided that 'the building would be fully sprinklered to make it look safe and simplify the approval process, although this measure was not requested by the Fire Department' (Hopkins, 2012).



Figure 5 a, b and c: The 10-storey 'Forté' apartment building in Bourke Street, Melbourne Docklands, under construction (July 2012); CLT panels stored in a warehouse close to the site. (Source: C. Philpot, 2012; S. Lehmann, 2012)

4. Motivating people to swap backyards for balconies: a methodology for further research

High-rise timber building developments are now gaining recognition from designers and developers due to timber's many positive environmental attributes as well as construction benefits; being lightweight, having a known fire and thermal performance. This being said, there is still much work that needs to be done in demonstrating timber's benefits to regulatory and fire authorities as well as addressing social and cultural issues that arise from living in this new form of construction system. A fundamental question is the potential market penetration in Australia. The analysed cases show that not only technological but also social innovation is needed to introduce CLT systems more widely to Australians, who are used to having large backyards. Since the mid-1990s, CLT construction has been introduced in several European countries and more recently in Canada. Research from Canada indicates that 'a market penetration rate of up to 15 per cent in 5 to 7 years is realistic' (FPInnovations, 2011).

This ongoing study is a work in progress and findings are still emerging. Two problems require clarification: firstly, models of urban infill for intelligent densification; then the study of how the use of CLT systems can play an important role in achieving a more liveable city with better models of inner-city housing; the problems are intertwined. Three research strategies will be employed: in-depth analysis of case studies; a series of qualitative research interviews with residents and other stakeholders; and demonstration projects will help operationalizing concepts that can be measured over time and data extracted, with relevance to policy development. Further research is required to better understand the social acceptance of CLT multi-storey apartments in urban centres; what triggers people to choose a more urban lifestyle by moving back to the city centre, into timber high-rise. Researchers at the Zero Waste Centre for Sustainable Design and Behaviour are therefore aiming to increase the knowledge base required to introduce CLT construction systems into the Australian construction sector. This includes developing acceptable solutions for regulatory approval of CLT buildings and addressing the technical barriers required to ensure a safe, acceptable system for urban infill development.

5. Conclusion and further discussion

Better housing design can also significantly improve health outcomes. The integration of sustainability in housing is of crucial importance for the future development and re-development of Australian urban areas. The author found that the barriers and obstacles are not so much technical as human. Raising low-carbon construction systems to the top of our research agenda and transforming industry will move solid wood panel construction beyond being a niche innovation only carried out by a small network of pioneers.

For too long we have lacked real housing choices. Resistance to sprawl is growing. All future growth will have to be where abundant infrastructure and services already exist. Stopping the outer suburbs from further expansion means that the inner suburbs will have to accommodate more people; therefore more affordable, better typologies for inner-city living are necessary (Lehmann, 2013).

Australians will not swap their backyards for balconies just because of the construction material of an apartment. It is the cost savings from faster construction time and reduced cooling costs during hotter summers associated with CLT construction that might attract residents. Realistically, the wider sustainability issues are not sufficient to be major factors in the buyer's decision-making process; it would be overly simplistic to believe that sustainability credentials alone are sufficient. The discussion requires further delineation of the real barriers to acceptance of this interesting and innovative construction system.

One significant barrier is the slow uptake by industry and consumer resistance to denser inner-city living. It is necessary to find out whether residents are more likely to accept higher densities when they know that the density is created by green buildings. Proposing higher densities and multi-storey timber construction faces the general problem of Australians' historic resistance to apartment living (which has much to do with the apartments' poor design, small size, tall shape, lack of privacy, noise and high cost), and the lack of experience with infill sites in cities. The case studies reviewed make a strong argument for timber in the urban context. But the cases also show that there is still a need to instill confidence in the performance of solid wood panel buildings as designed, so that they will be accepted in Australia, by professionals required to certify construction to the country's standards and by the market. From the perspective of residents, social acceptance of CLT buildings will be influenced by public perception and factors affecting liveability, comfort and the consequent socio-economic outcomes.

Both the general public and the architectural community still lack knowledge about CLT construction and the impact of various design features on the carbon footprint of their use for infill development compared to other modern methods of construction. Education of architects and planners is therefore important, e.g. to develop new courses that focus on research methods into new materials and low carbon construction systems, aiming to reposition future architects as more knowledgeable (and again, as influential) in the construction industry. Government agencies and the building industry are involved throughout the research, as this will lead to an increased understanding and knowledge of the properties of CLT buildings and inform decision-making. The research will have to be

tested on actual housing developments, delivering demonstration pilot projects. In conclusion, the author has identified the following actions that government and industry could pursue:

- modify building codes to make sustainable building practice and urban infill the norm, zoning out car-dependent greenfield developments on the city fringe, re-assess unrealistically high fire requirements for timber infill;

- demonstrate the benefits of CLT construction systems by using them to create exemplary housing projects that are affordable and sustainable, and work towards the delivery of demonstration buildings showcasing the capabilities of the system;

- use the opinions of committed investors, engaging owners and occupants of CLT buildings to promote a positive identity change of the city, enhancing awareness;

- accompany realisation with performance data monitoring;

- conduct in-depth research on behaviour change to facilitate and accelerate the move towards more inner-city housing that is fully embraced by residents;

- identify the facilitators of and barriers to CLT technology transfer with industry, university and government partners internationally and produce a road map for implementation;

- ensure longevity of the implemented strategy via suitable up-skilling of industry professionals (from architects and engineers to builders);

- support the Australian design, construction and timber industries in the uptake and adoption of emerging engineered timber technologies, establishing the production of a standardized quality assurance process for fabrication, details for construction and the creation of technical specification literature;

- establish a green supply chain for domestic CLT panel manufacturing, and instigate a strategy for the suitable uptake of CLT system fabrication in Australia relative to market requirements, available technology and sufficient wood resources;

- advance evidence-based policy and practices through a user-centred approach to housing occupancy evaluation and effective understanding of feedback;

- implement zero waste concepts with detailed targets for the construction sector, doing away with construction waste going to landfill;

- make embodied energy and resource/material efficiency a key focus of government policy, setting minimum standards of efficiency that buildings must meet;

- produce peer-reviewed published work ensuring market and product confidence including worldwide dissemination of standardized information on engineered timber, e.g., publish a technical handbook and associated launch event with a conference on solid cross-laminated timber production and construction in Australia.

In this paper the author has assessed the potential contribution of CLT construction to the creation of innovative and long-lasting housing types to increase the urban density of existing cities. Inner-city housing using engineered timber construction also offers the opportunity to re-establish a more meaningful concept of material culture and enduring value, thus underpinning a more profound notion of society itself. Furthermore, the scope of application of the system is to be extended to include commercial and public buildings.

Acknowledgements

This paper draws on the author's work at the Zero Waste Centre for Sustainable Design & Behaviour at the University of South Australia, as the UNESCO Chair in Sustainable Urban Development for Asia and the Pacific, and research conducted in collaboration with the CRC for Low Carbon Living.

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A framework for designing sustainable real estate developments using Quadruple Net Value Analysis and Building Information Modelling

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Abstract

A decision-making framework for real estate development incorporating sustainable principles and using Building Information Modelling (BIM) may enable developers to explore real estate value in more comprehensive and profound ways than achievable through conventional practice. The framework uses the concept of Quadruple Net Value Analysis to structure evaluation of a project. Quadruple Net Value Analysis combines the triple bottom line of sustainable development (economic, environmental, and social sustainability) with sensory value that measure the appeal of the project with respect to sight, sound, touch, taste and smell.

The framework is described from a conceptual vantage and several proof-of-concept experiments of components of the software system are presented. The researchers envision a parametric BIM as a medium for representing designs with 3D modelling, rendering and animation, and the use of interoperable analysis tools to aid the developers and designers in exploring the consequences of the scheme along quantitative and explicit measures. Immersive visualization will help the users perform qualitative assessment of the sensory aspects of the design. Experiments with the software and analytic techniques provide evidence that the tools can enable rapid design of land and property development schemes, automated analysis of the performance of the schemes, rapid alteration of a scheme supporting what-if analysis, and sensory assessment in the immersive visualization environment.

The Quadruple Net Value Analysis framework implemented in a computer platform should enable a real estate developer to analyze a project proposal more holistically and more rapidly, explore more options through what-if scenarios and reach a wide range of empowered and unempowered stakeholders. A development can be designed not only to fulfil the demands of the triple bottom line, but also to appeal at the sensory level to become something that people want to preserve.

Keywords: **land and property development**, **real estate development**, **immersive visualization**, **sustainable development, decision support.**

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1. Introduction

We shape our natural, built and virtual environments and then these environments shape us. Whether it is the clearing of the Amazon rainforest, the building of the world's tallest building, or the latest version of the video game Halo 4, this shaping of our environment touches our lives and influences our experiences. In the mid to late 20th century, Lynch (1960); Alexander (1977); and Relph (1976) equipped us with the tools and the phenomenological framework to read and understand these elements and changes in our environment. The advent of personal computing and the development of CAD, BIM and a range of other simulation programs allow us to virtually design and model changes to our environment. Our research investigates how to capture and apply both tacit and explicit knowledge and test the impact and consequences that environmentally modifying actions would have on our lives.

The issue that interests us is how to increase the ability of real estate developers to design successful and sustainable projects. Our research envisions a computer-based platform for land and property development and design that enables the user to create and evaluate schemes from a comprehensive viewpoint of sustainability. We are employing the concept of Quadruple Net Value Analysis to assess a real estate and land development project along economic, social and cultural, environmental, and sensory (perceptual) dimensions (Jerke, 2008). By using Building Information Modelling technology to create a data-rich 3D model of an alternative scheme, we are able to analyze the scheme rapidly. Parametric modelling capabilities allow us to alter the scheme rapidly, permitting the exploration and comparison of many alternatives. An immersive visualization tool allows us to put people into the planned development in an interactive visual simulation with a full field of vision and the ability to walk or fly through the environment. The platform is intended to allow the user to base choices upon not only quantitative analysis but also, through use of virtual reality tools, formerly tacit knowledge that is now made explicit. We intend it to be a decision-support platform for real estate and property development.

Although our research is still in an exploratory stage, we have conducted several experiments to test feasibility and prove the concepts. Graduate student teams have conducted Quadruple Net Value Analysis of sixteen land and property projects in Texas and one in Chicago, Illinois. By preparing video presentations that incorporate narratives and music audio tracks, we are able to explore filmmaking techniques for conveying tacit, sensory dimensions of the projects. Another exploration has made use of BIM tools to test rapid modelling of alternatives using parametric techniques and the automation of analysis using software interoperability. These models have been introduced into the "BIM CAVE" immersive visualization environment to test both the speed of transfer from the designer's modelling environment to the immersive visualization environment and the sensory presence achieved. Finally, we are beginning a test study of our methods in the real world in conjunction with a homebuilder who is developing a subdivision.

2. Sustainability and modelling

Although some real estate developers achieve enviable records of profitability, there remains a significant amount of uncertainty in whether a project will be successful. Issues such as

carbon footprint and energy efficiency, social benefits, and inclusiveness of stakeholders both powerful and disadvantaged are leading to more complex definitions of success and more complex regulation and approval criteria. Our research makes use of two relatively new ideas in the hope of instigating profound change. Quadruple Net Value Analysis is a comprehensive system for assessing the economic, social and cultural, environmental, and sensory value that is created by real estate development. Building Information Modelling is a powerful information technology for accelerating processes.

2.1 Sustainability

In 1983 Gro Harlem Brundtland, the former Prime Minister of Norway, was asked by the Secretary-General of the United Nations to establish a World Commission on Environment and Development. The commission report formulates the idea that **"**Sustainable Development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (United Nations World Commission on the Environment and Development, 1987). It further defines three interdependent elements:

> "**Environmental sustainability** –involving the management and consumption of the Earth's renewal natural resources so as not to exceed the rate at which they are renewed, and ensure that the absorptive capacity of the natural environment to assimilate wastes should not be exceeded or degraded. The extraction of non-renewable resources should be minimized. Future degradation of the natural and man-made environment should be avoided and existing degradation remediated;
>
> **Social sustainability** – relating to the cohesion of society and its ability to work towards common goals. Meeting individual needs, such as those for health and well-being, nutrition, shelter, education and cultural expression are considered a priority; and,
>
> **Economic sustainability** – working in concert with environmental and social sustainability to create and maintain robust economies that better meet the needs of its citizens." (United Nations World Commission on the Environment and Development, 1987).

This formulation is widely known as the "triple bottom line" of sustainable development. A good sustainable development must not only be economically viable and profitable, it must meet long term objectives of environmental stewardship and social progress.

2.2 Quadruple Net Value Analysis

While there is wide consensus that shaping our natural, built, and virtual environments has economic, social and environmental consequences, there is a fourth important consequence that is often overlooked: the sensory, perceptual aspect that greatly impacts the appeal of a project. The sensory aspect focuses on how we perceive the environment in which we live and how we sense and appraise change in both the physical and virtual environment.

Apart from eating, breathing and sleeping the fourth thing humans do throughout our lives is assess place—be it a room, a dwelling, a workplace, district or city. In doing this we rely on all our senses—sight, sound, smell, taste, and touch. Place-making is the essence of real estate development value and community building. Places that are desirable to the senses we reward with repeat visits and in so doing ascribe economic and social value and, to varying degrees, environmental protection.

Dennis Jerke (2008) developed the conceptual framework of Quadruple Net Value Analysis to measure the economic, social/cultural, environmental, and perceptual. The technique uses a standard range of metrics that allows us to determine the attributes and performance of real estate assets and allows us to distil the sustainability dividend that arises from their conceptualization, design, delivery, activation, and management. It establishes, structures, and makes explicit knowledge on projects that hitherto existed only in tacit form.

Jerke's original Quadruple Net Value Analysis model focussed only on the visual in its perceptual category. Our research found this focus to be too narrow. We have expanded the perceptual component to include all the senses: sight, sound, taste, touch, and smell. Human experience and resonance of real estate assets rely on a rich combination of all five senses.

These four dimensions can be further defined to allow the computation of a "sustainability dividend" that measures the value of a project in a holistic manner (Booth, 2010). The definition of the sustainability dividend is, *the enhanced financial performance of real estate asset/portfolios that arises from the application of environmental design, science, and solutions to:*

(i) increase the percentage of the tenant's total occupancy cost that is paid to the landlord as net rent; and,

(ii) *groom existing assets, conceptualize, design and deliver new assets which cost less to operate thereby achieving comparatively lower capitalization rates*. (Booth, 2010)

Quadruple Net Value Analysis also allows us to better understand how costs and benefits are spread among the different stakeholders in real estate developments—which include the developer, owner, designers, constructors, regulators, government, tenants, neighbours, and the public. Through the expansion of Jerke's original focus from only the visual element of the perceptual component to embrace all five of the senses we are able to more accurately read real estate projects; determine what attracts repeat visitation; and, begin replication in computer modelling that will lead to refined economic, social and cultural, environmental and sensory performance.

2.3 Immersive visualization

Immersive visualization (also referred to as virtual reality) has advanced from an experimental technology to a commercial product category. The basic characteristics of an immersive visualization system are a computer display that captures enough of the field of

vision to achieve an illusion of reality, sufficient display speed so that the illusion of motion is achieved, and interactive tools that enable the user to navigate and transform the display in near real time. An early implementation was the CAVE (Audio-Visual Experience Automatic Virtual Environment) (Cruz-Neira, et al 1992). We hypothesize that the assessment of sensory aspects of a development project could be achieved through immersive visualization technology.

Architectural projects have been portrayed in animations of 3D models. The animation of the construction sequence as a so-called “4D model” has achieved widespread adoption in industry and is analyzed for effectiveness using numerous industrial cases (Hartmann, Gao and Fischer, 2008). Mafty and Harty (2012) have employed a CAVE to study hospital patient rooms from the architectural and construction viewpoints.

2.4 BIM

BIM has been described thoroughly in various books and references. General discussions of the theory behind information modelling and its applications in architecture have been presented (Eastman et al. 2008; Smith and Tardiff, 2009). Training texts describe how to use tools such as the popular Autodesk Revit BIM authoring system (Vandezande, Read and Krygiel, 2011). Various authors have emphasized the data modelling and computer science perspectives for understanding BIM, the commercial products and how to use them in a practical setting, and the human factors and transformation of design workflow in adopting new integrated software systems.

For our discussion, it is important to emphasize software capabilities provided by BIM that can be exploited to produce our concept of a decision-support platform for real estate and property development. These can be summarized as modelling and visualization, rich models, analysis and simulation, parameterization, and software extension.

BIM builds upon the capabilities long offered by Computer-Aided Design (CAD) software. CAD has been widely used in architecture firms since the 1980’s (Kemper, 1985) to provide 2D drafting and 3D modelling capabilities. Generation of photorealistic imagery and even physically accurate lighting studies has been possible for many years. BIM provides all of the capabilities of CAD so that the designer can create and depict a building of any shape and complexity.

Although CAD systems are essentially graphic editors and visualization tools, BIM adds the ability to create enriched models that associate non-graphic information with the elements in the digital model, a concept often described as “intelligent objects.” While CAD systems consist of tools for drawing lines, arcs, cubes, spheres and other geometric figures, BIM systems provide tools for drawing walls, roofs, floors, windows, doors, and other architectural components. The elements inserted into the model have non-graphic attributes in addition to the geometric descriptions. A wall element may, for example, have a construction type, an assembly definition that describes gypsum board, studs, insulation, and sheathing, a materials cost per unit, an installation cost per unit, and thermal attributes. While CAD models inherently suffer from a paucity of building description limited to the

geometric description, a BIM is more dense and rich in terms of the information expressed about the building.

This rich and extensive building information can be extracted from the BIM to provide input into analysis and simulation tools that can aid in the decision process. Building energy simulation, airflow simulations, daylighting analysis, construction cost analysis, construction scheduling analysis, structural performance and other kinds of analysis have all been integrated with BIM, although these capabilities are not all fully commercialized.

Parameterization enables the rapid creation of complex forms and investigation of designs using “what if” analysis. A BIM tool such as Autodesk Revit allows the user to adjust control points for curves and shapes based upon formulas and computations. By changing the parameters of an equation, a design can be “flexed” to alter the shape in subtle or dramatic ways. Each variant may be analyzed and the variant with the best performance selected. Closely related to parameterization is the concept of constraint modelling that permits the software user to define limits upon dimensions between elements, enforcing such concepts as symmetry, equal spacing, alignments, or offsets.

Autodesk Revit also provides an Application Programming Interface (API) that enables someone with skills in software development to extend the software in profound ways. API extensions may include complex geometric modelling, preparation of input to analysis software, validation and verification of designs, or presentation of analysis output on the geometric model.

These various capabilities appear sufficient to allow the implementation of a modelling, analysis and simulation platform for land development. The API and parametric modelling allow the creation of extensions to the software that enable rapid modelling and exploration of design alternatives. Three-d modelling and visualization enable the portrayal of the design alternative in an immersive visualization environment. The rich model and its integration with analytic tools supports the decision process of the developers and designers.

3. Experiments

Our exploration of contemporary software tools from a theory standpoint suggests that they are sufficient for developing a decision-support platform for real estate and property development. We have conducted several experiments to test the capability of our methods from a practical standpoint.

3.1 Case studies and video documentation

We hypothesize that computer-based modelling which combined visualization with auditory elements has the potential to evoke the other three senses. Although ultimately, we hope to integrate auditory cues in an immersive visualization environment, we have used filmmaking as an intermediate step in the virtualization of real estate projects. In one ongoing experiment, students have tested and refined the Quadruple Net Value Analysis method by analyzing sixteen land and property projects in Texas and one in Chicago, Illinois.

Teams of graduate students conducted site investigation and research using each of the economic, social and cultural, environmental, and sensory value criteria outlined in this paper. A detailed written report was produced for each of the sixteen case study real estate projects. Each team also prepared a video using filmmaking techniques such as combining live footage with still images, panning and zooming on still images, dubbing a narrative onto a visual track, and overdubbing an evocative music track. The videos are meant to express and convey sensory aspects of the project.

An example of these films can be viewed at:

http://www.youtube.com/watch?v=8o_Megxg2fk

The video details the conceptualization of the project, identifies the component parts of the design of the project that accentuate each of the five senses, and presents details on the project's delivery, activation, and management (Sierra, 2011).

Students also used this approach in the interdisciplinary submissions made in the 2010, 2011, and 2012 ULI—the Urban Land Institute HINES competition submissions.

3.2 Seed BIM

To explore the power of BIM to enable a designer to design quickly a building and assess the design with analysis tools, a series of studies have been conducted that resulted in the concept of Signature Architecture Franchising (Clayton et al. 2012). These studies have used Autodesk Revit software for BIM authoring to enable student designers to model a building in a matter of hours. The process depends upon use of template files, referred to as a "seed BIM", that collect the graphic presentation style, the sheet layout, the components to express a design style, and the use of constraint modelling to enforce dimensional and proportional requirements. Depending on the skill of the designer, schematic design of a modest house can be accomplished in as short as four hours of work and modifications can be made in a matter of minutes. Further work is attempting to accelerate the process and include the creation of construction documents.

3.3 BIM CAVE

Other research at our institution has produced an example of a "BIM CAVE" that achieves an immersive visualization environment by using popular commercial software for BIM coupled with multiple displays and high-powered commodity computers (Ganapathi Subramanian, 2012). To test the interoperability between our design tools of Autodesk Revit and the BIM CAVE, seven house models were collected into one immersive visualization model and viewed in the BIM CAVE. The modification of the BIM files for use in the CAVE required no more than five minutes of effort, demonstrating that it is feasible to employ immersive visualization in a design process that involves iteratively viewing a model, and changing it. Students with minimal training are able to navigate the models in the BIM CAVE. Future studies will explore the ability of extending the BIM CAVE to support tacit, sensory evaluation of projects.

3.4 Parametric Urban Modelling

Another experiment investigates parametric urban model development using BIM to enable stakeholders to explore rapidly the implications of urban developments. A software prototype is under development using the Autodesk Revit API. The first step of our implementation is creation of a parametric urban model that can represent a set of urban design components, such as open spaces, roads, pedestrians, properties, buildings, and parking structures, and representation of the associations among urban components using parametric modelling in BIM. With the parametric modelling approach, urban models can store any information as parameters, elements of urban models may be generated according to any parametric values, and relationships among parameters can be demonstrated in the urban model. As such, our prototype enables real-time design changes as users manipulate the model data using parameters, which offers a degree of flexibility for testing multiple development scenarios.

The second implementation step is creating analytical applications using Application Programming Interface (API) and Object Oriented Programming (OOP) in C#. OOP is an advanced software development approach that allows for rapid software development, high degree of maintainability, and high performance with a formal set of rules for creating and operating objects (Cox, 1986; Pinson, 1988). API allows users to access the model data, generate and edit model elements, create customized functions and user interfaces, perform analysis, as well as produce documentations. With API and OOP BIM platform provides, users will be able to modify building information in parametric urban model and link such model information to external databases and calculation engines for performance assessments.

The parametric urban model in BIM and our OOP applications will enable iterations of design, real-time evaluations, and interactive redesign by applying a set of model parameters. It will allow design optimization for a set of evaluation criteria throughout the life cycle.

3.5 REAL PROJECTS

To guide further development of our concepts, we have embarked upon a test case of a real development in partnership with a commercial homebuilder and land developer as part of the REAL PROJECTS educational initiative. Pursuant to a grant made by the College of Architecture, Master of Land and Property Development and Master of Landscape Architecture students are currently undertaking a Quadruple Net Value analysis of the Brazos Valley Affordable Housing Corporation's *Falls Creek Ranch* land subdivision to ascertain how the project's sustainability dividend can be enhanced. Using the BIM platform, Department of Architecture students are conceptualizing, designing, and building a new prototype home. In future semesters, the design process will be supported by a seed BIM, immersive visualization system, and analysis software.

3.6 Quadruple Net Value Analysis

While our previous studies using Quadruple Net Value Analysis, we believe that the technique can be scaled to all types of real estate development, including the residential scale effort in the REAL PROJECTS initiative. Table 1 presents important categories for achieving a thorough and effective analysis. Some of the metrics are already supported by analysis tools or simulation software. We are in the process of developing standard procedures and new software to implement additional metrics.

Table 1. Factors used in Quadruple Net Value Analysis.

Economic	
Return on investment	Profitability, occupancy revenue to investor.
Tax revenue increases	Increased assessed value, sales tax revenue
Increased employment	Construction employment, long-term employment
Economic and infrastructure enhancement	Community advantage and improvements
Cost avoidance	Energy, maintenance, and transportation cost
Insurance and legal costs	Fire, flood, health, lawsuits
Environmental	
Waste reduction	Construction waste, landfill waste, and sewage
Carbon reduction	Energy use, embodied energy, landscape
Water conservation	Rainwater capture, storm water management, flood reduction
Biodiversity	Ecological preservation, native plants, wildlife
Indoor air quality and health impacts	Health, walkability, nature, greenways, paths
Food production	Gardens, farmland
Shelter	Structural integrity, climate protection
Social	
Security and safety	Crime prevention, injury avoidance
Recreation and community interaction	Parkland, public gatherings
Private space	Contemplation, spirituality
Diversity	Racial, socio-economic, cultural
Convenience	Shopping, transportation, schools, place of employment
Sensory	
Sight	Architectural beauty, natural beauty
Sound	Nature, nuisance
Taste	Associations
Touch	Texture, material
Smell	Planting, materials, attractions, nuisance
Temperature and thermal	Temperature, humidity, insolation and shade, wind

4. Platform

From our experiments, we suggest a computational platform for supporting the land and property development process. The activity of creating candidate scheme can be aided by 3D modelling within a parametric BIM software system. The analysis activity produces scores for the scheme from each of the dimensions of the Quadruple Net Value. Quantitative analyses of economic, environmental and social dimensions will be computed using software tools that are interoperable with the BIM and can be done largely in an automated way. An immersive visualization system will be used to assess the sensory effectiveness of the scheme. Finally a scheme may be selected for execution based upon comparison of the sustainability dividend of the multiple candidates. The process and the tools are illustrated in Figure 1.

5. Conclusions and next steps

We conclude that a framework for Quadruple Net Value analysis of real estate development projects using a modelling system for rapid creation of designs, analysis tools that are interoperable with the modelling environment, and immersive visualization for sensory assessment is feasible with modest enhancements to current technology. The capabilities of BIM to provide modelling and visualization, rich models, analysis and simulation, parameterization, and software extension all appear sufficiently robust to allow us to proceed with development of the envisioned platform.

Future work will implement a computer-based research testbed using commodity hardware and software. Research will develop custom software that integrates with the BIM tool to facilitate interoperability to analysis tools. Students will be trained in the theory and technique of using the testbed. Empirical studies in our laboratory will test whether the

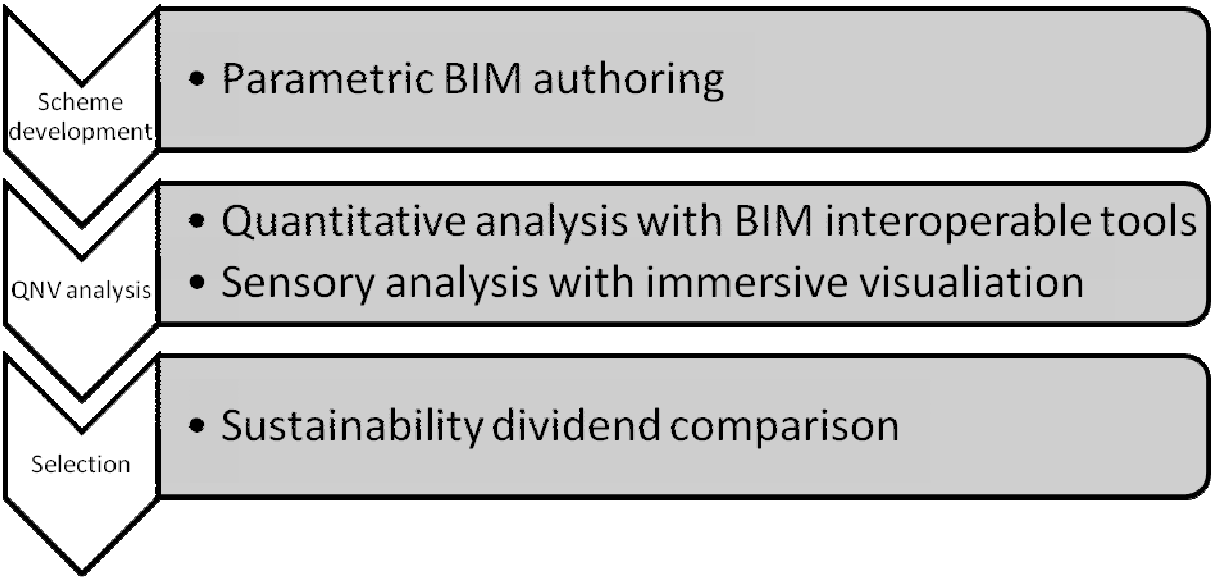

Figure 1. Platform for land and property development.

testbed enables better, more sustainable land and property development projects.

The goal of our research is to produce developments that will not only be profitable, but also will express good citizenship and have lasting appeal. They will be sustainable not only because they meet technical criteria, but also because people want them to be preserved.

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Universities playing in the construction field: how the universities can facilitate collaboration for systemic process innovation

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Implementing Building Information Modeling (BIM) in the construction industry is expected to ease designing and planning, decrease costs and enable customer involvement. In order to meet the expectations, BIM has to be seen as a tool for process innovation that enhances collaboration in a project network. Developing new processes for inter-organizational interaction necessitates mutual understanding, collaboration and coordination. The task is especially challenging in the fragmented construction industry. In this paper, we examine, to what extend academic research using action research methods can facilitate knowledge creation in an inter-organizational network in order to support the development and implementation of a new systemic innovation. The empirical data is collected in a project network, in which nine firms and two academic research institutes were collaborating to develop BIM-based processes. The data is analysed using the knowledge creation framework originally formulated by Nonaka and Takeuchi (1995). The findings imply that active participation of an academic researcher supports mutual trust between different organizations, increase the involvement of the practitioners and enhance the relevance of the results from the view point of practice.

Keywords: knowledge creation, collaboration, building information modelling (BIM), systemic innovation, action research.

1. Introduction

Building Information Modelling (BIM) is claimed to be the catalyst of the paradigmatic shift in construction industry reducing complexity and fragmentation providing ICT tools to process information and collaborate across a project network in a cost-effective way (Succar, 2009). BIM refers to the software and processes which are used to make a 3D digital representation of the physical and functional features of a facility. As defined by National Institute of Building Science in the USA, Building Information Model forms a shared knowledge resource for the stakeholders in the project organization. (A Council of the National Institute of Building Sciences, 2012; Eastman, et al., 2009)

Besides being a huge opportunity, BIM seems to be a huge challenge. The full deployment of BIM has been hindered by practical and political problems, established work processes and business models, and attitudes in the industry. As noted by Harty (2005, pp. 517, 521) BIM

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as a “single Model Environment (SME)” integrating all information and elements and providing the ultimate tool for collaboration and information sharing within a project organization, is at the present only as an official vision. According to Harty’s research, firms are adopting BIM-based practices remarkably slower than its predecessor tools for two-dimensional (2D) computer aided design (CAD). Empirical research has suggested that slowness of the construction industry to implement BIM originates from the networked and complex nature of the project-based production within the industry. The construction industry seems to have no specific problems implementing and diffusing incremental innovations (Taylor & Levitt, 2004; Dubois & Gadde, 2002), unfortunately the fragmentation of the industry makes almost all innovations systemic (Gann & Salter, 2000; Winch, 2003). 2D CAD changed working practices inside an organization, but BIM necessitates coordinated change across the whole project network (Taylor & Levitt, 2007, p. 24; Taylor & Bernstein, 2009, p 70; Harty, 2005, p. 521).

In this paper, we define BIM as systemic process innovation using the division between process and product innovation suggested by Edquist: Product innovations are new or better material goods or intangible services. Process innovations, technological or organizational, are new ways to product goods and services. (Edquist, 2005, p. 182.) BIM as a systemic process innovation is not a new bundle of software to make design in 3D, but a bundle of ICT-tools and processes used to coordinate disparate parts of the construction. In order to meet the expectations, new BIM-based procedures have to be collaboratively developed and coordinated implemented in a fragmented, inter-organizational project network context. In order to ensure the viability of a systemic innovation, the coordination of different parts of the value network is required. In contrast to an autonomous innovation, coordination is needed not only with the suppliers and customers, but also with the producers of complementary products and competitors. (Maula, et al. 2006.)

In order to create a systemic process innovation, different pieces of knowledge from several professionals need to be integrated. However, the pieces of knowledge related to organizational innovation are often tacit or scattered (Egbu, 2004). In order to implement a systemic process innovation in a network, coordination and collaboration is needed. But systemic innovations are typically too complex and required changes are too large that no single integrated firm has enough financial resources or technological and market capabilities to implement a systemic innovation alone. (de Laat, 1999; Maula, et al., 2006.)

Since Gibbon et al. (1994) coined the term “mode 2” to describe locations, practices and principles of contemporary knowledge production that are more heterogeneous than what they used to be, various authors have participated in the discussion, what is the role of universities in the knowledge production (Godin & Gingras, 2000; Hessels & van Lente, 2008). Gibbons et al. (1994, 85) predicted, that universities are going to comprise only a minor part in knowledge production. In this paper, we focus on the role of university research when implementing a systemic innovation. We are not asking, whether or not the main role of universities in the knowledge creation is diminishing, but how the academic research could assist in the problem solving in collaboration with practitioners.

We investigate, to what extend an action research project can participate in integrating knowledge for developing a systemic process innovation in the construction industry and creating a mutual understanding to support the coordination in a network. We have analysed thoroughly a case in which an academic research unit and industry actors have collaborated within an open innovation network in order to develop BIM-based procedures. Earlier studies have shown empirical evidence that research pursuing active interaction with practitioners while planning the study, interpreting results, suggesting implications and testing findings may increase the relevance and usefulness of the research and interest of practitioners (Rynes, 2007; Rynes, et al., 2001). Because learning is a socially constructed process (Nicolini & Meznar, 1995), practitioners and academic researchers, coming from different backgrounds, create divergent possibilities for creating new knowledge.

2. Literature review

2.1 The challenges in creating systemic innovations in construction industry

Research has shown that implementing a systemic innovation in the construction industry is a challenging task. Many researchers agree that the challenges embedded in innovation activities in the construction industry are connected to the project-based production, the complexity of the end product, and the fragmentation of the industry. (Winch, 2003; Taylor & Levitt, 2004; Kadefors, 1995). Harty (2005, p. 513) mentions also how crucial the role of inter-organizational communication and collaboration, and dispersed distribution of power are in innovation activities.

Taylor and Levitt (2004, p. 6) define systemic innovations as “innovations that reinforce the existing product but necessitate a change in the process that requires multiple firms to change their practices. Systemic innovations typically enable significant increases in overall productivity over the long term. But these may create switching or start-up costs for some participants and reduce or eliminate the role of others.” The definition highlights the key challenges of the systemic innovation implementation in a project-based industry.

First of the key challenges is related to the need for coordinated changes among multiple stakeholders. Process innovation typically requires reorganization in the existing system. In the case of a systemic innovation, processes span over organizational boundaries. Because of the fragmentation of the construction industry and complexity of the end product, the construction processes involve multiple task interdependences making the coordination especially challenging (Dubois & Gadde 2002).

Second is the tension between (inevitable) short term costs and (possible) long-time benefits. The systemic character of innovation decreases the ability of a firm to control the benefits and increase the dependency on others. The context in which BIM has to be implemented, is characterized by “multiple inter-organizational relations, complex interdependencies between firms and the lack of a single authoritative driving force that can see through implementation across a whole project” (Harty 2005, 514). According to Maula et al. (2006), optimizing the use of resources within a company may lead to suboptimal situation when the target is to create a systemic innovation.

Third challenge is to achieve changes, not only in the function of the system, but also in the relations of the components in the systems. The actors of the systemic change need to balance between developing the new procedures and maintaining their existing business base (Maula, et al., 2006). The construction industry is an established industry characterized with strong institutions and practises. Researchers have noted that the institutions, which are created in order to manage complexity and decrease uncertainty as well as the costs of transactions may support the established order and hinder the transformation of the industry (Dubois & Gadde 2002, 629; Kadefors, 1995).

Forth challenge is the inter-organizational knowledge creation in project organizations. Researchers have noted that temporary project organizations do not promote cumulative learning and knowledge transfer between projects (Dubois & Gadde, 2002; Taylor & Levitt, 2007). Production based on temporary, unique project organizations is commonly remarked as a feature that is hindering the implementation of systemic innovations in the construction industry (Taylor & Levitt, 2004; Kadefors, 1995; Harty, 2005).

The features of the construction industry turn the attention to the dynamics in a network: How to get the stakeholders of the construction industry from yesterday to collaborate and to pool their pieces of knowledge in order to develop the new procedures for the construction industry tomorrow, when the traditional control mechanism based on hierarchy or integration is not an option.

2.2 Knowledge creation in the relation between the university and practitioners

Basically, innovation is knowledge about how to do things better than the existing state-of-the-art (Teece, 1986, p. 288). Thus, the questions how and where the knowledge is produced and which kind of knowledge benefits innovating activities are relevant for innovation studies.

In their highly influential book “The new production of Knowledge” Gibbons et al. (1994) distinguished a new mode of knowledge creation, “Mode 2”. According to Gibbons et al. (1994), the Mode 2 consists of five constitutive claims describing together the transformation at the research system. First, the knowledge is produced in the context of application. The process of problem solving is organized around a particular application, not inside a particular discipline. Second, the knowledge is produced by transdisciplinary collaboration. The transdisciplinarity principle defines a framework for problem solving, in which the solutions have both theoretical and empirical components and solely arise as an application of the existing knowledge, but require contributions from diverse ranged specialists. The knowledge is also diffused through participants, instead of using institutional channels. Third attribute is the heterogeneity and organizational diversity of knowledge production suggesting that numerous sites, other than scientific universities, take actively part to the knowledge production. Forth feature, social accountability and reflexivity of the knowledge production, refers to the growing sensitivity to the impact of the results. Various interest groups participate actively in defining the research problems and setting priorities. Fifth, as a contrast to mode 1, in which the quality of the knowledge produced is determined through the peer reviewed publications, the quality control at the mode 2 is more broadly based. The

quality of the science outcomes is not determined by disciplinary peers, but also political, social and economic interests are taken into considerations.

The main argument made by Gibbons et al. (1994) is that universities role as the principal locus of knowledge production would diminish while locations, practices, values and principles of knowledge production become more heterogeneous. However, Godin and Gingras (2000, 277) argue that universities using collaborative methods are able to stay at the centre of knowledge production.

The knowledge diffusion between universities and industry is often rigid. Especially broad the gap between research results and deployment of results is in the field of organizational sciences, where the creation and commercialization process of an organizational innovation is more complicated than in the physical sciences (Rynes, et al., 2001; Ramsted, 2009). According to Powell and Owen-Smith (1998), a strong network with university researchers enhances the position of the corporation to solve problems hindering further progress. However, it also requires a strong capacity for identifying and evaluating the results of scientific research and new techniques of disseminating especially organizational innovations for companies. (Ramsted, 2009, p. 547)

Rynes et al. (2001) have discussed strategies how organizational scientists and practitioners might develop the pace and quality of knowledge creation and dissemination through collaborative efforts. They use the framework of knowledge creation developed by Nonaka and his colleagues (E.g Nonaka & Takeuchi 1995) to explain the gap between scientific research and practice. Nonaka`s model of knowledge creation is based on an idea that there are basically two kinds of knowledge. Tacit knowledge is often intuitive, unarticulated and undocumented, context-specific and difficult to communicate. It includes cognitive patterns as well as technical knowledge. Explicit knowledge is documented and structured and it can be transmitted in formal, systemic language. According to Nonaka and Takeuchi (1995), knowledge creation is a cyclical process comprising four phases of knowledge conversion: Socialization (from tacit knowledge to tacit knowledge), externalization (tacit to explicit), combination (explicit to explicit) and internalization (explicit to tacit).

In socialization, tacit knowledge is exchanged through joint activities such as individuals learning together in order to create shared understanding or a mental model. Successful socialization is difficult to achieve without face to face experience. In externalization, tacit knowledge is converted into tangible forms such as metaphors, hypotheses and models. In combination, pieces of explicit knowledge from different sources are analysed in order to produce a new synthesis. Combinations of explicit knowledge comprise the majority of scientific contributions published in journals. Explicit information is also transmitted from scientific researchers to practitioners through books and practice oriented publications. In internalization, explicit knowledge is converted into tacit knowledge through learning by doing. (Nonaka & Takeuchi 1995; Rynes et al. 1995.)

Rynes et al. (2001) argue that organizational science is focused excessively on making explicit knowledge explicit through the new combinations of theories. There are three kinds of implications. First, researchers fail in the mobilization and conversion of tacit knowledge that

should be fundamental in knowledge creation according to Nonaka and Takeuchi (1995). Second, also the majority of the publications aimed at practitioners fail in integrating practitioners and academic perspectives and are only either combining explicit scientific theories or translating them to the presumed practitioners' language and format. Third, without a successful socialization of the new knowledge, attempts to transfer explicit knowledge across organizational boundaries are likely to fail.

Rynes et al. (2001) propose that collaborative methods, such as action research, provide both researchers and practitioners an opportunity to increase tacit knowledge. Transdisciplinary collaboration within diverse set of people with different interests and backgrounds are vulnerable to conflicts. There are also evidences (Rynes et al. 2001 346-347) suggesting that certain "creative tensions" springing from interactive dialogue between different disciplines, between different types of knowledge and between theories would enhance the quality and rate of knowledge creation. Rynes et al. encourage researchers to seek tensions between academic-practitioner interactions instead of trying to avoid them (Rynes et al. 2001 pp. 346-349).

3. Methodology

The central phenomenon, knowledge creation between a university and practitioners for a systemic innovation, was approached here with a case study. The other researcher participated in a research project where companies were involved and at the same time, she collected the data with qualitative methods. The authors of this paper are working in Aalto University within a research consortium developing the construction industryThe case can be seen as an action research project because of the contribution to solve a practical problem and the research are made in joint collaboration between practitioners and researchers (Rapoport 1970, p. 499).

The action research method utilized in the case project is called SimLab™ process simulation method (Smeds, et al., 2006). During the action research project, researchers prepare and implement a social process simulation in collaboration with the case stakeholders usinga visual process map. The primary data consists of the observations, notes and video recordings of the meetings between researchers and case companies and the simulation day. The secondary data includes documents, interviews and the feedback questionnaire answered by the participants of the simulation day. The data was gathered during the first half of 2011. We use Nonaka's framework of knowledge creation circle to capture relevant moments from the perspective of knowledge creation in the interaction between researchers and practitioners during the case project and to analyse to what extend academic scientists deploying action research methods may meet the challenges originated from the features of construction industry, facilitate knowledge creation in a network, and support BIM implementation.

4. Case description

The research project case is conducted as a part of a larger research project, which is initiated, supervised and mostly financed by Finnish government. The research project forms

a consortium which is composed of nine firms and two research institutes. Industry shareholders compose the majority and research units the minority, which characterize the network as industry-driven. The common objective of the research consortium is to study and develop a new business model and new practices based on BIM for the Finnish construction industry. The studied case is a part of a larger three year research project.

The target of the case project was to create common understanding how BIM is used in Finland in inter-organisational processes during the design and construction of a building and what are the main challenges and bottlenecks in the inter-organisational collaboration and coordination. The case project was based on a real construction project where a school was designed and built in eastern Finland utilizing building information modelling.

The method consists of seven steps. First, the common objectives of the simulation project are formulated together. For that reason, a face to face meeting was organized with case companies and researchers. Second, the first rough process model is made by researchers based on tentative analysis of the case. In the case project, the tentative process model was formulated in a meeting, where two focal actors in the construction process with the help of researchers formulated the first version of the process model. Third, all the key actors are interviewed and the process model is refined based on the interviews. In the case project, altogether 18 semi-structured individual or group interviews were conducted in order to achieve holistic perspective on the process. During the interviews, the first version of the process model was validated and improved.

The culmination of the simulation project was the simulation day, when all the key stakeholders were gathered in one room to develop the process together. In the case project, 47 incumbents of the project or members of the research consortia participated in the simulation day. The researchers acted as facilitators of the simulation during which representatives of every key actor of the process explained the process from their own perspective. The visual process model was used as a boundary object. The discussion on simulation day was focused on the key challenges on the process. On the second half of the day, the participants were split up into smaller groups. Each group had a specific question or theme, which were selected based on the propositions made by participants. After the simulation day, the data gathered during the interviews and simulation day was analysed and results were published in a report that was shared with the participants.

Findings

4.1 Knowledge creation

The result of a successful **socialization** is a shared understanding that can be used as a foundation for the further knowledge creation. Because it requires participants to understand and accept the perspectives and beliefs of the others, it is difficult to achieve without close interaction. In the case project, the attempts of socialization were found at two levels: 1) between practitioners and researchers and 2) between different specialists and practitioners across the construction project network. Face-to-face meetings between case companies and researchers were used to define the objectives and targets of the research project.

Involvement of practitioners to the research project design increased the commitment of the case companies and assisted the researchers to focus on questions that had practical relevance. The role of researchers enhancing knowledge socialization within a construction project network was first to provide a shared place and time, and organise and facilitate the discussion between practitioners.

In **externalization**, tacit knowledge is made explicit. In this action research project, researchers facilitated the externalization of the tacit knowledge gathered from practitioners. In this case, 1) one tool used to transform the tacit knowledge into a concrete and tangible format was the visual process model. It was found as a practical way to express the complex construction project in a simple manner, so that the participants could get the picture of the process as a whole and understand the reciprocal interdependences between the tasks, eventually promoting mutual understanding. During the simulation day, the process model was used to identify and communicate the focal interaction point of the inter-organisational interaction. 2) Another tool was the final case report, where the identified best practices and specific challenges were linked to the process model to assist companies design their own processes. 3) The researchers also facilitated the externalization of tacit knowledge during the interaction between case companies and researches by gathering, articulating, formulating and documenting the common targets and boundaries of the project.

In **combination**, external knowledge is combined with external knowledge from different sources in order to create new knowledge through synthesis. 1) In this action research project, the focus was on combining different perspectives and pieces of knowledge gathered from the practitioners within the value network. 2) From the perspective of the researchers, the main function of the action research project was to collect empirical data. The combination between scientific theory and practitioners' tacit knowledge was a subject for further studies. 3) According to feedback from industry incumbents, a focal benefit of the action research methods applied in the case project was their ability to combine perspectives and information from all of the key organizations in the project network at several levels. For example, the software developer did not know that certain modeling programs were used at the construction site.

In **internalization**, the created explicit knowledge is transformed to tacit knowledge. 1) At the level of research consortium the knowledge achieved during the first simulation project was used as a shared experience further in the case project. 2) At the level of practice, the kn knowledge created during the simulation day was diffused through participants. As a part of final report the list of identified best practices and summary of the project results were used to ease the internalization process.

4.2 Creative tensions

As suggested by Rynes et al. (2001), we paid attention also to the tensions appearing in the data. 1) During the discussion during simulation day, focal tensions stemming from the BIM implementation were related to the allocation of resources used and compensation received during the development of the new procedures. For example, if the BIM use at the

construction site or in the maintenance will require more exact and time-consuming modeling from designers, who should be responsible for paying for it.

2) Another tension emerged between the different attitudes to changes and schedules of different designers. From the perspective of the architect, the creative design phase characterized iteration and changes should go on as long as possible. From the viewpoint of the structural engineers, the central structures of the building should be determined as early as possible. Solving this kind of fundamental tensions between practitioners in the project network was beyond the scope of the case project. But identifying the sources of the contradictions, making them explicit through visualisation, and increasing mutual understanding within the network, the use of action research prepared the network to compromise.

3) Most tensions between the researchers and practitioners stemmed from the different opinions concerning the format of the results. Based on the feedback gathered from the participants, the practitioners were generally pleased with the results of the action research project, but more concrete, detailed and short list of suggestions based on the project results would have been appreciated.

5. Conclusion

In this paper, we have examined how academic research using action research methods can facilitate the knowledge creation in order to support the development and implementation of a systemic process innovation such as BIM implementation in the construction industry. According to our findings, action research methods may facilitate the knowledge creation within the construction industry. The case project also reflected the elements of mode 2 knowledge production as defined by Gibbons et al. (1994) and thus participates in discussion about the universities role in innovation processes.

In the case project, the socialization of the tacit knowledge was promoted in face-to-face meetings and facilitated the discussion. The research project was able to integrate representatives from all of the key organizations in the project network that helped participants to create an overall picture of the whole construction process. The understanding of the overall process can be seen to form a shared mental model that can be used as a framework when moving further in the knowledge creation process. Achieving mutual understanding of the impact of BIM implementation seemed to be especially beneficial in the construction industry, which is characterized with complex end products and the fragmentation of the production network involving several different specialists. As the case project increased the researchers` understanding about the phenomenon and produced quality and rich data to use for scientific study, the interactive action research methods may also have enhanced the quality of the academic research and the relevance of the results, as suggested by Rynes et al. (2001).

In the case project, the most important tools for converting tacit knowledge into a tangible format were a visual process map and the final report. The visual process map was used to integrate the different perspectives of the different organizations and represent the complex

interdependencies of the individual tasks in a simple manner. The accurate presentation of the complex interaction point can also be used to coordinate change that was identified as a crucial challenge during BIM implementation based on the literature. For example, the visualization helps to identify, which problems can be solved by developing software and what can be solved through education and instructions. In the final report, the key challenges were gathered and best practices were identified from the project. In the project-based industry such as the construction industry, documenting the lessons from a project in such a detailed manner may facilitate the knowledge transfer between projects and thus enable diffusion of BIM practices.

The knowledge combined during this case project was mostly practical. Combining the theoretical knowledge with practical knowledge gathered during the case was left beyond the scope of this case study, however the empirical data gathered during the project also is a part of academic research. The combination of the different perspectives across the project organization facilitated inter-organisational learning. Most organizations were well aware of their own processes, but did not know how they were affecting the function of the other organisations within the network. Combining different attitudes, in a manner of speaking, opened the interfaces of individual organizations to be used in inter-organisational process development. The role of researchers as a neutral facilitator was seen to be beneficial to balance power distribution and thus relieving tensions in the project network and facilitated the collaborative knowledge creation. The internalization of the knowledge produced during the case project was mostly left for the companies. Most of the results of the research project were not ready to be implemented as such, but required development and application. That created minor tensions, because some of the participants would have like to get more ready, consulting-style answers to their practical problems.

Elements of Mode 2 knowledge production can be identified. The most evident element is the knowledge production in the context of application: The knowledge produced during the case project was intended to have direct practical relevance. The quality of the scientific publications is determined by disciplinary peer review judgements but the benefits of the action research project in general are evaluated more broadly, as in Mode 2. The transdisciplinarity in the case project stemmed not from the collaboration of scientists utilizing methods and theories from different disciplines, but from the collaboration of diverse set of specialists with different academic or practical background. In addition, the results were diffused in the first instance by the participants and only in the second instance through institutional channels reporting results in professional journals. In regard to heterogeneity and organizational diversity of knowledge production, academic research in the action research case project did not have a monopoly of knowledge production, but it still had a crucial role.

To conclude, action research methods seems to be a way to bridge the gap between practice and theory. The organization researchers have much to achieve, if they come down from the theoretical ivory tower. It seems that the action research methods used in the case increased the involvement and interests of the practitioners and enhanced the relevance and applicability of the results of the project. We are not urging researchers to abandon theoretical studies. Theoretically focused research could be seen as a link to the knowledge generated by other researchers on the other part of the world. For the practitioners in

construction industry, scientific research may be the way to get rid of the grass root perspective and achieve a radical paradigmatic shift. Theoretical ivory towers are advantageous if they are used to get higher and to look further.

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Can programs such as the Master Builder Green Living Program improve the capacity of builders to respond to sustainability issues in construction?

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Abstract

The increasing importance in the marketplace of sustainability features in both domestic and commercial construction has seen the development of the Master Builder Green Living program to improve the ability of building practitioners to respond to these requirements. In the commercial sector builders are increasingly asked to respond to developer or tender requirements that require them to meet a number of sustainability objectives. At the domestic level many consumers only contact with the building industry is through a builder. The program provides builders with practical solutions on sustainability relevant at all stages of the construction process in an easy to digest format which in turn increases the likelihood of effective implementation.

Consumers interested in addressing sustainability issues during the construction or renovation of their homes can seek out these builders. By bringing together like minded individuals the chances of improved sustainability outcomes for everyone are increased. Through education the Green Living Master Builder becomes a key advocate for the adoption of sustainable solutions. On successful completion of assessment the participants are awarded a nationally recognised unit of competency. Career pathways are opened subsequently for the builder who seeks opportunities in the field of sustainable construction.

This paper explored the ability of programs such as the Master Builder Green Living Program to improve the capacity of builders to respond to sustainability issues in construction. Over 850 building practitioners have been trained by Master Builders Victoria since 2006. In this case, the self reporting received as a part of an accreditation program has shown a range of positive sustainability outcomes from Master Builder Green Living Builders including for the year 2012, a reduction of 523 tonnes of CO_2 emissions and the diversion of 1010 tonnes of waste from landfill.

Keywords: sustainability, building, energy efficiency, training.

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1. Introduction

The Master Builders Association of Victoria is a member organisation that represents approximately 9000 commercial and domestic builders. As a registered training organisation it is also responsible for providing industry training to more than 14,000 participants annually. The majority of this training is linked to legislative requirements in the fields of Occupational Health and Safety. In order to encourage and facilitate individual career pathways and development, the majority of courses are linked to accredited outcomes particularly units of competencies and or qualifications from national training packages.

Building and Construction Industry practitioner needs inform the selection and development of the training courses. Many of the participants come from a range of educational backgrounds that range from unskilled construction workers through to tertiary qualified project managers. In the past this has resulted in a general lack of training culture. The diversity of cultural and education backgrounds can also be a challenge and in this case participants are provided with comprehensive training support in the form of a Workplace English Language and Literacy (WELL) program. Participants are also challenged by the realities of tight project timelines and the cost of time release offsite means that there is a need for flexibility such as offering short blocks of half days or days over a period of weeks.

While the majority of this training is linked to legislative requirements there is an increasing awareness that sustainability outcomes are becoming an increasingly important part of the building process. As a result Master Builders Victoria in partnership with a number of State Government entities has developed a multifaceted education strategy. This consists of a full time Sustainability Officer whose broad brief is to ‘educate’ the industry and help to stimulate the adoption of sustainable practices. This takes a variety of forms including;

- Site visits to provide advice
- Telephone advice
- The development of training programs and units to be incorporated into other training programs
- Research and reports back to members on the findings
- Presentations and question and answer sessions at trade nights and section meetings in regional Victoria.

2. Industry sustainability programs

Often the first point of contact for people contemplating the construction of new houses or renovations is through a builder. Domestic builders and other trades have experienced an increase in questions from their clients about sustainability issues, helping to raise the awareness amongst builders of the importance of incorporating sustainability into their operations. This has subsequently driven the demand for increased information from industry associations that has led to the development of a number of programs.

These associations are most often well placed to present the required information in a format that is accepted by participants that usually do not have a strong academic

background. There is a large amount of information available on improved sustainability outcomes in the construction sector. The challenge is to be able to translate this information from the academic to a series of goals, strategies and techniques understandable to and accepted by builders.

These programs include those that are delivered by builder associations such as the Housing Industry Association's (HIA) GreenSmart program (HIA n.d.) and in the United States, the National Association of Home Builders certified green building professionals program (NAHB 2013). There are also a number of programs delivered by or developed by trade associations and private entities such as the EcoSmart Electricians (National Electrical and Communications Association 2009), the GreenPainters (Green Painters Ltd n.d.) and the Green Plumbers (Green Plumbers n.d.). These programs all provide an incentive by identifying the practitioner as having completed extra training in the sustainability area. They can then use branding to set them apart in the market.

2.1. The Master Builders Green Living training course

The Master Builder Green Living program is designed to provide builders involved in the residential sector with improved management and business skills to enable them to pursue energy innovations in their constructions. These include the necessary tools and information to identify design features of energy efficient structures that not only meet minimum standards but set a new benchmark in the housing sector for energy innovation. The builder is also able to improve their customer service by providing informative advice to clients about sustainable solutions in the design and construction of their dwelling.

This innovative program focuses on sustainability issues relevant at all stages of the construction process from important design considerations through materials selection and site management to interior fit out and health considerations. The information is easy to digest and focuses on common sense, practical solutions that are not necessarily expensive.

The other benefit for the builder is the linking of the program and work practices with a unit of attainment from the national training system which encourages further training for a nationally recognised qualification. The program was initially developed by the Institute of Sustainable Futures for Master Builders through an Australian Greenhouse Office grant in 2005. Since then the program has been further developed by Master Builders Victoria in response to changing industry needs, techniques and products. Over the last 6 years, Master Builders Victoria over 850 builders have completed the 2 day training program (Table 1). Master Builders Victoria has also assisted other Master Builders to present the program in Western Australia, Tasmania, Queensland and the Australian Capital Territory.

Table 1: Green Living course enrolments.

Year	Courses	Numbers
2006	4	39
2007	5	77
2008	8	125

2009	8	150
2010	9	182
2011	12	164
2012	8	120

Associated branding allows builders who have completed the Master Builder Green Living program and become accredited to be identified as builders that view sustainability issues as an important part of their business. This gives consumers interested in addressing sustainability issues during the construction or renovation of their homes the ability to seek out these builders. By bringing together like minded individuals the chances of improved sustainability outcomes for everyone are increased.

The Master Builder Green Living Program consists of a 2 day course, an accreditation system and the provision of a number of resources. It focuses on the often used, reduce, reuse and recycle message and considers the need to reduce impacts, energy consumption and water use in the first place. The program then explores a group of ideas that have a big impact on minimising the environmental impact of the house, without necessarily imposing an increased cost.

The Training Course is structured in a manner that follows the building cycle. It commences with a look a number of environmental issues such as greenhouse gas production and biodiversity loss and the impact of construction on these issues.

It then looks at the importance of project planning by emphasising the importance of thinking about sustainability features right from the beginning of the project. This is where features can be easily incorporated into the building project at minimal additional cost, as they are integrated at the design phase.

The importance of design is then introduced, in particular passive solar design ideas. Once again the focus is on providing ideas that will reduce operational energy use and environmental impact without necessarily introducing additional costs.

The next few topics address the environmental issues to be considered during the construction phase such as on site management, waste management and erosion and sediment control. Materials selection used in the framing and structure and the building envelope becomes important when we consider, where these materials come from, their recycled content and embodied energy. Concepts such as sustainably sourced and grown timber resources are also introduced.

Methods to reduce water and energy use are then explored by focusing on the big users and easy methods to reduce consumption. The importance of design considerations are not forgotten as a series of activities allow the participants to apply the ideas to real plans. These practical activities deliver a number of other outcomes such as group work and the sharing of ideas.

Once the construction of the building is completed the issues to be considered during interior fitout are explored. As well as again looking at the importance of materials selection and embodied energy, indoor air quality is introduced as a topic. The potential health impacts from emissions given off by solvents, glues, carpets and paints used in homes are investigated, as well as the methods to reduce or eliminate them.

The final topic covers business strategy and discusses methods to incorporate what they have just learnt into their day to day operations to make the whole process as easy as possible. In order to sell their increased knowledge of sustainable construction the accreditation process is discussed and a number of ideas of how to best use the brand to differentiate their business from others in the market are introduced.

2.2. Resources

The goal of the program is to increase the chances of builders incorporating sustainability considerations into their developments. A number of resources are issued to participants during the course in order to make this process as easy as possible.

As well as a set of training notes, a checklist is distributed as part of the Green Living domestic builder course. It is designed for the builder to use with their client to determine the range of environmentally friendly options to be incorporated into their development. This not only helps to remind the builder of the options available but also helps to clarify the client's requirements. The checklist follows the construction process and considers outcomes concerned with passive solar design, materials selection (environmental impact and embodied energy), water and energy conservation, recycling and indoor air quality.

All participants are also issued with a list of useful resources which is continually updated on the Master Builder Victoria Green Living webpage (www.mbav.com.au/training/greenliving.html). This list of useful suppliers and resources is once again designed to make the process of finding environmentally preferable materials as simple as possible. If the sourcing of a product or service becomes too difficult it is likely to be dismissed by the builder.

Participants are also given a copy of the "Your Home" manual (Department of Climate Change and Energy Efficiency 2010), a technical guide to environmentally sustainable homes. The guide provides participants with additional information that they can read at their leisure or use as a future reference.

Once builders complete the program they continue to be supported through e-newsletters and an annual workshop. The newsletter, which is sent out tri-monthly, is able to keep Master Builder Green Living builders updated on regulatory changes, events that may be of interest and useful new products and resources. A one day workshop is also held annually which includes guest speakers from government who are able to provide insight into proposed regulatory changes, industry speakers and useful product suppliers. This also provides an opportunity for the builders to seek clarity by having their questions answered. Each year a number of builders are also asked to speak about their own developments. This

is often well received by the attendees as they are able to hear from a real builder about some exciting projects, how they overcame various problems and what they found useful along the way.

2.3. Accreditation

The accreditation process is the main point of difference between the Master Builders Green Living program and other similar program identified previously. The accreditation not only identifies people who have completed the program but those that remain committed by completing an annual reaccreditation process.

Only Master Builders members who complete the two day training program and sign a written commitment are able to refer to themselves as Master Builders Green Living Builders and to use the associated branding. The signing of a written commitment significantly increases the chances of the person putting a verbal commitment into action (McKenzie-Mohr and Smith 1999). The commitment includes:

- submission of an annual report to Master Builders that includes information and details on the total number of residential projects, their NatHERS energy rating and the number of rainwater tanks and solar systems fitted

- an estimate of the amount of material recycled or diverted from landfill

- an assurance that sand, soil, screenings, concrete and chemicals were confined to the building site (completion of annual report declaration).

The annual report is required from the builder in order to continue to maintain their accreditation and is considered to be evidence of sustainable strategies being put in place. On provision of this evidence participating builders can continue their accreditation and also be eligible to receive a nationally recognized statement of attainment for the unit of competency demonstrated - CPCCBC4020A Build thermally efficient and sustainable structures.

2.4. Other related courses

With the increased popularity of ecologically sustainable developments and Green Star projects, there is an increased requirement for commercial builders to be more familiar with these concepts. As a result a number of new courses have been developed by the Master Builders Association of Victoria in recent years.

2.4.1. Sustainable Construction – Commercial

This hands-on course provides guidance on how to understand and respond to developer or tender sustainability requirements and for site managers and contractors to comply with environmental requirements on site. At the end of the course participants will have produced

their own environmental policy and management plan which can then be adapted for other projects.

This program is similar in structure to the domestic program but differs by focusing on issues related to commercial developments. There is more emphasis on site management, environmental policies and site management plans, ratings systems such as Greenstar and uses case studies of commercial buildings. The program is supported by a DVD produced by the Master Builders Victoria.

2.4.2. Certificate IV in Building and Construction (Environmental Management)

This qualification was developed by Master Builders Victoria and first delivered in 2009. The course was aimed at people with a strong sustainable building focus or people working on building sites, who were finding that complying with onsite environmental requirements was becoming part of their role. The topics covered are similar to those in the Sustainable Construction course, but include more detail around legislation, monitoring and environmental management plans.

3. Method

As stated previously those builders who wish to become accredited Master Builder Green Living Builders must provide an annual report as part of the reaccreditation process. The information collected from this self reporting includes;

- The number of projects completed in the last 12 months
- The number of projects where waste was recycled
- The number of new projects and renovations
- The volume of waste generated
- The volume of this waste diverted from landfill
- The processes put in place to prevent discharges to storm water
- The number and size of rainwater tanks
- The number of photovoltaic systems fitted
- The number of solar hot water systems fitted.

The information from these self reports is collated and the mean values for each category were calculated.

4. Results and achievements

As of December 2012, 863 builders have completed the Master Builders Green Living program, 63 the Sustainable Construction – Commercial program in Victoria and 78 have completed the Certificate IV. Importantly 45% or 387 of those who completed the Master Builder Green Living course have signed a written commitment to incorporate sustainability objectives into their day to day operations and are accredited.

Results compiled from reports submitted by the builders as part of the accreditation process indicate that during 2012;

- On average each of these builders are working on 11 projects per year covering 4137 building sites (11*387).
- 89% of these sites are recycling 56% of their waste or 1010 tonnes diverted from landfill.
- all these sites are controlling discharges to the storm water system.
- 41% of the sites had rainwater tanks fitted that averaged 12,500 litres in size.
- 39% of these sites have solar hot water and 5% photovoltaic panels.

Five percent of 4137 building sites = 192 photovoltaic panel systems. If we assume that each system is on average 1.5 kilowatts in size and produces on average 6 kilowatt hours of electricity each day, then they produce approximately 420,000 kilowatt hours per year. If we assume each megawatt hour of brown coal fired electricity produces 1246 kilograms of CO_2 (Australian Gas Association 2000) then this equates to a saving of 523 tonnes of CO_2 each year.

5. Conclusion

Feedback from course participants has been excellent indicating that the information is presented in a format that they respond positively to. In evaluations completed at the end of each course 96% of participants rate the course as very good or excellent. There are also numerous comments on how useful they found the discussions and ideas shared with other like minded builders.

Providing training in a practical easy to follow format that is complemented by a variety of tools, ensures that builders feel more confident when discussing environmentally friendly practices with their clients. Providing improved training for builders in a format they are comfortable with and identifying builders, who have an interest in providing more sustainable housing, increases the chances that consumers who want these outcomes make contact with the appropriate person.

This approach results in an improved level of cooperation between client and builder which in turn increases the range and likelihood of these practices being incorporated into new developments. In this case, the self reporting received as a part of an accreditation program has shown a range of positive sustainability outcomes from Master Builder Green Living Builders.

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Cost Effective Energy Savings in Australian Commercial Buildings to 2020

Phil Harrington[1], Trevor Lee[2], David Devenish[3], Phil McLeod[4]

Abstract

This paper analyses the level of cost-effective energy savings that new commercial buildings could achieve in Australia by 2015 and 2020, relative to buildings compliant to the Building Code of Australia (BCA2010). It draws on research undertaken by the authors for the Australian Government (Department of Climate Change & Energy Efficiency). The study involved modelling typical a healthcare/hospital building form, a supermarket form, and 3-storey and 10-storey office building forms in all capital city climate zones in Australia, at a range of energy performance levels down to zero net energy (where achievable).

The results show that there are very significant cost effective opportunities for energy savings in new commercial buildings in Australia even by 2015, and greater opportunities by 2020. While there are variations in the degree of cost effective savings by climate zone and by building type, these variations are around mean values which are high and quite robust in the face of the sensitivity analyses included in the study. Savings of between 54% and 80% are shown to be cost effective for commercial buildings in the Base Case (*i.e.* on current policy settings), with an average value of 68% by 2020. This high level of cost effective savings is attributed primarily to the relatively low stringency for commercial buildings in BCA2010, which means that many opportunities for energy savings that were cost effective at that time were not taken up. Energy prices for electricity and gas, and also the mix of fuels used in different building types and climate zones, influence the results. With rising energy and carbon prices through time, more such opportunities also become cost effective by 2020.

Keywords: commercial buildings, energy savings, cost effectiveness

1. Background

The study from which the results are drawn is a contribution to the National Building Energy Standard-Setting, Assessment and Rating Framework measure described in the *National Strategy on Energy Efficiency* (NSEE), approved by the Council of Australian Governments (COAG) in July 2009 (COAG 2009). The COAG Framework aims *inter alia* to lay out a pathway for future stringency increases in the Building Code of Australia (BCA) to 2020, in

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order to increase certainty for stakeholders and to facilitate strategic planning and innovation by industry. The study commenced in the first half of 2011, and initial assumptions on gas electricity prices were revised to take into account the carbon price. It should also be noted that assumptions on photovoltaic costs are in hindsight conservative, with costs having fallen more dramatically than assumed in the modelling.

2. Methodology

This section outlines the approach used to undertake the study.

2.1 Building types

Four commercial building types form part of the study; a 3-storey and 10-storey office building, a supermarket, and a health-care building.

2.1.1 3-storey and 10-storey office building details

Table 1 below shows the details of the 3-storey and 10-storey office buildings. The Base Case assumes minimal compliance with BCA 2010 using conventional technologies, such as variable air volume (VAV) HVAC plant with economy cycle and hot water terminal reheat, and air cooled chiller and gas-fired boiler with 80% efficiency.

Table 1: 3-storey and 10-storey office form

	10-Storey Office	**3-Storey Office**
Area Total (GFA)	10,000 m^2	2,000 m^2
NLA	9,000 m^2, (10% services and common areas)	1,800 m^2, (10 % services and common areas)
Ratio of length to width	1:1	1:2
Storeys	10 storeys of 3.6m overall height each	3 storeys of 3.6m overall height each
Floor Plan	Carpeted, open plan within zones	
Replication	All floors identical	
Occupancy	1 person per 10 m^2 of NLA	
Ventilation	7.5 l/s per person	
Internal loads	15 W/m2	
Electric hot water	4 litre/person/day	
Lighting	Offices- 9 W/m^2 Services & Common areas - 5 W/m^2	
Air changes	Allowance of 1.5 l/s.m2 for the perimeter zone	
Lifts	Annual energy consumption 24 MWhr.	

Source: Engineering Solutions Tasmania and Energy Partners

Table 2 below shows the HVAC details for the 3 and 10-storey offices.

Table 2: Office building HVAC details

	10-Storey Office	**3-Storey Office**
Zoning	4 perimeter zones, 1 interior zone. Central core unconditioned. Note the zoning visible in the figure above. The perimeter zones are 3.6m deep.	
Plant type	Central plant, VAV with economy cycle and hot water terminal reheat	
Boilers	Gas-fired with 80% efficiency	
AHUs	Single AHUs for each zone, *i.e*. 5 AHUs serving whole building	
Control Strategy	14°C supply air temp which is reset in the perimeter zones based on room temperature.	

Source: Engineering Solutions Tasmania and Energy Partners

Table 3 below shows the glazing details of the office buildings.

Table 3: Office building glazing details

Location	**U-Value**	**SHGC**	**Fenestration height**	**Window to Wall Ratio**	
				External	**Internal**
Climate Zone 1	4.7	0.44	0.9m	25%	31%
Climate Zone 2 & 5	4.7	0.44	1.2m	33%	41%
Climate Zone 6	3.4	0.38	0.9m	25%	31%
Climate Zone 7	3.4	0.41	0.9m	25%	31%

Source: Engineering Solutions Tasmania and Energy Partners

2.1.2 Healthcare Building

The Healthcare model is similar to the 10-storey office building but reflects the greater importance of external views for patient care and has a 2:1 length to width ratio compared with 1:1 for the office building. The healthcare simulation is based on guidance provided by the BCA under the simulation protocol for a Class 9a Ward and that of actual experience with a healthcare facility as provided by Partridge et al (2008). Table 4 below summarises the Healthcare building details.

Table 4: Healthcare building details

Storeys	10
Ratio of length to width	2:1
NLA	9,000m^2
Occupancy	Ward: 1 person per 10 m^2 Treatment: 1 person per 5 m^2
Hot Water	70 litres/patient.day 430 patients total Gas-fired boiler (80% efficiency)
Internal Loads	Ward: 5 W/ m^2

	Treatment: 15 W/m^2
Lighting	Ward: 10 W/m^2 (Continuous) Treatment: 7 W/m^2 (JV3 Profile)
Plant Operation	24/7
Lifts	147 MW/hr annual energy consumption

2.1.3 Supermarket

The Supermarket model is a typical suburban, standalone, single-storey supermarket. The external walls are steel clad, insulated with glass fibre quilting and building foil, and lined internally with plasterboard. The building is all-electric with space cooling dominating energy use. A ducted direct expansion heat pump system (Constant Air Volume (CAV) HVAC) is used in the BCA2010 solution. Space heating is limited to cooler climate zones, where it makes up a small portion of total energy use. The building dimensions, insulation details and window areas of the BCA 2010 supermarket are shown below in Tables 5, 6, and 7, respectively.

Table 5: Supermarket building dimensions

	External Wall Dimensions (m)	**Internal Floor Dimensions (m)**
Width	79.8	79.3
Depth	53.4	52.9
Ceiling Height	4.2	

Source: Energy Partners

Table 6: Supermarket insulation details

Climate Zone	**Insulation Type**	**Total R-Value (m^2K/W)**	**Total U-Value (W/m^2K)**
1 and 2	Medium Weight Glass Wool (high performance panels)	3.37	0.297
5, 6 and 7	With EPS Expanded Polystyrene (Standard)	2.808	0.356

Table 7: Window area (front of building) to meet DTS when facing north

Climate Zone	**1**	**2**	**5**	**6**	**7**
Height of Window (m)	2.12	2.12	2.25	2.23	2.06
Total Width of Window (m)	53	53	53	53	53
Window Area (m^2)	112.36	112.36	119.25	118.19	109.18

2.2 Energy saving improvements

Starting with a BCA 2010 minimally compliant design using standard technology, the energy consumption baseline of each building type was established. Then, using the thermal analysis package, 'Virtual Environment' Version 6.2, the Base Case buildings were modelled with various improvements in order to meet increasingly higher energy performance levels: BCA2010 –40%, BCA2010 –70% and BCA2010 –100% (or zero net energy buildings). Modelling was undertaken in each state/territory capital city climate zone of Australia.

Table 8 below summarises the key variations modelled[5], for both office buildings and the health building, to achieve the required performance levels.

Table 8: Energy savings improvement to Health building and Offices

Health Building and Offices		
40% energy reduction	70% energy reduction	100% energy reduction
• Increased insulation levels (including lower U-value glazing) • Improved HVAC • Reduced infiltration to perimeter zone of building • Condensing boilers for HW • Regenerative braking in lifts [6] • Lighting improvements (lower W/m^2)	• Further lighting improvements • Advanced glazing • Co-generation in 10-storey office (cold climates only), • Trigeneration (health building) • Preheating hot-water (through PV or cogen) • Roof-top photovoltaics	• Reclaim ventilation • 'Switchable' glazing • Trigeneration (10-storey office) • Maximum utilisation of PV

Table 9: Energy savings improvement to Health building and Offices

Supermarket		
40% energy reduction	70% energy reduction	100% energy reduction
Same as 3 storey office, expect: • Greater improvements in lighting • Improved insulation to cold and freezer rooms • More efficient refrigeration cabinets • CAV HVAC	Same as offices except; • Further lighting improvements • More efficient CAV	• Solar HW • Refrigeration Cabinets to HEPS with selective heat sink to ambient • Advanced fenestration SHGC to suit climate • Maximum utilisation of PV

[5] Comprehensive details of energy saving improvements, and savings that individual improvements provide, can be found in the report at http://www.climatechange.gov.au/publications/nbf/pathway2020-increased-stringency-in-building-standards.aspx

[6] Note that regenerative drive systems reduce Base Case lift energy consumption down to 17.6 MWhr and 107.8 MWhr for the office and health buildings respectively. They are considered in all the reduced energy scenarios.

The implementation of Cogen/Trigeneration systems affected the design strategy of the building, in that the availability of 'waste' heat from these systems means that the building needs to be designed to minimize the cooling requirements rather than heating requirements. As a result improving the energy performance of the building involved balancing the availability of waste heat and the U-values of windows. Furthermore, it was found that there was noticeable difference in the glazing requirements of the Health building (24 hour operation) and the Offices. For the office buildings in warmer climates, the same reductions in U value as the Health building could not be justified since they generally benefit from being able to passively release heat through windows at night.

2.3 Cost estimation

A quantity surveyor, Davis Langdon, provided cost estimates associated with achieving the different energy performance levels for each building type and climate zone studied, based on the building specifications detailed above. Regional variations in the costs of plant and materials, as well as climate zone based variations in the building specifications, were taken into account. The analysis provided a commercially-relevant incremental cost to be established for improving each building type to the required 40%, 70% and 100% energy savings relative to BCA2010. The *incremental* or additional costs of each scenario relative to the BCA2010 Base Case were then calculated as an input into the benefit cost analysis.

2.4 Benefit Cost Analysis

The benefit cost analysis considered the value of (purchased) energy savings over an assumed 40 year building life arising from the higher energy performance requirements modelled, compared to the energy costs that would have been incurred had the same buildings been constructed to BCA2010. This means, for instance, that energy derived from a building's PV installation is represented as a reduced requirement for purchased electricity[7]. Separate calculations were made for each scenario, building type, climate zone and performance level from 2015 (the first year in which savings are assumed, due to application of higher building energy performance standards) through to 2060.

Electricity prices were constructed as the sum of major cost components, comprising wholesale costs, network (transmission and distribution) cost, operating costs, and retail margin. Real network costs were assumed to increase by 1% per year to 2020, and remain constant thereafter. Retail operating costs, derived from the cost component data, are assumed to remain constant in real terms throughout the projection period. The wholesale cost component was calculated as the sum of two sub-components. The lesser sub-component is costs other than the direct cost of purchased electricity and the major sub-component is the average pool price of sent out cost of electricity generated. The approach used to construct projected natural gas prices was similar to that used for electricity. For this

[7] Note that this values the output of PV systems at the prevailing retail price – other assumptions could be made, but we note that different arrangements for the pricing of PV apply in each state.

analysis, energy prices reflect the decisions announced in the Government's *Clean Energy Package* (2011) and underpinning Treasury modelling, including a carbon price of $23/t in 2012 rising at 2.5% (in real terms) per year for two years and then assumed to increase 4% per year. Learning rates were modelled by assuming reductions in the real costs of building materials used to reduce future energy costs for the Base Case (15% by 2015, 30% by 2020). The cost reduction is meant to encompass reduced labour costs resulting from learning, lower manufacturing costs from scale economies and market competition, and new technology developments that offer equivalent outcomes at lower costs. The benefit cost analysis used a real discount rate of 7% in accordance with The Office of Best Practice Regulation for present value calculations.

3. Results

Table 10 below shows the BCRs that are attained by the 10 storey office. By 2020, it is cost effective at BCA2010 -40% in all climate zones except Hobart and Canberra. Even at the BCA2010 -70% level, it remains cost effective in Brisbane and Darwin. Higher electricity costs in Brisbane, and the high cooling load in Darwin, help explain this result.

Table: 10 Storey Office - Benefit Cost Ratios of Energy Savings by Capital city, Year

	40%		**70%**		**100%**	
	2015	**2020**	**2015**	**2020**	**2015**	**2020**
Sydney	1.0	1.2	0.6	0.7	0.1	0.2
Darwin	1.6	1.9	0.9	1.1	0.2	0.3
Brisbane	1.3	1.6	0.8	1.0	0.2	0.2
Adelaide	1.1	1.3	0.7	0.9	0.2	0.2
Hobart	0.7	0.9	0.5	0.6	0.1	0.1
Melbourne	0.8	1.0	0.6	0.7	0.1	0.1
Perth	1.1	1.4	0.7	0.9	0.2	0.2
Canberra	0.7	0.8	0.4	0.4	0.1	0.1
Average	**1.0**	**1.3**	**0.6**	**0.8**	**0.1**	**0.2**

3.1 3-Storey Office

Table 11 below shows the BCRs that are attained by the 3 storey office. The 3 storey office responds better than the 10 storey office. It is cost-effective in all climate zones at BCA-40%, and preserves this cost-effectiveness at BCA2010 -70%. In percentage terms, the incremental construction costs required to reach these energy performance levels are quite modest, of around 7% and 11% respectively. This may be explained by the absence of trigeneration systems in this building. Incremental costs and benefits remain reasonably proportionate until at least the 70% energy reduction level, leaving BCRs relatively unchanged. At the -100% level, however, incremental costs jump up to around 46% above the Base Case, rendering this step not cost effective in all climate zones

Table 11: 3-Storey Office: Benefit Cost Ratios of Energy Savings by Capital city, Year

	40%		70%		100%	
	2015	**2020**	**2015**	**2020**	**2015**	**2020**
Sydney	1.3	1.6	1.3	1.6	0.4	0.5
Darwin	1.2	1.5	1.4	1.6	0.4	0.5
Brisbane	1.4	1.6	1.4	1.7	0.5	0.6
Adelaide	1.6	1.9	1.7	2.0	0.5	0.6
Hobart	1.5	1.8	1.4	1.8	0.4	0.5
Melbourne	1.2	1.5	1.3	1.6	0.4	0.5
Perth	1.4	1.8	1.5	1.8	0.5	0.6
Canberra	1.2	1.5	1.1	1.4	0.3	0.4
Average	**1.4**	**1.7**	**1.4**	**1.7**	**0.4**	**0.5**

3.2 Supermarket

Table 12 below shows the BCRs that are attained by the supermarket. The supermarket reaches very attractive benefit cost ratios. In Darwin and Brisbane, for example, the present value of energy savings at BCA2010 -40% in 2020 exceeds that of cost by around 6 times. Even in Canberra, which has the lowest cost effectiveness for this building type, the BCR is greater than 3 at this performance level. At BCA2010 -70%, the supermarket remains cost-effective in all climates. Even at BCA2010 -100% - that is, zero net energy – the supermarket is cost effective in 2020 on average across Australia registering BCRs of at least 1 in all climates except Hobart and Canberra.

The primary explanation of the high cost effectiveness of energy savings for the supermarket is its relatively simple form, including low glazing ratio and single storey, expansive form – together with the modest performance requirements implicit in the BCA2010 starting point. Relatively straightforward treatments to HVAC systems and lighting, and improvements in refrigeration cabinets to currently projected 'high efficiency performance standard' or HEPS, and additional insulation of cool and freezer rooms, significantly reduce energy consumption. The building's mechanical services are able to 'free ride' on the reduced heat output modelled from improved refrigeration and lighting systems. Ideally additional sensitivity analysis would be conducted to test the importance of this factor.

Table 12: Supermarket - Benefit Cost Ratios of Energy Savings by Capital city, Year

	40%		70%		100%	
	2015	**2020**	**2015**	**2020**	**2015**	**2020**
Sydney	3.9	4.7	1.5	1.8	0.9	1.0
Darwin	4.8	5.9	2.2	2.6	0.9	1.0
Brisbane	5.0	6.0	1.7	2.1	1.0	1.2
Adelaide	4.5	5.4	1.7	2.1	1.0	1.2
Hobart	3.0	3.6	1.3	1.6	0.7	0.9

Melbourne	3.2	3.9	1.3	1.6	0.8	1.0
Perth	4.4	5.4	1.7	2.1	1.0	1.2
Canberra	2.7	3.3	1.1	1.4	0.6	0.8
Average	**3.9**	**4.8**	**1.6**	**1.9**	**0.9**	**1.1**

3.3 Health building

Table 13 below shows the BCRs that are attained by the healthcare facility. The healthcare facility performs well at BCA2010 -40%, being cost effective in all climate zones. As noted earlier, the health facility is unable to reach BCA2010 -70% without purchasing Green Power to supplement on-site renewable energy generation, with the sole exception of in Darwin. Gas savings, relative to the Base Case, are negative – as the buildings are using trigeneration to cover as much electrical load as possible but at the expense of additional gas consumption – with the net result that realised purchased energy savings are much less than 70%, indeed only around 10% to 20%, and even negative in Darwin.

Table 13: Health Building - Benefit Cost Ratios of Energy Savings by Capital city, Year

	40%		**70%**		**100%**	
	2015	**2020**	**2015**	**2020**	**2015**	**2020**
Sydney	1.8	2.2	0.9	1.1	0.3	0.3
Darwin	3.0	3.7	0.9	1.1	0.4	0.5
Brisbane	2.6	3.1	1.0	1.2	0.3	0.4
Adelaide	2.4	2.9	1.3	1.5	0.5	0.5
Hobart	2.0	2.5	0.9	1.0	0.2	0.3
Melbourne	1.9	2.4	0.8	0.9	0.3	0.3
Perth	2.5	3.0	1.1	1.3	0.3	0.4
Canberra	1.9	2.3	0.6	0.8	0.1	0.2
Average	**2.3**	**2.8**	**0.9**	**1.1**	**0.3**	**0.4**

Given this performance at BCA2010 -70%, the Healthcare facility becomes increasingly dysfunctional in its energy use at BCA2010 -100%. As they already have deployed close to the maximum amount of PV, energy efficiency and trigeneration at -70%, the buildings need to purchase additional Green Power to reach the -100% level. As a result, no or few additional *capital* costs are incurred at this performance level. Despite this, the BCRs fall to very low levels (on average, around 0.4) due to the cost of Green Power purchases.

Summary

The general pattern of these results is that those buildings that are able to save the most electricity consumption (such as the supermarket – which is all-electric - and all buildings in cooling-dominated climates) tend to produce the most cost effective savings, as electricity is

around three times more expensive than gas. However, some buildings in cooler climates that save significant amounts of gas (for space heating and hot water) are also able to produce significant cost effective savings. Cost-effective savings are generally lower in Canberra than in other cooler climates due to the relatively low price of gas in the ACT.

A further general driver of these results is that all these buildings are able to achieve at least 40% energy savings in most climate zones at quite modest incremental construction costs, of generally around 4% (6% - 7% for the 3-storey office). At these performance levels, none of the buildings adopt the more expensive solutions of cogeneration, trigeneration or photovoltaics, but rather rely on more efficient HVAC equipment, lighting systems and hot water, along with improvements to the thermal shells, deploying technologies that are generally well understood and readily available.

3.4 Break-even energy savings

As described above, benefit cost ratios were calculated for each of the -40%, -70% and -100% performance levels (by building type and climate zone). Simple regression analysis was then undertaken to establish the break-even energy savings *i.e* BCR=1.

On average, 68% energy savings are expected to be cost effective for commercial buildings by 2020 (see Table 14 below) relative to BCA2010. These results show a reasonable spread of results by climate zone, from Canberra at 54% to Darwin at 80%.

Table 14: All Buildings- Break-even energy savings by Capital city, Year

	2015	**2020**
Sydney	58%	68%
Darwin	74%	80%
Brisbane	70%	77%
Adelaide	67%	76%
Hobart	49%	61%
Melbourne	52%	63%
Perth	66%	75%
Canberra	41%	54%
Weighted Average	**58%**	**68%**

3.1 Benefit-Cost Analysis of PV in Commercial Buildings

The results are not transparent as to whether PV is deployed at the break even performance level. Depending upon the building type and climate zone, PV is typically deployed at BCA -70% but not at BCA2010 –40%. When the break even performance level falls in between these two points, it is therefore ambiguous whether or not PV is deployed.

Table 15 below shows the projected cost effectiveness of PV for commercial buildings by climate zone. Future cost projections were based Raugei et al (2009). The benefit cost ratios are generally well below 1 except in Perth, where in 2020 it reaches 0.97. The break-even results for commercial buildings are therefore largely insensitive to the presence or absence of PV.

Table 15: Benefit Cost Ratios for PV- Commercial Buildings in 2020

Sydney	Darwin	Brisbane	Adelaide	Hobart	Melbourne	Perth	Canberra
0.56	0.62	0.61	0.75	0.57	0.56	0.97	0.44

4. Conclusion

A critical driver of the results is the starting point implicit in BCA2010. The targeted BCR for commercial buildings in BCA2010 was 2, while the results in this study imply an even higher starting point. Such high BCRs indicate that many highly cost-effective energy savings options for commercial buildings were not captured in BCA2010. As a result, these savings opportunities remain available, and this significantly increases the overall level of savings that are now available at the break-even level of cost effectiveness. In addition, energy prices for electricity and gas, and also the mix of fuels used in different building types and climate zones, also impact upon the results. Fuel mix is also important. For example, all-electrical buildings in Darwin tend to have higher cost effective savings than buildings with significant gas use (normally in cooler climates such as Canberra and Melbourne), given the lower cost per GJ of gas. Also, supermarkets in this study are all electrical buildings, and this is one factor that contributes to the high level of cost effective savings in this building type.

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Cost Effective Energy Savings in Australian Houses to 2020

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Abstract

This paper analyses the level of cost-effective energy savings that new residential buildings could achieve in Australia by 2015 and 2020, relative to buildings compliant with the energy standards in the 2010 Building Code of Australia (BCA2010). It draws on research undertaken by the authors for the Australian Government (Department of Climate Change & Energy Efficiency). Twelve different residential building forms/construction types were modelled in each capital city climate zone in Australia. Cost effectiveness in this study was defined as a social benefit cost ratio of at least unity at a 7% real discount rate.

The results show that on average, building shell thermal performance improvements and more efficient fixed appliances provide only modest cost effective energy savings by 2020, but there is significant variation in cost effective energy savings by climate zone. However, the results change dramatically when photovoltaics (PV) are included as part of the energy saving solution. Zero net energy for new residential buildings is shown to be cost effective by 2020 in all capital city climate zones, and even by 2015 in most climate zones.

It was found that the key factors influencing the results are (1) the expected prices of electricity and gas in each climate zone over time, as these determine the economic value of the energy savings; (2) the differences in climates, as the severity of winter/summer conditions influence the total energy demand for space-conditioning purposes, and therefore the benefits of improving thermal shell performance; (3) the cost of achieving given levels of improvements in the building shell (in turn reflecting differences in construction techniques and distribution of residential building types by state/territory); (4) the cost of achieving energy efficiency improvements in the fixed appliances, such as hot water, lighting and pool pumps (which also vary by state/territory including due to differences in the starting point distribution of hot water appliance types in particular, e.g., solar, electric storage, gas storage, instantaneous gas, etc); (5) the 'starting point' energy efficiency (e.g., 6 star houses required in BCA2010); and (6) whether or not PV is allowed as part of the building solution.

Keywords: Residential buildings, cost effectiveness, energy savings

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1. Study Background

This paper reports the results of analysis of the cost effectiveness of possible future improvements in the energy performance requirements of the Building Code of Australia, compared to current residential energy requirements introduced in 2010 (BCA 2010). The study was commissioned by the Commonwealth Department of Climate Change Energy Efficiency as a contribution to the National Building Energy Standard-Setting, Assessment and Rating Framework measure described in the *National Strategy on Energy Efficiency* (NSEE), which was approved by the Council of Australian Governments (COAG) in July 2009 (COAG 2009). The COAG Framework aims *inter alia* to lay out a pathway for future stringency increases in the Building Code of Australia (BCA) to 2020, in order to increase certainty for stakeholders and to facilitate strategic planning and innovation by industry.

The study commenced in the first half of 2011, and initial assumptions on gas electricity prices were revised in late 2011. It should also be noted that assumptions on photovoltaic costs are in hindsight conservative, with costs having fallen more dramatically than assumed in the modelling.

2. Approach

The study comprised four key steps. First, twelve different and representative residential buildings were identified and their energy performance simulated at a range of performance levels in each capital city in Australia. The performance levels begin with BCA2010 as a Base Case (not including any jurisdictional variations), and then move through successively challenging energy performance levels: BCA2010 –40%, BCA2010 –70% and BCA2010 –100%, or zero net energy buildings.

Second, independent estimates of the costs of these buildings at each performance level were provided by quantity surveyors, Davis Langdon, and also by Dr Mark Snow, a leading expert on building-integrated photovoltaics (BiPV), specifically with respect to PV system costs. This enabled the *incremental* cost of achieving the higher energy performance levels to be calculated with some precision, using conventional costing approaches routinely employed for building commissions in Australia.

Third, benefit cost and break even analysis was carried out for each building type, climate zone, and performance level. For this analysis, the Base Case reflects the decisions announced in the Government's *Clean Energy Package* and underpinning Treasury modelling (2011), including a carbon price of $23/t in 2012 rising at 2.5% (in real terms) per year for two years and then assumed to increase 4% per year. (3) The Base Case also assumes a rate of industry learning (how rapidly the real incremental cost of complying with new performance requirements declines through time) of 30% over 10 years, and a real discount rate of 7%.

All buildings are assumed to have an economic life of 40 years and the benefit cost analysis is conducted over this period. It is important to note that the economic analysis in this report is based on energy required for space conditioning, hot water, lighting and swimming pool

pumps – all of which are subject to regulation in BCA2010. Like conditioning energy, the energy requirements for hot water and pool pumps are climate sensitive.

3. Energy and Economic Modelling Details

3.1 Building Stock

There are significant differences between climate zones in terms of the distribution of construction types and, to a lesser extent, the prevalence of detached and semi-detached houses and flats. For example, medium-sized detached houses with brick veneer walls and concrete slab on ground (CSOG) represent over 50% of the current housing stock in the ACT and SA, but only 11% in NT and just 6% in WA. Cavity brick walls feature in over 70% of the housing stock in WA and 40% in NT (EES 2008). These differences affect both the potential for realising energy efficiency gains in the new housing stock and the costs of doing so in particular locations.

The varying composition of the housing stock is taken into account when weighting results in this Report. The results for each individual climate zone are the weighted averages of the results for that climate zone of the 12 building types modelled, with weightings for each climate zone based on ABS building stock surveys reflecting the prevalence of each building type in the state stock. Full details of the construction types are available in the full study report.[4]

3.2 Building Improvement Cost Estimates and Assumed Learning Rates

An independent quantity surveyor, Davis Langdon (an AECOM company), was retained to provide robust estimates of the costs associated with achieving the different energy performance levels for each building type for key building elements (Full details can be found in the full study report). Regional variations in the costs of plant and materials, as well as climate zone based variations in the building specifications, were taken into account.

This analysis generated, firstly, robust estimates of the total costs of each building type in each climate zone as specified to comply with the BCA2010 Base Case (noting that this version of the Code is not yet in force for all building types in all states/territories). Secondly, the analysis provided a commercially-relevant incremental cost to be established for improving each building type to the required 40%, 70% and 100% energy savings relative to BCA2010.

Learning rates were modelled by assuming reductions in the real costs of building materials used to reduce future energy costs for the Base Case (15% by 2015, 30% by 2020). The cost reduction is meant to encompass reduced labour costs resulting from learning, lower

[4] http://www.climatechange.gov.au/publications/nbf/pathway2020-increased-stringency-in-building-standards.aspx

manufacturing costs from scale economies and market competition, and new technology developments that offer equivalent outcomes at lower costs.

3.3 Photovoltaic Cost Estimates

Dr Mark Snow, an Australian expert on applications of PV to buildings, provided PV system output (solar yield by location with standard orientation) and cost data. It was assumed that residential buildings would use standard PV modules rack mounted on the roof (rather than integrated as part of the roof or façade). Using current technology, the area required for 1kWpeak mono-crystalline module (m-Si) system with 15% efficiency is 7m². However, module efficiency is expected to improve in the future, thus reducing the area required for a 1kWp system over time. This approach simplified cost estimates, though at the time it was recognised that rapid market and technology improvements made cost forecasts rather difficult. The cost estimate was based on a turnkey approach per 1kWp, and did not include any government subsidy through the RET/SRES certificates.

Table 1: Cost of 1kWp PV system (standard PV modules) 2010-2020

	2010	2015	2020
Turnkey price (AU$/kWp)	AU$/kWp	AU$/kWp	AU$/kWp
Standard PV modules	$5,950	$4,400	$2,990

From the perspective of 2013 these are very conservative estimates, and single per kWp prices do not recognise scale economies from purchase of larger systems. In subsequent modelling, the discrete nature of PV is recognised by limiting PV additions to the nearest 0.1kWp required to deliver an appropriate reduction in utility energy. In subsequent economic modelling, it is assumed that PV systems are replaced after 20 years and inverters are replaced after 10 years. It is assumed that in all jurisdictions that net PV pricing is applied – that is, householders receive a price from utilities for each kWh generated by PV that equals the cost per kWh, without any feed-in tariff.

3.4 Energy Modelling and Climates

All energy modelling was undertaken with the AccuRate energy modelling software, which includes 69 separate climate zones across Australia, and a much finer delineation of energy performance requirements than the 8 climate zones relevant to deemed-to-satisfy (DTS) requirements in the BCA. Energy efficiency performance standards in BCA2010 are defined in terms of DTS construction requirements, or modelled energy performance that equates to AccuRate 6-Star performance, expressed as total conditioning energy in MJ/m^2 of conditioned space. In addition, BCA2010 contains requirements relating to hot water system efficiency, lighting requirements, and pool pump performance. Full details of the residential energy modelling can be found in the full study report.

The sensitivity of 6-Star energy performance to climate can be seen in Table 2. Note that the Sydney climate used is Richmond, which is relevant to residential land developments in

Western Sydney rather than to coastal areas of Sydney. The climates range from tropical (Darwin) through relatively mild climates to the heating dominated climates of Melbourne, Hobart, and Melbourne.

Table 2: Residential Space Conditioning Energy Requirements (MJ/m2.a) by AccuRate Star Band and Climate Zone

	5 star	6 star	7 star	8 star	9 star	10 star
Sydney (West)	112	87	66	44	23	7
Melbourne	165	125	91	58	27	1
Brisbane	55	43	34	25	17	10
Adelaide	125	96	70	46	22	3
Perth	89	70	52	34	17	4
Hobart	202	155	113	71	31	0
Darwin	413	349	285	222	140	119
Canberra	216	165	120	77	35	2

The 10-Star performance is virtually zero conditioning energy, except for removal of latent heat due to humid air. Prior to BCA2010, many jurisdictions had set energy performance standards at the 5-Star level. The step from 5- to 6-Star represented a typical energy performance improvement of 20-25%. The specific requirements of the study required modelling 40% and 70% reductions in energy consumption – significant steps to ~7.5- and 8.5-Stars, respectively.

3.5 Energy and Carbon Prices

Electricity prices were constructed as the sum of major cost components, comprising wholesale costs, network (transmission and distribution) cost, operating costs, and retail margin. Real network costs were assumed to increase by 1% per year to 2020, and remain constant thereafter. Retail operating costs, derived from the cost component data, are assumed to remain constant in real terms throughout the projection period. The wholesale cost component was calculated as the sum of two sub-components. The lesser sub-component is costs other than the direct cost of purchased electricity and the major sub-component is the average pool price of sent out cost of electricity generated. The approach used to construct projected natural gas prices was similar to that used for electricity. For this analysis, energy prices reflect the decisions announced in the Government's *Clean Energy Package* (2011) and underpinning Treasury modelling, including a carbon price of $23/t in 2012 rising at 2.5% (in real terms) per year for two years and then assumed to increase 4% per year.

It is important to note that both electricity and gas prices vary significantly by climate zone (see Table 3). Those climate zones with higher electricity or gas prices tend to show more cost effective savings. These two factors interact so that, for example, Darwin has a high use of electricity (natural gas is not reticulated in Darwin) but a relatively low electricity price.

These two effects tend to cancel each other out, leading to modest savings being reported for Darwin residential buildings.

Table 3: Gas and Electricity Retail Prices (real 2012 prices) - Residential Sector in 2020, by Climate Zone

	Sydney	Melbourne	Brisbane	Adelaide	Perth	Hobart	Darwin	Canberra
Gas ($/GJ)	21.1	17.6	31.4	19.2	28.4	26.1		23.2
Electricity ($/GJ)	60.6	62.3	66.7	78.2	70.7	65.4	54.9	46.9

3.6 Economic Modelling

The benefit cost analysis considers the value of (purchased) energy savings over an assumed 40 year building life arising from the higher energy performance requirements modelled, compared to the energy costs that would have been incurred had the same buildings been constructed to BCA2010. This means, for instance, that energy derived from a building's PV installation is represented as a reduced requirement for purchased electricity. Separate calculations are made for each scenario, building type, climate zone and performance level, for each of the 40 years of building use after construction in 2015 or 2020. The energy savings are measured in annual MJ/dwelling for residential buildings. Electricity and gas are treated separately, and use of minor fuels (e.g., wood, LPG) is also measured for residential buildings and is taken into account in the benefit cost analysis. All prices and costs are represented as *real* 2012 prices, so that the effect of inflation is excluded.

Finally, it should be recalled that the energy costs considered for these buildings exclude those costs associated with internal appliances and equipment ('plug load') that are not currently regulated by the BCA, including cooking energy. The exception to this rule is for the -100% or 'zero net energy' buildings, where the study required inclusion of the plug load and cooking energy. This has the effect of increasing the incremental costs of this solution, when compared to the other performance levels targeted, as the PV system has to be sized to also cover the plug load and cooking energy.

The value of future energy savings and incremental costs are discounted back to a present value. The primary rationale for discounting is the observation that people display 'time preference'; that is, a dollar today (of benefit or cost) tends to be valued more highly than a dollar in the future. This effect is reinforced by the 'opportunity cost of money', which in effect is defined by the real interest rate. That is, one can choose to spend a dollar today or next year, but the value of the dollar next year is increased by the real interest rate available. In effect, the real interest rate represents the amount that must be offered to induce someone to defer the value of present consumption. In this way, the real interest rate is taken as a working proxy for the time value of money.

The Office of Best Practice Regulation requires a 7% real interest rate to be used for present value calculations for regulatory analysis. Energy savings at break-even and at 40%, 70% and 100% have been calculated using a 7% discount rate. It may be noted that this is considerably higher than current real interest rates in Australia, and relatively high for long lived assets.

4. Modelling Results

The starting point stringency of the energy provisions in BCA2010 (6-Star) is a factor that could be expected to influence the overall level of future cost effective savings. The Regulatory Impact Statement (RIS) on the introduction of 6-star into the BCA indicated that it was marginally cost effective on an Australia average basis. This tends to limit the scope for further cost effective savings beyond that level - at least, in the absence of PV, as discussed below.

4.1 Impact of PV

Where PV is allowed as part of the building solution, it has a dramatic effect on the break-even level of energy savings reported, and results are presented below on a without/with PV basis. Where, for a given climate zone, PV becomes cost effective in its own right, then the break even energy savings for residential buildings in that climate zone becomes 100%. This is because any level of residual energy demand can be covered cost effectively by the PV system due to the scalability of PV systems to any size through the addition of extra modules and components, subject only to physical constraints such as suitable roof area and the capital cost. The results *without PV* are driven by the cost effectiveness of: a) improvements to the thermal shells, and; b) improvements to fixed appliances.

In this study, PV systems were treated as if they were another 'fixed appliance' which may be traded off against efficiency gains in the thermal shell and those fixed appliances already regulated by the BCA (hot water, lighting, pool pumps) in determining a least cost mix of measures that provide at least break-even benefits (BCR = 1.0). We therefore analysed the cost effectiveness of PV systems in each climate zone, taking into account the differences in electricity prices and PV yield by climate zone.

As previously discussed, the cost of PV is projected to fall dramatically into the future. The most significant price reduction is occurring for the cost of panels (and to a lesser extent for inverters). While these costs currently represent a large share (60+%, depending on total installed capacity) of the current total cost of the turnkey price of a solar energy installation, there is no certainty about future market prices of these components in Australia. The capital cost assumes a 20-year life for the PV panels and replacement of the inverter after 10 years, both of which are conservative.

Table 4 shows the resulting benefit cost ratios (BCRs) for residential PV systems. It can be seen that in 2020 PV is cost effective in all climates. All the economic modelling for residential buildings is based upon improvements being added to dwellings in order of declining BCRs until the break even or specified energy reduction is achieved. This means

that building shell or other improvements are made up to the point when the BCR of PV is reached but no further. Moreover, when the BCR >1 for PV, any required level of energy reduction can be achieved cost effectively (i.e. above breakeven), although not necessarily at low absolute cost. Further, there may be a practical limit in terms of suitably oriented and unshaded roof area for real dwellings, which has not been explicitly taken into account in the modelling.

Table 4: BCRs for Residential PV by Climate Zone

	Sydney West	**Darwin**	**Brisbane**	**Adelaide**	**Hobart**	**Melbourne**	**Perth**	**Canberra**
2015	1.01	1.07	1.12	1.36	1.01	0.98	1.39	0.77
2020	1.41	1.47	1.57	1.89	1.41	1.37	1.96	1.09

4.2 Break Even Energy Savings

Table 5 shows the energy savings at break even for the Base Case compared to the same buildings constructed according to the energy performance requirements of BCA2010.

The energy savings from reductions in space conditioning and fixed appliance (hot water, lighting, pool) energy are expressed as reductions from BCA2010 performance. The building shell rating (in AccuRate stars) indicates that most energy savings relate to improved performance of fixed appliances and not improvements in the building shell. The 6-star building shell performance means that in mild climates (Brisbane, Perth, Sydney, Adelaide) the space conditioning energy requirement is small both in absolute terms and as a share of total energy consumption (excluding plug load and cooking which is not regulated under the BCA). As a result, there is relatively little space conditioning energy remaining to save in these climates and there are very few improvements that can be shown to be cost-effective for these climate zones. By contrast, in the locations with the highest space energy requirements (Canberra, Melbourne and Hobart) some improvements in the building shell performance are cost effective in this scenario.

Table 5: Break Even Energy Savings Relative to BCA2010, All Residential Buildings, Without PV, Base Case, 7% Real Discount Rate

	Space Conditioning and Fixed Appliance Savings		**2020 Break Even Thermal Shell Star Rating#**	**2020 Space Conditioning Energy**	**2020 Space Conditioning Energy at Break Even**
	2015	2020			
Sydney West (CZ6)	9%	14%	6.0	30%	4.7GJ
Darwin (CZ1)	3%	3%	6.0	69%	17.3GJ
Brisbane (CZ2)	7%	7%	6.0	20%	1.6GJ
Adelaide (CZ5)	11%	11%	6.0	45%	6.9GJ
Hobart (CZ7)	14%	17%	6.4	67%	18.3GJ

Melbourne (CZ6)	3%	7%	6.2	66%	21.8GJ
Perth (CZ5)	18%	32%	6.0	29%	2.8GJ
Canberra (CZ7)	4%	7%	6.2	70%	26.8GJ

Notes: # = composite star rating for Class 1 (detached) and Class 2 (flats) buildings. Space conditioning energy consumption is shown in Column 5 as a percentage of total energy consumption excluding plug load and cooking energy then, in Column 6, in absolute terms.

Additional sensitivity analysis around these 'without PV' results was undertaken to examine the impact of assuming a range of 'no cost' design changes to some of detached dwelling forms which resulted in building shell improvements in the range 0.2 – 0.9 stars (depending on climate). In such cases, the overall energy savings improved and the building shell rating at break-even also improved.

When PV is added into the mix, the results change dramatically. Zero net energy housing is shown to be cost effective by 2020 in all climate zones studied. The cost of PV panels has declined dramatically in recent years and is projected to decline further by 2020. This combined with rising electricity prices is making the electricity produced from PV installations increasingly cost effective. Indeed by 2015, except for Melbourne and Canberra, PV installations are cost-effective in their own right, and by 2020 this is true for all climate zones. This means that essentially any level of energy savings, relative to BCA2010, is also cost effective when PV is allowed in the building solution - constrained only by physical considerations such as the area of North-facing roof upon which to mount PV systems. As soon as this condition occurs in a climate zone, the break even or cost effective level of energy savings immediately rises to 100% (i.e., zero net energy).

Another way to interpret these results is to note that the various 'treatments' or upgrades that may be applied to a 6 star, BCA 2010 house have different costs and benefits. In our analysis, these treatments are selected in declining order of cost effectiveness (that is, the most cost effective are selected first). As soon as PV panels become the next most cost effective treatment, no further treatments (and hence no further costs) are required to reduce the house's energy consumption to zero. While PV is a cost effective solution, the break even with PV results required 1.5 – 7.4kW of PV, with net present costs from $5,000 to $30,000.

4.3 Benefit Cost Analysis at Targeted Performance Levels

Modelling was undertaken to determine the benefit cost ratios at reductions of 40% and 70% from the BCA 2010 level (covering the building shell, water heating, lighting and pool pumps). Additionally, at 100% reduction, a net zero energy solution was required in which all cooking and plug load energy was also offset by renewable energy. The results shown in Table 6 are the 'without PV' solutions. There are no cost effective solutions, with the best results occurring for the three cool climates. For both -70% and -100% energy reductions, the best results occur for Canberra at around 40% BCR.

The results shown in Table 7 below are the 'with PV' solutions. All climates except Canberra and Melbourne have cost effective solutions for each energy reduction target. As soon as

other improvements with BCRs better than that of PV are exhausted, PV is then used to reach the required energy reduction at the BCR of the PV. If the BCR of PV exceeds break even, any level of energy reduction is possible at better than break even because of the scalability of PV systems. It should be noted, however, that the upfront cost of PV systems may be significant, even if they are cost effective: the current net present costs per kWp of PV installed are about $7,300, $4,900 and $3,600 (7% discount rate) in 2010, 2015, and 2020, respectively. It should also be noted that around 7m^2 of appropriately oriented and un-shaded roof is required per 1kWp.

Table 6: Benefit Cost Ratios without PV in Solution, at 40%, 70% and 100% Reduction from BCA2010 by Climate Zone, 7% Real Discount Rate

	-40%		-70%		100%	
Climate Zone	**2015**	**2020**	**2015**	**2020**	**2015**	**2020**
Sydney	0.17	0.21	0.13	0.17	0.13	0.17
Darwin	0.25	0.31	0.24	0.31	0.24	0.31
Brisbane	0.35	0.41	0.10	0.12	0.10	0.12
Adelaide	0.25	0.33	0.16	0.21	0.16	0.21
Hobart	0.47	0.60	0.27	0.35	0.27	0.35
Melbourne	0.37	0.47	0.20	0.26	0.20	0.26
Perth	0.20	0.26	0.19	0.25	0.19	0.25
Canberra	0.40	0.55	0.30	0.41	0.31	0.42

Table 7: Benefit Cost Ratios with PV in Solution, at 40%, 70% and 100% Reduction from BCA2010 by Climate Zone

	-40%		-70%		-100%	
Climate Zone	**2015**	**2020**	**2015**	**2020**	**2015**	**2020**
Sydney	1.03	1.43	1.02	1.43	1.01	1.42
Darwin	1.07	1.47	1.07	1.47	1.07	1.47
Brisbane	1.14	1.58	1.13	1.58	1.13	1.57
Adelaide	1.38	1.90	1.38	1.90	1.37	1.90
Hobart	1.10	1.53	1.05	1.47	1.03	1.44
Melbourne	0.98	1.38	0.98	1.37	0.98	1.37
Perth	1.43	1.99	1.41	1.98	1.40	1.97
Canberra	0.77	1.09	0.77	1.09	0.77	1.09

5. Sensitivity Analysis

A sensitivity analysis was undertaken using a higher carbon price and a higher rate of industry learning. Table 8 below shows that the cost effective level of energy savings,

relative to BCA2010 and without PV, is significantly higher than in the Base Case, reaching 23% on a weighted average basis. The spread of results by climate zone continues to reflect differences in relative fuel prices, which are exacerbated by carbon pricing, increasing the relative attractiveness of electricity savings. Note that in Australian conditions, this result also leads to higher greenhouse gas emission savings than occur from savings of natural gas.

Table 8: Break Even Energy Savings Relative to BCA2010, All Residential Buildings, Higher learning rate and higher carbon price, Without PV

Scenario 2	**2015**	**2020**	**2015**	**2020**
	@ 5%	**@ 5%**	**@ 7%**	**@ 7%**
Sydney West (CZ6)	19%	26%	14%	19%
Darwin (CZ1)	5%	23%	3%	15%
Brisbane (CZ2)	7%	30%	7%	22%
Adelaide (CZ5)	11%	22%	11%	22%
Hobart (CZ7)	19%	30%	16%	25%
Melbourne (CZ6)	13%	33%	4%	25%
Perth (CZ5)	32%	32%	26%	32%
Canberra (CZ7)	13%	43%	7%	29%
Weighted Average:	**15%**	**30%**	**11%**	**23%**

6. Conclusion

The study demonstrates that there is limited scope to regulate further cost effective building shell improvements other than in the heating dominated cooler climates of southern Australia. Energy reductions of 1-Star (or ~30% below the BCA2010 6-Star level) would be cost effective. Such regulation would need to be applied by AccuRate Climate Zones rather than by the wider BCA climate zones or by jurisdiction with wide ranges of climates.

It is clear that improvement of the current building shell performance level cannot cost effectively compete against future improvements of fixed appliances covered within the BCA. More significantly, PV as a fixed appliance with its output valued at the householders electricity tariff (net metering), is a more cost effective approach than building shell improvement for most of Australia. This is demonstrated by the conservative cost approach used for PV in the study undertaken in 2011 – from the perspective of 2013 PV makes an even more significant contribution to cost effective reduction of energy consumption and greenhouse gas emissions.

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Life Cycle Energy Analysis of Residential Building Retrofits Incorporating Social Influences

Melissa Gaspari[1]

Abstract

Retrofitting is a front-runner in sustainable options to improve residential lifecycle energy consumption as Australia's home energy use rises. Over the past 20 years there has been a growing trend for larger houses within Australia; combined with the residential sector being responsible for 7% of Australia's energy use, the need to improve our current housing stock is hard to ignore.

The average household is overrun by various rebates, technology, and fashionable quick fixes to improve their home's energy efficiency, but how do these households choose? This paper explores the way Life Cycle Energy Analysis supports decision-making when retrofitting for energy efficiency and incorporates how social influences, such as age, income, goals, time constraints, thermal comfort, gender and technology factor into the way homeowners prioritise their retrofitting options.

Current research identifies many different approaches to using Life Cycle Analysis to support decision-making in retrofitting. However, few have addressed the influence of social aspects. This research incorporates the human and social aspects into a decision-support framework. This framework uses Life Cycle Energy Analysis as a tool to support decision-making and intends to identify a means to align the most effective life cycle improvements to the social intentions, objectives and constraints of homeowners. Using information gathered from interviews with over 10 different homeowners, the framework integrates the real life scenarios to outline the social effects, whilst simultaneously allowing homeowners to meet their needs and still consider energy efficiencies and improvements over the lifetime of their home.

To fill the gap in connecting social aspects with lifecycle decision-making this paper is designed to incorporate energy efficiency into the decision matrix using Life Cycle Energy Analysis, while supporting the social objectives of homeowners over the entire lifecycle of an Australian residential building.

Keywords: Sustainability, Life Cycle Energy Analysis, Social Influences, Retrofit, Residential.

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1. Retrofitting Residential Buildings

Retrofitting is an attractive option to improve residential life cycle energy consumption in Australia; it is an emerging industry helping to determine how the energy use of an existing home can be reduced. This concept of building retrofit is more commonly seen in commercial buildings, and has been proven to lead to considerable reductions in energy use (Yohanis and Norton, 2002).

Life Cycle Analysis (LCA) is one technique to assess the environmental aspects and potential impacts of products from raw materials to production, end use and disposal (Australia/New Zealand Standard, 1998). Life Cycle Energy Analysis (LCEA) uses this same approach with energy being the only indicator. One of the key components of a LCEA is embodied energy. That is, the energy used in the production of the materials and a significant contributor to the amount of energy used to complete a retrofit (Hogan, 2011). For this reason, studying the outcomes of LCEA of retrofit options should include embodied energy, operating energy (the energy consumed during a buildings lifecycle), as well as maintenance and disposal energies, in order to provide a complete insight into the most energy efficient options. LCEA may be used to assist in decision-making for many factors including social influences and gives a comprehensive cradle-to-grave appraisal (Australia/New Zealand Standard, 1998).

The existing housing stock in Australia requires significant retrofit as it currently threatens to be the biggest liability in long-term energy efficiencies. Approximately 2% of new housing is constructed each year in Australia, leaving 98% of the existing housing stock to be retrofitting or retired (Department of the Environment, 2008). Of this only approximately 80% of housing is occupied –3.3% of which is already undergoing retrofit or renovation and only 1% is being retired - leaving over 75% of the existing housing market open to some form of energy retrofit and improvement (Department of the Environment, 2008).

Behavioural attitudes, climate, housing size, occupancy, level of education and other social influences affect the overall energy consumption of a home, and although some homes may be deemed to require energy retrofit, they may consume less energy in their operation than others due to their occupants. Climate zones offer static parameters and many retrofitting options can be used across multiple climate zones, highlighting that behavioural attitudes or social influences will have the greatest impact on results. The most effective retrofit options are limited without knowing the exact conditions of the existing housing stock that requires retrofitting.

The implications of social factors in this study will be the most notable, as they will provide an insight into decision-support of retrofitting options. LCEA can incorporate these parameters to provide a whole of life evaluation, providing an insight into retrofitting options for the existing Australian housing stock.

1.1 LCEA as a decision support tool for building retrofitting

A recent study, *Comparing life cycle implications of building retrofit and replacement options,* discusses the question of when it is best to retrofit a building rather than rebuilding it (Dong, Kennedy *et al.*, 2005). Typically, LCEA models and tools are aimed towards improvements in design of new dwellings. However, with the large stock of existing residential buildings, this attention has recently shifted toward energy retrofit (Dong, Kennedy *et al.*, 2005).

To analyse a whole of life approach Dong, Kennedy *et al.*, (2005) use a LCEA methodology, with a series of environmental indicators, (global warming potential, waste, water pollution, cost, economic indicators as well as energy), highlighting the parameters and context of this LCEA. LCEA supports the decision-making process in this analysis, as the conclusions of this study show that, despite the high energy saving in rebuilding at any one stage, the waste produced by this process is severe. This concludes that in the context of one of the indicators, waste, the views of LCEA can be altered and the impacts varied from the initial energy assessment.

Reductions in both embodied energy and operational energy need to be balanced in order to identify the whole life cycle energy efficiencies. When determining retrofit options, indicators provide alternative ways of analysing this balance. LCEA uses energy as the singular indicator in this balancing process. Ramesh, Prakash *et al.,* (2010) emphasise this in their research of seventy-three case studies from thirteen different countries, considering the energy consumption of either conventional or low energy buildings. Their analysis of both the operating and embodied energy highlighting the significance each energy phase has on the overall building life cycle energy.

This research indicates the usefulness of the LCEA approach in determining energy savings, and is paramount to the decision making processes. Trade-offs and balancing energy phases is crucial in LCEA.

1.2 Indicators for Life Cycle Energy Performance

Indicators used for life cycle performance aid in determining environmental impacts. LCEA is rarely completed alone, often using key indicators, impact assessments, or characterisation factors to help identify the full influence of the choices at hand and the long-term effects. Existing research presents a number of commonly used indicators and impact assessments, as per AS/NZS ISO 14042,yet for the purpose of this research, indicators that will be used in the decision making process, will be social influences and energy.

Research completed by Peter Clinch and Healy (2003) explore the single factor of comfort, which focuses on LCEA of energy-efficient retrofits in Ireland. This research further defines the limitations and impacts of this indicator (comfort). Peter Clinch and Healy (2003) discusses the clear trade off indicators create, most importantly illustrating the limitations of various indicators and factors in their analysis. Emphasising the individualistic nature of home ownership and retrofit decisions, Peter Clinch and Healy (2003) conclude that dependant on these individual characteristics, what may have initially been retrofit for

energy, may not decrease energy consumption, but instead, increase comfort (or an alternative factor).

One key perspective that needs to be considered is the national code of building construction, known as the Building Code of Australia (BCA). Morrissey and Horne (2011) suggest that the minimum standards set in the BCA do not necessarily promote the most cost effective options available when constructing a home, or updating an existing home to meet the current standard. Although the BCA sets the minimum code for energy efficiency, it is suggested that LCEA combined with exceeding the BCA requirements provides a more cost effective energy choice for a greater time period (Morrissey and Horne, 2011).

From these studies, it is clear that indicators, factors and characteristics beyond energy, including environmental impact factors (such as CO_2, pollution, waste), and most significantly regulations and social influences, play a vital role in supporting and assisting decision-making in the retrofit area, as well as illustrating a more accurate understanding of energy efficient retrofits, trade-offs and impacts of a residential buildings lifecycle.

1.3 Retrofit for climate and LCEA

One key element common to all studies is climate. Fay, Trealoar *et al.* (2000) discuss the relevance of temperate areas and the affect this has on the embodied energy, suggesting that the LCEA of dwellings in temperate zones, such as those analysed in this paper, will gain significant operational savings but suffer high-embodied energy. Dong, Kennedy *et al.* (2005) support this in their conclusions, as in the Canadian climate of Toronto, the energy efficiency gain through operation outweighs the large embodied energy components.

Whether embodied energy has a greater impact over operational energy is due to the heating and cooling requirements. A temperate climate has minimal heating and cooling requirements compared to those in more severe climatic zones. Using a breakdown of embodied energy, operational energy and maintenance energy, indicators and cost relevant to the identified climatic zone, energy components can be isolated and analysed against one another and as part of the overall assessment. Dong, Kennedy *et al.* (2005) also conclude that there is a trade-off for energy reduction within the separate phases and that the severity of other impacts should be analysed.

The Australian *Your Home Technical Manual* (Reardon, Milne *et al.*, 2010) categorises Australia's overall climate into eight different climatic zones, from high humidity and warm winters to alpine winters and cooler summers. Australian housing must cater for varied climate conditions dependant on location. Falcone's (2011) research in warmer climates is just one example of the impact climatic zones have on the boundaries and context of retrofitting options.

Without the boundaries set by climate, retrofitting for energy efficiency is extremely unreliable. Therefore climate must be considered as an essential input in LCEA, as the energy efficiency gains are made to improve the energy consumption during the operation and use of a residential building and these are directly linked to climate requirements.

2. The Proposed Framework

The framework of this study intends to support decision-making in retrofitting residential dwellings primarily analysing trade-off impacts from the available retrofit choices, the life cycle cost and the social impacts or influences of these choices. Figure 1 presents the high level framework, showing the relational dependencies of social influences when prioritising retrofitting options, and determining LCEA outcomes.

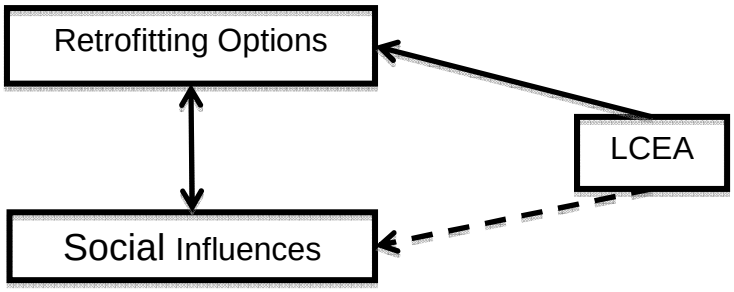

Figure 1 High Level Framework to using LCEA to support Retrofitting choices

Any number of social influences can affect a homeowner or occupier when making choices related to energy within their home. The framework seen in Figure 2 suggests one approach for incorporating these social variables into specific retrofitting choices. It allows social factors to be identified and for physical factors (such as building age and condition) to be excluded as a social variable. This framework enables multiple social variables to be considered while still incorporating house specific details. It allows the LCA process to be seen through these social influences, as well as feed impacts of these choices back into the decision-making process. Further development of this framework would provide a comprehensive understanding of specific social influences; retrofitting options and choices that occur during energy related retrofitting of residential buildings.

2.1 Physical and Social Constraints for Retrofit Options

Every retrofitting scenario is unique and varies based on constraints of each specific dwelling. Building age, condition, location, material make up, and historical significance are some examples of the constraints that determine feasible and available retrofitting choices. Together with the social context of the owners of the dwelling, these variables and constraints determine the priority of retrofitting choices.

2.1.1 Physical Constraints

Different physical constraints influence retrofitting options in various ways; some by eliminating options and others by priority or lack of current techniques. However, physical constraints cannot be changed without some form of retrofit or renovation, and therefore have a significant impact.

The type of building is also a key factor when identifying retrofit choices, and can immediately eliminate options for reasons such as accessibility. Climate and location are

also significant physical factors in building retrofit. Location often incorporates the features of climate as well as building location and orientation (including aspect); housing and population density; historical relevance; and other area constraints. For comprehensive Life Cycle Analysis to be completed, both physical variables and social variables need to be considered. Noting that social variables can be more flexible and vary through means of education, resource availability and incentives

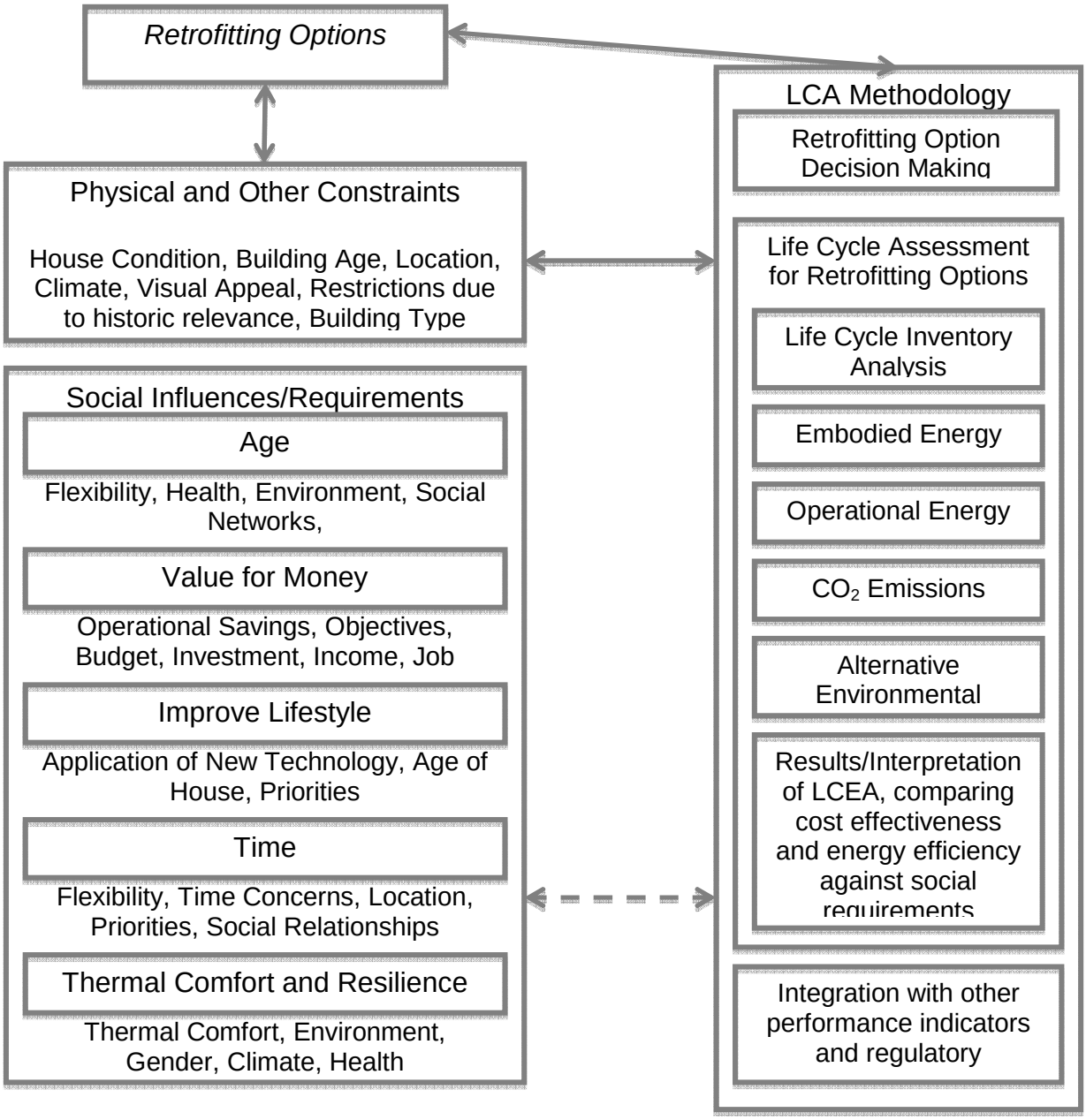

Figure 2 Detailed Framework

2.1.2 Social Variables

Social Variables defined as the personal influences on homeowners, such as age, gender, availability, education, any social influences on a homeowner that significantly affects the choices they make regarding their home. For the purpose of this research the identified framework will enable the use of social variables and themes identified in the pilot survey of

10 different homeowners. The purpose of the survey was to identify key social variables that influence each homeowner's choice of retrofitting options. The survey specifically focused on homeowners from two separate age groups, those less than 30 years of age and those over 50 years of age, as they displayed often opposing views. Table 1 displays the extracted themes and key survey results.

2.1.3 Social Variables – Survey Methodology

The survey was conducted by asking a series of closed questions regarding the social status of the participants, before open ending questions sort to establish participant understanding of terminology such as energy efficiency. Beyond this participants were asked to rank preferred retrofitting options and list key arguments to support this ranking. It was clear in the initial discussions, definitions of terminology pose the greatest risk when selecting retrofit options due to the differences in perceived and actual understanding. This survey regulated the variables of terminology, by stipulating each retrofitting option's benefits, impacts on time and specifications. Participants were selected to ensure, they all originated from the same location, and created diversity in age and education, and involvement in energy efficiency practices for the small group of participants. Joint homeowners were considered and interviewed, as individuals to ensure definitions and education factors were not altered by joint ownership influence, or perceived understanding.

The survey presents clear distinctions between younger and older generations and their understanding and perspective of retrofitting and energy efficiency. Younger generations showed a more comprehensive understanding of the diversities within energy efficiencies and options for improvements; whereas, older generations highly regarded maintenance to improve energy use. Younger generations were also more likely to retrofit solely for energy improvements, even replacing working appliances or components; whereas older generations preferred to maintain items for longer and then replace them at the end of their useful life with the most efficient technology. This concept is evident in each age group's readiness to prioritise energy retrofit over other improvements.

Social variables assist in pre-defining the needs of individuals and available retrofit options, prior to completing LCEA. However, they also assist in post-LCEA, where individuals can assess the social influences in conjunction with the whole of life results for any singular retrofit option. The social variables outline the priority of retrofitting options under specific social influences (in this research age was most dominant). This highlights that despite the comprehensive understanding of the whole of life efficiencies LCEA demonstrates, it is overshadowed by individual preference dominated by their social influences, outcomes and objectives.

2.2 Retrofitting Options

Varying age groups and building constraints determine various retrofitting options. The retrofitting options considered for this research can be seen in Table 1 and are prioritised by the age of households, specifically the two age groups that identified to have the most common trends. Different aged households have diverse priorities and these priorities

determine the best retrofitting choices for each social perspective. These are the perspectives that will be tested through LCEA to determine if the social requirements of either group to achieve greater energy improvements.

Table 1 Modelling Parameters Used in Accurate or LCADesign Software and Priority of Age Group

Product		***Modelled as***	***Priority <30***	***Priority >50***
			(6 being top priority, 0 being least priority)	
Replace Single Glazing with Double Glazing Windows	Low U-Value, Mid range Solar Heat Gain Coefficient, Season Specific Shading	Modelled as Double Glazing with a 6mm air gap between high performance glasses.	4	1
Installing Wall Insulation	Achieve an R-value of 2.8	Modelled with an R-value of greater than 3.5 regardless of material selection/material type	5	0
Installing Ceiling and Wall Insulation	Achieve an R-value of 2.8 for walls and 4.1 for ceiling	Modelled with an R-value of greater than 3.5 regardless of material selection/material type	5	0
Installing Floor Insulation	Achieve an R-value of 1.25 (expect for slabs on ground)	Modelled as plastic sheeting between floor slab and ground; or in suspended floor with R-value greater than 3.5 regardless of material selection/type	5	0
Installation of various Air-Sealing techniques	Installation of foam/rubber compression material, draft protection on doors, self closing doors, exhaust fans fittings with a flap/dampener	Not modelled; taken from literature or negligible	2	4
Installation of various Shading Devices	Add shading either devices or deciduous trees to prevent summer sun and aid winter light	Not Modelled	1	3
Installation of Skylights to reduce artificial lighting	Low U-Value, Mid range Solar Heat Gain Coefficient, Season Specific Shading	Modelled as Double Glazing with a 6mm air gap between high performance glasses.	0	0
Replacement of Appliances to all 3.5 stars or above		Modelled as appliances with 3.5 star rating or where no half star available 4 star rating	0	5
Replace solar heating for water		Modelled as single solar panel, with 0.75 efficiency	0	2

2.2.1 LCEA Decision Support Tool

LCEA can be used as a decision support tool when comparing available retrofitting options. The most significant of advantages is ability to use LCEA to give a whole of life understanding of energy uses and demands. This is the process that software packages will be used to calculate in order to determine embodied and operational energy used over the lifetime of a case study.

2.2.2 Embodied Energy – LCADesign

For the calculation of embodied energy LCADesign and Building Information Models were used to assess the total embodied energy of the base case studies as well as retrofitting scenarios. LCADesign is a software tool used to analyse and assess the embodied energy of a building. By using Building Information Models, LCADesign can comprehensively assess the embodied energy of the components used to construct a building. Each material can be 'tagged', identifying it from the Australian specific Life Cycle Inventory. Analysis for a single dwelling can be run with multiple inventory models, allowing comparison between retrofit options.

2.2.3 Operational Energy – AccuRate Sustainability

For the calculation of Operational Energy, AccuRate Sustainability was used. AccuRate Sustainability is currently one of the software products recommended by Australian Government when assessing a dwelling's star rating. AccuRate Sustainability predicts the required operational energy consumption for one year given building parameters. Building parameters required include occupancy, room size, volume and orientation, hot water heating, lighting and water sources. AccuRate Sustainability provides star rating indicators, energy consumption in Mega Joules/area, as well as water heating energy and water consumption assessment.

Other indicators can be assessed from both software packages, such as water usage, gas usage, as well as other environmental factors, including CO_2 and Greenhouse gas emissions. For the purpose of LCEA, energy is the primary indicator, however there are a number of alternative software packages that take these environmental factors into consideration beyond LCADesign and AccuRate Sustainability, but are beyond the bounds of this research.

2.3 Findings and Discussion

2.3.1 LCEA and Social Influences

In the case studies tested, the operational energy decrease appears to coincide with embodied energy increase, with the introduction of new materials. Embodied energy does not accurately reflect the reasons to retrofit, objectives or retrofitting priorities of homeowners. In understanding the trade-off between this increase and the operational energy benefit to be gained we can begin to deduct the social impacts of these results.

Younger generations' choices are fuelled by their objectives to reduce their environmental footprint and consumption, something not reflected in their reasoning when choosing a retrofit option. When prioritizing the available retrofitting options, younger people chose options that reflected their objectives and offered large operational energy savings, with high embodied energy costs. These choices, however, resulted in a life cycle energy reduction, improving the energy efficiency of their home. Despite younger people's comments regarding limited budgets and significant time constraints, they prioritised retrofitting choices that met their objectives before other choices.

Older generations' reasons to retrofit, objectives and retrofitting priorities were very much in line with one another, indicating a clear understanding of their goals when it comes to retrofitting their homes. Their choices reflected their time and budget constraints and their understanding of the impact of retrofitting on their daily lives. Unlike younger people, their choices did not have large operational savings, or high embodied energy, instead they offered a more diverse consumption reduction, indicating that a LCEA cannot assess the total environmental impact of their choices.

It is clear that for the survey group in this study that their retrofitting priorities were based very much on their overall objectives for their homes rather than their reasoning to retrofit, these objectives reflected high-level thinking and goals, as opposed to lower level outcomes.

The younger age group chose better retrofitting options in terms of LCEA, as they opted for retrofitting priorities, which significantly reduced their energy consumption. This suggests that in isolation LCEA shows younger generations make more effective choices, however does not fully consider all environmental impacts that are affected by these choices. Older generations choices reflect a broader perspective on energy efficiency and environmental sustainability that LCEA does not adequately measure or account for in this research.

LCEA supports decision-making with respect to energy consumption, and this whole of life view is crucial in understanding what energy trade-offs are made with each retrofitting decision. Assessing the social influences on retrofitting options through LCEA gives a clear understanding that most retrofitting options will improve the life cycle energy of a home. However, it does not fully assess the environmental impacts beyond energy demand, and this can be seen as one of its greatest limitations.

2.3.2 Limitations

There are a number of limitations to this research. The pilot survey conducted was limited to a specific climate zone, and sought out particular participants, those in a position to retrofit. Due to the small sample size, it is hard to ascertain key trends beyond the two age groups listed and their key objectives and retrofitting priorities. Presenting the results on the clearest trends in data has mitigated this limitation.

The Life Cycle Inventories used, were based on assumptions from software developers. The software programs offer only a single Life Cycle Inventory (LCADesign) and have their own methodologies and frameworks for the calculations used to simulate energy performance.

The development of Australian Life Cycle Inventory Data is limited by the research available for each individual product and, therefore, retrofitting options such as appliances cannot be fully assessed via simulation.

Conclusions

The framework presented in this research has highlighted a number of areas for further development and research to complete a comprehensive understanding of the social influences that affect retrofitting options.

Operational energy is the largest consumer in Life Cycle Energy accounting for approximately 80% of the total Life Cycle Energy demand. Reducing this operational energy is the largest trade-off when making retrofitting decisions, regardless of social influences present. There are key limitations and gaps in the current research regarding common household appliances and how they can be used to reduce energy. Capturing these reductions in energy, from appliances, such as water heaters, dishwashers, and TV's, can help to assess the impact of purchasing higher rated appliances. Social consumerism is already prominent in many appliances, with star rating systems in place. However, there is a lack of integration between these star ratings and the total impact on the life cycle energy of a residential building.

Similarly, little is understood about the impact of appliances on embodied energy of a residential building, despite an understanding of the impact of these individual products. The results presented indicate, even with large embodied energy increases from the introduction of further materials, the operational energy savings is decreased significantly, often outweighing the impact of embodied energy on the total life cycle. This currently is not the case for appliances, or solar heating.

Social Influences pose the biggest threat to reducing residential buildings energy impacts. Social Influences affect not only the choices homeowners make when retrofitting, but also, how they make these choices. The survey completed in this research is applicable to many retrofitting scenarios and further analysis from the data available could present further trends in this particular set of scenarios. Understanding the motivation behind the choices made by various social groups allows a more comprehensive understanding of the way policy, rebates and enticements can be introduced to produce a more energy conscious and more energy efficient homeowner.

Life Cycle Energy Analysis allows the homeowner to understand the whole of life impact of their choices with respect to energy and is crucial to being able to better predict home energy consumption and better improve energy choices for new homes, as well as retrofitting existing homes. Trends in Australia suggest comprehensive research into the social influences of homeowners and their motivations and understanding of energy retrofit.

Future Research

Life Cycle Energy Analysis is a comprehensive tool in understanding a whole of life scenario in residential dwellings in Australia. It allows homeowners the ability to assess the long-term and short-term energy benefits of any retrofitting scenario. Further studies into how social variables affect the understanding and decision making of homeowners is necessary in order to fully understand the energy needs in Australia's existing housing stock. A thorough knowledge of Australia's average dwelling, average occupancy and social attitudes will critically influence energy outcomes in all aspects of the residential sector, and is vital in ensuring our energy demand

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An Investigation of Practices and Attitudes to Quality in Large Chinese Construction Firms

Shang Gao[1], Sui Pheng Low[2]

Abstract

Toyota is one of the most admired automobile manufacturers in the world, and is well known for its high-quality cars. This study begins with an overview of Toyota's quality practices, to uncover the secret behind its success. Toyota's ability to produce high-quality products can be credited to its employees' practice of not allowing defects to pass on to the next station (*jidoka*), as well as to its team-oriented forms (such as the company-wide quality circles), and the firm's culture of encouraging the workforce to expose problems in the process as much and as early as possible. These concepts appear to have been introduced by construction professionals into their day-to-day project management tasks. However, little is known about the extent of such practices and the attitudes towards quality present in the Chinese construction industry. This study draws on surveys and interviews of building professionals in China to investigate three central issues: (1) the extent to which the *jidoka* concept is implemented, (2) the workforce's current attitude and commitment to quality, and (3) how the quality circle (QC) concept is established and operated within Chinese construction firms. The results show that, in general, the basic concepts of *jidoka* have been implemented in large Chinese construction firms. It also reveals that the attitude side of quality management, such as forming QCs and continuous quality improvement, is generally lagging behind. The QC concept is not practiced as frequently or as actively in Chinese construction firms as in their Japanese counterparts. It seems that in these Chinese firms, the QC concept is not implemented voluntarily, but is largely driven by external factors, such as company requirements.

Key words: Toyota Way, *Jidoka*, quality circles (QCs), Chinese construction firms

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1. Introduction

Toyota is one of the most admired automobile manufacturers in the world, and is well known for its high-quality cars. Researchers from both Japan and abroad have attempted to understand the key elements in its successes. Efforts have been made to reveal the underlying culture and thinking of the Toyota Way (Liker, 2004; Liker and Hoseus, 2008), the Toyota production system, and the associated tools and techniques (Monden, 1998; Ohno, 1988). However, the recent massive recall incident has lead people to question the quality of Toyota cars, and some have interpreted this incident as evidence that Toyota has lost its way on quality. Yet this appears to be ungrounded, as in recent years Toyota has continued to win quality awards after quality awards (Liker, 2010). Nevertheless, it is worth making a timely return to the basics of the Toyota Way quality management principles and practices, and to reflect upon the implications for professionals both within and outside manufacturing (e.g. in construction). Toyota Way-styled quality management is particularly worth studying in the context of the Chinese construction industry, given that the Chinese construction workplace has never been completely free of quality problems. Construction quality in China has, however, improved over the years, which may be a result of the implementation of the mandatory construction supervision system (Yung and Yip, 2009) and Total Quality Management (TQM) practices (Tang et al., 2009).

2. Review of Toyota Way quality management

This paper begins with an overview of Toyota's quality practices, to uncover the secret behind its success. Toyota's ability to produce high-quality products can be credited to the adoption of *jidoka* which aims to eliminate possible defects from being moved downstream (Liker, 2004; Monden, 1998), to its team-oriented forms (such as the quality circles), and to the firm's continuous improvement culture which encourages the workforce to expose problems in the process as much, and as early as possible. These three practices and their tools form the framework of this study (see Figure 1).

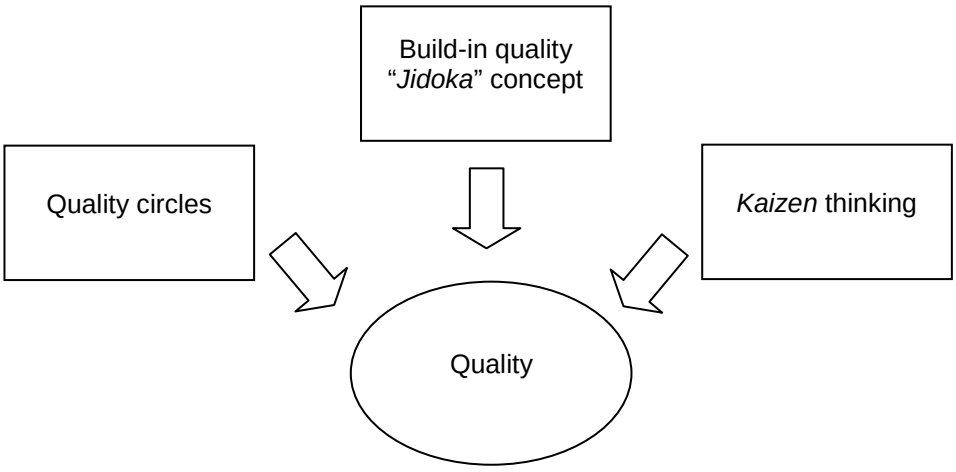

Figure 1: A model of the Toyota Way-styled quality management

2.1 *Jidoka* (build-in quality)

Jidoka is a Japanese word, meaning the practice of not allowing defects to pass on to the next station. It is commonly known as one of the twin pillars of the well-known Toyota Production System (Ohno, 1988), and is also in agreement with the principle of build-in quality (Liker, 2004). The principle of build-in quality prevailing at Toyota can be interpreted as "*do it right the first time*", which is the overarching goal of TQM. Literally, *jidoka* represents a machine with human intelligence that has the simple task of detecting deviation from the standards and stopping itself to wait for help (Ohno, 1983; Liker, 2004; Monden, 1998). This concept has been extended to shop-floor process, where it is usually implemented using a rope cord. Any team member who judges the situation to be abnormal can pull the cord to stop production and indicate the location of problems. The team leader proceeds immediately to the site to investigate the situation and provide assistance. Under this principle, quality can be guaranteed to a large extent. It is worth mentioning that several preconditions need to be in place before embarking on implementing the concept of *jidoka*. These include: (1) a standardized process and detailed working instructions need to be created and thoroughly understood by workers, so that variations can be easily uncovered; (2) the quality of workers' skills: workers should have in-depth understanding of the process and be skilled in problem solving; (3) a supportive company culture: the company culture should see problems as opportunities; this would encourage workers to pull the cord when necessary to reveal quality problems; and (4) empowerment: empowerment from the top management also plays a vital role. Only when employees feel trusted and are empowered, will they pull the cord to reveal quality problems without fear.

In the construction industry, a culture of quality would preferably use an inspection period to fix occurring problems, rather than applying the Toyota Way's build-in quality or *jidoka* approach to eliminating defects in the first place. In this case, the principle of build-in quality could be understood as the adoption of preventative approaches, and as whether employees' attitudes towards quality parallel the "stop-and-fix" approach. The literature reports limited cases in the construction context where firms have employed preventative tools to produce better quality.

2.2 Engagement with *kaizen*: attitude and commitment to quality

According to Liker (2004), most of what is discussed today about continuous improvement generally comes from the interpretation of the Japanese practice called *kaizen,* which means continuous improvement involving everyone - top management, managers, and workers (Imai, 1986:xx). Brunet and New (2003) summarized three key characteristics of *kaizen*: (1) *kaizen* is continuous: this is the unique nature of the practice, viewed as a never-ending journey towards quality and efficiency; (2) *kaizen* is incremental in nature: in contrast to organizational or technological innovation, *kaizen* activities appreciate incremental improvement; and (3) *kaizen* is participative: it entails the involvement and intelligence of the workforce. In the *kaizen* philosophy, improvements in all areas of business serve to enhance the quality of the firm. The starting point for quality improvement is to recognize a need. In Toyota, each employee sees problems as an opportunity for improvement. Liker and Meier (2006) noted that employees only do this when the organizational culture focuses on

continuous improvement. The problem is that, in most firms, problems are perceived as failure, and are thus hidden rather than exposed. This is particularly true in some of the stated-owned enterprises (SOEs) in China. Secondly, a non-blaming culture is also important. When fostered, employees are motivated to expose problems. Gradually, employees become willing to expose as many problems as they can.

2.3 Quality circles (QCs)

Quality circles are a vital part of *kaizen* at Toyota. As indicated by Liker and Meier (2006), unlike the American quality movement, QCs have never been a fad at Toyota. On the contrary, they have been an ongoing management tool for quality improvement. Historically, the first QC was developed and formalized in the early 1960s (Ishikawa, 1985). According to Ishikawa (1985), a QC is a small group that is voluntarily organized as a series of company-wide and participatory quality-control activities. People at Toyota choose to participate because they want to help improve the work area. Participation levels of over 80 percent are not uncommon in Japan (Liker and Meier, 2006). The purpose of QC activities, as outlined by Ishikawa (1985), includes: (1) to foster study groups in which foremen or workers study quality issues together; (2) to apply the results of their study to their workshops, so that more effective management and improvement of the work environment may be accomplished; and (3) to expand and enrich the personality of foremen and workers.

In the construction context, Rosenfeld et al. (1991) are among the few who had discussed the QCs in construction. Rosenfeld et al. (1991) listed a number of unique features of QCs in construction projects, and claimed that the special characteristics of project organization actually create even better opportunities for QCs than stable work-settings. This is because the former was always faced with the new lifecycle of a new project, while the latter may fall into an inevitable decay phase, as the most significant issues are tackled in a repetitive environment.

3. Quality practices in the Chinese construction industry

3.1 Status quo

Construction projects are subject to quality problems. The quality issues within the Chinese construction industry, in particular, are increasingly drawing the attention of researchers (see Yung and Yip, 2009; Zeng et al., 2003). Broadly, there are two views of quality in Chinese construction projects. On the one hand, a number of symbolic projects have helped China to win many accolades, and indeed these exemplary projects (such as the National Stadium, the Three Gorges Dam, and the Shanghai World Financial Centre) reflect the highest level of Chinese construction quality. Having observed these enormous achievements, Yung and Yip (2009) underlined that Chinese construction quality is expected to improve on a continuous basis, but at a decreasing rate as the economy develops. Moreover, Yung and Yip (2009) have highlighted that improved construction quality in China cannot be achieved without (1) the gradual implementation of mandatory construction supervision systems; (2) improved labour productivity; (3) the availability of resources, including machinery and labour; and (4) the use of more plant or machinery.

However, these exemplary construction projects do not represent the average level of the Chinese construction industry in terms of quality. On the other end of spectrum, there are the criticisms and complaints relating to poor construction quality, which appear to continue unabated elsewhere in the country. Poor construction quality was recognized as one of the critical problems in China in the 1990s (Chen, 1998; Lam and Cheng, 2004) and it is still a major problem (China Daily, 2010). There has been an alarming increase in fatal accidents caused by bad construction quality across the country. For example, a large number of schools and hospitals collapsed during the Sichuan earthquake in 2008, resulting in thousands of students being killed or seriously injured. In June 2009, a 13-storey building in the Lotus Riverside residential complex in Shanghai toppled, killing one worker. A recent tragedy includes the collapse of a bridge in northern China, at Harbin, which became at least the 18th collapse since 2007 (South China Morning Post, 2012).

3.2 How quality management works in China

Although quality management is increasingly practised in China, its implementation appears to be very uneven (Li et al., 2003). In China, construction quality is generally achieved under the supervision of (1) supervision firms (known as *jianli*), (2) relevant government authorities, and (3) the construction firms' own project management teams.

- Supervision firms: The roles and responsibilities of Chinese supervision engineers are in line with those of US design professional engineers (Wang et al., 2009). They act as the quality control team on site. However, Wang et al. (2009) have pointed out that the supervision professional's unclear scope of quality liability and safety liability in current laws, along with low level of competence seen in the practice of quality supervision, have become major causes of supervision liability risks, and ultimately would affect construction quality supervision.

- Government authorities and the building quality check programme: According to the Ministry of Housing and Urban-Rural Development (MOHURD, 2010), a number of quality awareness activities (e.g. "Safety Year activity") have been organized, to continue to stress the importance of quality awareness. Nevertheless the expected improvement is slow and disappointing.

- Construction firms: Attempts have been made by the Chinese government since the 1990s to implement the TQM framework, and to introduce ISO 9000 certification (Zeng et al., 2003). Tang et al. (2003) and Zeng et al. (2003) have pointed out that TQM has been accepted and applied in the construction industry in China, and there is a popular trend to obtain the ISO 9000 certification. Apart from that, the current status quo of quality management practices at Chinese construction projects - i.e., how quality management practices are carried out and how quality circles are operated - still remains unclear. This paper therefore attempts to bridge the gap and investigate the practices and attitudes of Toyota Way-styled quality management within large Chinese construction firms.

4. Methods

Guided by these objectives, this paper draws on surveys and interviews of building professionals in China to investigate three central issues: (1) the extent to which the build-in quality or *jidoka* concept has been implemented within large Chinese construction firms, (2) how the Quality Circles (QCs) are established and operated within Chinese construction firms, and (3) the attitude and commitment of the workforce towards quality.

A questionnaire survey was adopted to collect data for the purpose of assessing the first objective. The design of the questionnaire on build-in quality was underpinned by the works of Liker (2004). A five-point Likert scale was used, ranging from 1 (not at all) to 5 (to a large extent) for implementation, and 1 (not very important) to 5 (extremely important) for level of importance in the measurement of 9 actionable attributes derived from the *jidoka* concept. The questionnaire survey was conducted from February 2011 to May 2011. Questionnaires were sent to a mailing list of firms through the authors' contacts, which consisted of multiple sources, including the Chinese Construction Association. The list consists of more than 400 large Chinese construction firms. In total, 93 copies of the questionnaire were returned, representing a 24% response rate. A majority of the respondents were managerial personnel, including 34 general (deputy) managers (36.6%), 23 project managers (24.7%), and 15 engineers (16.1%). Respondents from these three groups have a good understanding of construction work, and are thus able to provide reliable responses to the questionnaires.

With respect to the second and third objectives, interviews and multiple site visits were carried out. 27 semi-structured (face-to-face) interviews were conducted. The interviewees consisted of 17 site staff and 10 management staff (see Table 1), all of whom were Chinese building professionals. They were also willing to be involved in the follow-up interviews, which were designed to explore in greater depth about how the QCs are operated within construction firms, and to understand the attitudes and commitment of their workforce to quality.

Table 1: Profile of interviewees and their firms

No.	Code	Designations of interviewees	Company Grade	Ownership
1	A	1 Project Manager	Premier	SOE
2	B	1 Engineer-in-Charge	Premier	SOE
3	C	1 Engineer-in-Charge, 1 Site Engineer, and 1 Commercial Manager	Premier	SOE
4	D	1 Project Manager, 1 Managing Director, and 1 Contract Manager	Premier	SOE
5	E	1 Project Director and 1 Deputy manager	Premier	SOE
6	F	1 Manager, 1 Head of Engineering Management Department, and 1 Project Manager	Premier	SOE
7	G	1 Vice President	Premier	SOE
8	H	1 Manager	One	SOE
9	I	1 Regional Manager	Premier	SOE
10	J	1 Project Manager	One	Private

11	K	1 Vice President	Premier	SOE
12	L	1 Site Engineer	Premier	SOE
13	M	1 Project Manager	Premier	Private
14	N	2 Project Manager and 2 Site Engineers	Premier	Private
15	O	1 Site Engineer and 1 Quality Engineer	Premier	SOE
16	P	1 Project Manager	Premier	SOE

Noted: (1) General contractors in China are graded into the Premier Grade (highest level), Grade one, Grade two, and Grade three and below. (2) SOE (state-owned enterprises) and private firms are two common forms of ownership of Chinese construction firms.

5. Results

5.1 Questionnaire survey

From Table 2, all the *jidoka*-related practices were scored less than 4 in terms of the implementation level. It can be seen that the importance values were generally rated higher by the respondents.

Table 2: Descriptive statistics of the jidoka concept in terms of the implementation and perceived importance

Jidoka-related attributes	Implementation			Importance		
	Mean	S.D	Rank	Mean	S.D	Rank
Employees are dedicated to provide "built-in" quality into every aspect of operations	3.67	1.020	5	4.32	.779	3
Preventing defective or uninspected assignments from entering the next process	3.70	1.014	3	4.43	.695	2
Rejecting defective materials, components and equipment	3.99	.910	1	4.46	.650	1
Employees are encouraged to seek support from their supervisors when something goes wrong at work	3.92	.797	2	4.22	.735	4
Employees are empowered to be responsible for quality	3.67	.920	5	4.18	.829	5
Kaizen activities on the topic of quality are conducted in the workplace	3.47	.991	8	4.07	.871	7
Employees who work in the same team meet on a regular basis to discuss quality problems and lessons learned	3.41	1.082	9	3.98	.867	9
Feedback about quality is routinely given by the employees	3.57	1.000	7	4.04	.879	8
Management treats quality problems as opportunities for employees	3.69	.939	4	4.14	.911	6

Some highly implemented attributes include:

- Rejecting defective materials, components, and equipment.
- Encouraging employees to report problems that occur.
- Preventing defective or uninspected assignments from entering the next process.
- Management treats quality problems as opportunities for employees.

These four attributes have mean values of 3.99, 3.92, 3.70 and 3.69 respectively, which implies that quality management practices have been put in place within the responding firms. In the respondents' opinions, these attributes have all been crucial to improvements in the firms' performance. This is also reflected by the mean values given to the degree of perceived importance (see Table 2). However, under the principle of build-in quality, two less implemented attributes include "*discussion of quality problems and lessons being learnt*" (m=3.41), *"kaizen activities on the topic of quality are conducted in the workplace"* (m=3.47), and "*feedback about quality is routinely given by employees"* (m=3.57). All these lowest-rated attributes showed that the quality culture in the responding firms has not yet been fully established, as employees and frontline workers seemed to less proactively discuss quality problems and lacking the "*kaizen*" mindset for engaging in meaningful and continuous quality improvement activities. In addition to that, the relatively low mean values given to these three were partly due to the pressure of tight schedules; employees' time is compromised, and thus they were left with limited time for quality-control activities.

5.2 Interviews

5.2.1 Workforce's attitude and commitment to quality

Poor attitude and commitment to quality

Quality problems that emerge repeatedly in day-to-day operational activities are important for signifying improvement opportunities. However, a large number of interviewees claimed that quality continuous improvement activities were completely absent from their firms. They also reported that neither employees nor frontline workers have the *kaizen* mindset. This corresponds to the survey finding, in which a few softer *jidoka*-related activities received low ratings from the survey respondents. The largest challenge - cited repeatedly by many interviewees - was that the rapidly expanding construction industry in China takes in a large number of unskilled construction workers who have fairly low levels of awareness of and commitment to quality. The majority of frontline workers in China are migrant workers registered with various labour-only subcontractors. The engineer-in-charge from Firm C revealed that: *"It is really hard to manage the quality of such workers. Too often, they kept silent about damage or results of poor workmanship."*

This was confirmed by a number of interviewees, such as a manager from Firm H, who said: *"Take wall plastering for instance. The quality of wall will be affected if the 'wet' treatment is not properly done, and this will lead to cracks in several months. The frontline workers knew that the cracks would not immediately be noticeable by the auditor, and so some irresponsible workers will be 'clever' and skip this essential step, and proceed to the next."*

A manager from Firm H also commented that one recurring problem was responsible for the continuing problems at the construction site. Efforts were made to fight this, but do not seem to work well, as ultimately it relates to workers' working habits and attitude, which lack *kaizen* thinking.

Lack of a non-blaming culture

Culture has a huge impact on the quality problem-solving process within the firm. Most interviewees replied that when they encountered a problem, they certainly have to consider the consequence of surfacing it, instead of surfacing the root cause. In most cases, exposing problems will in turn bring potential economic loss. Moreover, the interviewees stated that in facing up to quality problems, some project managers were more concerned about who should take responsibility for problems, or else leaders from SOEs desire problems to be solved according to their own philosophy, such as "reduce major issues to minor ones, and minor ones to nothing". Under such leadership, techniques such as the 5 Whys (means ask the question 5 times to reveal the root causes for the problem) have no place at all. If people do not look at problems as opportunities to build a better problem-solving system, they will then just take the shortest path to remove the symptom. Regardless of how much professional know-how and skills they possess, their wrong behaviours can deter all progress.

5.2.2 Quality circles

Given that the Chinese government is actively promoting the introduction of quality circles, it is not surprising to see that all the firms interviewed have had embarked on the quality route using QCs for quality improvement. However, in comparison with QCs in Japan, the QCs presently conducted in China's construction industry tended to be characterised by some differences, which are highlighted in Table 3.

Table 3: Comparison of Chinese QC and Japanese QC in construction projects

	QCs conducted within Chinese construction firms	Japanese QCs activities (Imai, 1986; Ishikawa, 1985)
Quantities	• One or two QCs were conducted within one project • No meetings to discuss the quality problems	• A large number of QCs (e.g. per year) • Frequent meeting to discuss the quality problems
Enabler	• External forces such as to fulfill the requirements and be eligible for the quality competition	• Employees recognize the potentials for improvement
Approach	• Top down approach: Project manager determines a QC topic for his team to carry out	• Bottom up approach: employees voluntarily participate in the QCs activities
Overall goal	• Aim at "ad hoc" improvement if possible	• Continuous and small improvement

(1) Quantities

According to the interviewees, QCs are not actively conducted at the project level, even though most responding firms are aware of its importance. Generally, one construction project only aims to foster one case of successful QC. An interviewee from Firm J explained that: *"It is good enough to have only one QC. This is because if more QCs are conducted,*

extra management efforts, as well as more human resources from different departments are needed, and perhaps more budget for it. We really do not have time and resources for this."

Given that all the firms interviewed were large Chinese construction firms, they are expected to have widely-spread sites geographically and numerous projects going on at the same time. Fortunately, by the end of the year, construction firms may achieve multiple cases of successful QCs, as well as attain tangible results. In order to recognize the outstanding contributions to project performance and to give the QC participants the satisfaction of achieving their goals, a number of responding firms introduced award schemes to recognize excellence in QC achievements in their construction projects. What is more meaningful is that a number of successful QC cases were compiled, published, and circulated within the firm and between the projects, so that all employees can learn from the experience.

(2) Enabler

Today, specific requirements such as to conduct effective QCs in construction projects are indicated in the contract documents. Based on the interview results, the by-product of QC, namely employee motivation, was largely ignored. Conversely, the ultimate drive for them to carry out QCs has nothing to do with striving for excellence, but to simply fulfil the contractual obligations, or to use quality awards as the selling point to increase the likelihood of winning future projects.

(3) Approach

As Table 3 indicates, QCs in the Chinese construction industry are pre-dominantly conducted in a top-down fashion. Many of the firms interviewed pointed out that the project manager acts like a moral supporter, rather than a leader of the QC team, whereas the real efforts came from the project engineer who is in charge. Moreover, the interview findings suggest that some QC teams are inappropriate in terms of their structures, in that the frontline workers are often excluded. This implies that the QCs are limited to among the site personnel and the frontline workers may not even be aware of the existence of QCs throughout the project. One interviewee from Firm D explained that: *"It is close to impossible, at least at this moment, that our workforce could contribute their feedback and be participating in QCs. All in all, the quality of workforce is the biggest difference compared to their Japanese counterparts."*

(4) Overall goal

Some respondents stated that they were currently struggling to define an appropriate QC problem to form a QC topic. For a number of projects that the research team visited, most have not yet identify a QC topic even though the QC team has been formed. A majority of the firms interviewed outlined that efforts have been made in searching for relevant problems in the hope of achieving breakthrough improvements. One interviewee from Firm M pointed out that: *"It is getting harder for us to choose a topic. Many have been investigated by colleagues or industrial practitioners. So far, our QC team has still not decided on what to*

work on. This perhaps is the reason why our project has progressed to almost half way but the QCs have not yet been formally kicked off."

6. Discussion and conclusion

The Chinese construction industry and firms have been facing quality challenges for some time and are expected to face more of such challenges in the future. While many business organizations have become leaner and reliable as a result of the adoption of build-in quality principles, construction firms have not been affected by this to as great an extent. This study shows that quality management practices derived from *jidoka*, or principle of build-in quality, are vital and worth learning. It is clear that the *jidoka* approach to quality management do apply to Chinese construction firms. The results show that, in general, the *jidoka* approach has been implemented in large Chinese construction firms. The findings are consistent with Li et al.'s (2003) research, which indicates that the procedural aspects of quality management - i.e. "rejecting defective materials, components, and equipment", "preventing defective assignments from entering the next process" - and other prevention means are already in place. This could be attributed to the fact that employees from the project team have followed the ISO 9001 guidelines (Zeng et al., 2003). On the contrary, the softer aspects of the *jidoka* approach - such as group meetings, discussion of quality problems, quality *kaizen*, and others - appeared to be less commonly conducted activities at the workplace. The implications for management here is that these less-implemented attributes should be recognized as weaknesses in terms of the implementation of the *jidoka* approach; hence they require immediate attention. Endeavours should be made as follows:

- greater empowerment should be given to employees, who should take responsibility for quality,
- teamwork on quality issues should be encouraged, i.e. quality circles should be formed to assist in quality improvement, and
- *kaizen* thinking should be embedded in the quality culture.

Furthermore, the study also reveals that employees' attitude towards quality shows inconsistencies. In the survey, one attribute, namely "employees are encouraged to seek support from their supervisors when something goes wrong at work", was rated highly, perhaps owing to the fact that workers are surrounded by site engineers. However, in the interviews, a majority of the interviewees highlighted that this is not always the case. One possible explanation is that, in the Chinese construction industry, workers' attitudes and commitment to quality are mixed, and heavily depends on the quality of the crews that the construction firms have recruited. Nevertheless, it was pointed out that a majority of the workers are still far from their Japanese counterparts with build-in quality thinking, as these practices and concepts have evolved over time there and are a part of the firm's culture in Japan. In contrary, what is uppermost in the minds of the Chinese workers is how to get more work done per day for higher earnings. Worse, this encourages them to cut corners in their daily operations and leads them to neglect build-in quality in their operations. As far as these challenges are concerned, it will probably take a long time for the Chinese construction firms to develop a workforce with build-in quality thinking. Certainly, the labour-

only subcontractors should play greater roles in developing the workforce they supply to construction projects.

In the case of implementing quality circles, the results are also consistent with the studies completed by Rosenfeld et al. (1991), in which the QC in the project environments is different from the regular QCs in the manufacturing setting. In this context, the QC team should, for a start, take advantage of the uniqueness of each project and seek wider opportunities for improvement (Rosenfeld et al., 1991). Moreover, QCs were not practiced as frequently or as actively in Chinese construction firms. In addition, it seems that QCs were not implemented voluntarily, but were largely driven by company requirements. Therefore, management must realise that the true purpose of the QC is more than to simply fulfil contractual requirements; QCs should be integrated into the daily running of the companies or projects. QCs or other forms of *kaizen* should be embraced as part of the firm's culture and objectives. Likewise, management should facilitate participation in QCs with possible rewards, and more importantly, the frontline workers should be invited to participate given that they know better about the processes and are better able to identify the possible problems in their workplace.

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A Policy Framework for Zero Carbon Buildings in Australia

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This paper reviews the current dilemmas confronting building efficiency policy in Australia, outlining the factors that are inhibiting progress towards the necessary and achievable goal of zero carbon, or zero net energy, buildings. It notes that policy settings are deeply conflicted, with different arms of government working towards very different goals – with net result being a stalemate. Policy makers are also seemingly unsure how to respond to the paradigm shift that has hit them from left field, with the new-found cost-effectiveness of photovoltaic (PV) technologies in particular, and other embedded electricity generation technologies to a lesser degree.

Positive initiatives include tentative steps towards mandatory disclosure of building energy performance. Also, despite their many critics, building ratings schemes are leveraging significant improvement in building energy performance through both voluntary and mandatory measures. However, despite evidence that minimum performance standards for buildings are too low – dramatically so for commercial buildings – and that zero net energy is already a cost effective performance target for some building classes, ineffective governance arrangements for buildings policy nationally and a significant flaw in the Carbon Pricing Mechanism are holding back movement towards this goal. This paper proposes a '10-point plan' to get Australian buildings policy back on track.

1. Background and Context

1.1 Energy and Emissions Profile of Buildings in Australia

Buildings – or perhaps more accurately, human activity in constructing and using buildings – are a major source of energy consumption and greenhouse gas emissions in Australia, and also around the world. The International Energy Agency attributes around one third of global final energy consumption, and a similar share of global greenhouse gas emissions, to buildings (IEA 2011). In Australia, buildings' share of final energy consumption is much lower, due to the distribution of energy consumption being skewed towards minerals processing in particular. Also, official statistics in Australia are organised by economic sector and allow only approximations to be made with respect to buildings as an end-use for energy. On this basis, building use accounts for around 18.5% of final energy consumption in Australia, while the construction sector accounts for less than an additional 1% (RET 2011). The share of greenhouse gas emissions in Australia attributed to buildings is higher, at around 23% (pitt&sherry 2010), due to the predominance of electricity as the final energy carrier in buildings together with the very high greenhouse intensity of electricity generation in Australia, where brown and black coal dominate as the primary fuels. Further, the same

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source cites ABARE data showing that total energy use in residential buildings more than doubled between 1973 and 2004, while total energy use in commercial buildings tripled over the same period.

There are excellent reasons to seek to reduce, and perhaps eventually eliminate, this source of energy use and greenhouse gas emissions.

1.2 The Climate Change Driver

First, and some six years ago now, the Intergovernmental Panel on Climate Change declared that "Warming of the climate system is unequivocal…" and that "Most of the observed increase in global average temperatures since the mid-20th century is *very likely* due to the observed increase in anthropogenic GHG concentrations" (IPCC 2007). Since then, and based on more recent scientific observations, research and modelling, some climate scientists are concerned that "BAU scenarios result in global warming of the order of 3 – 6°C"; that "…goals of limiting human-made warming to 2°C and CO_2 to 450 ppm are prescriptions for disaster"; and that "Rapid reduction of fossil fuel emissions is required for humanity to succeed in preserving a planet resembling the one on which civilisation developed." (J.E. Hansen and M. Sato, 2012).

1.3 The Energy Price Driver

Second, around the world, but very notably in Australia, energy prices have been rising strongly and are expected to continue to do so in future, albeit with some moderation expected in the short to medium term due to continuing weak global economic conditions and other factors. Electricity prices in Australia have increased most impressively in recent years, with nominal retail prices rising by 72.4 per cent in the five years to June 2012, equivalent to an increase of over 50% in real (inflation-adjusted) terms (Productivity Commission, 2012). Natural gas prices in Australia, retail or wholesale, are much less transparent than electricity prices and also show distinct variation by State. However, there is evidence that wholesale gas prices in Western Australia have more than doubled since 2009-10, while average retail gas prices have increased by over 40% in real terms since 1991 (AER, 2011). As a result the 'business case' for saving energy in buildings in Australia has never been stronger.

1.4 Efficiency and Abatement Potential of Buildings

Third, it is extremely well established that the technical and economic potential for saving energy in buildings is very large. A recent review of Australian and international literature in this area showed that international literature suggests that up to 70% of energy use in new buildings could be avoided in most OECD countries with no or very low incremental costs, while Australian literature is more conservative, with savings potentials clustering around 30% (pitt&sherry 2010). It should be noted that this literature focuses on energy efficiency and does not consider the potential for embedded generation from low or zero carbon sources to cost-effectively reduce the demand for purchased or networked energy in buildings.

A more recent reference examines more closely the potential for cost effective energy savings in Australian buildings, based on social benefit cost analysis and detailed, bottom up modelling of a wide range of building types, over the period to 2020 under a number of energy price, carbon price and other scenarios. This work finds that for new residential buildings, without PV, and in a reference scenario for energy and carbon prices, only some 16% of space conditioning energy consumption could be cost effectively saved by 2020, relative to the 2010 standard requirements, on average across Australia (pitt&sherry 2012). This value was significantly higher in some States where electricity prices are relatively high, for example, 36% savings were found to be cost effective in Perth, Western Australia. However, these results do not include the value of avoided energy network infrastructure savings – a key factor that is discussed further below. More importantly again, when PV was allowed as part of the building solution, the cost-effective level of savings rose to 100%. That is, zero net energy houses are shown to be cost-effective in Australia, indeed by 2015 or earlier in all States except those with the lowest electricity prices.

For commercial buildings, the 'reference scenario' level of cost effective savings (without PV), relative to 2010, is much higher than for residential buildings – 58% on average by 2015 and 68% on average by 2020. Again significant regional variations were in evidence, with the highest result being 80% in Darwin, Northern Territory (where electricity prices and ambient temperatures are high and (cheaper) natural gas is largely unavailable). For many commercial building types, the availability of PV or other embedded generation options does not make proportionately as much difference to the cost effectively level of energy performance as it does for residential buildings. With respect to PV, this is due to the often restricted façade area with appropriate solar access, but also higher energy densities, of commercial when compared to residential buildings.

However, the same study notes that for supermarkets, zero net energy is marginally cost effective. Supermarkets in Australia are cooling dominated, large and low-aspect-ratio 'box' form buildings, with limited glazing and significant internal heat loads from lighting and refrigeration adding to their already substantial cooling task. The study suggests that there is an expectation of significant improvements in the efficiency of lighting, refrigeration and space cooling energy technologies over the period to 2020. Further, these buildings almost invariably use (high cost, high carbon) electricity for 100% of their energy needs, and they also generally have excellent solar access for PV. It is the combination of all these factors that generates the result of cost effectiveness at a zero net energy performance level.

1.5 The Network Cost Driver

It was noted above that real electricity prices in Australia have risen by over 50% in just five years. While more than one factor has contributed to this outcome the Productivity Commission, amongst many other analysts, has noted that "Spiralling network costs are the main contributor to these increases, partly driven by inefficiencies in the industry and flaws in the regulatory environment." (Productivity Commission, 2012, p. 2).

While a full description of this issue is beyond the scope of the present paper, the fundamentals are that some 70% of the peak electrical load in Australia is attributable to

buildings and around two-thirds to residential buildings alone. Most climate zones in Australia experience wide diurnal and seasonal variations in temperature. Air conditioned commercial buildings are the norm, while residential air conditioning has grown strongly over the last decade or more. The percentage of households with air conditioners increased from 20% in 1970 to around 75% in 2011 (Productivity Commission, 2012b), and this is generally cited as the proximate cause of rising peak system loads in Australia. The cooling demand of buildings (and, to a lesser degree, heating demand of buildings in winter), is therefore by far and away the dominant driver of rising peak load, and rising peak load is far and away the dominant driver of rising electricity prices in Australia. The Productivity Commission has noted that "capacity that caters for less than 40 hours a year of electricity consumption (or under one per cent of time) accounts for around 25 per cent of retail electricity bills" (Productivity Commission 2012b, p. 301). This leads not only to higher than necessary electricity prices, it also creates poor productivity for investment in network assets and electricity generation. It should be understood as a misallocation of economic resources driven by poor market design.

However, we could express this conundrum another way. We could say – on the above evidence – that the demonstrably sub-optimal thermal performance of buildings in Australia, the non-realisation of the very large, demonstrated cost-effective potential for efficiency improvement in buildings, is the largest single cause of rapid growth in electricity prices in Australia, and also of rising energy demand and associated greenhouse gas emissions associated with buildings. Clearly, other factors are also at work. These will include rising incomes, larger houses (and commercial building space per capita), longer operating hours for commercial buildings, rising 'plug load' (notably electronic equipment) and standby power. An investigation of their role falls outside the scope of this paper.

Instead, this paper focuses on why – given the remarkably strong prima facie case for strengthening building energy efficiency policy in Australia – there appears to be little or no appetite for policy reform? Despite the opportunity to cost-effectively reduce energy consumption and costs for businesses and households alike, and despite the opportunity to realise cost-effective greenhouse gas emissions savings, in some cases all the way down to zero net energy or carbon – why is it that there seems to be little appetite or momentum for policy development?

2. Building Energy Efficiency Policy in Australia

2.1 A Potted History

It is not within the scope of this paper to provide a comprehensive history of buildings efficiency policy in Australia. Suffice to note that Australia embraced energy performance regulation of buildings late, at least at the national level. Some States, like Victoria and the Australian Capital Territory (ACT), had introduced some prescriptive requirements (such as insulation requirements) into their state Building Codes in the 1990s. The ACT introduced mandatory disclosure of residential building energy performance in 1999…something that has still not been implemented across Australia despite being agreed by the Council of Australian Governments in 2009 (NSEE 2009).

Building energy performance measures were first introduced for some residential buildings (Classes 1 and 10) in 2003 and for others (Classes 2 – 4) in 2005. Class 1 building requirements were lifted to 5-star (see below) at that time and to 6-star in the 2010 version of the Building Code of Australia. For commercial buildings, energy performance requirements were first introduced in 2006 and then lifted in 2010. In addition the scope of Code requirements has been broadened; for example, requirements for lighting energy density, hot water greenhouse gas intensity and pool pump energy usage were included for residential buildings.

There is some evidence that the stringency of both past and current requirements is modest, particularly for commercial buildings. For example, it was retrospectively calculated that the required social benefit cost ratio set as the 'hurdle rate' for commercial buildings in 2006 was a remarkable 4.9:1 (CIE 2009). This clearly indicates that much more 'benefit' (energy savings) could have been realised whilst remaining cost effective. More recently, the benefit cost analysis of future Code stringency (pitt&sherry 2012) indicated high benefit cost ratios for commercial buildings even in the very short term, suggesting that BCA2010 performance requirements were once again very conservative.

Also, it should be noted that individual states were then (and are today) given considerable latitude in both the timing of the implementation in their states of nationally-agreed performance measures in the Building Code of Australia, and secondly in making state-based 'variations' to these provisions, notionally to accommodate local factors. COAG first agreed to 6-star housing in 2008, for example, but this performance requirement will not be adopted in Tasmania until 2013, fully five years later.

Building ratings schemes deserve a brief mention in this context. The benchmark rating system for residential buildings is NatHERS (the National House Energy Rating System), developed and administered jointly by Federal and State/Territory governments since at least 1995, although other ratings tools have been developed (FirstRate, BERS). For residential buildings, energy performance requirements in the Building Code of Australia (or, more strictly, space conditioning energy consumption) is determined by reference to NatHERS star ratings levels, although other solutions (including a 'Deemed to Satisfy' or prescriptive route) are also accepted.

For commercial buildings, the NABERS (National Building Energy Rating System) is the most widely used energy rating tool, although the Green Star sustainability rating is also popular for premium buildings (and in any case draws on NABERS for its energy ratings component). NABERS underpins the mandatory disclosure regime for commercial buildings, known as Commercial Building Disclosure, but may not be used to demonstrate compliance with the energy performance requirements in the Building Code of Australia (Section J). Instead the Code uses a 'reference building' simulation approach.

Despite having many critics, it is clear that these ratings tools have a) enabled firstly a small market for building energy efficiency to be established on a voluntary basis; b) enabled a much larger market to evolve through mandatory application (BCA, and now Commercial Building Disclosure); and c) continue to support 'beyond minimum compliance' and best

practice on a voluntary basis, by providing a credible and reliable 'metric' for the measurement and demonstration of building energy performance.

In 2009 the Council of Australian Governments (COAG) endorsed a National Strategy on Energy Efficiency. This Strategy included, inter alia, the development of an 'integrated framework for national building energy standard-setting, assessment and ratings' (NSEE 2009). The Framework has the laudable goal "...to drive significant improvement in Australia's building stock through establishing a pathway for future increases in minimum building standards to 2020, and improving the approach to assessing and rating buildings" (DCCEE 2012). It is intended that the the Framework will:

- set increasingly stringent minimum building standards over time for new buildings and renovations
- cover all types of residential and commercial buildings
- apply to new and existing buildings
- cover the building envelope including roof, walls, doors and windows, as well as the energy efficiency of key building equipment and services
- aim to harmonise assessment and rating tools for existing and new buildings
- include common measurement and reporting methodologies to help in setting building standards and assessing building performance
- encourage innovation in meeting defined performance standards
- continue to communicate building performance using star ratings, and
- facilitate effective monitoring and compliance.

The process has proceeded from a policy commitment in 2009 to a Discussion Paper in 2010 to a Draft Framework by late 2012. Stakeholder consultations were held in early 2012. It is unclear when or whether a Final Framework will appear and also when or whether the above goals will be achieved. The barriers are discussed in the following section.

2.2 The Present Malaise

At least five factors appear to working against the establishment of a fit-for-purpose building energy efficiency/carbon framework that would take Australia towards the goal of zero carbon buildings within a defined timeframe. These may be summarised as:

1. A lack of political will, which in turn reflects a) Australia's weak climate change target, and b) a view that Australia's carbon pricing mechanism makes most other policy measures – and certainly building energy performance requirements – redundant;

2. A lack of a credible national energy efficiency policy, and the absence of energy efficiency targets;

3. A lack of co-operation between the Commonwealth and major States/Territories, augmented by unclear accountability for buildings policy and regulation between jurisdictions and even agencies within jurisdictions;

4. An apparent unwillingness to deal with the 'paradigm shift' that is being worked by low-cost PV, which in turn reflects short-comings in wider energy policy and regulation;

5. At a more technical level, a lack of appropriate guidelines, research and data to underpin realistic benefit cost analyses and regulatory impact assessments – the net effect of which is generally to overstate the costs and understate the benefits of building energy performance regulation.

Each of these barriers is discussed briefly below.

2.3 Climate Policy and the Carbon Pricing Mechanism

One might suppose that the potential for large and highly cost-effective greenhouse gas abatement benefits, as well as significant economic and social benefits, would be welcomed and embraced by the designers of climate policy in Australia, and responded to with much strengthened and forward-looking policy settings. The reality is somewhat different.

The Australian Government views its carbon pricing mechanism (CPM) as its primary policy instrument to achieve its climate policy goals. It is actively discouraging new policy measures and indeed seeking to prune out as many existing policy measures as possible. It justifies this view on the grounds that pricing carbon represents a 'least cost' approach to reducing emissions. Setting to one side the research that conclusively demonstrates that this is not (necessarily) so, the CPM presents two major threats to the development of a policy framework that would enable the realisation of a goal of cost-effective, zero-energy/zero-carbon buildings in Australia.

First, the carbon saving effect of what are now referred to (disparagingly) as 'complementary measures' (that is, any measure that is not the CPM) is not 'additional' to the cap mechanism under the CPM. Under a cap-and-trade scheme, it is the level of the cap that determines the volume of allowed emissions, in every year, from the sectors of the economy 'covered' by the scheme. The *Clean Energy Act 2011* prescribes a number of factors that must be taken into account when recommending to the Minister the level of future caps (the decision itself, however, is left to the Minister's discretion). These factors fail to include the abatement effect of existing (or future) 'complementary measures', even if a discretion exists for the Climate Change Authority (that advises government on the caps) to consider 'other relevant matters'.

While this may seem a technical point, it means that the very substantial abatement effect of building energy efficiency measures – and indeed of many other measures besides – counts for precisely nothing once the cap mechanism is in place (from 2015). Therefore, building energy policy – as with most other 'complementary measures – is vulnerable to the criticism

that ‘it won’t add one gram of abatement to the national effort, so why don’t we get rid of it?’. This view has been starkly put to government, and indeed to COAG, by the Productivity Commission (Productivity Commission, 2012c). Those who put this view fail to acknowledge that this ‘additionality’ problem is entirely a creation of one section of one Act of Parliament; ie, a policy failure that could readily be corrected. The fact that this is neither acknowledged, nor less acted upon (by amending the Act), may be traced back to the afore-mentioned view that carbon pricing must be the primary climate policy instrument. This view is pursued in Australia with a degree of zeal that suggests that it is based on something other than rational analysis.

However, the second threat that climate policy poses to building energy performance regulation is complacency. Australia’s official climate abatement target is to achieve a 5% reduction in 2000 emissions by 2020. Due to the slow down in the global and large parts of the domestic economy; a particular slowdown in forest harvesting due to both global and local economic factors; changes in the national energy market that largely preceded carbon pricing (and many of which are attributable to the same energy efficiency and renewable energy policy measures that are now under threat on ‘complementarity’ and ‘additionality’ grounds), and – to be fair – to some additional abatement effect from the CPM itself, there is now a view that Australia may achieve its target without further policy development...including building energy efficiency policy.

Given the climate science reviewed very briefly above, it is at least a tenable view that we have no grounds for complacency. Australia is amongst the highest per-capita greenhouse polluters in the world. The Australian Treasury’s analysis of the carbon pricing mechanism clear states an expectation that by 2050 (nearly 4 decades into the future), actual emissions in Australia will be just 2% below their level in 2000, while the difference between this any political goal (which has been set at 80% below 2000 by 2050) will be made up by purchasing offsets (Treasury, 2011). Our plan to rely on carbon trading, and to import ‘certified abatement’ rather than reduce emissions domestically through genuine structural reform and best practices, is of questionable ethical integrity, and may not even pass the purely mercantile test of ‘least cost’.

2.4 Energy Efficiency Policy

In 2009 the Australian Government established an Energy Efficiency Task Force to report directly to the Prime Minister on strategic energy efficiency policy. The Task Force duly reported in July 2010, making 44 detailed recommendations, starting with the setting of a national energy efficiency target or goal. To date, only two of the 44 recommendations have been responded to by government. First, it rejected out of hand the concept of a national energy efficiency goal or target. The justification for this may be found in the above discussion on climate policy and the role of the CPM. Second, it agreed to ‘consider’ a national energy savings initiative (conceived of as a ‘white certificates’ scheme). At the time of writing, the consideration process goes on, with only a ‘Progress Report’ having been publically released. The balance of 42 detailed recommendations to the Prime Minister remain unresponded to, either in the positive or in the negative.

2.5 Policy Governance

Building regulation has traditionally been viewed as a Constitutional responsibility of the States and Territories. Australia's Constitution – unlike many – assigns an 'exclusive' list of functions to the Commonwealth, while all functions remain with the States…at least in theory. Building regulation apparently did not rate highly in the minds of our 'founding fathers', and therefore does not rate a mention in our Constitution. On this basis, it belongs to the States. However, the Commonwealth is responsible for the regulation of corporations, and also for implementing ratified international treaties (such as the UN Framework Convention on Climate Change and Kyoto Protocol, for example). The Commonwealth has also most of the taxation powers in Australia and therefore captures the vast majority of government spending power, even if much of the revenue is 'recycled' to the states under various mechanisms.

As a result of these factors, and others besides, governance of buildings policy generally in Australia is contested and unclear. At the time of writing, political tensions and budgetary pressures are also adding to a policy 'stand-off' between jurisdictions, with building energy efficiency policy apparently one of many casualties. It is hard to judge whether, given the two factors noted previously, whether this third factor is material or not. We can, however, be sure that it is not helping.

2.6 The PV Paradigm Shift

PV technology – originally developed by NASA for use on satellites – has until very recently suffered from high capital costs. However, since around 2007, the price of panels has fallen by up to 90% (pitt&sherry 2012). This is one of the key factors – along with rising electricity prices – that is making PV on buildings increasingly cost effective.

One might again be forgiven for thinking that this development would be a cause for much rejoicing and celebration amongst policy makers, however no such levity is evident. PV is a 'disruptive technology' – one that breaks the current electricity market paradigm – itself based on remote, large-scale and generally fossil-fuel powered generation, owned by large (and, in the past, state-owned) corporations, transmitted and distributed by either state-owned or private regulated monopolies, and sold by retailers to passive consumers. The flow of energy is one way; the flow of money, the other. Energy efficiency in this system is remarkably low, while greenhouse gas emissions are very high.

PV, and other low-carbon embedded generation technologies, turns this paradigm on its head. The generation technology is low- or zero-carbon; it is owned by consumers; it is distributed not centralised; the flow of energy and money is two-way between consumers and others in the power system; and large corporations – state-owned or otherwise – have little to do…other than cope with more complex and dynamic power flows (another paper would be required to describe this in detail). Interestingly the extremely high level of electricity prices that have, as noted above, been generated in Australia, as a result of the first paradigm, is also driving consumers with increasing rapidity towards the second. A 'market response' indeed. Thus, an industry that has evolved to 'clip the ticket on the way

through', as power flowed downhill in the first paradigm, suddenly can feel its business model being undermined. Not surprisingly, the industry is pushing back, as are the governments that design the energy market, regulate the market players and often own the businesses that participate in the market.

The result that PV may make zero energy or zero carbon buildings cost effective in Australia is troubling for policy makers…not in buildings policy, and not for those interested in a clean, low carbon and sustainable future, but in energy policy and in our Treasuries.

2.7 Analytical Constraints

While a lesser and more technical issue, the lack of adequate data, statistics and funding for the development of the same, does hold back the creation of compelling 'business cases' for buildings policy *inter alia*. Further the Orwellian-named Office of Best Practice Regulation in Australia – which essentially sets the rules for quantitative and impact assessment of regulation in Australia – insists on high hurdle rates (at least 7% real) and does not prescribe that learning effects, technological change and other factors (that might improve the business case for regulation) be included in the analysis. Of course, these may be included…provided they are specified in the briefs let by the policy agencies (which is rare), and provided research has been done to enable these factors to be quantified (which is even more rare).

3. Conclusion – A 10 Point Plan

What would it take to overcome the barriers noted in this paper, and instead to realise the opportunities presented by cost-effective, zero energy/zero carbon buildings in Australia?

The answers are suggested in the above points. For economy, they are summarised in point form:

1. Australian governments should publically acknowledge that building energy performance in Australia is poor, and that this is a major drive of a) greenhouse gas emissions, b) costly and unnecessary energy consumption, c) energy system cost impacts, and d) therefore, a major driver of rising electricity prices in Australia;

2. Australian governments should publically acknowledge that there is very large potential for improving the thermal and energy performance of buildings, and that creating policy settings to capture this potential would be a highly effective and cost effective strategy for responding to point 1) above. Alternative solutions to these issues should be benchmarked against building policy and the least cost options chosen…if indeed we believe in least-cost and rational public policy;

3. Australian governments must set high, but evidence-based, standards and goals, not the low ones that have applied, and continue to apply, today. This includes with respect to climate policy, energy efficiency policy and buildings energy efficiency policy more narrowly.

4. The *Clean Energy Act 2011* must be amended to remove the policy failure that results in the 'non-additionality' of building energy efficiency policy and all other non-CPM policies and measures; the pejorative term 'complementary measures' should be consigned to the dustbin of history.

5. The governments' laudable goal of creating an integrated framework for regulation, assessment and rating of building energy performance should be put into effect as soon as possible. To the framework I would add an effective mechanism to ensure compliance with existing and future buildings regulation.

6. The Australian Government should respond without further delay, in detail and positively to the 44 recommendations of the Prime Minister's Task Force on Energy Efficiency, including by setting an ambitious national energy efficiency (not intensity) target, with a detailed, measure-by-measure, year-by-year plan for its achievement.

7. Governance arrangements for the building industry must finally and definitively be settled. The flood of powers from the states and territories to the Commonwealth suggests the direction in which this might be resolved. However, that outcome should be contingent upon the commitment of the Australian Government to put in place – and keep in place – and to fund – a credible buildings policy in Australia.

8. Governments in Australia, and their agencies responsible for energy policy, must come to grips with the PV/distributed energy paradigm shift. To date, the key response has been to worsen economic conditions for PV, in the hope that it will go away. It won't.

9. Governments in Australia, and primarily the Australian Government, must fund the creation and maintenance of adequate, fit for purpose and publically-accessible data sets, and also the conduct of public interest research on public policy matters, including building energy efficiency, on an adequate, secure, long-term and independent basis.

10. Above all, Governments in Australia should offer genuine leadership on climate policy in particular, ensuring *inter alia* that targets are based in science and not politics; that policy is based in genuine and rational analysis, sound data and not ideology; and that buildings policy in Australia receives the enhanced focus and support that it deserves.

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Overview of Key Indicators of Team Integration in Construction Projects: New Zealand Practitioners' Point of View

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Abstract

The purpose of this paper is to provide an overview of the key indicators of team integration in construction projects, based on an online survey of a construction peer group in New Zealand. A literature review was initially conducted to review the concept of team integration in construction projects and, from this, 15 key indicators were identified. A set of questions designed to confirm and rank the indicators was included in an online questionnaire survey. Analysis of the survey results revealed that all 15 indicators have a strong influence towards determining the success of team integration in construction projects. The top-ranked factors that contribute towards successful team integration are free flowing communication, single team focus and objectives, commitment from top management, trust & respect, and encouraging initiative. In addition, suggestions on how to improve team integration were identified as part of the survey.

Keywords: Construction Projects, Key Indicators, Team Integration, New Zealand

1. Introduction

Project delivery performance within the construction industry has, in the past, been criticised due to its fragmented approach to project delivery (Latham, 1994; Egan, 2002). The traditional procurement approach does not encourage the integration, coordination and communication between project teams needed to overcome this fragmentation (Latham, 1994: Love et al., 1998). Indeed, the characteristics of the contract can hinder effective collaboration and cooperation (Love et al., 1998: Walker et al., 2002), resulting in various teams being unable to collaborate and work together as expected to deliver projects effectively (Egan 2002; Evbuomwan and Anumba 1998). It is also acknowledged that the fragmented transactional

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agreements in the traditional approach have a negative impact on team dynamics, and channel various team efforts to meet contractual deliverables instead of defining best solutions (Forques and Koskela, 2009).

Teams from different types of organisations must be able to coordinate and cooperate to fully utilise their knowledge and experience to ensure that the information can be shared and transferred effectively throughout the project life cycle. Moore and Dainty (1999) indicated that successful project delivery and the performance of the construction industry depend, to a large extent, on how the knowledge and experience of many people can be integrated together as a team. Teams and individuals possessing substantial diversity in skills, knowledge and expertise, but who may not have previously worked together, make integration more difficult to achieve (Baiden et al., 2006). In addition, the process of integration in a team does not happen automatically, as it may be hindered by various issues, such as lack of collaboration, inconsistent shared vision, poor communication and inadequate participation from team members (Constructing Excellence, 2004).

This study was designed to validate, through an online survey of practitioners in New Zealand, key indicators of team integration in construction projects identified from a previous review of the literature (Ibrahim et al., 2011a; 2011b). The indicators were assessed based on their level of significance. Finally, suggestions on how to improve team integration were identified based on practitioners' experience in the construction industry.

2. Key Indicators of Team Integration

A previous review of literature was conducted by Ibrahim et al. (2011a; 2011b; 2012) to understand team concepts and integration approaches in construction projects. This resulted in a set of 15 indicators that contribute to team integration as identified in Figure 1. This study aims to validate these 15 indicators from a practitioners' point of view.

Through observation of the existing literature, relationship based attributes are seen as key as they have a direct influence on the relationship between project teams. Indicators such as trust & respect, no-blame culture, commitment from top management, and communication, among others, are identified as the main behavioural factors influencing the development of team integration practice.

The literature also indicates that the use of systems or processes in influencing human behaviour is important, for example having an integrated ICT system. The importance of having systems and processes actively promote desired behaviours among project teams in delivering projects is often underestimated, or overlooked altogether (Boedker et al., 2011). Although project teams normally aspire to a culture of collaboration and efficiency, the existence of "red tape" restricting the capacity of teams to demonstrate initiative and get things done, and a lack of processes in place to promote, or even allow, members of different functions to collaborate have contributed to the disintegration of team integration practice (Lawrence & Scanlan, 2007).

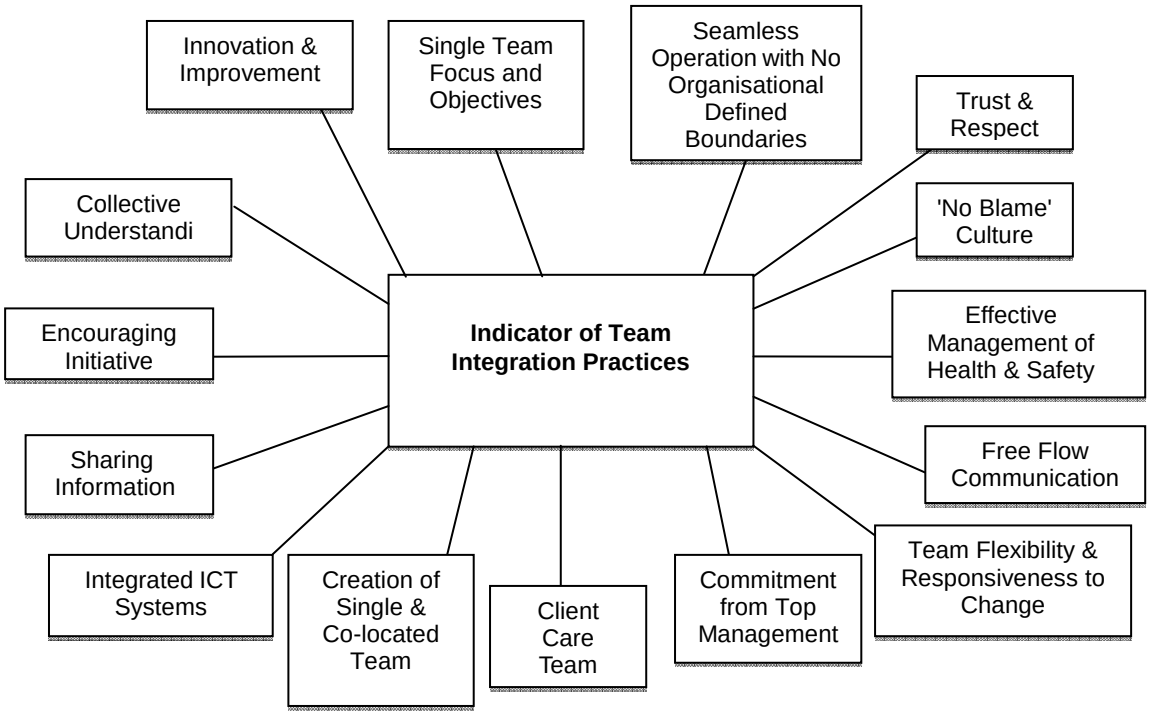

Figure 1: Summary of 15 indicators identified from existing literature (Adapted from Ibrahim et al., 2011a; 2011b).

3. Research Methodology

The research methodology for this study included the development and distribution of a questionnaire survey for data collection purposes. A construction peer group from New Zealand, the Construction Clients' Group (CCG), was selected to participate in this study. The CCG is an established peer group for public & private sector clients of construction in New Zealand. Its members typically hold top and senior management positions in the industry. Consequently, it was considered extremely useful to draw on the CCG members' experience, knowledge and expertise regarding the subject of team integration. This survey had the following objectives:

- To validate the key practice indicators of team integration identified from the construction management literature.

- To rank the key practice indicators in terms of their importance in assessing team integration in construction projects.

- To elicit feedback and suggestions on how to ensure team integration practice.

The questionnaire comprised of both closed-ended and open-ended questions and was divided into two parts. The first part of the questionnaire (SECTION A) sought background

information on each participant's level of experience, how many years they have been in the industry and the type of contracting arrangements that they have been involved in over the years. The second part (SECTION B) focused on what key practice indicators they considered important for assessing the success of team integration in construction projects, as well as their views on methods to ensure team integration in construction projects.

The survey was administered online. An email with a brief introduction about the survey was sent to the participants between 13 September 2011 and 15 October 2011 with the help of CCG, along with the survey hyperlink, and an attachment of the survey summary for their reference. According to CCG, the survey was sent to 588 individual members' email accounts. From the invitation, 38 responded, which is equivalent to 6.5% as the response rate. However, from the 38 responses received, only 35 respondents (6% response rate) could be used for analysis purposes as the other 3 respondents did not complete SECTION B of the questionnaire.

4. Survey Results and Discussions

4.1 Section A: Profile of Respondents

The various designations and varying years of experience of respondents to this survey are included in Table 1. Eighteen of the respondents (52%) identified themselves as managers, five respondents (14%) were directors, six respondents (17%) held other positions such as senior consultant, project engineer or technical advisor, and the remaining six respondents (17%) did not reveal their current positions. It is clear that the majority of respondents belong to senior and top management decision makers, with the balance predominately senior engineers and advisors.

Overall, there was a fairly good mixture of designations of respondents with 66 per cent of the respondents holding upper level management positions in their organisations. On average, respondents had about twenty six (26) years of experience in the construction industry. The survey results are discussed in the following sections.

Table 1: Summary of respondents

	Respondent characteristics	**No. of respondents (Total = 35)**	**(%)**
Designation	Directors	5	14.3
	Managers	18	51.4
	Others	6	17.1
	Unknown	6	17.1
Years of experience	0-10	5	14.3
	11-20	5	14.3
	21-30	12	34.3
	31 and above	8	22.8
	Unknown	5	14.3

4.1.1 Respondents' Involvement in the Construction Industry

Respondents were asked for their involvement in the construction industry in terms of type of sector and project delivery systems. Referring to Table 2, the majority (89 per cent) of the respondents were involved (at some stage of their career) in the infrastructure sector. The commercial and maintenance sectors follow with 60 per cent and 51 per cent, respectively. The residential sector comes fourth with 40 per cent, followed by other sectors with 17 per cent. Based on the survey, responses on the other sectors included aeronautical, macro planning and public / civil building. Overall, it reflects the fact that in New Zealand, infrastructure has become a political priority and the government is committing billions of dollars to infrastructure projects as one means of fighting the recession (McCormick, 2010).

Table 2: Respondents involvement in industry by sectors and delivery systems

		No. of respondents (Total = 35)	(%)
Sectors in Industry	Infrastructure	31	89
	Residential	14	40
	Commercial	21	60
	Maintenance	18	51
	Others	6	17
Type of Delivery Systems	Traditional	33	94.3
	Design & Build	32	91.4
	Joint Venture	22	62.9
	Partnering	23	65.7
	Alliancing	15	42.9
	Others	4	11.4

As expected, the most prevalent project delivery system that the respondents had been involved in throughout their career was the traditional system with 94.3 per cent. Design and Build follows behind with 91.4 per cent. The respondents were also involved with more advanced project delivery approaches, notably partnering and joint ventures, with 65.7 per cent and 62.9 per cent respectively. Alliancing comes fifth with 42.9 per cent and the least percentage was for other types of project delivery with 11.4 per cent. Based on the responses, the other types of project delivery included early contractor involvement (ECI), construction management and private finance initiative (PFI) / public private partnership (PPP).

Overall, Zuo et al. (2006) describe procurement systems such as traditional, and design and build as well established and developed in the New Zealand construction industry. Although these still dominate the New Zealand construction industry, this study has shown that approximately 40% and 60% of the respondents had been involved in alliancing and partnering, respectively, which suggest an increasing understanding and use of new procurement forms. According to McCormick (2010), in New Zealand, alliances and other forms of collaborative contracting are now a major procurement force and the trend is growing.

4.2 Section B: Ranking of Team Integration Indicators

4.2.1 Significance of Key Indicators of Team Integration

Respondents were asked to rate the 15 indicators of team integration on how significant they thought each was for determining the success of team integration in construction projects. They were asked to rate the indicator based on the selection of a score according to the 5-point Likert scale, ranging from 1 = Not Significant, 2 = Least Significant, 3 = Neutral, 4 = Significant, to 5 = Highly Significant. Results are shown in Table 3.

Overall, the indicators "Single Team Focus and Objectives" and "Free Flowing Communication" received the highest mean ranking of the team integration indicators with a 4.7 mean rating. This is followed by "Trust & Respect" and "Commitment from Top Management" which both received a 4.5 mean rating. These four highest rated indicators can be classified as "Highly Significant" in determining the success of team integration in construction projects.

Indicators such as "Encourage Initiative" with a mean rating of 4.4, "No Blame Culture", "Sharing Information" and "Innovation and Improvement" which shared the same mean rating value of 4.2 and "Team flexibility & Responsiveness to Change" which received a mean rating of 4.1, can be classified as "Significant" in terms of influencing team integration. The remaining choices among the 15 indicators were "Integrated ICT system" with a mean rating of 3.9, "Seamless Operation with No Organisational Defined Boundaries" with a 3.8 mean rating, while "Client Care Team", "Collective Understanding" and "Creation of Single & Co-located Team Location" received the same mean rating value of 3.7. The least important indicator according to the ranking is "Effective Management of Health & Safety", with a mean rating of 3.6.

Table 3: Mean rating of key indicators of team integration

Indicators	Significance (Mean Rating)	Ranking
Free Flowing Communication	4.7	1
Single Team Focus and Objectives	4.7	1
Commitment from Top Management	4.5	3
Trust & Respect	4.5	3
Encourage Initiative	4.4	5
Innovation & Improvement	4.2	6
Sharing Information	4.2	6
No Blame Culture	4.2	6
Team Flexibility & Responsiveness to Change	4.1	9
Integrated ICT system	3.9	10
Seamless Operation	3.8	11
Creation of Single & Co-located Team Location	3.7	12
Collective Understanding	3.7	12
Client Care Team	3.7	12
Effective Management of Health & Safety	3.6	15

Even though indicators such as integrated ICT system and single team location received a lower mean rating compared to others, their value should not be underestimated. As described by Alshawi and Faraj (2002), the application of ICT systems as a tool in construction projects is considered an important element in developing integrated construction

environments between construction teams. While, Baiden et al. (2006) suggested that the establishment of co-located design and construction teams will increase the integrated culture between teams.

In addition, it should also be noted that these types of indicators, for example, single team location, are only practiced under certain types of contract that utilise an integrated approach such as project alliancing. As mentioned by Baiden et al. (2006), some procurement approaches do not necessarily call for the creation of a single co-located team although collective working was encouraged on the project. Thus, the lower mean rating might be caused by the fact that approximately half of the respondents were not familiar with collaborative contracting such as partnering and alliancing.

The top 5 indicators which appear to have the greatest effect on team integration success based on the ranking were; (1) Free Flowing Communication; (2) Single Team Focus and Objectives; (3) Commitment from Top Management; (4) Trust & Respect and (5) Encourage Initiative. Overall, the survey results confirm that all the 15 indicators which received an average of towards "significant and highly significant" responses are needed to ensure the success of team integration practice.

In determining the consistency and consensus of the experts' ranking on team integration indicators, the intraclass correlation coefficient ICC(k) (combination of Interrater Agreement (IRA) + Interrater Reliability (IRR)) method was adopted. Interrater reliability coefficients (IRR) indicate the consistency of the pattern of ratings by two or more raters and interrater agreement coefficients (IRA) indicate the degree of similarity in the level or magnitude of ratings by two or more raters (Kumaraswamy and Anvuur, 2008). The ICC is estimated when attempting to understand the IRR + IRA among multiple targets rated by a different set of judges on an interval measurement scale. ICC values range from 0 (total lack of agreement) to 1 (perfect agreement) and a value of 0.7 has been used as the traditional cut-off point signifying an acceptable ICC value (LeBreton and Senter 2008). In this study, values of 0.807 (IRR) and 0.768 (IRA) were scored, both of which exceed the 0.70 threshold.The high IRR value indicates a high level of consistency among the experts in assessing the team integration indicators. The high value of IRA indicates strong consensus of experts on the ranking of team integration indicators.

4.2.2 *Approach to ensuring team integration*

In the last question of the survey, respondents were asked for their advice and suggestions on approaches to ensure team integration in construction projects. The results from these open-ended comments indicated that there is a difference of opinion amongst the respondents towards ensuring team integration in construction projects. Given the wide experience of CCG members, it has perhaps been the case that respondents had different dimensions of experience (e.g. different background, contracts, procurement systems), thus the open-ended comments are vital and essential input for this study as they reflect the reality in construction projects. From the comments, a number of suggestions on how to ensure team integration are related to the previously mentioned top 5 indicators. The related comments are shown in Table 4 below;

Table 4: Comments related to ensuring the top 5 key indicators of team integration

Rank	Indicator	Comments
1	**Free Flowing Communication**	• Encouraging the "culture of team" through organising off-site and on-site events to assist with *relationship* building and understanding individual styles of *communication*. • Ensure *mix* of capabilities and experience, foster an *open collegial* working environment, *co-locate* and *communicate* clearly.
2	**Single Team Focus and Objectives**	• *Co-location*, if possible, has proven to be essential. This goes a long way to creating the atmosphere of *One Team One Goal*. • Every member needs to feel they have an *important contribution*. Project *objectives* need to be strictly adhered to (no side tracking) and deadlines constantly reviewed.
3	**Commitment from Top Management**	• *Strong leadership* from key managers seeks to have early alignment, and keep pursuing the goal of team integration. Try different methods, until one works, and if it stops working, try something else. It's a relentless pursuit. • *High management* need to buy in early, nothing will short circuit a project team effort more than a contrary unilateral high level decision based on a left field parameter like politics etc.
4	**Trust & Respect**	• Early team interaction. Involve everyone; seek opinions and advice from all. Be *open* and *honest*. *Trust* exists from day 1, it can only be lost. • *Communicate* freely to build up *trust* and ensure all are aware of the *objectives*.
5	**Encourage Initiative**	• Acting as a *role model* all the time to encourage the "feeling of team". • *Lead by example*, someone will show the way and this makes others (if it is contractually embedded) fall into the collective line. • *Frequent gatherings* of team personnel in order to establish a more collective understanding that could lead towards *initiatives* and *innovation* in solving problems.

The majority of respondents indicate that relationship attributes such as leadership, openness, honesty, trust, shared vision and collective understanding are essential in ensuring team integration. However, approaches such as having a co-located team are also mentioned as helping create a good team work atmosphere with a more collaborative working approach. It is therefore evident that there is an element of interdependence between some of the idicators, for example co-location is seen as promoting Free Flowing Communication and Single Team Focus and Objectives. Similarly, communicating freely is required to build up Trust & Respect.

Overall, based on the comments provided, it can be summarised that team integration practice can be improved by using specific mechanisms, as follows;

- Establishing or enhancing a culture of acknowledgment (and appreciation) of a team;
- Implementing a rigorous selection of individuals for a team on a “best for project” basis;
- Contract based model that emphasizes the concept of early involvement and shares pain and gain in order to ensure that all parties are playing to the same rules;
- Having a regular team meeting / workshop / social event in order to update and resolve any key issues, and at the same time try to get an understanding of, and improve, team bonding and relationships;

- Team building to strengthen relationships, build trust and better social relations and remove all interpersonal past barriers; and

- Contract management plan and performance drivers can be used to monitor the responsibilities (performance) of the teams involved.

5. Conclusions

This study has provided an overview of the key indicators of team integration in construction projects from a New Zealand practitioners' point of view. This study also assessed the significance of the key indicators and provided insight into methods for ensuring team integration in general. The findings suggest that all 15 indicators are important and the results of the analysis also revealed that they have a strong influence towards determining the success of team integration in construction projects.

This study has ranked the key indicators based on the significance of the indicator towards ensuring team integration practice. The top-ranked factors that contribute towards successful team integration are free flowing communication, single team focus and objectives, commitment from top management, trust & respect, and encourage initiative. In addition, various dimensions of approach in ensuring team integration practice have been identified. Based on these, continuous improvement guidelines can be established which will be beneficial to practitioners in need of advice on how to ensure team integration practice.

Overall, the variability in the responses suggest that different experience in the construction industry may have an impact on assessing the significance of the team integration indicators and approaches in ensuring team integration in construction projects. The difficulty lies in assessing the extent of the impact. In addition, the degree and type of interdependence of these indicators may also present a challenge in any future research. Finally, this study was limited to the views and opinions of respondents from the New Zealand construction industry that are registered with CCG. As such, the findings of this study may not represent the views of the entire New Zealand construction industry.

Future research should therefore focus more on enhancing our understanding of how the procurement approach influences a team's ability to perform. In addition, further reseach is needed to understand the degree and type of interdependence of the proposed indicators. Finally, since the key indicators were assesed from a New Zealand practitioners' perspective, it is suggested that further research should be conducted in other countries for comparative purposes.

5. Acknowledgements

The writers gratefully acknowledge the Ministry of Higher Education, Malaysia and Department of Civil and Environmental Engineering, The University of Auckland, New Zealand for providing funding to support this research study. Special gratitude is also extended to Mr. Peter Cunningham and Mr. Tim Warren, in particular, and New Zealand's Construction Clients' Group (CCG) members who responded and contributed their valuable input in

completing the survey questionnaires. Those who indirectly participated in making this survey possible are also acknowledged with sincere thanks.

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CIB 2013 World Congress

Mitigating CO_2 emissions from the cement industry: potential of feasibility *versus* the market challenge

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Abstract Title

Public demands for a larger and better built environment in the developing world are steadily increasing, and will oblige the production of cement to increase at least 2.5 times between 2010 and 2050. Unless affirmative action is taken, the low availability of blast-furnace slag and fly ash, together with the limited potential for gains in energy efficiency, will cause the share of CO_2 emissions from cement production to be as high as 30% by the year 2050. Such recently proposed options as carbon caption and storage are very expensive and could double prices, negatively impacting the costs of infrastructure in developing countries.

This paper presents an additional option for decreasing CO_2 emissions from the cement industry – an environmental demand – without decreasing production – a social demand. An increase in binder use efficiency can be measured by a binder intensity index (mass of binder for each MPa of compressive strength). Laboratory results show that binder content can be reduced by up to 75%, which means that the same amount of concrete could be produced with less than half the clinker content.

Nonetheless, practical market experiments are in general responsible for the lowest binder efficiency found in literature. In this scenario, the contradiction between technical advances and market restrictions to putting them into practice will be discussed to construct a perspective of the future of the concrete and cement chain, as well as identify the main actions required for increasing the sustainability of the chain.

Keywords: global warming, CO_2, cement, binder efficiency, concrete market.

1. Introduction

Cement is essential to almost all built environment production and consequently the world's most used material. Current loads from cement production represent 5-8% of world CO_2 emissions (BERNSTEIN et al, 2007; MÜLLER; HARNISCH 2008). Due to the needs of all sources of infrastructure in developing countries – from housing to basic sanitation and

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highways –, the current production of approximately $2.2x10^9$ t/year is projected to increase to more than $5x10^9$t/year in a high growth scenario (IEA; WBCSD, 2009; Müller; Harnisch, 2008), which would make the cement industry responsible for up to 30% of global CO_2 emissions (BERNSTEIN et al, 2007) if current chain strategies and actions are maintained.

As discussed in Damineli; John (2012), the main industrial strategy to mitigate CO_2 emissions from cement production – replacing clinker with mineral admixtures such as blast-furnace slag (BFS) and fly ash (FA) – does not have long-term potentiality. These materials are not available in scale enough to supply the increasing demand for cement; at best a 22-25% replacement would be reached, and national technical standards allow up to 50% of FA or 70% of BFS in the cement mixture. And this does not take into account the real possibility of a long-term decrease in the availability of the products, as well as it does not consider the possibility of a change in CO_2 allocations in pollutant chains that produce BFS and FA, which could significantly change the current "environmentally-friendly" aspect commonly linked with the use of these wastes as binders for replacing clinker (Chen et al, 2010; Birat, 2011).

This lack of potential for reducing CO_2 emissions in cement production on a worldwide scale is also true of other known mitigating strategies. Even Kilns efficiency, very popular with most of world's big producers, would not be capable of new gains without huge efforts (Gartner, 2004). The use of alternative fuels also falls within this category (WBCSD, 2007). Together, the three strategies, even if developed to their highest level and commonplace among all cement plants, would just decrease CO_2 emissions by 20-30%, which is clearly unsustainable if compared with targets discussed in the Kyoto Protocol, Stern Review (OCC, 2005), IPCC (2007) and other recent world climate change meetings.

The latest industry strategy for mitigating CO_2 emissions is carbon capture and storage (CCS). Despite its effectiveness – the potential to eliminate 100% of CO_2 emissions–, this strategy is also unsustainable, from a social point of view. CCS is very expensive, with estimated costs varying from USD 40 to 250/t CO_2 (HOENIG; HOPPE; EMBERGER, 2007; ANDERSON; NEWELL, 2004), which could more than double cement's net price, with a negative impact on the economies of developing countries.

So, to increase concrete production, while at the same time decrease CO_2 emissions, a new strategy is imperative: binder use efficiency. This paper aims to: 1) present solutions already tested in laboratory scale to increase efficiency in the use of binders in structural concrete production; and 2) discuss common market obstacles to the implementation of this technology, and develop a more comprehensive discussion about the feasibility of gains.

2. Solutions for increasing binder use efficiency: benchmark and technical possibilities

For measuring the potential of the binder use efficiency strategy, three main steps were developed: 1) creation of a Binder Intensity (BI) index, which allows a comparison of different concrete mixtures objectively in terms of binder use; 2) literature research with the aim of establishing a benchmark of BI worldwide; and 3) laboratory research (main part of the PhD thesis of the primary author) to find ways and limits of binder efficiency in concretes. They are summarily presented in the following subject matter.

2.1 Binder Intensity (BI) and the benchmark

Binder Intensity (BI), an index for measuring binder use efficiency (DAMINELI et al, 2010a) was developed. It adapts a concept that is almost universally adopted by the ready mix concrete industry to measure efficiency: the amount of binder per 1MPa of compressive strength at 28 days. This has several advantages: the concept and range of resulting values are familiar to potential users and very simple to estimate, and it is easy to develop a benchmark of current performance. Since the aim was to access the efficiency of using scarce energy intensive material the amount of "cement" was replaced by an equal amount of binder, by removing the amount of limestone filler from the calculation. Therefore, binder intensity (bi_{cs}) is hereby defined as the amount of binder (B, in $kg.m^{-3}$) needed to provide 1MPa of compressive strength (CS, in MPa) at a given age. The concept is to change the functional unit of concrete from one cubic meter to a relevant performance indicator.

bi_{cs}= B/CS

Using the same concept, all series of indicators are easily defined, including the expected service life, changing both impact and performance indexes. One other index was also developed for this research –CO_2 intensity (ci), which measures the amount of CO_2 released for each MPa. To calculate ci, using simplified literature data, clinker was considered as emitting 1 kg of CO_2 per kg of clinker produced, and other binders (fly ash and blast-furnace slag) were considered as zero emissions. This makes ci very dependant on clinker content. So, when clinker is the main binder in the composition, ci tends to be very similar to bi. However, progressively reducing clinker content by replacing it with other alternative binders progressively decreases the ci, whereas bi remains unchanged. Detailed discussions about ci are found in Damineli et al (2010). Since these supplementary binders are scarce (DAMINELI; JOHN, 2012), and their CO_2 emissions are the topic of current discussion, bi analysis is the most important for the aims of the present paper.

For establishing a benchmark of current stage of bi_{cs} worldwide, 156 random papers from 29 countries were used, and also some preliminary data from the real market (one ready-mix concrete company from São Paulo, Brazil). Fig. 1 presents benchmark.

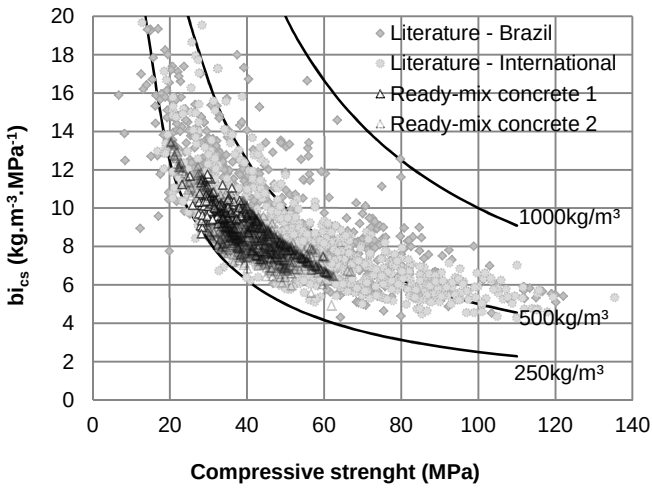

Fig. 1 – Benchmark of bi. This includes data from 29 countries (Damineli et al. 2010) as well as a comprehensive dataset from two ready-mix companies in São Paulo.

Available data indicates that the minimum bi is around 5 kg.m^{-3}.MPa^{-1} for concretes above 50MPa, using current technology. Below that, minimum bi follows the 250kg.m^{-3} binder content line, which corresponds roughly to the minimum cement content found in many national standards (ABNT, 2006; Grube; Kerkhoff, 2004). Since most of the concretes are below the 50MPa class, actual bi is much higher than the possible minimum. More detailed discussions about bi potentials for assessing binder use efficiency are found in Damineli et al (2010a).

2.2 Laboratory results

Preliminary laboratory results presented in Fig. 2 show that by controlling dispersion and packing of the system (ORTEGA et al, 1999; BONADIA et al, 1999) and replacing binder with engineered inert fines (MOOSBERG-BUSTNES; LAGERBLAD; FORSSBERG, 2004; VOGT, 2010) it is possible to mix concretes with compressive strengths between 20 and 40MPa (same as market requirements) and *bi* between 5 to 7 kg.m^{-3}.Mpa^{-1}, which fills in an empty area of the graph– the area with binder consumption under 250kg.m^{-3}. This implies in mixtures with binder contents lower than that required by national standards yet still having good strength, which shows that national standards can be a big hindrance in the search for increased binder efficiency. Also, most of these concretes are self-compacting, which means, in practice, that lower *bi* results could be achieved if rheological requirements were decreased to allow the production of concretes with higher yield stress.

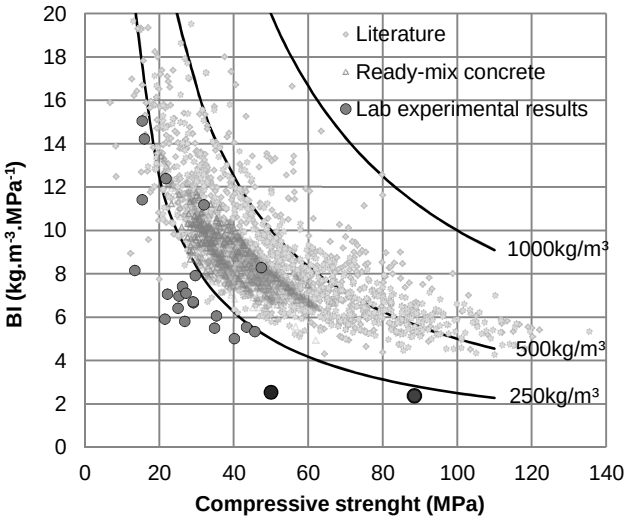

Fig. 2 – Examples of the potential to reduce bi of concretes. Concretes formulated and produced in lab at USP as well as in collaboration with CBI/Sweden. Most concretes are self-compacting. The two with bi below 3 have slumps above 180mm.

A serious limitation to introducing packing strategies is the large number of controlled fillers. Taking advantage of the large variety of these raw materials in Sweden, we were able to produce some highly efficient concretes. One formulation, using only 210 kg.m^{-3} of total binder (including 10 kg of silica fume), slump of 180mm, reached 88.4MPa (100x200mm cylinder) at 28 days. This corresponds to a *bi*o f 2.37 kg.m^{-3}.MPa^{-1} – less than half that of the

best practices found in the literature benchmark[3]. Compared to marketable concretes this means cutting total binder consumption by a factor of 4. In the same project another concrete having only 126.3 $kg.m^{-3}$ of total binder content was also designed and achieved 190mm of slump and 28 day-compressive strength of 50MPa, which delivered a *bi* of $2.53kg.m^{-3}.MPa^{-1}$.

These essays show that the restrictions to designing concretes with very low cement content can be overcome by employing scientific methods of packing and dispersion of particles, requiring lower binder content for achieving rheological parameters.

3. Market challenges, trends and potential

However, introducing the highest binder use efficiency concretes, such as those presented above into the market, would involve enormous obstacles. This subject matter will discuss the most important related issues, which must to be overcome for a real, more sustainable concrete/cement chain.

3.1 The lack of inert filler production and technical knowledge

Concretes with very high binder use efficiency (experimental lab data shown in Fig. 2) are produced with a significant content of clinker replacement by inert fillers, which are not produced under high temperature and release much less CO_2 emissions than clinker or other heat-processed binder. Inert filler CO_2 emissions result from their production at mills and subsequent transport.

A simple comparison of the pros and cons of inert filler production versus clinker production would seem to indicate that the first is cheaper and more environmentally-friendly. But, this scenario changes drastically when market regulations are added to the equation. At present, the demand and production of clinker is much greater than fillers, and good inert fillers are still very expensive in contrast and could, if used in a short-time perspective, increase concrete costs. Just for comparison, when cement production surpassed 2x109 tons in 2004 (WBCSD, 2009), limestone filler production was $6.9x10^6$ tons, for all industrial uses (BRITISH GEOLOGICAL SURVEY, 2006) – a 10^3 tons magnitude of a lower order.

This production difference has a direct impact on prices. One ton of cement costs, on average, USD 75 in Asia (lowest price), USD 90 in Europe, USD 120 in America or Africa, and USD 148 in Oceania (SNIC, 2011) – world average near USD 100-110. Similar data is found on the website of the Massachusetts Department of Transportation, which quotes USD 105 as the price of cement (http://www.mhd.state.ma.us/default.asp?pgid=content/fuelPrices&sid=about), October 2012. But these prices can more than double due to transport and other market costs – one

[3]Research in collaboration with Prof. Björn Lagerblad (CBI -KTH). One of the concretes formulated in this research won the "Starkast Betong" (The strongest concrete) international competition, which was held in CBI Betonginsituten, 2012. This competition established a maximum cement content of 200 $kg.m^{-3}$ and did not limit the use of supplementary materials. The winning concrete just used 200$kg.m^{-3}$ of cement and 10 $kg.m^{-3}$ of silica fume as total binders.

bag of 50kg in Brazil costs from USD 9 to 10 to the final consumer, which makes the per ton cost (20 bags) from USD 180 to 200.

In Brazil, bagged limestone filler, , can cost the final consumer between USD 40 and USD 500 per ton, depending on the production control process, particle grain size , purity of raw material and other variables. So, these variations in price can have a heavy impact concrete's final cost. Therefore, a good understanding of filler characteristics is fundamental when choosing the material for use in concrete, avoiding high costs at the same time that high efficiency in binder use is reached.

However, even though demand is low, cost-competitive inert fillers are becoming more familiar on the concrete market. If in some countries inert fillers are still very expensive and uncommon, Europe, to the contrary, already has some inert filler producers that are supplying the concrete chain with high quality, bagged fillers at competitive prices. The concrete chain is now offering these materials as a replacement for clinker, although comprehensive instruction as to their potential is still lacking. The authors' opinion here is that this will only occur when the cement industry begins developing its own technology for producing fillers that are adequate and compatible with clinker, a very singular material in terms of physic-chemical characteristics. The envisioned concrete/cement chain for this end is one that understands clinker interactions, and also the only one that has a process line developed, in terms of size and organization, required for this task. The large scale production of inert fillers could result in a substantial reduction in the cost of cement/concrete and even be added to new lower clinker and binder cements.

3.2 Quality of aggregates

The quality of aggregates has been continuously investigated since the beginning of concrete technology. Forty years ago, Renninger (1969) said that the quality of aggregates had already been an extensively covered subject in concrete technology, showing that the rounder the aggregate, the lower the water content required for the same formulation and same slump, which implies in lower w/c ratio and higher compressive strength – and so, higher binder use efficiency. The study still links aggregate quality to concrete durability, showing that even when concrete paste is very low in voids content, aggregate quality can influence durability indexes.

Rached; De Moya; Fowler (2009), another example of work which studied the correlation between aggregate shape, texture and grading, found that these are characteristics which require control when minimum cement content in concrete is required.

A detailed analysis of studies that vary the quality of aggregates in concrete while maintaining other formulation parameters unchanged can give a better understanding of how binder use efficiency and the aggregate quality are linked. Fig. 3 presents data from Angulo et al (2010) analyzed under bi_{cs} index concept.

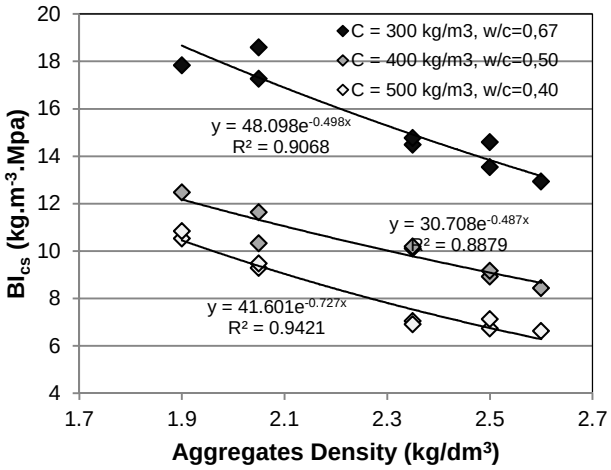

Fig. 3 – Recycled aggregatedensity versus binder intensity (Angulo et al, 2010).

As shown in Fig. 3, the density of aggregates is a good parameter for controlling their quality. This study divided Construction and Demolition Waste (CDW) recycled aggregates by density and mixed concretes with different binder contents (C) and water/cement ratios (w/c). The tests revealed that bi increases (lower efficiency of binder use) as well as the aggregates density decreases, for the same w/c and C (total binder consumption) curves. Since aggregate densities determine the different levels of quality of recycled aggregates, the real environmental balance of the use of these aggregates in concrete can be negative in terms of binder consumption unless they are used with some caution. Poor quality aggregate decreases binder use efficiency, and requires increasing binder consumption to reach the same levels of mechanical properties, which, in turn, will produce more CO_2 emissions and additional costs, binder being the most expensive component of ordinary concretes. Notwithstanding, it is also shown that controlling the quality of aggregates – recycled or not – makes it possible (and so is a condition) to mix real more eco-efficient concretes.

The main obstacle to achieving this is the size of the aggregate chain worldwide. Concrete consists of 15-20% cement and the remaining 80-85% is basically, aggregates. This huge amount, combined with the very distinct aggregate mineralogical sources, makes controlling the quality of aggregates very difficult in the market practice, as previously discussed by Damineli et al (2010b).

The authors believe that the main obstacle to introducing some aggregate control tools, as aggregate selection is currently practiced, is mainly a lack of knowledge as to the real benefits it will bring. If binder use efficiency is increased, costs can decrease for the same mix, which will produce beneficial impacts for the economy and the environment.

3.3 Cement market share: a portrait of binder use inefficiency

Ready mix concrete will continue to be the fastest-growing market for cement through 2015, when it will account for 27 percent of global demand. Construction contractors will be the second largest market, followed by consumers, concrete products and other markets (THE FREEDONIA GROUP, 2011). Despite continual growth of the ready-mix concrete business, the biggest share of the market is composed of local concrete producers who do not exercise nor have the same technological control that ready-mix producers do. And this is

even more conspicuous in developing countries, where informal do-it-yourself construction is still one of most popular ways to construct. So, as ready- mix concrete dominates the demand for cement in developed, world markets, but in many developing countries sales to consumers or construction contractors are more common. As a good example, India, the second largest cement producer in the world, sold only 11% of its total cement production to ready-mix concrete producers, while 53.7% was sold directly to independent consumers (see Fig. 4.a). Forecasts predict the growth of the ready-mix business up to approximately 13.7% by 2020, when consumers will buy 50.1% of total cement consumption (Fig. 4.b). THE FREEDONIA GROUP, 2011, demonstrates that the change in market will occur very slowly and the trend of using cement in informal construction will continue.

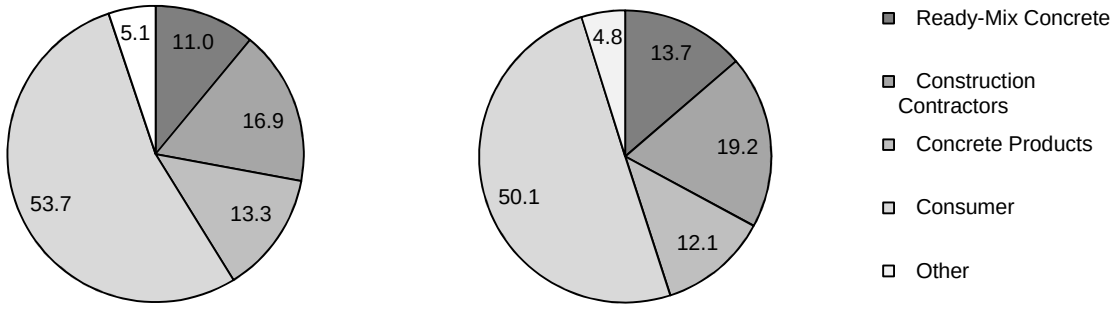

Fig. 4 – Cement market share in India: a) left – in the year 2010; b) right – forecast for the year 2020 (The Freedonia Group, 2011).

In Brazil, another developing country with a big share of total world cement production, direct sales to the final consumer were, in 2011, 54% of the total cement market, while 19% was sold to ready-mix producers, as shown in Fig. 5 (SNIC, 2011).

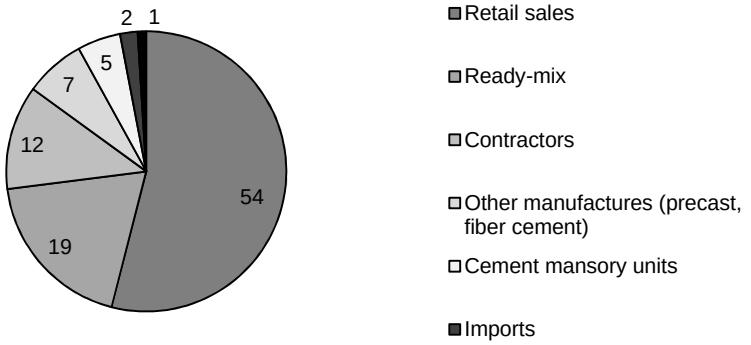

Fig. 5 – Cement market share in Brazil in the year 2011 (SNIC, 2011).

As cement used for informal concrete mixtures is not only sold to final consumers, total bagged cement sold in 2011 was 68% of market share, against 32% sold in large quantities to industrial users (including ready-mixers) (SNIC, 2011).

As bagged cement is sold in small quantities to final consumers, the main purpose being to supply small and informal constructors, there is a great variety of manuals containing instructions for mixing concrete filled with very simple proportioning and mixing methods that fill the technological gap in these markets. A rough assessment of these manuals

(calculation of bi) showed that the concrete mixes presented are very inefficient in terms of binder use – one of the evaluated mixes used more than 350kg.m^{-3} of cement to deliver a 25 MPa 28-day compressive strength, which results in bi>14kg.m^{-3}.MPa^{-1}. And this scenario is most likely even much worse, considering not all informal constructions follow a manual or some previously established concrete proportioning design.

Therefore, the authors consider the size of bagged cement market share as a good measurement parameter for binder use inefficiency. The larger the share of bagged cement, the greater the amount of wasted cement embedded in inefficient concrete formulations, which will require, on a large scale, an increase of cement – and clinker – production, directly affecting CO_2 emissions.

3.3.1 Changing binder use efficiency by changing cement market share: ready-mixbagged concrete

On a long term perspective, the authors believe that only a complete restructuring of the cement chain will lead to an increase in cement use efficiency. So, instead of selling pure cement and shrinking from the responsibility of proportioning efficient cement-based materials to the final consumer, who is usually not qualified to perform this task, the authors recommend that cement be sold already inserted in cement-based- materials such as concrete ready-mix formulations. The industrial sector, which has the most technological knowledge and the best quality control, is the only sector able to design more efficient mixtures. This means a decrease in the bagged cement market share and an increase in the production of ready-mix concrete, which could even be sold from ready-mix producers or as new ready bagged materials, such as bagged concrete, where all the final consumer has to do is add water– no proportioning care is needed, this task will be developed in controlled industrial processes. Perhaps this is the best way to increase binder efficiency on a large scale since it would very difficult to change the informal, cultural aspects embedded in developing country constructions.

Diverse initiatives of developing ready-mixed bagged concrete are already available in some countries (http://www.cemix.co.nz/bagged-concrete-guide; http://www.quikrete.com; http://www.spec-west.com/pd12069/buddy-rhodes-new-buddys-ultra-green-concrete-mix). But, these initiatives are still small scale and an effective increase in binder use efficiency will demand an enormous effort in the development of this strategy.

4. Conclusions

This paper presents laboratory results that prove refining binder use efficiency in concrete is possible and already attainable by applying the concepts of packing and dispersion of particles to mix designs. The authors of this research created the Binder Intensity (BI), an index for measuring binder use efficiency that measures the ratio between the total amount of binder, in kg.m^{-3}, and compressive strength, in MPa. Results show that it is possible, in laboratory essays, to produce concretes with 88MPa of 28-day compressive strength using only 210 kg.m^{-3} of binder, resulting in a concrete with bi = 2.37 kg.m^{-3}.MPa^{-1}, which is more than 2 times as efficient as that currently used by the market to produce the same strength. Also, a concrete of 51 MPa was delivered – a bi = 2.47 kg.m^{-3}.MPa^{-1} using 126 kg.m^{-3} total

binder, which is a concrete within the parameters of those used by the market to produce common strengths but, by using less than half of the total binder commonly consumed.

Although the goal of producing highly efficient concretes in terms of binder use efficiency was reached in PhD research by the first author, the biggest challenge is yet to come – conducting the market to an implementation of this technology, which is a huge challenge due to the size of the market. This is a completely different scale on which to work, where there are many obstacles related to the variability of raw materials and the way the concrete business is commonly practiced. Some of these obstacles are presented and discussed in the second part of this paper and give a better understanding of what is needed to do, such as: 1) changing the inert fillers market and technological knowledge; 2) changing quality control parameters for aggregates; and 3) changing how the cement market is currently shared.

In first case,, increasing the use of inert fillers in concrete depends on a market strategy for increasing the production of high quality fillers, a solution that depends on greater technological comprehension of clinker-filler interactions, which, once implemented, would lead to a decrease in prices . The solution enables the cement industry to increase cement production without needing to increase clinker production or invest in new expensive kilns. And, benefits in terms of sustainability are equally high. Social sustainability will benefit since the costs of cement-based materials will not rise and can even be reduced. Environmental loads of the cement industry can be greatly reduced. The cement industry can benefit economically since, it seems improbable that more sophisticated and energy intensive grinding could be more costly than operating a kiln or capturing and storing carbon.

Second challenge, improving the quality control of aggregates is another strategy also dependant on profound changes in the market. And, the benefits of better aggregates for concrete – which would increase binder use efficiency – need to be better understood by the market. The size of this chain – more than 80% of the world's production of concrete is aggregates – as well as the enormous variations found in the different sources of aggregates -- are certainly the worst enemies of this strategy. But again, high environmental benefits can be achieved by increasing the quality of aggregates, mainly by decreasing the binder content required for the same mix.

The third involves changing the method of selling cement. Pure bagged cement is the most inefficient way of using the material since the final consumer has to design proportioning mixtures relying on his usually, poor technical knowledge – which is quite the norm in the informal constructions of developing countries. In order to change this, the responsibility for designing mixes needs to be an industrial competence, which can use the accumulated expertise derived from high technological efforts to increase the efficiency of binder use. The more cement is sold in final mix proportioned materials, such as bagged, ready-to-use concrete, the higher the binder use efficiency on a global scale, with real benefits for sustainability since more concrete will be produced with less clinker. This allows to supply increasing social demands for infrastructure in developing countries at the same time that environmental loads are decreased.

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Mechanisation in Construction – A Malaysian Perspective

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Abstract

Many developing countries have suggested policies to increase mechanisation or prefabrication in their respective construction industries to improve on quality and to increase construction productivity. Mechanisation is widely acknowledged to significantly reduce the reliance of the construction industry on labour; a problem particularly acute in developed economies where skilled labour is increasingly scarce, expensive or both. The trade-off between capital and labour in the production function is clearly illustrated by investments in plant and machinery to produce precast concrete components as compared to employing labour to manually carry out the concreting works in-situ. There is evidence that the low wages of migrant construction labour may preclude the use of the more capital intensive precast concrete technology in developing countries. This paper examines a number of precast systems currently in use in Malaysia and attempts to characterize the factor inputs to support the decision for a semi-mechanised approach. Various constraints against the adoption of precast concrete technology is exposed and discussed. The impact of current labour policy, employment of migrant labour, training, and technology is discussed to identify appropriate policies and incentives that could increase the adoption of mechanised construction systems into the building industry. The current financial incentive for the adoption of mechanised construction system in Malaysia is clearly deficient.

Keywords: Mechanisation, Precast concrete, Malaysia

1. Introduction to Mechanisation

The primary objective of mechanisation or prefabrication in general is to enhance productivity at project, company and industry level, reduce construction time, reduce wastage and improve quality. In many developing countries, it may be proposed as one of a suite of strategies for the construction industry to adopt advanced systems and technologies to enable construction companies to penetrate global markets and export professional services and construction expertise. The introduction of greater mechanisation and prefabrication was also proposed in developed countries to improve the performance of their respective construction industries (NAO, 2001)

In 1999, the Malaysian government initiated a program to introduce prefabrication methods into the construction industry with the aim of improving productivity, quality and safety. An

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eight-year road map to drive the adoption of industrialised building systems (IBS) in order to reduce cost, improve quality and reduce the dependence on migrant labour was introduced in 2003 (CIDB 2003). The main IBS systems proposed include pre-cast concrete, advanced formwork system, steel framing systems, prefabricated timber frames, and block work systems (such as interlocking concrete masonry units). Key targets to be achieved include a gradual reduction of the percentage of migrant workers in the construction industry from the existing level of 75% in 2003 to 15% in 2009, and to increase utilisation of IBS from 30% of total public housing in 2004 to 70% in 2008.

A survey carried out in 2003 indicated that the utilisation of IBS in building construction was extremely low at approximately 15% (Shaari, 2003). Earlier efforts by the government to encourage greater mechanisation in the industry have not gained traction as the construction companies continue to practice conventional methods of in-situ construction. It was reported by Hamid et al. (2008) that only 10% of the completed building projects utilised IBS in 2006; less than 35% of total construction projects used at least one IBS product, compared with the projection of utilising IBS 50% of all building projects by 2006 and 70% by 2008, as recommended in the IBS road map.

Financial incentives such as the abolition of a 0.25% levy on low, and medium cost houses, and a 50% levy reduction for building incorporating more than 50% IBS components were announced in 2003. In 2005, buildings with at least 50% IBS components were exempted from this levy altogether to further encourage adoption of IBS components. In October 2008, the government (Ministry of Finance, 2008) further advanced the full utilisation of IBS in government projects by stipulating that the use of IBS components in public projects must not be less than 70% and that the IBS had to be specified for all public building works.

The aim of this study is to characterise the cost structure of the mechanised and conventional methods of concrete construction in Malaysia to enable construction managers and cost engineers to gain a deeper understanding of the drivers behind the adoption of mechanised building systems in Malaysia. Material and labour costs, as inputs to these forms of construction, are estimated and analysed to identify and recommend appropriate policies and reforms that could promote the greater use of mechanisation in Malaysia or in developing economies in general. The main focus of this paper is to review the extent to which a semi-precast panelised wall system may be utilised for residential construction to replace the conventional reinforced concrete frame with brick infill walls. This semi-precast wall panels may be produced with simple flat moulds and hence a smaller capital investment in plant and machinery. The ability to cater for complex shapes and designs with the use of a cast in-situ column or section is an added advantage for designers and builders who are not well versed with the methods of installing fully precast components. This semi-precast system may allow for the numerous benefits of precast construction such as greater productivity, shorter construction programmes, and improved quality to be achieved at a lower cost compared to a fully precast system.

2. Literature Review

Many developing economies have been reported to be looking towards improving the quality of the products of construction and increasing the productivity of the sector with greater use of mechanisation, prefabrication technology and upgrading the skill of workers. Various precast concrete building systems were created in the early 1970s by construction companies in Europe and the US to cope with increasing demand for housing. High levels of precast utilisation were reported in Denmark, Netherlands, Sweden and Germany in the 1990s (Construction 21 Steering Committee, 1999).

In many countries, prefabrication is applied in the building sector to enhance productivity, improve quality, and cope with a shortage of skilled labour. However, in land scarce Hong Kong, the Housing Authority had advocated the usage of precast concrete methods since the mid-1980s and contributed to major precasting innovations in the industry. Although the Hong Kong Construction Industry Review Committee (CIRC) recommended a wider adoption of prefabrication to improve the quality and to reduce the generation of construction waste, Jaillon and Poon (2009) reported that the private sector still relies heavily on cast in-situ methods of construction involving the use of timber formwork, in-situ concreting, substantial amount of wet trades and bamboo scaffolding. In the same article, Jaillon and Poon reported major advances in precast construction techniques involving volumetric and modular precast elements, and large increases in number of precast elements used in public housing projects. It is interesting to note that incentive schemes were required to encourage the private sector to promote the use of prefabrication such as prefabricated non-structural external wall in the Joint Practice Note 2 (Government of Hong Kong, 2002).

Similarly, precast concrete was introduced in the early 1980s in Singapore, and have resulted in volumetric precast elements being used to provide additional space to existing high rise apartment blocks for the Public Housing Upgrading Program. The main driver for adopting prefabrication technology was to reduce Singapore's dependence on foreign labour and technology through increased construction productivity. Given the many technical and social constraints of operating in a highly built-up environment, Lau and Tay (1996) reported that prefabrication has improved the efficiency and cost effectiveness of concrete construction while at the same time minimise disruptions for their upgrading programs.

A survey on the use of precast concrete systems in Turkey and the US (Polat, 2010) indicated that American respondents considered restrictions on transportation, poor communication, and the lack of qualified specialised contractors as the three most important barriers to the extensive use of precast concrete systems in the US market. On the other hand, Turkish respondents ranked poor communications amongst parties and the lack structural engineers and specialised contractors as the most important factors in Turkey. Polat suggested that the cost of exploiting labour-intensive methods of construction may be much lower than the cost of implementing advanced technologies such as precast concrete systems in a developing country.

Precast concrete construction in Australia took off in the 1990s when designers and building owners realised that the economics and speed of construction of precast walls and floors

were favourable compared to conventional in-situ systems. Benefits of precast flooring such as the long-spanning ability to eliminate conventional concrete beams and therefore the need for formwork during construction was recognised early (National Precast Concrete Association Australia, 2009). Reports of cost savings of 10% of the structure costs by using precast walling and flooring were common.

More recent studies by Lou and Kamar (2012) identified a series of critical success factors for the adoption of mechanisation in construction but had not fully considered the economics of the precast versus cast in-situ option in detail. Elliott (2002) had previously pointed out that precast cannot compete with cast in-situ concrete where the ratio of labour-to-materials or plant is low, say one man-hour pay is less than 1/50 tonne of cut-and-bent rebar, or one man-hour pay is less than 1/500 daily hire of a large mobile crane. This observation clearly lends weight to the discussion on the two opposing policies of greater mechanisation and the continued employment of cheap migrant labour by the construction industry in Malaysia.

3. Methodology

Based on the review presented above, the case for promoting pre-cast technology as a means of mechanisation in a developing country is obvious and has been proven in many instances to bring about immediate gains in productivity, shorter construction periods, improved quality and safety performance, and in specific cases a reduction in overall construction cost. There is clear evidence to indicate that the concept of greater productivity with large-scale precast buildings can be achieved in Malaysia (Lai, 2005).

The relative cost of the cast in-situ, precast and semi-precast systems was examined by either studying the precast manufacturer's bid submitted to the builders or by estimating the cost of each system from published cost guides. The cost comparisons for cast in-situ and precast construction systems were previously conducted by Yong (2010) to assess the effects of wages and material costs on the price of each system. The cost for the semi-precast system was obtained from a precast manufacturer and was valid for projects in the states of Selangor, Perak and the Federal Territory of Kuala Lumpur.

4. Comparison of Construction Costs

Conventional building construction in Malaysia consists of reinforced concrete frames with brick in-fill walls, timber or cold formed metal trussed roof with either clay or concrete tiles, or sheet metal roofs. Concrete is cast in-situ into timber moulds while steel reinforcement is generally fabricated off-site but may still be bent on-site in less developed areas. This method of construction is very labour intensive, involving many wet trades on the work site: carpenters to fabricate the moulds and scaffolding, bar benders to cut, bend and place steel reinforcements, concreters to place, vibrate and finish the concrete, and brick layers to build the walls.

A case study was conducted by Yong (2010) on proposed hostel blocks for an institution of higher learning in the state of Perak, Malaysia where the builder was obligated to construct 4 blocks with the use of precast components while the remaining blocks were to be

constructed with conventional in-situ technology. Each hostel block provided a total area of 3,088 square metres of floor space. As both precast and in-situ construction methods were to be employed, it was possible to obtain construction drawings and cost estimates for both these modes of construction. A reinforced concrete structural frame was the proposed structural form with a slab and beam arrangement. The walls were all in clay brick with cement render on both faces. In comparison, the proposed prefabricated system was precast columns, precast inverted-T beams supporting hollow core precast prestressed planks. The hollow core planks were eventually topped up with an 80 mm structural screed.

4.1 Material and Labour Costs for In-situ Construction

A close examination of the builder's cost for cast in-situ slabs indicated that the supply and installation of sawn timber formwork cost approximately RM 7 (12%) whereas the materials (supply and fix concrete and steel reinforcements) cost RM 47, or 88% of the of the total cost of a suspended reinforce concrete slab.

The concrete structure complete with reinforced concrete slabs, beams and columns worked out to a cost of RM 250 per square metre for the cast in-situ option. This conventional construction method necessitated the deployment of a large number of workers to fabricate and install sawn timber formwork and timber props to support the fresh in-situ concrete. Materials now constitute 70% of the total cost with site labour and machinery accounting for 24% and 6%, respectively, as shown in Table 1.

Table 1: Comparison of concrete structure cost

Case Study Items	MALAYSIA Unit Cost (RM, %) (per sq.m)
In-situ Suspended Slab and Beam	RM 250 (100%)
- Supply of Materials and Forms	RM 175 (70%)
- Site Labour	RM 59 (24%)
- Crane Rental	RM 16 (6%)
Precast System (Slab and Beam)	RM 411 (100%)
- Manufacture & Supply of Materials	RM 360 (88%)
- Site Labour	RM 23 (6%)
- Crane Rental	RM 28 (7%)

4.2 Manufacturing and Labour Cost for Precast Construction

In comparison, a fully precast solution with hollow-core slabs and planks, beams and columns, cost RM 411 per square metre, an increase of more than 60% over the cost of the cast in-situ concrete. The supply cost of the manufactured precast components was more than double the supply cost of materials and forms for the cast in-situ option as shown in Table 1. The reduction in site labour from RM59 to RM23 per square metre did little to mitigate this large increase in material supply cost. There was also a significant increase in

the cost of crane rental as larger capacity cranes were required for the heavier precast components.

These results indicate two important observations in the cost structure: (a) the supply of precast components is clearly more expensive than the supply and fixing of concrete, steel reinforcement and forms, and (b) the cost of site labour for cast in-situ construction is double that of precast construction. It is clear that the saving in site labour costs cannot compensate for the higher material cost incurred by adopting a fully precast solution. Construction labour in Malaysia consists of migrant workers from neighbouring countries, often working illegally and unregistered, and earning RM 50 and RM 100 per day as unskilled and skilled workers, respectively (CIDB 2009). The presence of these migrant workers in large numbers naturally put downward pressure on the wages for local workers in the same industry leading to a situation where local workers shun working as skilled workers in the construction industry. This observation confirms the assertions by Shaari (2003) that construction firms in Malaysia have continued to adopt labour intensive practices due to the availability of cheap migrant labour instead of investing in plant and equipment for the manufacture of prefabricated components.

5. Semi-Precast Construction

A semi-precast system comprising of a series of precast wall panels that are interconnected with cast in-situ joints or columns were developed in 2002 for residential construction. This method of construction was particularly suited for detached, semi-detached or multi-storey commercial buildings with complex architectural designs. The semi precast system allowed various sizes of wall panels to be erected and fully adaptable to most existing designs and provides sufficient versatility for architect's design intent to be expressed. The cast in-situ joints or columns are reinforced with conventional reinforcements, provide stability to the building, and eliminate the possibility of ingress of water. These in-situ columns can also act as load carrying members to support heavily loaded beams and allow a hybrid system of conventional and precast systems to be achieved.

Figure 1 shows typical wall panels being cast flat with openings for windows and doors predetermined. The edges of the precast wall panels are cast with a shear key joint providing a strong interlock with the in-situ concrete. This method of casting allows wall panels of various thicknesses to be easily cast. Figure 2 shows the shear keys and continuity bars at the edge of each wall panel. Figure 3 illustrates how a plastic tube is used as backing for the sealant between the wall panel and floor slab. Figure 4 shows a partially completed double storey house built using this semi-precast system. The entire semi-precast panelised system can be demonstrated by the model shown in Figure 5 where the wall panels are shown in grey and the cast in-situ sections are shown in white. The model shown here has a revised shear key for improved vertical shear resistance. The size of the in-situ columns can be easily increased or reduced depending on the structural requirements.

5.1 Manufacturing and Labour Costs

The precast panel walls were generally 100mm or 120mm thick with a layer of mesh reinforcement placed mid-thickness. A local precast manufacturer quoted a price of RM 110 per square metre to supply and install these panels with approximately 30 pieces 3 metre by 3 metre panels to construct a double storey townhouse. These wall panels were 40% more expensive compared to the cost of a conventional 260mm brick wall which comprises RM 38 per square metre for the brick wall and an additional RM 40 for the cement render on both faces (total brick wall = RM 78 per sq.m). The proposed floor slab was a half slab (80mm thick semi-precast slab with an additional 70mm in-situ concrete) supported on the edges of the wall panels. When compared on a per unit basis, the estimated cost for the panel wall system worked out to be RM 42,460 whereas the conventional RC framed with brick wall was costs RM 23,917. The panel wall system was 78% more expensive as tabulated in Table 3.



Figure 1: Precast wall panels at the casting yard

The installation rate of 40 panels per day for a team of installers indicate that the construction schedule can be shortened considerably with the associated cost savings making up for the marginally higher cost of these panels. This semi-precast system has several advantages over a fully precast construction: the panels are connected with wet cast in-situ joints providing full structural connection at a low cost, wet-joints for all floor slabs to prevent water ingress or leakages, ability to allow for large tolerances due to wide cast in-situ joints, able to create complex shapes and configurations to comply with architect's design intents, adaptable to last minute design changes, and excellent quality finishes.

These large prefabricated panels create potential for transportation, handling and temporary stability hazards which must be adequately addressed. Suitable braces must be installed to provide stability during installation. These additional items combine to increase the total cost

of the semi-precast system but the overall productivity, quality and schedule benefits far outweigh these costs.



Figure 2: Shear key at the edge of the precast wall panel

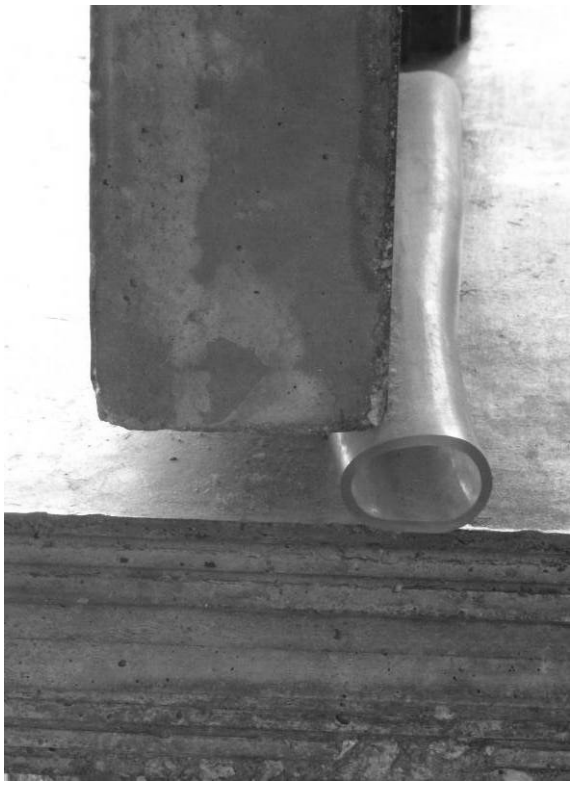

Figure 3: Plastic tube to act as backing for the sealant

6. Discussion

The cost comparison of the semi-precast panelised wall system indicates that it may be feasible for large scale residential housing construction in Malaysia. This system, although not fully mechanised and require substantial labour input to construct the in-situ joints may bridge the path between a conventional cast in-situ construction and the more capital intensive fully pre-fabricated precast slab, beam and column system.

The comparison between conventional cast in-situ against a fully precast solution indicates that the availability of cheap migrant labour in Malaysia generates an artificially low cast in-situ cost that is hard to beat. The cost of precast components is generally higher to cater for the additional capital investment in plant and machinery. If one considers the additional financial risk involved with investing in a precasting plant whilst having to compete for projects on a continuing basis, the total financial viability of the investment may not be feasible.

Table 3: Comparison of Panel Wall and RC Frame with Brick In-fill Wall

Item	Description	Unit	Qty	Rate	Amount
	Double Storey House – Panel Wall System				
1	Panel Wall (external & internal)	cu.m	29.37	1,100.00	32,307.00
2	Column – Car Porch	cu.m	0.08	1,100.00	88.00
3	Beam – Car Porch	cu.m	0.55	1,100.00	605.00
4	Floor Slab (150mm thick)	cu.m	8.60	1,100.00	9,460.00
	Total per unit				42,460.00
	Total gross floor area	sq.m	136.94		310.06
	Double Storey House – RC Frame & Brick Wall				
1	Brick walls	sq.m	244.78	38.00	9301.64
2	Plastering	sq.m	489.56	20.00	9,791.20
3	Column – Car Porch	sq.m	0.08	280.00	22.40
4	Beam – Car Porch	sq.m	0.55	280.00	154.00
5	Floor Slab	sq.m	8.60	280.00	2,408.00
6	Structural Frame	sq.m	8.00	280.00	2,240
	Total per unit				23,917.24
	Total gross floor area	sq.m	136.94		174.65



Figure 4: Completed precast wall panel with in-situ columns

Pan et al. (2007) identified through their survey of the UK's leading house builders that significant barriers against the use of off-site and other modern methods of construction in the house-building industry were considered to be higher capital cost, difficult-to-achieve economies of scale, complex interfacing between systems, lack of ability to freeze the design early on, and the nature of the UK planning system. Sadafi et al (2012), on the other hand, reported that factors preventing the wider application of IBS components in Malaysia were skill shortages and design conflicts were the two most challenging categories for the

respondents, followed by installation issues, manufacturing and cost difficulties and lack of knowledge. The disadvantages pointed out by participants included prohibitive cost and maintenance issues and limitations in architectural and detail design.

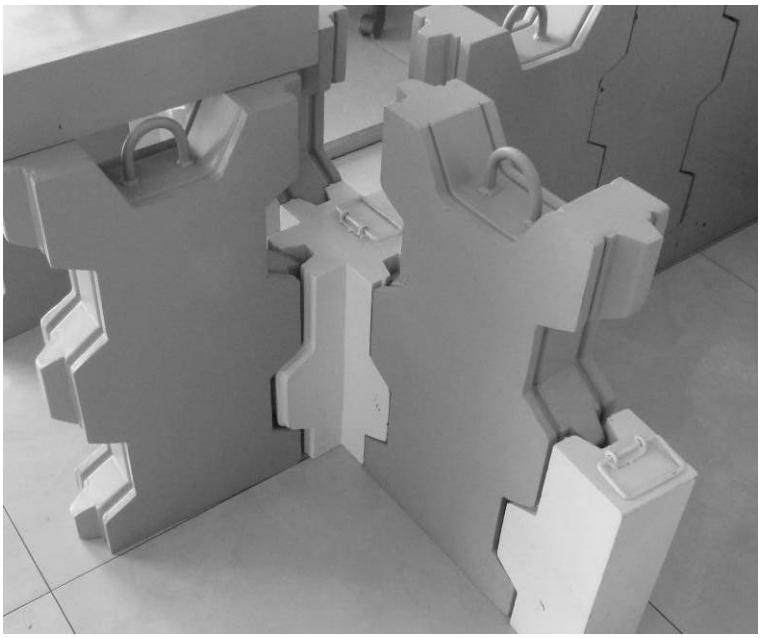

Figure 5: Model showing the precast wall panels (grey) and cast in-situ column sections (white)

Lou and Kamar (2012) also reported that barriers to a greater IBS adoption in Malaysia include the following points: not popular among design consultants; lack of knowledge among designers; the need for mind-set change; the chicken-and-egg dilemma; lack of support and slow adoption from the private sector; lack of push factor from responsible bodies; volume and economy of production in scale to IBS components; monopoly of big boys, limiting opportunities to other contractors; low IBS construction components available in the market; IBS requires on-site specialized skills for assembly of components; lack of special equipment and machinery; lack of local R&D on technologies and testing facilities; mismatch between readiness of industry with IBS targets; insufficient capacity for contractors to secure project; and a sustainability issue, with the government to lead during a downturn.

With the prevailing conditions in Malaysia, it may be worthwhile considering the lower investment in a semi-precast panelised wall system combined with increased utilisation of labour to complete the in-situ connections. This semi-precast system seem to require little specialised skills for the assembly of the wall panels, fully adaptable to complex designs and shapes, and may be able to address many of the concerns mentioned above.

If mechanisation or off-site construction is to make a sustained positive contribution in the marketplace, research is needed to identify the pervading issues that constrain the uptake of this, or conversely, can promote this in a more reasoned and defendable way, especially taking into consideration the existing societal, cultural, and current business models associated with conventional thinking and practice (Arif et.al. 2012). The core finding here is that as far as mechanisation is concerned, the semi-precast system seem to be the logical way forward for Malaysia at this stage of its development and taking into account the large

number of migrant workers in the country at this point in time. Once a clearer policy with regards to the reduction of these migrant workers is outlined, the economics of the various systems of construction may evolve leading to a different system being optimal once the number of migrant workers is substantially reduced.

7. Conclusion

The case studies presented here have illustrated the trade-off between capital and labour in the production of reinforced concrete buildings. Construction firms in a developing economy like Malaysia with access to cheap migrant labour can choose to keep construction costs down by utilising greater labour inputs. On the other hand, construction firms in a developed economy, e.g. Australia, with high labour wage rates can easily opt to increase capital input and decrease labour input to minimise costs.

The cost comparisons clearly indicate that the choice of inputs for construction is market driven, and that financial incentives to increase mechanisation in construction must be coupled with a reduction in the supply of cheap migrant labour.

The semi-precast system seem to be the logical way forward for Malaysia at this stage of its development and taking into account the large number of migrant workers in the country at this point in time. Once a clearer policy with regards to the reduction of these migrant workers is outlined, the economics of the various systems of construction may evolve leading to a different system being optimal once the number of migrant workers is substantially reduced.

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Householders' Maintenance System for Former Rental Houses in the Historic Urban Structure of Budapest

Gergely I. Molnarka[1]

Abstract

The urban structure of historic districts of Budapest, Hungary can be described with the semi-intensive installation of rental houses. The building stock that determines the cityscape was largely constructed between 1890 and 1944. The economic and social environment of this era influenced the life cycle of these buildings. The war damage and the compulsory socialization that followed the war (and therefore the centralized maintenance protocol) were major factors in the degradation of their condition.

Due to the transition to democracy in the '90s changes have happened in the property structure of apartment building stocks. Nowadays, the maintenance of former rental houses causes serious problem for owner communities (inhabitants). The overall cause of decay of global consistence is complex and only a (not negligible) segment of this originates from economic factors. The lack of technical knowledge and the ignorance of the methods of Facility Management also influenced the state of the buildings adversely. In practice the interventions have been ad hoc, based on avoiding life-threatening failures.

Based on the statements above it is clearly evident that the former rental houses, which represent a dominant proportion of the building stock of the inner districts of Budapest are 'heavily handicapped'. Due to their age these low quality buildings made of weak building constructions are in critical state; the applied maintenance protocol is insufficient (value added repair processes were done in small rate only).

The preservation of historical urban structure, the total commercial value of concerned apartments and the global national economy status also justify the sustainment of rental buildings, despite the fact that the individual architectural value of these buildings is low.

In this paper we propose a decision support tool that considers its user's competency in Facility Management and the attributes of the former rental houses discussed above. This method may support the unprofessional owners' communities in managing the renovation process of the given building.

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The construction of the evaluation method is based on the fuzzy signature rule base, where the needed information and data is obtained from former surveys and analyses.

The application of the method is represented on an overall analysis of the total building construction of a rental house built in 1912. Beyond the analysis of the results of the case study we recommend further developments for expanding the efficacy and availability of the method.

Keywords: historic rental house, evaluation method, Facility Management, fuzzy signatures, decision support

1. Introduction

In the frame of an overall survey of changing living conditions in Budapest, the rehabilitated urban areas were examined focusing on social, economic and environmental sustainability. In the near past, two major urban rehabilitation projects were (almost) accomplished in the interior districts: one in the Mid-Francis' Town (district N° 9) and another in Joseph's Town (district N° 8). At present time, the building stock built before the WWII in eight blocks of Mid-Francis' Town are being studied.

Among the 88 houses located in this area, 41 apartment houses were built before 1944; 24 buildings were totally rehabilitated with the organization and financial support of the Local Government before the privatization of apartments. The rest (17 buildings / 320 apartments) were sold without important repairs – a previously accomplished visual diagnostic survey considered them as houses in good physical condition. As a matter of fact, these buildings also have several defects, and an overall comparison with the other historic buildings in the examined area visibly shows that these buildings and their owners are the losers of the urban rehabilitation.

The ownership communities of these houses are now in an uncertain situation: they have to manage their maintenance without any strategy and little financial background.

In the present article a proposal for a decision-support tool is outlined that is based on a collection of technical information of the involved buildings. The attributes of buildings can be arranged in a predefined structure, where all information on the buildings can be evaluated systematically. Without any detailed explanation it is obvious that the goal (decision-support tool) and the circumstances (classified data structure, involvement of experts) strongly recommend the application of an expert system. Issuing from the character of data on hand and the observation methods applied, the expert system may well be based on fuzzy set theory, especially on the approach of fuzzy signatures that is an effective tool for describing and characterizing objects with multiple and vague uncertain attributes.

2. The Examined Type of Apartment Houses

2.1 History of Rental Houses from the End of 19th Century in Hungary to the present time

The golden age of Budapest took place between 1870 and 1920. During these fifty years the urban structure of inner districts was developed; the closure of streets almost obtained their present state. The main characteristic architectural element that represents Budapest's golden age is the rental house-type apartment building. There are several different rental houses by the quality, the style, the owner, the inhabitants' social status, the location, etc. This together reflects well the mood of the nineteenth century-fashioned downtown of Budapest. Another urbanization progress happened after 1928 that ended in 1942; the social rental houses that were built in this period represent the so-called modern attitude to life.

The socialization of building stock extended to the rental houses of historic districts of Budapest; this procedure took ten years only after the Second World War. Since these houses symbolized the middle class of an ancient regime, the political leadership took more effort in developing new quarters then maintaining existing former rental houses. A state-owned company maintained the flat stock with low efficacy. The result: old and untouched rental houses were in bad condition at the end of socialist era.

After the transition to democracy (1989) the obligatory maintenance task in the housing sector was the task on the new political leadership Since there was not any economically powerful customer, the state sold the apartments to their tenant for an artificial low price (regulated by the housing laws, 1991; 1994). In ten years the ownership system has changed totally: before the privatization the state owned more than 50% of total apartment stock, in 2001 only 8,6% of apartments were in the hand of the state.

2.2 Actual Status of Former Rental Houses in Historic Urban Structure

After analysing the available nationwide statistic survey it is ascertainable that a significant number of existing apartment houses were built before the WWII (see ***Error! Reference source not found.***). This percentage becomes higher when the analysis focuses on the historic districts of towns. In the examined area 57,5% of apartments is located in buildings more than seventy years old.

Table 1: The distribution of flat stock by building period by Aczél G and Gutai B (2006)

	district N°9	Mid-Francis Town	Rehabilitated Area	Nationwide
before 1919	15 351	6 862	1 238	484 677
1919-1944	5 285	1 120	394	442 403
1945-1959	630	205	2	424 950
1960-1969	7 764	246	2	550 944
1970-1979	1 242	62	0	861 271
1980-1989	1 206	699	10	685 518
1990-2001	1 575	1 359	1 190	273 279
Total	33 053	10 553	2 836	3 723 042
before 1944	**20 636**	**7 982**	**1 632**	**927 080**
	62,43%	*75,64%*	*57,55%*	*24,90%*

The Act of Freehold Flats (2003) regulates the law regarding discussed apartment houses. Among other instructions it also determines the organization structure of the living community and the owners' responsibility in maintenance procedure. The annual meeting of house tenants makes decision about the maintenance processes; the process is managed by the community's freely elected joint representative.

Twenty years after a transition to the market-based sector in the housing market the financial consolidation of rental houses has not yet finished. The experienced migration process resulted in the appearance of new inhabitants in the historic districts of Budapest and the available capital of the owners' community is still insufficient for supporting total renovation procedures.

Beside the unfavourable financial situation and the interdependence of the owners, the lack of knowledge and experience in building maintenance on the part of joint representatives also hinders the technical consolidation of former rental houses. However, Local Governments give limited financial aid for houses improving their condition; this support may be effective with well-organized reconstruction plans.

In major cases the society of owners is able to repair only the most dangerous damage that originates from obsolescence process. The required interventions override every previously determined schedule; therefore the inhabitants may feel that the physical condition of their house remains unchanged year after year.

3. Attributes of the Examined Rental House

In the examination area a representative building was chosen from the seventeen rental houses involved. In this five-storey building (built in 1912, the copy of original blueprint is presented in ***Error! Reference source not found.***) there are 52 apartments at several sizes and lived in by residents with different social status. Considering the shape, the materials and the decorations applied, this building can be classified as an historic rental house. The ownership community (52 owners) has a small bank savings that grows slowly year by year and is reserved for renovation and repairs.

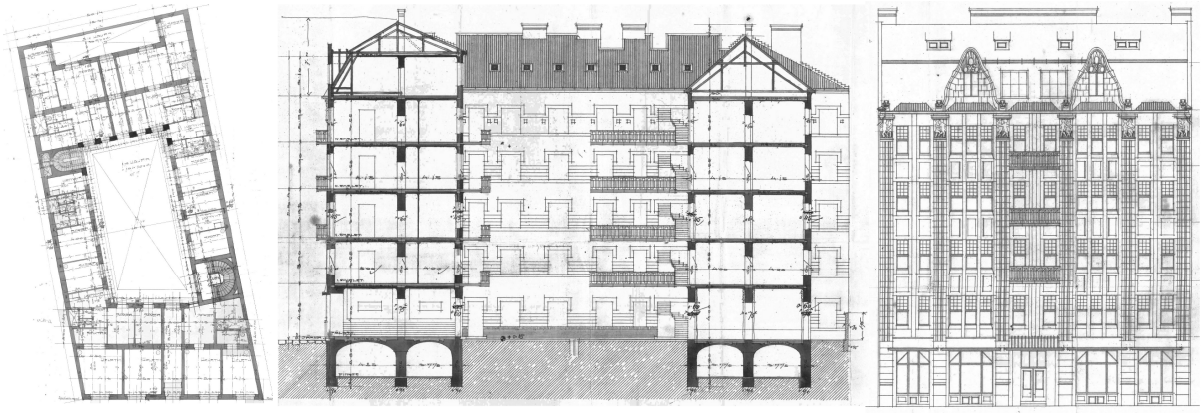

Figure 1: Site plan, section and elevation of the examined building (1912, source Budapest Archives)

After a joint representative election an overall visual diagnostic survey was done by an independent professional team in 2012. The survey report describes the observations of professionals - statics, constructional, mechanical and electric - divisions. The statements of this report represent an average former rental house of the historic areas of Budapest with typical failures. The report summarizes the problems that have to be solved, without proposing any action plan or giving a priority list of interventions.

With the information obtained by diagnostic surveys the owners' community aimed to develop a maintenance action plan. Although a well-constructed Facility Management application can help scheduling the repair tasks, the available FM software is overpriced for such building size.

The building failures and their repairs can be ordered in several ways. The main aspects for the comparison are the dangerousness and the repair costs; but there are other important factors that have to be taken into consideration (the interrelation of building failures, possible Local Government financial supports, comfort and aesthetic demands of inhabitants, etc.). Many of these aspects cannot be measured or there is no data that can be evaluated. In addition, the number of total collected factors that cannot be handled with a simple decision-support tool is twelve.

Without any detailed description of the experienced failures, the report emphasizes more than twenty significant building failures that have to be repaired. The evaluation of the failures by all factors with a traditional method would take long and would be inefficient.

4. The Fuzzy Signature-based Expert System

4.1 Application of Fuzzy Signatures

In the case of the planned decision support tool the generalization of fuzzy sets first introduced by Zadeh's proposal (1965) has to be mentioned; Zadeh's early student, Goguen (1967) proposed the concept of L-fuzzy sets. Vector-valued fuzzy sets are introduced by Kóczy (1980). Vector valued fuzzy sets assign to each element of X a set of quantitative features rather than a single degree – this way providing additional information about the specific element.

Fuzzy signatures (Kóczy et al, 1999) are generalized vector valued fuzzy sets, where each vector component is possibly another nested vector. This generalization can be continued recursively to any finite depth, thus forming a signature with depth *m*.

The structure of fuzzy signatures can be represented both in vector form and also as a tree graph (

Figure 2 represents both the vector form and the tree graph of the proposed structure).

Fuzzy signatures can be considered as special, multidimensional constructions that are applicable for storing structured fuzzy data. In this structure the dimensions are interrelated in that a sub-group of variables determines a character on a higher level. Therefore, complex and interdependent data components can be described and evaluated in a compact way.

In many applications, the observation of experts can be described in different ways, even the structure of observation can be different; nevertheless decisions have to be taken based on these data. With the assistance of signatures these alterations in structures can be handled. The main advantage of the application of fuzzy signatures is that they can handle situations with uneven data structures and information.

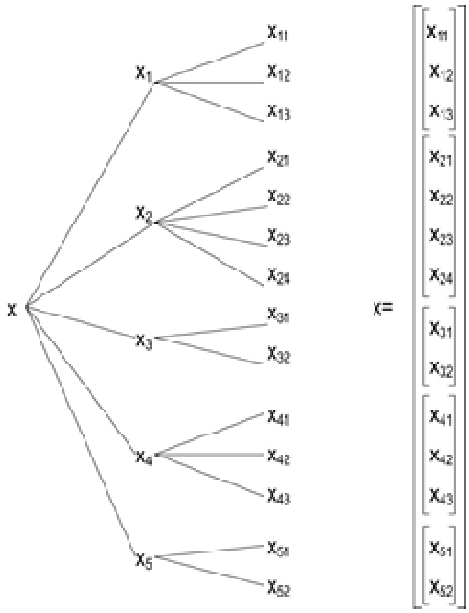

Figure 2: Tree structure and vector form of fuzzy signature

Furthermore, the model created for the given task can be arranged hierarchically (Wong et al, 2003); this feature is very similar to the way of thinking of human experts. This fact underlines the argument that fuzzy signatures are deployable in the area of decision making.

The advantage of fuzzy signatures is that they organize the available data components into hierarchical structures. This hierarchy determines the basic structure of fuzzy signature-based observations. It may occur that some elements are missing at several observations. Therefore, it is necessary to have a kind of structure modifying operator for comparing signatures with quite different structures. It is advisable to apply aggregation operators for reducing sub-trees to their parent node. In the case of a multileveled hierarchy, a recursive process leads to the aggregated value of the parent node being generated.

In our case, the most important question was definition of the aggregation operators. The structure of the fuzzy signature supports the use of different aggregation operators for each node.

5. Proposal: Application of Fuzzy Signature-based System in Building Maintenance Protocol

As described in *Section 3*, it is difficult to rank the necessary interventions if every aspect is kept in mind. This fact ends to decisions in the maintenance process, being based on professionally incomplete information.

In the following a formal system will be proposed that may support the decisions of owner communities in the maintenance procedure. The proposed tool offers an effective solution for applying the experts' knowledge in responsible decision making. This system is based on fuzzy signatures described in *Section 4*.

The application of fuzzy set theory was proposed in bridge maintenance systems recently (Szaradics, 2007). As Agárdy implies (2008), soft computing techniques may help differentiating sets of objects of built environment by several aspects. As a decision support tool the fuzzy expert system was also proposed for determining the ranking of intervention in case of building failures (Molnárka, 2010).

The circumstances determining of intervention ranking discussed above are quite different from the core problem being considered here. The methods of the assessments that were implied in the mentioned papers are applicable for examining the physical condition of the buildings and their elements without considering the financial, energetics and other non-professional context in their place. The aim of the present paper is to obtain a comprehensive and comparable data set for each needed maintenance action; therefore it was not possible to narrow the aspects to the physical and measurable conditions without losing important information.

This intent has resulted in a large scale set of examination aspects that is difficult to handle without any classification abilities. This also explains why the adaptation of hierarchical system of fuzzy signature makes the support tool effective.

5.1 The model

As the first step, the basic structure of the fuzzy signature is developed from the available data and the experts' knowledge; then the adequate fuzzy sets of data elements must be determined. The next step is the identification of fuzzy signature based rules applying the experts' knowledge and the available input-output pairs. When the rule base is ready, the fuzzy signature based observation can be directly evaluated, thus generating a suggested decision.

Let us overview the concrete structure of the fuzzy signature suitable for representing the set of attributes and their respective relations used in the maintenance order evaluation approach.

In the context of this study the accessible information on a building failure may be arranged in three main groups, which constitute the first level of the fuzzy signature structure (nodes x_1; x_2 and x_3).

For aggregating sub-trees within the fuzzy signatures the WRAO operator (Weighted Relevance Aggregation Operator, introduced by Mendis et al. (2006) was applied. With the application of weighted aggregations more expert knowledge can be involved in the examination. Via this operator the owners' community may also articulate its intention in the decision making without decreasing the weight of technical and financial factors. The initiated relevance weight determines the relevancy of a child node on a higher level. For determining the relevance weights by observation Mendis et al. (2006) propose a method that is applied in the current evaluation; in addition, questionnaires of experts of several professional fields (architects, urban sociologists, diagnostics) were taken into account.

For describing different components of the structure linguistic variables may be applied. The next step is to define these linguistic variables and their membership functions.

The global evaluation and range determination of maintenance process is a complex task. As mentioned above a large number of factors have to be considered when a failure and its repair are evaluated. The goal of the discussed study was to obtain a comprehensive character of each intervention. Therefore, the parent nodes in the fuzzy signature structure are the three basic factors of the decision making in the given situation: importance of intervention; financial aspects and subjective components.

In the following, the parent and child nodes are described in groups: their relevance weights are denoted with *w*. For the proper application of fuzzy set signatures it has to be confirmed that at the leaves, membership functions shall be applied over the [0,1] interval: for this reason the basic sets of the determined attributes have to be normalized to [0,1]. The closer the value of observation is to 1 the better is the quality in each respect.

At the nodes and at the leaves of the fuzzy signature structure partitions of triangular or trapezoidal sets are applied forming Ruspini partitions. Accordingly to this, the aggregate of function parameter of sets is 1 for every elements of basic set.

The results of the building diagnostic report are represented with the *Importance of Intervention (x_1; w_1=0.8)* input variable in the parent node; its leaves describe the different attributes of the subjected failure (dangerousness, interdependence, etc). The assessments are evaluated and encoded with the assistance of a knowledge base of building diagnostic expert system.

The financial calculations that are only estimated data in the present state are based on available statistic data base of building industry. These calculations are supplemented with additional information of the possibility of Local Government Support and the analysis of financial perspective of the owners' community. In addition, the possible value improvement of the subjected building was also examined with a separated variable. *The Financial Aspects* (x_2; w_2=0.6) input variable as a parent node synthetizes these data. However while

some information consist of numerical values, several data can be described with linguistic variables only.

After presenting the results of the diagnostic survey an opinion poll was taken in the owners' community about their preferences. In this survey the owners had to rank the experienced failures subjectively. With this survey the most bothering failures were compared to each other from the users' point of view. The *Subjective Factors* (x_3; w_3=0.3) input variable gives an extra aspect that cannot be evaluated with classic methods.

It is clearly visible that the data structure is mainly vague; therefore the application of fuzzy logic is reasonable. *Table 2* represents the input variables in hierarchy with remarks about data sources.

Table 2: Classified and weighted input variables and data source

First level (parent nodes)	Leaves (child nodes)	Data source
Importance of Intervention x_1; w_1=0.8	danger x_{11}; w_{11}=0.8 interdependence with other failure x_{12}; w_{12}=0.7 protection of other construction x_{13}; w_{13}=0.5 energetic performance x_{14}; w_{14}=0.3 accessibility x_{15}; w_{15}=0.2 hygienic, aesthetic aspect x_{16}; w_{16}=0.1	diagnostic report database built on former building diagnostic analyses technical literature
Financial aspects x_2; w_2=0.6	estimated cost x_{21}; w_{21}=0.9 Local Government support x_{22}; w_{22}=0.7 schedulable expenses x_{23}; w_{23}=0.4 value improvement effects x_{24}; w_{24}=0.3	quotation of contractors Local Government regulations estimations based on experiences
Subjective factors x_3; w_3=0.3	non-professional priority x_{31}; w_{31}=0.8 visibility x_{32}; w_{32}=0.5	data mining from a questionnaire

The *Figure 3* represents the child nodes of the *Financial Aspects* variable. This figure summarizes the aggregation procedures and other consecutive steps of calculation.

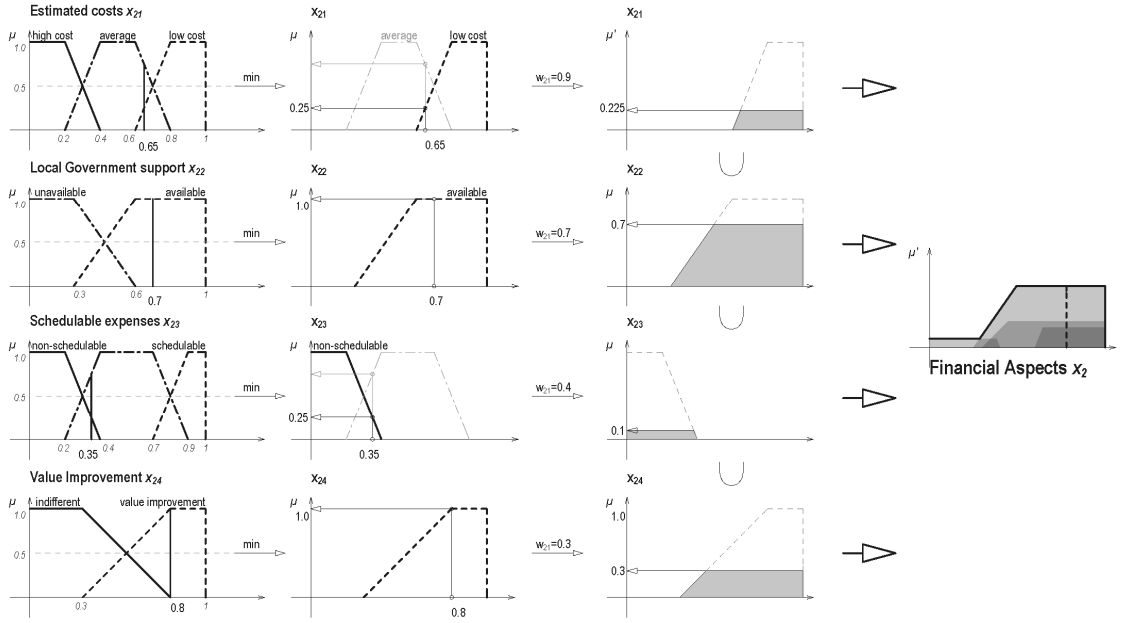

Figure 3: The membership functions of 'financial aspects' (x_2)

5.2 The Rule Base

At the first level the number of available input variables is three. Their partitions (6;4;2 partitions) result in the total number of rules in the rule base being 48. At the level of child nodes a different (much higher) number of rules can be identified from the partitions of input variables. The detailed description of these input variables and their partitions can be found above. The hierarchical structure of the signatures necessitates dealing with a rule base of very high complexity.

5.3 Inference Method

Basing on Mamdani-type inference (introduced by Mamdani and Assilian, 1975), Tamás (2007) introduced the generalized method that operates on signature based rule bases. In this method the alteration is only in the first step, where the degree of matching between observation and the rule antecedents is determined.

In the discussed procedure this method is applied, where the minimum conjunction is taken as the aggregation operator for reducing the signature structure.

6. Results

The examined buildings were evaluated with the method discussed above. The partial results are collected in the *Table 3*. The experienced failures are denoted by keywords, the detailed diagnostic report gives further explanations.

Table 3: Evaluation of construction failures (section, rounded-off values)

			inter-floor slab control	side corridor sealing	court slope ratio	moisture in firewall	basement ventilation	footings	cracked stairs	cat-walk elements	shifted chimney-tops	roof structure	tiling & accessories	firewall edges tinning	finishing & insulation	side corridor drip edge
Importance of Intervention	danger	x_{11}	0.92	0.62	0.49	0.7	0.65	0.34	0.45	0.42	0.95	0.78	0.15	0.1	0.1	0.45
	interdependence	x_{12}	0.65	0.35	0.22	0.68	0.77	0.85	0.05	0.05	0.05	0.76	0.89	0.75	0.18	0.85
	protection role	x_{13}	0.76	0.86	0.66	0.25	0.62	0.88	0.05	0.65	0.15	0.95	0.99	0.96	0.86	0.95
	energetic performance	x_{14}	0.11	0.05	0.05	0.86	0.77	0.78	0.02	0.02	0.05	0.66	0.15	0.15	0.99	0.05
	accessibility	x_{15}	0.21	0.95	0.95	0.16	0.98	0.22	0.9	0.67	0.35	0.55	0.28	0.68	0.86	0.95
	hygienic& aesthetic aspects	x_{16}	0.16	0.8	0.65	0.9	0.84	0.77	0.63	0.3	0.95	0.2	0.19	0.05	0.95	0.78
		x_1	*0.82*	*0.55*	*0.51*	*0.69*	*0.68*	*0.62*	*0.54*	*0.46*	*0.8*	*0.65*	*0.5*	*0.5*	*0.5*	*0.52*
Financial Aspects	estimated cost	x_{21}	0.84	0.38	0.27	0.54	0.1	0.86	0.27	0.14	0.64	0.78	0.65	0.24	0.89	0.26
	Local Government support	x_{22}	0.1	0.09	0.64	0.36	0.06	0.4	0.35	0.38	0.82	0.59	0.46	0.37	0.85	0.38
	schedulable expenses	x_{23}	0.93	0.93	0.96	0.15	0.08	0.23	0.11	0.26	0.16	0.25	0.8	0.85	0.85	0.73
	value improvement effects	x_{24}	0.74	0.64	0.55	0.72	0.19	0.77	0.63	0.58	0.72	0.78	0.68	0.54	0.9	0.66
		x_2	*0.77*	*0.53*	*0.43*	*0.41*	*0.15*	*0.55*	*0.37*	*0.37*	*0.52*	*0.57*	*0.52*	*0.42*	*0.71*	*0.42*
Subjective Factors	owners' priority	x_{31}	0.16	0.28	0.15	0.1	0.28	0.34	0.21	0.38	0.77	0.57	0.48	0.16	0.76	0.28
	visibility	x_{32}	0.26	0.31	0.44	0.09	0.23	0.42	0.74	0.69	0.94	0.74	0.78	0.87	0.87	0.76
		x_3	*0.13*	*0.13*	*0.12*	*0.12*	*0.13*	*0.13*	*0.19*	*0.13*	*0.64*	*0.19*	*0.25*	*0.37*	*0.59*	*0.23*
	weighted result		***0.38***	***0.27***	***0.23***	***0.28***	***0.22***	***0.29***	***0.24***	***0.21***	***0.38***	***0.31***	***0.26***	***0.25***	***0.33***	***0.24***

As a result, the current study discloses the range of listed repairs (the defuzzification step is omissible in this case).

Whilst the discussed project was in process, the owners' community had the damaged chimney repaired, since an extra support was available from the Local Government. Our assessment also justifies this intervention; therefore it may prove the community's view correct.

In a further evaluation of the study was provided to the owners' community and their joint representative. After a short discussion at the annual meeting of the community, the list was accepted and a schedule of overall maintenance procedure was ordered based on this analysis.

The results of analysis underline the importance of the façade insulation procedure. However this statement surprised the community, the priority of this intervention is justifiable: the court and street façade insulation and finishing can be executed independently from other failures, and gives saving options in heating expenses – the extra savings may help in organizing faster and better maintenance procedure.

7. Conclusions and Future Work

In summary it can be stated that that the results of calculations correlate to the former assumptions. The utilization of linguistic variables supported the evaluation of non-measurable (e.g. 'aesthetic') and uncertain (e.g. 'value improvement') values. The application of weighted relevance aggregators in the reducing phase also maintained the professional aspects of the evaluation. The unique hierarchical construction of fuzzy signature structure enhanced the adequacy of the overall evaluation.

The complexity of the building (different structural and sub-structural components, spatial object with complicated relation to the users and the surroundings, etc.) required more complex analyses. That is why it is necessary to increase the number of attributes and to create more precise linguistic variables. To avoid the confusion in the system, in the process of the enlarging structure, it is advisable to create further sub-trees (sub-sub-trees).

The developed decision support tool may take the intermittently determined aspects of the owners' community. Therefore the application of controllable relevance weight on the parent nodes has to be examined.

8. Acknowledgements

The author wishes to record his gratitude to László T. Kóczy, Attila Koppány and György Alföldi for their advices and professional assistance during each phase of the project.

The research was supported by by Széchenyi István University Main Research Direction Grant and TáMOP 4.2.2/B-10/1-2010-0010 at Széchenyi István University, Győr.

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The role of procurement in embedding sustainability along the life cycle of a construction project

Robyn Hardy

Procurement and Sustainability

Incorporating broader sustainability principles and objectives (not just green building) across the full life cycle for construction is becoming a more common prerequisite, particularly in the government sector, for successful project delivery superimposed upon the time honoured on-time, on-budget, good quality paradigm. ~~However, it is at best addressed in a piecemeal way due to a number of factors – the complexity of modern construction projects and the inability of current project management systems to take on further layers of requirements; the failure of construction project managers and clients to give full consideration to the role of procurement in the outcomes of the project; the lack of sufficient information about the relative costs and benefits of various options of inputs, processes and techniques with further sustainability outcomes; and long held organisational and contractual frameworks which constrain innovation. Recent studies have highlighted the need to improve relationships and communication between project participants in construction, particularly at the design stage, in order to improve the outcomes in terms of financial, environmental and social value. This research is demonstrating that collaboration and information sharing through structured methods leads to improved sustainability outcomes. However, this is only part of the project life cycle.~~ This paper contends that the procurement function is in the driver's seat in determining many of the sustainability outcomes of construction projects ~~from the time of preparation of the functional brief to the time of commissioning, handover to end users and decommissioning~~ over their life cycle. ~~The choice of procurement method, the articulation of user requirements and key performance indicators through tender and contractor engagement processes, the determination of the governance and collaboration models, and the supply chain for material are all down to the procurement people in the first instance. This function is given little attention.~~ Through literature review and an informal workshop with ~~project managers~~ construction industry representatives and procurement professionals, this study will highlight how the procurement function can facilitate the achievement of improved sustainability outcomes in construction.

Keywords: construction, procurement, sustainability, procurement function, lifecycle.

1. Introduction

Procurement or purchasing is often ~~a function of the construction management process~~described as bidding or the tendering element in a linear model of the project construction process ~~and it is spread across the project lifecycle~~ (see Uhr and Davenport, 2009). However it is also a functional group as well as an activity (Monczka et al, 2011,

pp10). –While managing a major portion of the procurement process is ultimately in the hands of a client project manager or head contractor, many of the tasks involved in achieving the end result are, or should be, in the domain of the ~~professional~~ procurement/purchasing officer acting on behalf of various stakeholders in the project – client, contractor, sub-contractor and user.

Project management success and project success are not directly correlated according to Munns and Bjeirmi (1996) as they have different drivers. While project management success is judged principally on time, cost and quality; the factors which might cause failure include poor project scoping, poor project management techniques, lack of commitment and lack of management support (Munns and Bjeirmi, 1996). The success of the project however is dependent upon factors such as client satisfaction, the perceived value of the project and its profitability (Munns and Bjeirmi, 1996). ~~Under this concept, project management is a subset of the *project* because it has a shorter timescale and stops when the project is delivered to the client/user (Munns and Bjeirmi, 1996) while the project lifecycle continues on with the user to its end of life.~~ This paper contends that the procurement function merits greater attention not only because it supports the achievement of both project and project management objectives but also because procurement decisions impact on the whole lifecycle of a project and provide an opportunity to influence broad sustainability outcomes. The choice of concept designer, choice of contract method, the articulation of user requirements and key performance indicators through tender and contractor engagement processes, the determination of the governance and collaboration models, the supply chain for material, maintenance programs and decommissioning are all down to procurement people or a procurement role in the first instance. ~~This paper contends that the procurement function supports the achievement of both project and project management objectives. This study aims to illustrate this broader role of procurement in particular with respect to the implementation of sustainability principles in the construction sector.~~

2. Study Approach and Method

Through a deductive approach of literature review and an informal workshop with project managers and procurement professionals, this study will highlight the importance of ~~how~~ the procurement function ~~can facilitate the achievement of improved~~ to sustainability outcomes in construction projects~~. across the full lifecycle.~~ The aim of this research is to demonstrate that more attention should be paid to the function of procurement within the *whole* lifecycle of construction projects in order to maximise sustainability objectives.

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3. Literature Review

There is a growing body of literature about sustainability and the construction industry (Ortiz et al, 2009; Albino and Berardi, 2012; Lombera and Rojo, 2010; Glass et al, 2011; Sidwell and Budiawan, 2001; Lenferink et al, 2012; Seuring, 2011). Since the report of the Bruntland Commission (Commission on Environment and Development, 1987) and the establishment of the Intergovernmental Panel on Climate Change (IPCC) in 1988, researchers, governments, citizens and industry have begun to appreciate a connection between the environment~~, and~~ economic and social activity and welfare. This has led to initiatives to limit

energy use, waste and associated emissions through various means including voluntary action, regulation, voluntary codes and standards, manufacturer incentive programs, and research and development (IPCC, 1996, pp17-20; Albino and Berardi, 2012, pp387).

Coupled with this is a growing world movement to hold companies to account for their actions and supply chains in terms of social, ethical and environmental principles. Corporate social responsibility and the consideration of broader sustainability principles is now more important and seen in terms of leveraging competitive advantage, managing reputational risk and just good business (Porter and Kramer, 2006; Leonard and McAdam, 2003). In order to compete and be sustainable in this new environment, the construction industry needs to innovate – to seek out new products and processes for doing things. Indeed Fukasaku (2000) noted that not only are new products and processes required but also new means of distribution and use. The OECD has agreed that innovation will play an important role in achieving environmental sustainability (OECD, 2000).

~~The Intergovernmental Panel on Climate Change reported in 1996 that the building sector was responsible for approximately one third of all global energy use in 1990 (IPCC, 1996, pp13) and 40 per cent in 2010 (Okoroh et al, 2012). Consequently, governments began to limit energy use and associated emissions through various means including regulation, voluntary codes and standards, procurement programs, manufacturer incentive programs, and research and development (IPCC, 1996, pp17-20; Albino and Berardi, 2012, pp387). Coupled with this is a growing world movement to hold companies to account for their actions in terms of social, ethical and environmental principles such as dealing with the disadvantaged in society, the exploitation of resources and in terms of managing their impacts on the environment. Following several corporate collapses and failures in ethical standards corporate social responsibility and the consideration of broader sustainability principles is more important and now seen in terms of leveraging competitive advantage, managing reputational risk and just good business (Porter and Kramer, 2006; Leonard and McAdam, 2003). In 2009, the World Economic Forum described sustainability as … 'the capacity to maintain a certain process or state indefinitely. In an ecological context, sustainability is defined as the ability of an ecosystem to maintain ecological processes, functions, biodiversity and productivity into the future. In a social context, sustainability is expressed as not compromising the ability of future generations to meet their own needs. When applied in an economic context, a business is sustainable if it has adapted its practices for the use of renewable resources and is accountable for the environmental impacts of its activities '(World Economic Forum, 2009, pp35-36).~~

~~The British Standards Association depicts sustainable procurement as a circular process from inception to post implementation review with a framework of principles of leadership and governance, people centred values such as integrity and quality of life, management of risk and uncertainty and measurement and continuous improvement (The British Standards Institution, undated, pp2-6).~~

Supporting this sustainability drive, ~~T~~there is also now a ~~growing~~ body of literature describing innovation and sustainability in construction ~~and~~as well as the barriers to construction innovation ~~sustainability~~ (Blayse and Manley, 2004; Williams and Dair, 2007; Albino and

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Berardi, 2012; Ortiz et al, 2009; Miller et al, 2009). Some have also made the link between procurement activity, innovation and sustainability, for example Sidwell and Budiwan (2011) examined the importance of the tendering process for the encouragement of contractor-led innovation and noted the limitations of traditional methods. Blayse and Manley (2004) identified six drivers/barriers to construction innovation one of which was *procurement systems*. Miller et al (2009) not only identified a similar list of barriers to innovation but also obtained survey results about the significance of the impact of each barrier. Procurement systems rated moderately highly as having significant impact on innovation. Williams and Dair (2007), in their study of barriers to sustainability in building in England, produced a table of issues cited in their surveys. The list provides a useful method of analysing the barriers and the procurement elements.

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Drawing on research by Gann and Salter (1998, 2000) and Marceau et al (1999), Blayse and Manley (2004~~, pp145~~) described the construction process as a *network* of stakeholders (regulators, suppliers, users, project firms, other technical support institutions) and a *system*, partly manufacturing and partly services in which innovation takes place in a wide variety of areas, *including in procurement*. Blayse and Manley (2004) found~~reported~~ that 'procurement systems that tend to discourage construction firms from risking the adoption of non-traditional processes and products' (pp148) ~~as~~were most detrimental to the adoption of innovative approaches. They noted that traditional methods have been found to have the 'highest cost risk for contractors, the highest incidence of adversarial relationships, the lowest level of integration across the supply chain, and the poorest innovation outcomes' leading them to recommend partnering, alliancing and relationship contracting (Blayse and Manley, 2004, pp149).

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Blayse and Manley (2004, pp147) and Uhr and Davenport (2009, pp208-212) also drew attention to the typical method of dividing construction work up into separate discrete packages which are separately procured with contracts with cascading performance measures to pass risk down the supply chain. This is usually to the lowest level of sub-contractor and sometimes sub-sub-contractor, with the effect of severely dampening innovation.

Rahman and Kumaraswamy (2005) found that *procurement arrangements* (the sourcing point) which support collaborative working arrangements between clients, suppliers, contractors, consultants and sub-contractors and strike a balance between control and flexibility allow more meaningful interactions, better understanding and lead to more efficient outcomes. Similarly, Kuhlmann et al (2011) noted that 'increased attention for soft aspects matches with the notion that project cooperation enhances project performance. Project performance is here defined in terms of cost, time, quality, environmental impact, work environment and innovation' (pp2). Lenferink et al (2012) also found that integrated and inclusive contract and project working arrangements led to more sustainable infrastructure development in their study of Dutch infrastructure projects. Albino and Berardi (2012) discovered that the realisation of sustainable benefits in residential construction processes

requires a higher level of integration of the contractor and suppliers, careful selection of the design team and specialised suppliers, all of which are highly influenced by procurement.

The limitation of these studies is that the procurement function is either regarded narrowly as a single element in the project lifecycle when in fact it pervades the whole lifecycle of a project and is undertaken by different stakeholders at different stages along the process; or it is regarded only as a process and not also as the role of a functional group in an organisation as described by Monczka et al (2011). This is probably because in construction, there is rarely a purchasing area – the role is a one of the many held by project and contract managers.

~~In comparison, Morlege et al (2006) presented the construction procurement process in terms of activities, identifying seven basic components of a construction procurement process: development of a functional needs analysis; selection of a procurement philosophy or strategy (eg design led); selection of the most appropriate form of relationship (eg collaborative); detailed design of the procurement approach; formalising contractual relationships; selecting the optimal supply chain (contractors, consultants) and implementation (pp34-35).~~

Contrast this to The Chartered Institute of Purchasing and Supply Australasia (CIPSA) which principally represents the goods and services procurement profession within Australasia and which has observed "One of the difficulties in defining the term 'procurement' is that it does not deal with a single action or process. Procurement covers the complete range of events from the identification of a need for a good or service through to its disposal or cessation. Procurement includes activities and events before and after the signing of a contract as well as the general management activities associated with a range of contracts: pre-contract activities such as planning, needs identification and analysis, and sourcing; post-contract activities such as contract management, supply chain management and disposal~~,~~; and general activities such as corporate governance, supplier relationship management, risk management and regulatory compliance" (CIPSA, 2005 ~~undated~~, pp5). ~~CIPSA's charter is to enhance the professionalisation of procurement and has long advocated for specialist procurement education and training.~~

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~~Separate~~ ~~Other~~ studies confirm the~~have identified roles for procurement~~ involvement of the procurement function along separate the separate points in the lifecycle of construction projects. For example, Williams and Dair (2007) in their study of barriers to sustainability in building in England, produced a table of issues cited in their surveys. The list provides a useful method of analysing the barriers and the procurement elements.

Brammer and Walker (2007) in their study of sustainable procurement in the public sector, identified four factors which influence the degree to which organisations implement sustainable procurement practices: the level of skills and competencies that procurement staff possess in terms of sustainable practice; perceptions about the relative financial viability of sustainable procurement methods; organisational attitudes and culture supportive to sustainable practice; and the supply chain of sustainably produced products to enable implementation of sustainability objectives (pp9-10). Glass et al (2011) considered the role of

responsible sourcing of materials and products in construction, finding that there is a gap between corporate sustainability goals and operational expertise and that while clients and specifiers of construction projects have the most influence on sustainability outcomes they too lack knowledge and understanding. ~~Rahman and Kumaraswamy (2005) found that *procurement arrangements* (the sourcing point) which support collaborative working arrangements between clients, suppliers, contractors, consultants and sub-contractors and strike a balance between control and flexibility allow more meaningful interactions, better understanding and lead to more efficient outcomes (pp1098). Similarly, Kuhlmann et al (2011) noted that 'increased attention for soft aspects matches with the notion that project cooperation enhances project performance. Project performance is here defined in terms of cost, time, quality, environmental impact, work environment and innovation' (pp2). Lenferink and Jos Arts (2012) also found that integrated and inclusive contract and project working arrangements led to more sustainable infrastructure development in their study of Dutch infrastructure projects. Albino and Berardi (2012) discovered that the realisation of sustainable benefits in residential construction processes requires a higher level of integration of the contractor and suppliers, careful selection of the design team and specialised suppliers. Blayse and Manley (2004) reported that 'procurement systems that tend to discourage construction firms from risking the adoption of non-traditional processes and products' (pp148) as most detrimental to the adoption of innovative approaches. They noted that traditional methods have been found to have the 'highest cost risk for contractors, the highest incidence of adversarial relationships, the lowest level of integration across the supply chain, and the poorest innovation outcomes' leading them to recommend partnering, alliancing and relationship contracting (Blayse and Manley, 2004, pp149).~~

Albino and Berardi (2012) found that contractors seeking sustainability outcomes contacted suppliers early, often at the design stage, in order to confirm supply and feasibility of the design and materials.

~~Blayse and Manley (2004, pp147) and Uhr and Davenport (2009, pp208-212) drew attention to the typical method of dividing construction work up into separate discrete packages which are separately procured with contracts with cascading performance measures to pass risk down the supply chain usually to the lowest level of sub-contractor and sometimes sub-sub-contractor, with the effect of severely dampening innovation.~~

Said and El-Rayes (2011) and Ping Tserng et al (2006) have pointed not only to the optimisation of material supply chain sourcing for construction projects but also the importance of *procurement of materials* to storage and work efficiency on the site (the construction phase). Integrated supply chain management (whereby supply is matched to demand) has been adopted by the manufacturing sector for some time (Ping Tserng et al, 2006, pp395) while the construction industry adopts less optimal methods and tends to store large amounts of inventory and materials on site before they are required reducing the level of efficiency and labour productivity about the site and increasing cost (Ping Tserng et al, 2006, pp395).

Meistad and Valen (2012) have emphasised the importance of involving facility managers in the *early design procurement phases* of construction projects so that they can input knowledge about the operation, cleaning, layout, maintenance, and energy usage during the occupation phase of a building project. After all, while procurement of cleaning and maintenance is not a construction activity, it is part of the lifecycle of the project and decisions on design and materials impact on the success of the project over its life.

At the *end of project life*, demolition or refurbishment become building project owner decisions and involve significant procurement processes and decisions. 'Building materials account for about half of all materials used and about half the solid waste generated worldwide. They have an environmental impact at every step of the building process - extraction of raw materials, processing, manufacturing, transportation, construction and disposal at the end of a building's useful life' (Department of Sustainability, Environment, Water, Population and Communities, 2011, pp4). ~~Given this impact, as noted above, governments are framing markets and regulation to encourage waste minimisation and material reuse not only at the end of life stage but also during construction.~~

The literature identifies various points along the lifecycle of construction projects where procurement activity and functions are negatively influencing the level of sustainability outcomes. ~~Notwithstanding the above point of lifecycle approaches illuminating roles for procurement in embedding sustainability objectives, o~~Other literature examines innovation and ~~specific~~specifically innovation in procurement. For example, Miller et al (2009) identified procurement *policies* which focus on lowest up-front cost rather than value for money as key impediments to innovation in construction. This literature ~~is important because it~~ enables a link to be made between the procurement activities along the lifecycle, the barriers/drivers of innovation and the way procurement could innovate to support sustainability objectives in construction.

~~barriers to innovation and sustainability; and finds further procurement influences.~~

Miller et al (2009) ~~also~~ considered construction procurement innovation and developed a simple matrix (Table 1 below) to distinguish between *procurement product* innovations and *procurement process* innovations (pp50). This matrix provides a useful framework for conceptualising procurement innovation. Under this model, the emergence of alliance contracts and public-private partnerships would be seen as a *procurement product* innovation, whereas early contractor involvement or design work-shopping with multiple stakeholders might be seen as *procurement process* innovation. E-tendering and e-procurement could be seen as both a *procurement product innovation* and a *procurement process innovation*.

Table 1: Type of Innovation and procurement (Miller et al, 2009, p50)

	Innovation of procurement	Innovation within procurement
Product innovation	New/improved financial instrument/contractual form	Innovation in components/structures of buildings and infrastructures
Process innovation	New/improved organisational forms, structures, sequences, financial arrangements	New/improved processes in construction

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~~Complexity and the difficulty of communication within large complex projects and the traditional hierarchical approaches to project management may also be barriers to innovation in construction (Miller et al, 2009 and Blayse and Manley, 2004). Miller et al (2009) also identified procurement policies which focus on lowest up-front cost rather than value for money as key impediments to innovation in construction (pp54).~~

~~Brammer and Walker (2007) in their study of sustainable procurement in the public sector, identified four factors which influence the degree to which organisations implement sustainable procurement practices: the level of skills and competencies that procurement staff possess in terms of sustainable practice; perceptions about the relative financial viability of sustainable procurement methods; organisational attitudes and culture supportive to sustainable practice; and the supply chain of sustainably produced products to enable implementation of sustainability objectives (pp9-10). These complement the issues identified by Williams and Dair (2007) in their study of barriers to sustainability in building in England. Williams and Dair (2007) list a number of frequently recorded issues in their survey including that the sustainability measure was not required by the client, the sustainability measure cost too much or that it was not available (Williams and Dair, 2007, pp141)~~

~~The theory points to a role for procurement across the full lifecycle of the construction project and to a number of barriers to sustainability in the construction industry which may be influenced by procurement.~~ The findings in the literature review were subsequently tested in an informal workshop with industry representatives.

4. Informal workshop results

Invitations were sent to a broad cross section of the Australian Capital Territory construction sector (academics, government regulators, government procurement, quantity surveyors, construction companies, peak bodies and industry representative groups, legal advisors). Thirteen respondents participated in the informal workshop representing the industry broadly. The objective was to have a sufficient number to enable meaningful discussion and participation by all present. The workshop was divided into four themes: the definition of

sustainability and sustainable construction; sustainable materials; barriers to sustainability in construction and the role of procurement in sustainable construction.

The participants considered that sustainability objectives were set up in opposition to budget and up-front financial goals. ~~defined sustainability narrowly in terms of green building. They demonstrated a limited knowledge and adoption of broader concepts of sustainability although concern was expressed about building safet~~ *'Communities need to be liveable, there needs to be housing and environmental sustainability for the long term to support changing needs'.* ~~They did consider that sustainability objectives were set up in opposition to budget and up-front financial goals.~~ *'It [sustainability] is set up against another set of values, sometimes in opposition to durability'. 'The economic life of buildings varies from place to place'.* '*Do you want it to last for 30 or 150 years and will you be prepared to pay?'* Drawing on this discussion, the barriers to sustainability ~~(green building in their terms) w~~were discussed. *'It is seen as a niche'; 'People are expecting to change things, …, they go to IKEA and turn furniture over, there is no sustainability in that'; 'You can write perfect specifications in a tender but when it comes to the QS the builder says I've got to build and sell, I have to cut the cost, and the product goes out the window.'* Participants listed ~~seen as~~ up-front cost; regulations allowing unsustainable or less sustainable options; economic pressures and client pressures to complete works within constrained budgets and time; lack of knowledge of products and suppliers; lack of demand by clients for green or sustainable alternatives and green options being cut from projects by clients due to budget constraints. ~~; and green options being cut from projects by clients due to budget constraints.~~

~~With respect to materials, the discussion focused around the certification of products to meet Australian Building Standards. Although products are proven to be more sustainable alternatives and used overseas, the local market is not taking them up due to lack of certification and proof of performance to enable building certifiers to sign off.~~ Procurement or the procurement function was seen as a major barrier to sustainable building. *'Problem in procurement is cost~~. The best value for money may not be the best product for the service~~'; 'You can't have sustainability without whole of life analysis and risk. It needs to be up front, if you leave it until later in the process you have to back track. It is a key procurement right up front'; 'Innovation can be considered in the tender context but we are not looking for innovation'; 'Contracts are like leadership'; 'If you have a model that has too much competition there is not enough profit and industry loses money'.* Here participants cited adversarial contracts and relationships not conducive to innovation, lack of involvement of contractors and suppliers early in design and the lack of skills of both contractors and procurement professionals in sustainable building. Participants also expressed the view that sustainable building is still in its infancy with little demand pull from clients, although there is an increasing level of regulatory push from government. They particularly noted the difficulty in demonstrating and convincing clients of the value of sustainable building alternatives. *'The industry is very conservative. Trades like to do stuff they are used to doing. If you introduce a new product and they have never seen it they will put a premium on that because they are not used to using it'.*

The workshop confirmed many of the findings of the literature, particularly the results from Williams and Dair's (2007) surveys in the UK about barriers to sustainability and innovation.

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Participants also identified and confirmed the wider the role of procurement in this process ~~and international studies in relation to sustainable building and construction~~.

5. Analysis ~~and Discussion~~

The lifecycle of construction projects is typically represented by a number of distinct stages: concept, design, tendering, pre-construction, construction and commissioning (see Uher & Davenport, 2009, pp29). This approach limits the role of procurement, however, despite this~~Within this lifecycle or process~~ , the literature and workshop confirm that there are numerous points where procurement activity takes place. Figure 1 below illustrates the points of involvement of the procurement function along the *whole* project lifecycle as indicated by the research and the outcomes of the workshop described above~~supply chain~~. Having established a number of procurement functions across the lifecycle, sustainability outcomes may be enhanced through procurement product and process innovation.

An analysis of the barriers shows that procurement figures prominently in the functions responsible or able to influence sustainability. Linking together, the enhanced project lifecycle model depicting the broader role of procurement to the barriers to sustainability in construction and innovation identified in the literature, Table 2 ~~below summarises the barriers to innovation and sustainability revealed in the research and~~ applies a stakeholder role and responsibility to each listed barrier. It also categorises each issue in terms of whether a procurement product innovation or a procurement process innovation could bring about some improvement ~~ad~~ identified by the literature and the workshop according to the identifier matrix developed by Miller et al (2009). ~~Procurement figures prominently in the functions responsible or able to influence the barrier issues.~~

~~Figure 1: Project Lifecycle with procurement functions and roles~~

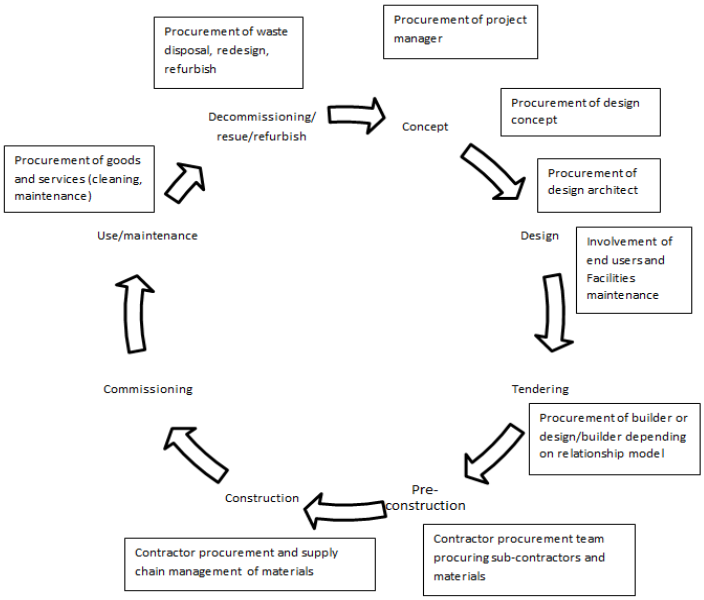

Figure 1: Project Lifecycle with procurement functions and roles over the full cycle

Table 2: The Role of Procurement in mitigating barriers to sustainable construction (Adapted from Williams and Dair, 2007, pp141)

Barrier to acting sustainably	***Lifecycle stage***	***Role/responsibility***	***Procurement product or process innovation***
Sustainability measure not considered by stakeholders	Concept, pre-construction	Procurement function should be able to advise clients about potential sustainability options.	Process
Sustainability measure not	Tendering	Procurement function should include measures in project briefs, statements of	Product

required by client		requirements and contracts.	
One sustainability measure forgone in order to achieve another (traded)	Pre-construction, tendering, construction	Client, Project Manager. Procurement function should be able to assist with making ~~the~~ business case for ~~the inclusion~~inclusion of sustainability measures.	Process
Sustainability measure restricted, or not allowed, by regulators	Pre-construction	Regulator. Procurement function ~~should~~ set~~s the~~ requirements in ~~briefs,~~ statements of requirements, ~~quality performance~~ in accordance with legislation.	Process
Sustainability measure cost~~s~~ too much. Focus on upfront cost not performance	Pre-construction, tendering, construction	Client, Project Manager. Procurement function should be able to assist with making ~~the~~ business case for ~~the~~ inclusion of sustainability measures.	Process
Site conditions mitigated against the use of a sustainable measure	Construction	Client, Project Manager, Contractor.	
Inadequate, untested or unreliable sustainable materials, products or systems	Pre-construction, design, tendering, construction	Client procurement, contractor procurement and designer should be able to consult on available tested materials.	Process
Sustainable measure not available	Design, construction	Supplier, supply chain. Procurement function should be able to innovate in sourcing.	Process
Unsustainable measure allowed by regulator (no impetus for a sustainable alternative to be used)	Design, tendering c~~C~~onstruction	Regulator. Procurement function can set the bar higher in briefs, statements of requirements, quality performance than is set by regulator.	Product
Stakeholder not included, or included too late, in the development process to implement sustainability measure	Pre-construction, design, tendering, construction	Responsibility of Project Manager and procurement function to include all stakeholders.	Process
Stakeholder lacked information, awareness or expertise to achieve sustainable measure	Concept, Pre-construction, design, tendering, construction	Client, Project Manager, Contractor and Procurement. Lack of training, knowledge, awareness. Obligation and opportunity for all stakeholders.	Process
Inflexible adversarial procurement arrangements	Tendering	Client however mostly down to Procurement. Contracting models and governance models for projects.	Product and process

Lack of integrated teams and separation of construction portions	Tendering	Procurement role directed by Project Manager/client.	Product and process
Less than optimal supply chain of materials and storage	Construction	Contractor Procurement and Project Manager, suppliers. Integrated team approach would allow collaboration. ~~on issues such as this.~~	Process
Lack of involvement of facility management in early design phase	Pre-construction, design	Client, Project Manager and Procurement.	Process
Lack of consideration of waste during construction	Construction	Client Procurement, Contractor Procurement and Project Manager. Can be a matter of contractual obligations.	Product and process~~.~~
Lack of consideration of waste at demolition stage.	Demolition	Client Procurement, c~~C~~an be a matter of contractual obligations.	Product and process
Poor communication or complex inadequate communication	Concept, Pre-construction, design, tendering, construction	Project Manager, Client Procurement and all other stakeholders. Clear communication methods can be stipulated as part of project briefs, statements of requirement. ~~Implementation is a matter for participants.~~	Product and process
Culture not conducive to adoption of sustainability objectives	Concept, Pre-construction, design, tendering, construction	Client ~~and~~ Procurement. Responsibility to engage contractors with appropriate culture.	Product and process

6. Conclusions

This study has demonstrated that the procurement function has a strong role over the whole lifecycle of a construction project supporting the project outcomes and the project management function. It has also shown that there is considerable potential to improve the sustainability of construction projects through process and product innovation in construction procurement. Given the increasing importance of projects achieving greater sustainability outcomes into the future, it is difficult to understand why procurement functions, processes and products would not become a priority for research and development serving both the client and the contractor side.

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The impact of the construction industry culture on the work – life balance of women employees: A case of South Africa

G. Dlamini, W. Shakantu, K Kajimo-Shakantu

Abstract

The debate on women's involvement in the different sectors of the economy has become progressively amplified than it was in the past where women's roles were understood to be synonymous with taking care of families. In most economies, both developed and developing, women form approximately half of the total population but their involvement in organized labour is still relatively lower because fewer opportunities are available for women as opposed to men. With the recent political commitments in South Africa, there has been an increase of opportunities for the advancement of women in construction, government and other industries. As a result women in the construction industry are confronted with the challenge of balancing their work, which in most instances is demanding, with their domestic and societal role of taking care of the family. Organizational culture provides a context for setting goals, taking action, understanding personalities and identities within organizations, but the critical area of concern is its impact on issues such as work-life balance. Work-life balance is an important issue in the construction industry because it has a direct bearing on organisational effectiveness and individual performance. This paper outlines, based on a literature review, the impact that organizational culture has on the work-life balance of women in the construction industry in South Africa. Break

Keywords: Construction Industry, Culture, Women, Gender, Work – life Balance

1. Introduction

Globally, more and more women are breaking the traditional barriers and stereotypes by being successful in the construction industry, which otherwise continues to be a male dominated industry. Within the South African context, major inroads backed by political commitments have been made, to encourage the participation of women in construction through various legislation and frameworks. Ironically, studies in certain African countries indicate that notwithstanding the countless successes, women are generally affected by patriarchal cultures, male resistance and hostility, apathy and domestic burdens, thus perpetuating the old age barriers of participating in the labour markets (Britwum, Douglas, & Ledwith, 2012: 49). Further research indicates that attitudes, behaviours and perceptions are grave barriers for women in all job roles and professions (Worrall, Harris, Thomas & McDermott, 2010: 279).

The construction industry is associated with high risk environments, labour intensive jobs, long working hours, poor health and safety(H&S) as employees are exposed to harsh conditions and operate dangerous machinery and equipment (James, Rust, & Kingma, 2012:

1553). It is project based and has long been recognized as a stressful industry due to the complexity of tasks, tight time frames, complicated working relationships and the general poor working environments (Fong & Kwok, 2009: 1348; Leung, Chan, Chong, & Sham, 2008: 636). Organizational culture, in this sense relates to the combination of these factors, artefacts, practices, expressive symbols or forms, values and beliefs and underlying assumptions that organizational members share about appropriate behaviour (Schein, 1992: 43). Although many have attempted to define organizational culture, research has established that there are indeed many descriptions and interpretations of organizational culture and it has been viewed widely as holistic, historically determined and socially constructed (Rashid, Sambasivan & Rahman, 2004: 164). According to Hofstede *et al.* (1990), organizational culture involves beliefs and behaviours existing in various levels and manifesting itself in a wide range of features in an organization. Consequently, empirical evidence for studies conducted in the UK show that with the existence of the intricate working practices within the construction industry, women often face career penalties in trying to balance work – life commitments and as a result, their potential career options and growth are jeopardised (Worral, 2012:17).

1.1 The Construction Industry in South Africa

The South African construction industry, similar to many around the world, has in the past been challenged by many systemic problems that are not exclusive to, unstable and insecure employment, financial instability, a bias towards urban development and erratic approaches to integrating the construction industry with overall government policy (Rwelamila, 2002: 435). However, to achieve its primary objective through the democratic dispensation of reconstruction and development programme, the South African government consolidated a process to create an effective strategy for the construction industry within the parameters of the national agenda of social and economic transformation (Rwelamila, 2002: 435). The South African construction industry also operates in a uniquely project-specific and complex environment, combining different investors, clients, contractual arrangements and consulting professions (Marx, 2012: 2). It plays an indispensable role in the economy of South Africa. Despite the numerous constraints facing the industry, it continues to make a significant contribution to the country's economy (James, Rust & Kingma, 2012: 1553). The industry has delivered significant growth, in the past six years employing about 1.8 to 2.25 million people in South Africa (van Wyk *et al.,* 2011: 5). The key driver of this growth has been governments' commitment towards improving the country's infrastructure (van Wyk, *et al.* 2011: 6). Accordingly, the transformation policies as implemented via the South African CIDB(Construction Industry Development Board), has provided frameworks for the increase of black and female contractors, to ensure that contractors reflect the demographics of the country (cidb, 2012: 32). A recent report further indicates that on average, an approximate percentage of contractors ranging between 30% - 40 %, of the Grade 2 to 4 bands are women in both civil engineering and general building (cidb, 2012: 32). This however, represents women contractors, not necessarily the other groups of women who are employed or being trained in the construction industry. Otherwise it would postulate a relative increase of women involved in the industry in general. According to Stats SA (2009), women accounted for about 3% to 17% of the construction workforce both in general

building and civil engineering prior to 2007 indicating a considerable increase from the period when women's participation in labour was largely domestic in nature.

2. Industry Culture

According to Tijhuis (2012), culture has evolved from the initial description of "how things are " to how things are done, what is done, why things are done, when and by whom; which makes culture a construct that concerns groups of people rather than individuals. An appreciation of culture is crucial for organizations because combinations of cultural manifestations such as language and behaviour have major business impacts (Tijhuis & Fellows, 2012: 52). The construction industry is set within the back drop of South Africa, a nation characterised by diversity at its best. Multilingualism, different races, ethnicity and religion are some of the qualities that render South Africa diverse and it is for this reason the country is colloquially known as the "rainbow nation" (Butler, 2009: 36). To trace the path, which perhaps has contributed to this diversity, it is evident that history, before and during the apartheid government system, was largely responsible for propagating this diversity through colonization and segregation. During the apartheid, multiplicity of culture arose as a result of different racial and ethnic groupings (Zegeye & Kriger, 2001: 1). In addition to that, the influence of the west cultivated new cultural patterns within the indigenous ethnic groups (Butler, 2009: 37).

It is undisputable therefore that the cultural climate in South Africa, in addition to the indigenous tribal systems, has been shaped by the overarching intellectual systems associated with white supremacy, segregation and apartheid and it is inevitable that these systems continue to manifest in contemporary South Africa (Butler, 2009: 180). Even though apartheid collapsed and the African National Congress (ANC) took over as the ruling party, its legacy lives on and true to form, labour practices in this country are still influenced by the past. The progressive urbanization and suburbanisation has brought massive changes in the nature of everyday community life (Butler, 2009: 174). Thus the nation persists as a pre-eminent constituent of identity and society, cultures and all other social processes are anchored on the national space (Edensor, 2002: 1). The broader organisational culture will therefore be reflective, to a greater or a lesser extent of the national culture. In other words, an organization's culture is grounded in the culture of its host, normally the country or society where the organization is located (Tijhuis & Fellows, 2012:16). Today the major sources of pressure on institutional norms or practices in South Africa are functional economic, political, and social norms. Several tenets of institutional theory are applicable to South African labour and they include: (i) inappropriate behaviour on the part of management as a result of a lack of understanding of how to adapt to new processes; (ii) the influence of informal cultural, societal, and social rules on South Africans; (iii) misconceptions and ignorance of the norms governing behaviour in the new and uncertain environments especially post-apartheid (Pillay, 2008: 373). There is also a strong indication that South African Government still operates within the constructs of a liberation movement rather than a democracy, which displays two different struggles standing in the way of transformation through socio economic and political progress (Ramphele, 2012).

Classifying organisational culture into defined types offers a simple and systematic method of establishing relationships with other organizational variables such as, work – life balance in the case of this paper and it creates a possibility of highlighting the experiences of those working in each type (Walker, 2011: 183). Many scholars have designed different models of measuring organizational culture and each offer an in-depth understanding of the patterns of meaning that link these manifestations together, sometimes in harmony or in conflict between groups and individuals in an organization (Martin, 2002: 3). Hofstede (1994) proposed six dimensions for analysing organizational cultures; Process – Results (technical and bureaucratic processes), Job – Employee Orientation (derives from societal culture as well as influence from founders and managers), Professional - Parochial (One category or people identifying with professions), Open – Closed System (Ease of admitting new people, styles, internal and external communications), Tight – Loose Control (degrees of formality, punctuality depending on technology and the rate of change), and Pragmatic – Normative (how to relate with the environment- e.g. customers).

Fellows, (2005: 51) reports that Cameron and Quinn (1999) devised a contemporary "Competing Values Framework" which yielded four quadrants; each denotes a type of organisational culture which most organisations are likely to adhere to. The quadrants are; Clan, Adhocracy, Market, and Hierarchy. Cameron and Quinn (1999) proposed a further framework, Organizational Culture Assessment Instrument (OCAI), for evaluating organizational culture based on core values, assumptions, interpretations, and approaches that characterize organizations and six artefacts were suggested; Dominant Characteristics, Organizational Leadership, Management of employees, Organizational glue, Strategic emphasis and Criteria for success.

Handy (1993: 183-190) described organizational culture as being founded and built over the years by the dominant groups, which are the central power source within an organisation. He came up with four main types of culture of which organizations would likely subscribe to; Power Culture – a centralised culture with few rules and procedures, represented by small enterprises, Role Culture – a bureaucratic culture where rules are coordinated by senior management and focus is on the role rather that individuals or groups , Task Culture – a project oriented culture which focuses on getting the job done and responding on market needs and Person Cultures – a culture that focuses on the individual and their professionalism.Liu (1999) identified nine artefacts to describe culture of the real estate professionals in Hong Kong which detail how power orientations, rule and procedure orientations, people orientation, external versus internal focus, team orientation, customer orientation and communications will affect business in construction. Although these models represent a fraction of the literature available on organizational culture, the general understanding is that they can be utilised to understand cultures in organizations and they are comprehensive enough and carry similar interpretations that can be linked to the organizational culture existing in the construction industry. Evidently, both employers and employees in the construction industry cannot avoid the influence of culture, all groups involved ought to be aware of it and use its influence positively (Tijhuis & Fellows, 2012: 175). Consequently understanding culture helps explain many of the puzzling and frustrating experiences of organizational life (Schein, 2010:7).

3. Women and Work-life balance

Work-life balance is essentially about individuals having some level of control of over where, when and how they work and have a life beyond paid work (Smith, Wainwright, Buckingham & Marandet, 2011: 604). A considerable amount of research has attempted to measure the conflict between work and other aspects of non-work life (Lingard & Francis, 2009: 77). Ever since the publication of Kanter's (1977) work, *Men and Women of the Corporation*, there has been a growing understanding of the interconnected nature of employees work and non-work life. Previously, early studies focused on men to examine the effects employment on family life and the results indicated that men did not see any connections between their work and family lives (Voydanoff, 1989: 2). Back then the relationship between structural characteristics of jobs, closely tied to family included the timing and the spatial locations of work and the fact that working long hours was associated with work – family conflict, particularly because job demands created job induced stress which negatively influenced family relationships and health (Voydanoff, 1989: 5). Prior to all these dispositions, Kahn *et al*.(1964) wrote that work-life conflict is a form of inter-role conflict in which the role pressures from the work and family domain are mutually incompatible to some respect (Kahn *et al.,* 1964: 20).

Much recent research shows that job demands bourne by construction professionals are damaging on their personal relationships (Lingard & Sublet, 2002: 507). The construction industry is a demanding and project based work environment where employees are expected to work for long and irregular hours (Lingard & Sublet, 2002: 508). Family life can also have a negative impact on the work interface which is why the notion of work-life conflict flows from the premise that workers are expected to perform multiple life roles, on one hand as a worker and on the other, as a parent, carer, student or community participant (Lingard & Francis, 2009: 78). Family provides an important resource and a diminished family functioning is likely to impact on employees' ability to cope with the demands and pressures of work (Lingard & Lin: 2004: 410). A critical evaluation of work-life balance shows that by isolating the issue of balancing paid work and life, from wider gendered and social class patterns runs the risk of obscuring inequalities. Work-life balance thus ignores the often blurred and ultimately socially constructed nature of what counts as work and what does not and tends to mask the large amount of reproductive work performed by women in the private sphere in some occasion (Smith *et al*., 2011: 604). Men and women experience the demands of work and family differently as it is generally women who assume greater responsibility for domestic and caring work whilst participating in a paid work economy (Gatrell, 2004: 43). Thus it is a useful departure point to examine how women's lives have been affected in the construction industry within this young democracy, which is still trying to find its footing in repairing the perils of the past. The nature of the status of the work-life balance of women in the country is not only confronted with the general cultural composition of the industry, but also a broader and more intricate socio economic and political climate. To juxtapose the literature and theoretical analysis that has been highlighted ushers a better understanding on the extent of the effect of the industry culture on work-life balance of women in the South African context.

4. Critical Issues

4.1 Policy and Politics

The South African cidb as established by an Act of Parliament (Act 38 of 2000) has a critical mandate of improving the construction industry through national, social, and economic development objectives, industry performance, efficiency and competitiveness and improved value for clients (cidb, 2011: 1). As such, significant inroads have been made to increase the number of women contractors participating in the sector through funding and training initiatives but the number is still low as the industry continues to fully utilise the potential of one gender (Haupt & Madikizela, 2009: 47). Although the national legislation has provided room for women, this is not easily translated and enforced into practice across the board, indicating a non-existent correlation between policy and practice (Mathur-Helm, 2005: 62-63). This in itself is an obstacle towards formulating workplace policies and frameworks to support work – life balance initiatives because the main focus is in the implementation of strategies that are aimed at increasing the participation of women in sectors previously reserved for men. The South African construction industry is also trailing behind regarding modern human resource practices and as a result workers experience stressors due to time constraints, pressure to complete jobs and hard working conditions (James, Rust, & Kingma, 2012:1553). Whereas human resources policies and programs to this effect represent the formal or espoused approaches to manage an effective workforce (Harrington & Ladge, 2009: 154). The great challenge remains in synchronising policy and practice.

4.2 Power and Dominance

South African women have always stood in the secondary echelons of society, as past policies were in favour of men to the extent that a culture of inequality of power between women and men, inevitably leading to the unequal sharing of resources such as information, time, and income was created (Mathur-Helm, 2005:56). The cultural implications militate against women's equal progression through the somewhat exclusionary and discriminatory environment that characterises construction (Haupt & Madikizela, 2009: 48). The industry culture plays a role in defining the leadership style, orientation in terms of human resource practices and the business ends. If for instance the leadership style or power relations in construction were extrapolated according to the organizational culture frameworks of *Hofstede, Handy, Cameron and Quinn*, to the construction industry which is largely project based, small and medium enterprise constructed, the culture in construction industries would depict a scenario where focus is in favour of the bottom line or the completion of the projects and little emphasis on the processes or methodology or even the development of women. (Marx, 2012:2). The postulation in this instance therefore is that construction firms, are likely not be keen to even formulate work – life balance policies that will negatively affect the bottom line, in the short term, due to the assumption that overheads associated with best practice in human resources are relatively time consuming and costly. The more enlightened senior management, possibly male counterparts often recognise the undesirable and debilitating effects of an entrenched male culture but little evidence suggest that significant strategies are often made change it (Drew & Murtagh, 2005: 264).

Furthermore research indicates that in some cases male workers actually do not recognize or appreciate that there exists a work family conflict (Drew & Murtagh, 2005: 273). With these factors in mind it would be tricky for women to even consider applying the principles of work-life balance in their lives because their responsibilities in construction are normally within high risk, competitive and tight time frameworks (cidb, 2008: 7). Women also see themselves as being blocked from advancement to managerial roles and participating in decision making processes, which foils any chance for them to challenge, change or influence policies which would incorporate work-life balance (Bowen, Cattell, & Distiller, 2008: 15). Ironically, it is common practice for construction firms to employ women in secretarial and administrative roles, a higher percentage to those that are contractors (Haupt & Madikizela, 2009: 64). To state that women do not have the necessary clout to apply work-life balance in the construction industry in South Africa is a worthy argument.

4.3 Gender Roles

The nature of the work place culture in construction is critical in explaining the under achievement of women in construction careers (Haupt & Madikizela, 2009: 48). Gender issues are a significant theme in the debate on work-life balance because work models continue to reward workers who are willing to sacrifice involvement in other life domains in order to manage larger workloads, demanding production targets and tight deadlines (Lingard & Francis, 2009: 283). Generally women come into construction already at a disadvantage in many ways. Women are expected to be able to combine careers, children, family and housekeeping responsibilities (Smith, Wainwright, Buckingham, & Marandet, 2011: 604). Secondly, women's patterns of work and childbearing are diametrically contrary to the expectations posed by construction particularly when the workload is intensive and high levels of commitment necessary to succeed are required (Drew & Murtagh, 2005: 266). Women have trouble keeping up with the intensiveness of their roles in construction and inflexible working hours although both have a bearing on their ability to perform (Drew & Murtagh, 2005: 265). The requirement to observe a strict separation between home and work frames is seen as appropriate workplace talk; women's collusion in this observance is emotionally demanding adding to their stress but essential in managing others' impression of their performance in role (Watts, 2008: 221). So in most instances women have to work twice as hard to gain any respect or recognition compared to their male counterparts (Haupt & Madikizela, 2009: 48). Alternatively, they are forced to actually make a choice between their careers and family, sometimes choosing to quit construction careers (Bowen, Cattell, & Distiller, 2008: 4). Depending on the role, women may not be able to complete certain tasks as easily as men in such a labour intense environment. Despite the difficulty in achieving work-life balance, other barriers exist such as discriminations, sexual harassment, adversarial attitudes and threats that render women psychologically unable to determine much of their fates in the industry (Fielden, Davidson, Gale, & Davey, 2000: 18). Increased participation of women in the labour force poses a challenge for them to balance work and family obligations. The situation becomes more complicated in patriarchal societies due to women's stereotypical domestic roles, religious prescriptions as well as cultural norms and values (Rehman & Roomi, 2012: 209). Eventually, the work culture of the construction industry will curtail any efforts of negotiating a work-life balance. (Lingard & Francis, 2009: 287).

4.4 Demographics

Apart from the many challenges that South Africa faces today, the disadvantage of women is still prominent because there are numerous impediments to their ability of exercising their human rights (Butler, 2009: 107). Poverty and poor access to services impact disproportionally on women in addition to their arduous primary responsibility of household maintenance and rural physical labour. This society has patriarchal cultures that elevate male dominance and stereotyped gender roles and racism, restricting women's professional and social development (Butler, 2009: 176). During apartheid black women especially, were victims of discrimination in two dimensions; gender and race. The added dimension of race in addition to gender, aggravated during apartheid still prevents women from achieving economic freedom (Mathur-Helm, 2005: 68). South Africa is encumbered by a backlog of social needs and demands as well as economic deficits which were created by the repressive apartheid policies and intensified by political inequality resulting in a situation where economic distance across racial groups was also exacerbated (Nkosi & Priscilla, 2007: 14). Unfortunately, these disparities are still woven in the South African social, economic and political landscape. In light of all the development gaps experienced by the population and women in particular, which are integrated into most work situations, work-life balance in the work place is the least important. Rather, most previously disadvantage groups are still negotiating for employment, better salaries and working conditions.

5. Conclusion

This review of literature reveals a direct relationship between the construction industry's culture and the work-life balance of women. Women are confronted with a catch twenty - two situation in construction because they are expected to work twice as hard to prove their worth against a backdrop of a difficult male dominated industry whilst performing other life responsibilities with the same vigour. Evidently a work-life conflict cannot be undermined. The nature of the industry culture effectively prevents the implementation of work-life balance both in policy and in practice. Nonetheless, women's integration into the economy is slowly changing as women are now more educated, have more opportunities of career advancement and are choosing to delay starting families. This may be perceived as an opportunity towards balancing work with a less hectic life domain but this is only applicable to a smaller percentage of women in general. The ordinary majority of women, particularly those who live along poverty lines continue to grovel between work and life to ensure that they meet their basic needs without even considering the importance of work-life balance. Achieving work-life balance in the construction industry requires an integrated approach that includes proper policy formulation and implementation. Obviously there remain major gaps in this area of research in the construction industry. Work-life balance has not received the necessary acclaim that it deserves in the South African construction community yet it has has a bearing on the general performance of the industry. There is an opportunity to investigate further, how work-life balance can become entrenched as a core component of maintaining a healthy and productive construction workforce in South Africa.

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BIM and Off-Site Manufacturing: Recent Research and Opportunities

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Abstract

Evolved from the early product modelling efforts of 1980s, Building Information Modelling (BIM) concept is maturing rapidly today. Recent academic and industrial efforts indicate that the use of BIM as an information management strategy for enabling agile construction is becoming a sine-qua-non for the construction industry. In parallel with the recent advancements leading to ubiquitous information transfer and provision, the implementation of BIM spreads different domains of construction industry and this expansion introduces new needs, problems and solutions which will be particularly important for Off-Site Manufacturing (OSM). In this context, this paper aims to analyse the recent evolution of BIM concepts and the impact of BIM to OSM in light of recent literature.

Keywords: **Building Information Modelling, Literature Review, BIM, Research, Off-Site Manufacturing**

1. Introduction

Construction Industry holds its position as one of the major contributors to the economies of most of the nations. In the UK, Latham (1994) and Eagan (1998;2002) reports criticized the industry's poor performance and pointed out the importance of Information and Communication Technology (ICT) investments to efficiently establish the information management capabilities. Featuring the one-of-a-kind product/process and group of partners forming the virtual organization, characteristics of the industry brings specific needs in the information management (Turk, 2006). Building Information Modelling (BIM) is one of the recent efforts which is aiming to increase data interoperability, information quality and collaboration between the project participants within a construction project. BIM can be defined as the information management process throughout the lifecycle of a building which mainly focuses on enabling and facilitating the integrated way of project flow and delivery, by the collaborative use of semantically rich 3D digital building models in all stages of the, project and building lifecycle (Underwood and Isıkdag, 2011).

Off-Site Manufacturing (OSM) refers to production of parts of a structure at a location that is different than the location of the overall structure. Providing the benefits such as; higher speed, enhanced quality, higher tolerances, lower costs and reduced labour re-works on site, it's believed that the biggest growth in construction productivity will come from automated off-site activities that is facilitated by BIM (Goulding et al. 2012; Juhola, 2011).

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Although the start of OSM in construction industry date back far beyond the BIM concept, both face barriers that are hindering their uptake in the industry. The aim of this research was to outline the impact of BIM in facilitating Off-Site processes. The main research technique used was literature review on recent BIM research trends and the developments in OSM. This paper, commences with presenting the results of review on recent research regarding BIM and OSM. The impact of BIM in facilitating OSM later is discussed in the paper.

2. Recent Trends in BIM Research

The results of the BIM related literature review covering last 10 years period can be grouped into 3 main theme areas as Practice, Strategy and Technology. Until 2008, it is possible to say that, researchers have been concentrated on technology area as the major research focus. In the technology related research, most of the studies were concentrated on modelling and standardisation of abilities of BIMs. These works emphasize the importance of data and information exchange in BIM related research. As the research focus on data and information gathering concept shift to semi-automatic and automatic data gathering tools and techniques, their uses, benefits and integration methods with the Building Information Models are emerging topics. The use of BIM in Construction Practice has been a major focus of the BIM related research. BIM's nature as a collaboration platform for the design phase also forms a key field of research. The publications in the Practice area indicate that, there is a tendency on facilitating the pre-construction phase, especially the design phase. Despite of the rapid development in technology, the uptake of BIM remained slow and that caused the increase in the studies about BIM strategy starting from 2006. Training & Education and Internal & External Integration are found as the main areas of focus in BIM Strategy research.

3. Developments in OSM

The roots of the off-site construction stem from the end of World War One that affected the construction industry by major shortages of skilled labour and building materials and this shortage triggered a need for search of new methods of construction that would mitigate this problem. By the end of World War Two the industrial capacity wanted to be used as a supplement for the traditional building operations and these efforts stimulated the shift in the industry from traditional techniques towards off-site technologies (Taylor 2009). Various nomenclatures have been used in the industry to define this subject, such as Off-Site manufacturing, Off-Site fabrication (OSF), prefabrication (Prefab), modern methods of construction (MMC), industrialisation etc. (Gibb and Pendlebury, 2006;NHBC, 2006; BRE, 2007; Nadim and Goulding, 2011). Pan et al. (2012) defined Off-Site Production (OSP) as the manufacture and preassembly of building components, elements or modules before installation into their final locations. They grouped the terms that are used interchangeably for off-site production, by affix, under four categories. (Table 1)

Table 1: The terms that are used interchangeably for OSP (Pan et al. 2012)

off-site	**pre**	**modern**	**building**
off-site construction	preassembly	modern methods of construction	system building
off-site fabrication	prefabrication		non-traditional building
off-site manufacturing	pre-work		industrialized building

The recent research on the benefits of OSP indicate that, compared to the traditional methods, the implementation of OSP give the benefits of; reduction in (1) time, (2) defects, (3) risks, (4) costs and (5) environmental impact while consequent increase in (1) quality, (2) consistency, (3) predictability, (4) productivity, (5) performance and (6) profitability(Goodier and Gibb, 2005; Blismass and Wakefield, 2009; Pan et al. 2012). There has been various examples for the increasing interest in adopting and utilizing OSM in construction industry in many countries and regions including; Japan, Germany, Malaysia, Australia, Hong Kong, Sweden, UK and USA. (Pan et al. 2012; Goulding et al. 2012). Blismas and Wakefield (2009) argued that OSM adoption, requires fundamental structural changes to the industry and underlined that OSM changes the way people in the building industry work, both in terms of the process and product. Pan et al. (2005; 2012) highlighted the lower levels of OSM uptake despite of the demand of higher implementation by house builders. They emphasized that the main driver for off-site manufacturing is addressing the shortage of skills while the main barrier that is perceived by the industry is, higher capital costs (see. Table 2).

Table 2: The drivers and the barriers effecting the uptake of OSM (Pan et al. 2005)

Drivers	**Barriers**
Addressing the skill shortages	Higher capital cost
Ensuring time and cost certainty	Difficult to achieve economies of scale
Achieving high quality	Complex interfacing between systems
Minimizing on-site duration	Unable to freeze the design early on
	The nature of the UK planning system

Nadim and Goulding (2010) explained the reasons for the low uptake of OSP in construction industry as; (1) difficulty to ascertain the benefits, (2) the negative image regarding prefabricated/modular homes, (3) poor quality (4) poor aesthetics, (5) lower choice and (6) previous failures.

4. OSM AND BIM

The OSM and BIM both serve as valuable solutions in terms of improving performance of construction industry. The off-site technologies are improving the speed and quality of construction delivery and using BIM with these technologies will increase the amount/scale of facilities that can be modelled while decreasing the modelling time and increasing the quality (ICE, 2012). This correlation has been the subject of recent research. The research has generally been focussed on benefiting from BIM's scheduling, design and information

storage and presentation abilities and the organisational, strategic and operational advantages that BIM implementation brings to OSM practices (Krawczyk, 2007; Moghadam et al. 2012; Alwisy et al. 2012; Smith, 2011; Lu and Korman, 2010; Nawari, 2012; McGraw Hill, 2012). Utilizing the principles of manufacturing industry in the construction environment, OSM is accepted as a way of streamlining construction processes with the advantage of industrialization. As a result of the different characteristics of traditional construction and the OSM processes, inconsistencies emerge between them and these act as barriers for the implementation of OSM. The recent literature in the field (i.e. Goodier and Gibb 2005; Blismass and Wakefield, 2009; Pan et al. 2012; Nadim and Goulding, 2010; Pan et al. 2005) stated the weaknesses of OSM. The following list presents the weaknesses stated in literature and then, for each item, discusses how OSM can benefit from BIM to overcome that weakness.

- *Need for high level of Information Technology(IT) integration:* High level of IT integration is required for streamlining the processes of OSM. → BIMs cover extensive amount of information regarding the attributes of the building (elements) and the processes of the construction lifecycle. They are accepted now as the sine-qua-non enablers of Architecture, Engineering and Construction (AEC) data level interoperability and integration. Today BIMs, with their enhanced capabilities, have the advantage of integrating with other information systems (Geographic Information Systems, Virtual Reality Simulations, etc.) or devices to acquire, store or share data. (Isikdag et al. 2008; Rüppel and Schatz 2011; Yanet al. 2010; Xie et al. 2011) Thus, the use of BIM during the OSM process will highly contribute to the IT integration.
- *Bad reputation because of the earlier "prefab" systems:* OSM concept has a bad reputation in the construction industry due to the massive post-war and 1960-70's social housing projects, because of the conservative characteristics of construction industry; clients, contractors or even the finance sources (banks etc.) approach this concept with suspicion→ The implementation of BIM concepts and BIM based pre-construction simulations would contribute to the acceptance of OSM as a modern method of construction, which makes the process controllable before production and component assembly. Using BIM abilities to facilitate better solutions for housing by reducing costs, optimizing schedules, generating nD models and improving design, it will provide a fundamental support for OSM (Eastman 2011; Alvarado and Lacouture, 2010, Sarno, 2012)
- *Limited experience of designers and contractors of OSM*: As the design philosophy has been built on the traditional approaches, the designers in the industry have very little expertise in OSM based designs. This is similar for the contractors who are responsible for implementing the designs on site.→The information contained in the BIMs can specially be helpful for contractors in the production and assembly process. BIM based simulations for training can be used to improve the limited experience of the parties. Utilization of 3D and 4D modelling aspects of BIM, improves interacting in a more visual way and enhances the experience in design, structural analysis, mechanical, electrical and plumbing (MEP) coordination, scheduling. (Barham et al. 2011; Korman and Simonian, 2008; Nawari et al. 2011; Peterson et al. 2011)

- Potentially difficult to modify: Once the building modules are designed it is difficult to make modifications based on on-site implementation difficulties or client demands→ BIMs' ability to generate 3D views from the base model, which involves the accurate information that is needed for fabrication of precast building components, facilitates the automated production. As the model stands on parametric rules, any update on a component, brings updates on the other objects that are related to it. Models' ability to detect inconsistencies, clashes and omissions, give users the chance to solve possible conflicts before they occur. The advanced visualization ability gives users a chance to see and predict the exact dimensions of some items that are needed to be constructed in the field. These not only reduce rework and execution time in all phases of design but also reduce the modification needs that rise during the construction phase, on site. (Eastman et al. 2011; Kim and Grobler, 2009; Goes and Santos, 2011; Leicht and Messner, 2007)
- *Transportation problems due to large components:* As the components of the building produced off-site may be large, problems on delivering them on-site and transferring them to the production area in the site may occur→The new generation of BIMs would include the state information of the building elements. The states and attributes of the elements (which can be large components or sub-components) stored in the model (states such as being on road, in site, in production facility etc.) and attributes such as(-part of-, -contains- etc) can facilitate in reassembly of smaller components into the larger components. The use of BIM based simulations and 4D schedules, provides advancements in the level of construction logistics planning. (Sarno, 2012;Harvey et al. 2009; Nummelin et al. 2011; McGraw Hill, 2008) This as a result will enable the production and transportation of smaller components.
- *Longer lead-in times:* The choice of using Off-Site Manufactured components may delay the processes in project site→ Combination of accurate scheduling with 3D model visualization abilities, results in faster production processes, better logistics and better collaboration in OSM. (Alvarado and Lacouture, 2010; Sarno, 2012;Eastman et al. 2011)
- *Higher capital costs, design fees, cranage costs:* Due to the limited skilled workforce and resources, for design and the cranage of the large components in the production facility and on site the costs of these processes are high→ BIM's technical capabilities give users the chance to not only reduce building costs but also monitor and control the costs and the cash flows related to them through all lifecycle of a construction project. According to the recent research, contractors believe that BIM can lead to cost reduction and improve budgeting and cost estimating capabilities. As an addition to its capabilities BIM has also has the potential to reduce costs by facilitating training and improving experience of the workforce. (Barlish and Sullivan, 2012; Steinkamp and Dionne, 2009; Watson et al. 2009; Chen and Gao, 2011; McGraw Hill, 2010)
- *Poor aesthetics:* Both the nature of off-site modules and the lack of art-trained people for design, limits the aesthetics→Due to their capacity to contain a rich set of information and the attributes associated with it, BIMs have the ability to generate different alternatives of design from the base information. Their ability to derive different model views respect to the needs, give users the chance of assessing different design alternatives that can be used to cover both aesthetic and

performance needs.(Schlueter and Thesseling, 2008; Lee et al. 2012; Stumpf et al. 2009; Raheem et al. 2011; Qi et al.,2011)

Table 3 provides a summary matrix that positions BIM benefits for overcoming barriers in OSM processes.

Table 3: Barriers/Benefits Matrix

BIM Benefits / OSM Barriers	Optimized Schedules	Reduced Costs	Improved Design	Better Training	Better Collaboration	Better Logistics	Reduced Design Errors	Accurate& Extensive Amount of Information	Reduced Modification
Need for high level of IT integration					●			●	
Bad reputation	●	●	●						
Limited experience				●	●				●
Modification Difficulties			●				●	●	●
Transportation problems	●		●			●			
Longer lead-in times	●		●		●	●	●	●	
Higher costs		●	●		●	●	●		●
Poor aesthetics			●					●	

The accurate and extensive amount of information that BIM presents with enabling better collaboration, provides basis for a high level of IT integration. On the other hand, the optimized schedules reduced costs and improved design provided by BIM helps in overcoming the bad reputation of OSM stemming from earlier prefab-systems. The experience gap that OSM practitioners possess would be eliminated by better training, better collaboration and reduced modification needs enabled by BIM. In order to reduce the modifications on site, BIM presents the benefits of improved design, reduced design errors, and modifications, and accurate and extensive amount of information. The transportation of big components can be facilitated by improved design / design decisions and logistics supported by optimized schedules. As an addition to this benefits reduced design errors, accurate information and improved collaboration between parties will provide the advantage to have shorter lead-in times. The design advantages, reduced costs with improved level of

collaboration enabled by BIM will help in reducing the OSM costs. By the help of improved design abilities powered by accurate and extensive amount of information BIM will help in maintaining the aesthetic quality in designs.

5. CONCLUSION

BIM is one of the most apparent aspects of a deep and fundamental change that is rapidly transforming the global construction industry. As it's been stated in the recent literature, BIM research is mainly concentrated on improving models' abilities of acquiring, storing and sharing the construction related data. These improvements not only increase its information management abilities but also give BIM a role as a facilitator for new technologies and building methods. OSM, using the industrialisation principles, is an effective method of improving construction industry's poor performance. Despite of the proven benefits, OSM adoption and use in the industry is limited by some barriers which have been subject to various research this far. The recent literature highlights that new technology is a facilitator to overcome these barriers of OSM. The aim of this research was to outline the impact of BIM in facilitating Off-Site processes. The recent literature shows that; providing an improved design, facilitating collaboration and covering accurate and extensive amount of information seem to be the most useful benefits of BIM for bridging the OSP implementation gaps, avoiding longer lead-in times, high costs and modification problems. This paper, taking recent literature as the basis, demonstrates the OSM's implementation gaps and then provides suggestions on bridging these gaps by the benefits that BIM brings. In order to have broader view with the input acquired from the industry, the research can be strengthened by collecting data with surveys and face to face interviews. The integration of automatic data acquisition approaches and improved web based collaboration will provide the chance to collect, store and share the 'state' information in BIMs and will increase the reach to BIMs over the cloud. Future research will be focussed on the impacts of these developments on OSM.

ACKNOWLEDGMENTS

The authors wish to thank The Scientific and Technological Research Council of Turkey (TUBITAK) for providing the financial support during this research.

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Public Sector Project Delay: The Malaysian Perspective and the Way Forward

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Abstract

Construction delay has been a protracted problem for the Malaysian construction industry. Recent report showed that 80% of public sector projects are behind schedule. This under-achieving time performance has led to many problems including public complaints, loss of reputation and revenue for the government and a slump in the industry's GDP contribution. Research in the area of project delay has mushroomed worldwide with attempts to place mitigation plans, but delay remains a global phenomenon. There is now an urgent need for revolutionizing construction practices and past research, backed up with few successful cases suggests that Supply Chain Management (SCM) could prove beneficial to reduce or eliminate delays in construction. SCM which originated from the automotive manufacturing industry promotes a more collaborative approach to construction management and has recently gained attention of the construction industry. However every country, including Malaysia, would certainly have disparities of their own compared to others being it from the cultural point of view, nature of problems, locality or improvements needed. Therefore, this paper will present part of a Ph.D. research which aims at illustrating the Malaysian construction industry experts' perception of the Malaysian public sector project delay, provide insight into these dilemmas, highlights the problems with current practices, its effects and the improvements needed. Subsequently, this paper would propose ratification to the problems using SCM. A semi-structured interview has been conducted to practitioners with at least 20 years' experience in the industry. The findings showed that Malaysia may be unique compared to other countries and that by considering a number of additional factors, SCM could prove beneficial to increase efficiency of the Malaysian public sector projects.

Keywords: Construction Projects, Construction Delay, Delay Mitigation, Supply Chain Management, Public Sector, Malaysia.

1. Introduction

Project success has always been highly sought. The inability to complete projects on time has been a very popular topic over the past decades. Recent reports showed that Malaysian construction industry as underachieving (CIDB 2009), as evidenced by the performance of public sector projects (Joshi 2009) and the time performance of government agency (Abdullah et al. 2010). Conventional practices still dominate the Malaysian construction

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industry (see Abd Shukor et al., 2011) and the urgent need for industry transformation has been reflected in the Malaysian Construction Industry Master Plan 2006-2015 (CIMP, 2007). Supply Chain Management (SCM) has been recognised as the potential saviour (Egan, 1998) while others acknowledge SCM as an important concept for the public sector (London & Chen, 2006).

An outcome of this research is to develop a conceptual guideline for the utilization of SCM tools and techniques towards mitigating/reducing delays in Malaysian public sector projects. This paper first provides an overview of the Malaysian construction industry scenario, followed by the results of a semi-structured interview conducted with industry experts. Based on the research findings, a conceptual SCM framework which aims at ratifying the problem is proposed. It is anticipated that the SCM framework can be used as a preliminary guideline towards understanding and strategizing solutions to address the problems of the industry.

2. Overview of Malaysian Construction Industry

Since the declaration of independence in 1957, Malaysia has started its development via the initial economic plan (1956-1960) towards achieving a developed nation by 2020. Given that most of the capital formation comes from construction works (Lewis, 1955), regular Malaysia Plans (published every 5 years) has been developed by the government towards a scheduled development of the nation. One recent government initiative responding to calls for improvement made worldwide is the Construction Industry Master Plan (CIMP) 2006-2015 aiming towards being world-class industry in 2015 (CIMP, 2007).

The industry was at its peak back in 1995 with a remarkable 17.3% GDP but since then, it kept slumping down to an average of 14% between 1994 to 1997, 5.2% between 1999 to 2004 (Ibrahim et al., 2010) while only recording an average 0.7% growth from 2000 to 2007 thus becoming the smallest contributing sector with an average input of only 3% to the GDP (CIMP, 2007). Being in the top three major economic sectors for the country (Ibrahim et al., 2010), sustainability of the construction sector is vital for the nation's survival.

3. Project Delay

Project success has been much desired by the industry. In general, project aims to achieve the best of the "Golden Triangle" – budget, schedule and quality (Chan and Chan, 2004). As such, timely completion stands as one of the main measures of success.

A common tenet for delay is the extension of time beyond the visible completion time planned by the contractor (Kaming et al., 1996). Project delay has been the subject of research in many countries such as Nigeria, Hong Kong, Lebanon and even Malaysia. Sambasivan and Soon (2007) reported that 17.3% of Malaysian public sector projects in 2005 are sick projects (more than 3 months delay or abandoned). A more recent report pointed out 80% of the government projects were delayed (Joshi, 2009) while Abdullah et al. (2010) indicated that 90% of MARA (government agency) projects exceeded scheduled completion dates. Meeting project schedule remains a challenge for Malaysia despite

approaching the end of CIMP 2006-2015. This suggests plans within CIMP have not been effective, thus signifying the need for major shift in practice.

4. Supply Chain Management (SCM) as the Way Forward

Traditional practices have been a subject of numerous criticisms. The industry has been described as adversarial in relationship, fragmented in nature, with lack of trust, full of conflict and disputes, poor customer/end-user focus and involvement; these have resulted in the industry to be resistant to improvement and innovation, shows poor time and cost performance, low quality, productivity and satisfaction level (Latham, 1994; Egan, 1998; Chan *et al.,* 2003). An urgent revolution is very much required towards improving the current practices, technology, mentality etc., to ensure an extra edge over old practices (Ibrahim et al., 2010).

Past initiatives support SCM for better construction management (Egan, 1998) and a good idea for public sector governance (London and Chen, 2006). Numerous definitions have also been proposed by previous researchers (e.g. Abd Shukor et al., 2009b). After further exploration, this research proposes the following as the definition for SCM:

"An innovative and revolutionary managerial approach which involves a working culture change and a voluntary initiated agreement for integration and synchronization of two or more inter-dependent members within variety organization level and boundaries as well as range of inter-linked construction life-cycle processes (initiation to handover). It promotes joint effort and strategy on all activities which are underpinned by mutual trust, responsibility, benefit and risk sharing based on a long-term perspective on relationship. Value is achieved through optimization and management of processes, resources, core competencies, talent, information, power and technology within the supply chain towards accomplishment of a set of shared objective and goals, enhance competitive advantage, breaking down any discontinuities and meeting distinctive client needs. Consequently, jointly agreed benchmarks, targets, expectation and values are put in place for continuous improvement efforts and are supported by aligned incentive schemes towards sustaining the endeavour."

Within the local industry, SCM is still at its infancy (Rashid, 2002), as are "lean" practices (Abdullah et al., 2009). Few collaborative initiatives have been attempted in the past. One of them is the Private Finance Initiative (PFI) which is still at an initial stage (Mehdi Riazi et al., 2011). However, the Malaysian PFI is deviated from the international PFI framework in terms of risk transfer to the private sector (Jayaseelan and Tan, 2006). Other similar initiatives have also followed but only with partial uptake (Mehdi Riazi et al., 2011). Ability of SCM to reduce delay has been well recorded. For instance - in the case of British Airport Authority (Brady et al., 2006) and the Heathrow T5 project (Potts, 2009). Inspired by the previous success some, however, Abd Shukor (2011) stressed that effective construction supply chain integration practices need to be in line with the current trend in Malaysia in order to enhance its competitiveness and innovativeness.

5. Methodology

Towards proposing a conceptual guideline, this paper proposes solutions via SCM based on literature surveys and relevant past research reports. In the quest of getting an overview of the real world scenario in the Malaysian construction industry and public sector projects, an inside on the delay dilemma as well as identifying the much needed improvements, a semi-structured interview has been carried out with six experts (two consultants, two contractors and two from Public Works Department). All respondents had over 20 years of experience in the industry.

All respondents held high managerial positions in their respective organisations with vast experiences in government projects. This ensure everyone have considerable knowledge of the industry so that they can provide a good overview of the delay predicaments. Respondents from Public Works Department were randomly selected while contractors and consultants were selected based on recommendations from the Public Works respondents. This is important to obtain a general view and not project specific standpoints, thus avoiding possible biased answers. Interviews were recorded while confidentiality agreements were also made to protect the respondents.

Despite only having six respondents, it is sufficient to provide an overview of what is happening in the industry towards proposing a conceptual mitigation guideline. Scarcity of research in this area means that even a preliminary outcome would prove beneficial in providing a platform for a kick-start. The highly and relevant experienced respondents ensures that they have sufficient exposure to the industry, thus were able to provide a thorough and meaningful perspective of the sector.

6. Results

6.1 Project Delay

In terms of definition of project delay, all respondents shared similar opinion that delay means deviation from the originally planned period. Delay in public projects was also considered a serious problem, blaming mostly on conventional procurement practices. Respondents also pointed out the delay causes as well as Malaysia-specific factors based on their experiences in public sector projects and these factors have been grouped into distinctive root causes (Table 1) to ensure that problems are solved right from the roots of it. Identification of underlying latent conditions is a first step to achieve a degree of process stability in construction (Love et al., 2008) thus making problems more manageable and could be solved right from its core.

Malaysia, as a multi-racial country, multi-festivals are celebrated each year. This resulted in a high number of public holidays. These holidays can sometimes last for a week or two, or even more, depending on individual organisations. This situation affects projects as multiple organisations (consist of multiple races) are involved and they depend on each other to progress. If any of them is missing in action, it would certainly affect others. This situation, if not accounted for properly would lead to huge project delay.

Table 1: A summary of respondents' perception on delay causes and its root causes

Root Cause	Delay causes	Root Cause	Delay Causes
Planning	(1)Shortage of equipment, labour and important material (2) Unrealistic project planning, allocation and duration (3) Fluctuation in labour and material prices (4) Lack of proper planning (5) Owner initiated changes	Commitment	(1)Delay in handing over site to contractor (2) Delay in approval by local authority (3) Delay in submission by consultant (4) No involvement of user in planning stage (5) Payment delay by client (6) Delay in material and equipment delivery to site (7) Delay in decision making by consultant
Discrepancies	(1)Inconsistent project brief (2)Mistake in pricing by contractor during tender (3) Low quality of documentation (4) Wrong project implementation (5) Incomplete document and design	Ethics/Moral	(1)"Baba Ali" practice (2)"Ali Baba" practice (3)Corruption (4)Political influence, interference and interest in project (5)Prioritizing personal interest rather than the project
Policies	(1)Policy Changes due to changing political masters (2)"Bumiputra" quota (3)Dependence on foreign labour	Vicinity	(1)Too many public holidays due to Multi-racial factor of Malaysia (2)Inclement weather and locality factors
Resour-ces	(1)Lack of expert in government organization (2)Too many unskilled labour (3)Financial difficulties	Invest-ment	(1)Lack of investment for Research & Development (2)Lack of training of new technical government staff
Communi-cation	(1)Lack of communication from within the organisation	Technical issues	(1)Technical factor such as unforeseen soil condition
Project team selection	(1)Wrong selection of project team	Social	(1)Problems dealing with aboriginal community (2)Social factor such as public interference/protests (3)Social unrest
Motivation	(1)Unfair contract terms (mostly favour the government)	Coordi-nation	(1)Lack of coordination between project parties
Qualification	(1)Incompetent consultant, contractor and government team (2) Contractor planning problem (3) Inadequate contractors skill (4) Incompetent local authority technical staff (5) Contractors supervision problem (6) Lack of knowledge by project parties	Personality	(1)Blame game between project parties (2) Clients, Public Works Department and Consultant ego (3) Top Management not walking the talk (4) Malaysian attitude and mentality (5) Disrespect between project parties (6) Interference from client
Administ ration	(1)Government and local authority bureaucracy (2) Too many decision makers involved in government projects (3) The practice of continuously transferring government staffs (4) Many voice not heard (5) Poor site management (6) Land acquisition problem (7) Problems getting utility supply		

***Highlighted in grey: Factors specifically applicable to Malaysia only*

The placement of "Bumiputra" quota on government jobs is another unique Malaysian but crucial delay factor. "Bumiputra" refers to individuals with one of their parents being either Muslim Malay or indigenous native, except for the state of Sarawak which requires both parents to be indigenous native of Sarawak. Unfortunately, some less ethical instances has surfaced, sabotaging this system such as "Ali Baba" practice whereby a Bumiputra company tenders for a job and then totally sub-contract the job to a non-Bumiputra company in exchange of an agreed sum. Maintaining this quota therefore should be followed with suitable initiatives in order to achieve its intended objectives.

High dependence of foreign labour was among others highlighted with majority of them were said to be unskilled. Due to the shortage of labour (Rajagopal, 2012), contractors are left with limited choice but to hire foreigners. Unskilled labours would have to go through a new learning curve thus their initial productivity is usually below standard. While there is nothing wrong with foreign labours, it should not be in the expense of efficiency.

Political interference, influence and interest in public projects have also been accentuated which also raises suspect on corruption activities. Despite this problem may not be uncommon in developing countries, if left alone, may further damage the country. This sensitive but urgent matter cannot be ignored and requires proper attention.

On top of all the above problems, the authors have also identified many problems directly related to the government deficiencies (Table 1) such as ineffective bureaucracy as well as the involvement of multiple decision makers. When combining incompetent officers' with a lack of experts in organisation, this automatically exposes high possibility for mistakes and inefficiencies in projects. Other practices include the high frequency of staff transfers from one department to another which affect productivity as a new learning curve starts every time an employee is transferred to a new department. To make things worse, the lack of training as well as allocation for research and development means there is paucity on room for improvement. Therefore, much repair is indeed needed towards a better performance of the sector.

6.2 Effects of Delay

Amongst the common effect of delay mentioned by the respondents was extended project time frame which eventually leads to increased overhead. Increased overhead poses worse problem for contractors as they may be unable to complete the project due to financial shortage or bursting of budgets. Respondents also stressed on the loss of opportunity cost as delay could cause resources to be trapped in a project. Project delay also affects government especially in terms of their periodic budget management as well as plan executions. This situation affects the public dearly in terms of delayed infrastructure and services, shortage of employee placement spots (i.e. housemenship doctors, etc.) and so on. Project delay almost always lead to cost overrun, thus, in some cases, budget from other projects may need to be taken to cover the additional expenses incurred, subsequently, the other project may need to be cancelled due to fiscal shortage. Reputation is always at stake in delay cases and the government risks losing public confidence. In these depressing situations conflicts are not uncommon and in some cases lead to arbitration and litigation.

6.3 Delay Mitigation

When asked about their opinion on mitigation or elimination of public sector project delay, surprisingly many of the strategies were closely related to SCM. This showed that the experts in the industry have thought of SCM components despite their minimum knowledge of the concept. Amongst the strategies proposed was the need for improved transparency which according to Lee and Billington (1992) is one of the foundations of SCM. Other approaches pointed which also coincided with previous research on SCM were the adoption of risk/profit sharing strategy (see Philips et al., 2000), increase trust level (see Ali et al., 1997), proper project team selection (e.g. see Potts, 2009), promotion of innovation which greatly depends on collaboration (Soosay, 2008) as the "*key driver*" of SCM (Horvath, 2001), and also incentive schemes to motivate continuous improvements.

7. Proposing a Conceptual Guideline

Based on the research findings, a conceptual guideline has been developed. SCM tools and techniques were carefully identified from the literature, with the aim to reduce and perhaps eliminate delays in Malaysian public sector projects as presented in Table 2 below. For a nation that is still new to SCM, this guideline could benefit in terms of providing a general idea of what SCM is made up of, what tools are available as well as serving as a basic and starting route towards the proper adoption of SCM in the industry.

Table 2: Proposed Conceptual Guideline Mitigate Delay using SCM

Root Cause	Definition of Root Cause	Proposed Solution through SCM	Reference
Discre-pancies	Arising from mistakes, missing information, errors, etc.	(1)Information sharing (2)Joint Risk Management (3)Early involvement of contractor and subcontractor (4)Building Information Modelling	(1)Ritchie and Brindley (2007); (2&3)Kumaraswamy et al. (2004); (4)Holness (2008)
Project team selection	Arising from the act of recruiting the right project team	(1)Performance-based contracting (2)Key Performance Indicators	(1)Kumaraswamy et al. (2000); (2)see e.g. Ugwu et al. (2006)
Planning	Arising from appropriateness and adequacy of planning different aspects of projects (i.e. design, procurement, etc.)	(1)Quality Circles (2)Collaborative logistics (3)Automated Material Tracking	(1)Salem et al. (2006); (2)Huang et al. (2001); (3)Rebolj et al. (2008)
Qualifica-tion	Arising from the qualification and competency level of selected project team	(1)Performance-based Contracting (2)Key Performance Indicators	(1)Kumaraswamy et al. (2000); (2)see e.g. Ugwu et al. (2006)
Resour-ces	Arising from inadequate resources for the proper execution of project	(1)Collaborative Logistics	(1)Huang et al. (2001)
Commu-nication	Arising from communication practices	(1)Project Management Information System	(1)Kumaraswamy et al. (2000)
Ethics	Arising from issues related to ethics, moral and integrity of individual or group of people that are directly or indirectly involved in projects	(1)Replace traditionally one person managing the whole job with teams for instance the use of multiple “delivery teams” in BAA which are in charge of separate project scope and a “coordination team” to liaise with the delivery teams (2)Risk Sharing	(1)Potts (2009); (2)Hammer and Champy (1994)
Social	Arising from the general public / community issues	(1)Quality circles (2)Joint Risk Management	(1)Salem et al. (2006); (2)Kumaraswamy et al. (2004)
Coordina-tion	Arising from coordination practices	(1)Early involvement of contractor and subcontractor (2)Building Information Modelling (3)Automated Construction Activity Tracking System (4)Project Management Information System	(1)Kumaraswamy et al. (2004); (2)Holness (2008); (3)Rebolj et al. (2008); (4)Kumaraswamy et al. (2000)
Persona-lity	Arising from personal character or attitude of project entities	(1)Introducing “No Dispute clause” in contracts (2)Introducing champion/driving personalities in project team	(1)Rowlinson and Cheung (2008); (2)Kumaraswamy et al. (2007)

Motivation	Arising from the act to motivate project participants	(1)Introducing champion/driving personalities in project team (2)Cross-firms Incentive System (3)Profit sharing (4)Risk sharing	(1)Kumaraswamy et al. (2007); (2)Cigolini et al. (2004); (3)Adani et al. (1998); (4)Hammer and Champy (1994)
Administration	Arising from the system, organization, management and decision making of projects	(1)Building Information Modelling (2)Project Management Information System (3)Quality Circles (4)Introducing champion/driving personalities in project team	(1)Holness (2008); (2)Kumaraswamy et al. (2000); (3)Salem et al. (2006); (4)Kumaraswamy et al. (2007)
Commitment	Arising from act of teamwork and solidarity	(1)Automated Construction Activity Tracking System (2)Automated Material Tracking (3)Last Planner System (4)Project Management Information System (5)Introducing champion/driving personalities in project team	(1&2)Rebolj et al. (2008); (3)Rimmer (2009); (4)Kumaraswamy et al. (2000); (5)Kumaraswamy et al. (2007)
Technical issues	Arising from technical issues relating to construction projects	(1)Joint Risk Management (2)Early involvement of contractor and subcontractor	(1&2)Kumaraswamy et al. (2004)
Policies	Arising from policies made by the government	(1)Collaborative Logistics (2)Benchmarking (3)Total Quality Management	(1)Huang et al. (2001); (2)Lema and Price (1995); (3)Cheng et al. (2001)
Vicinity	Arising from factors that are specifically associated to a nation / country / place / location	(1)Joint Risk Management (2)Quality Circles	(1)Kumaraswamy et al. (2004); (2)Salem et al. (2006)
Investment	Arising from improvement strategies and initiatives	(1)Total Quality Management (2)Continuous trainings (3)Enforcement of “training and development policies” in the team agenda	(1&3)Cheng et al. (2001); (2)Clarke and Wall (1998)

Table 2 above provides a general and basic guideline on how SCM could be utilized to mitigate delay. The root causes in Table 2 are an extension from Table 1 where by in Table 1 a group of multiple delay causes are grouped under distinctive root causes in order to make them more manageable. By identifying what the latent conditions are, a number of problems which are inter-related could be solved at once by tackling what initially leads to it. Therefore, this research selects this approach as to make the guideline more comprehensive and efficient. The authors propose a number of SCM initiatives suited to deal with each delay root cause with the aim of reducing or eliminating them. For instance, out of all the delay causes, it was identified that five of them were merely the problem of planning thus all of them were grouped under “Planning” root cause (Table 1). Then, a set of SCM tools were identified from the literature and proposed as possible solutions to address the planning problem (Table 2).

This guideline stands as a preliminary framework in this research. It provides a general awareness on how SCM can be beneficial and can prove effective for delay mitigation initiatives. As this research progresses, the delay root causes and SCM tools will be further validated to ensure its applicability specifically for Malaysian public sector construction environment. In the end, this PhD research strives to develop a comprehensive framework which proposes SCM tools that are beneficial to reduce delays in Malaysian public sector projects.

8. Conclusion

Construction project delay has been a major setback in the last decades and is an even more serious issue in developing nations. Awareness regarding this phenomenon seemed high while tremendous effort has been placed in identifying its contributors and mitigation plans but delay still remains an important topic within the industry. In Malaysia, delay is one of the most significant problems with major concern is given to public sector projects as it has a direct relationship with the public and the nation's socio-economic growth. Calls for improvement have been consistent worldwide with no exceptions made for Malaysia. Proven success of SCM in many countries suggests that Malaysia could also benefit from it. This paper has presented an outlook into the Malaysian construction industry with particular focus on public sector projects with respect to the industry's performance, delay dilemmas and government's effort to overcome this issue. A semi-structured interview has also been conducted on industry experts and the results have been tabulated to gain an insight to the industry as a whole. Their perceptions were summarized, delay causes identified and mitigation proposals made. Finally, a conceptual guideline is proposed (Table 2) with suggestion made on SCM tools and techniques that could be relevant and useful towards reducing or further eliminating project delays. It is anticipated that this guideline could provide a preliminary guide for the local industry practitioners, especially the public sector, towards starting the adoption of SCM as part of their improvement plans.

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Opportunities and Barriers related to Supply Chain Collaboration for Delivering Integrated Single-Family Home Renovations

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Abstract

Single-family home renovations often show deficiencies in project management. There might be a market addressing house owners who would prefer integrated renovation services and clear responsibilities. Companies that would respond to these client's needs would have a clear market potential, particularly for ambitious energy-efficient home renovations. Such enterprises could result from collaboration between different enterprises.

This paper first examined the business activity and supply chain collaboration of different actors offering smart and speedy single-family home renovations. Furthermore, new supply chain collaboration opportunities were studied using an innovative networking method that was developed in the framework of the ERANET-Eracobuild project "One Stop Shop - From demonstration projects towards volume market: Innovations for sustainable renovation". Based on the results of these studies we defined key elements for business model generation for ambitious integrated energy renovation of owner-occupied single-family houses.

The study detected novel opportunities for supply chain collaboration for delivering integrated single-family home renovations. The results showed that many examples of innovative business models can be found, but also that detected opportunities and barriers for supply chain collaboration need further business model and market infrastructure development. A handbook for such business model development was published and is now used to stimulate business deployment in various European countries. Further European research will now be carried out in the framework of an Intelligent Energy Europe project.

Keywords: business models, supply chain collaboration, **renovation, single-family homes, marketing**.

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1. Introduction

When planning a home renovation project somebody will need to manage the project. Homeowners often engage a designer or a contractor, but these actors are not always contracted as responsible actors for the whole project management. Many house owners decide to take on the project management role themselves - even if they don't have sufficient knowledge or competence. Amongst other, poor project management may result in insufficient planning, poor supply on-site, communication deficiencies, cost increase and limited obtained quality. Responsibilities and collaboration issues should be clearly defined.

Compared to the whole renovation market, few companies and formal collaborations of enterprises provide an integrated offer for project management of single-family home renovations. Particularly for ambitious energy-efficient home renovations, this market potential is still largely untapped. In theory, there is huge potential for reducing the energy consumed by existing single-family houses by thoroughly renovating them. For the successful market development of highly energy-efficient integrated renovations, supply chain collaboration is very important, while at the same time customer demand for integrated renovations has to be stimulated. Novel supply chain collaboration solutions may be found for single-family housing renovation projects. The solution to the lack of business concepts for renovation services for single-family houses is first of all that renovation service packages should be developed to include standard technical solutions for energy efficiency improvements regarding different building systems and ages (SuccessFamilies, 2012).

This business potential for single-family house renovations was explored in an international research project - the ERANET-Eracobuild project "One Stop Shop - From demonstration projects towards volume market: Innovations for sustainable renovation" (One Stop Shop, 2012) - that involved researchers from Belgium, Denmark, Finland and Norway. It examined the opportunities and barriers to establish a "One Stop Shop" for sustainable major renovations of single-family houses. The overall aim of the "One Stop Shop" project was to facilitate market uptake of whole house renovations for single-family houses to very high energy standard while providing superior comfort and sustainability to occupants. On the one hand, an integrated supply side was aimed for, to counteract the fragmented offer in sustainable retrofit of single-family houses and to increase the level of knowledge, skills and innovations of market players and owner-occupants. On the other hand, aspects of providing reliable information and guidance for house-owners were also included.

Central to the development of project management services for integrated home renovations are the questions how to deal with energy performance criteria and cost setting, customer's planning and design wishes, commissioning and quality assurance. These questions were explored by examining the market activity of different actors that may offer smart and speedy single-family home renovations (see section 2). After developing an actor categorisation in each partner country, a networking event produced additional research results to defining new business opportunities related to collaboration between various actors, to unburden the homeowner and to achieve less fragmented renovation processes (see section 3). Ideas and methods were detected for stimulating collaboration and business model generation between different players on the renovation market. Furthermore, a handbook for business

model generation for ambitious integrated energy renovation of owner-occupied single-family houses was developed to eliminate some of the perceived barriers (see section 4).

The researchers first defined various actor categories for advanced housing renovation in Belgium, Denmark, Finland and Norway.

2. Actor categories in various countries

The first step in determining which supply-side actors need to collaborate is to define existing actor categories. We identified important actors regarding supply chain collaboration in four different countries (Belgium, Denmark, Finland and Norway). As such we aimed to learn which actors need to cooperate and who plays what role in a customer's adoption process. Throughout the different studies within this research project, the adoption process of the homeowner was defined in different steps: Information > Persuasion > Decision > Implementation > Confirmation. These are five steps in innovation adoption decision processes, as defined by innovation researchers such as E.M. Rogers (2003). We continued the logic of the five steps in the innovation adoption process when categorising actors and defined actors for each country in actor categories as: informing, convincing, deciding, implementing, and/or confirming. We proposed that actors involved in an integrated communication channel – like a One Stop Shop - need to guide the homeowner through each step with information specific for that decision phase.

• Informing actors (information).

A very large group of possible actors in each country can be found with an informing role. This role can be fulfilled by federations, policy supporting actors, non-profit organisations, research organisations, energy distribution net managers, manufacturers of products, and so on.

• Convincing actors (persuasion).

In all country reports, persuasion was related to financial support, since this encourages homeowners to choose thorough renovation. Persuading actors are therefore mostly those actors that provide financial support, such as governments, banks or energy distribution companies. A number of different actors were identified who provide guidance on the subject of renovation. In the case of minor renovation work, the homeowner will rarely hire a consultant. In case of thorough renovation work, we found that the homeowner may hire an energy consultant, architect or interior designer to help guide the process and make the right decisions. Energy consultants and energy-conscious architects often illustrate increased relative advantage of high energy efficiency, and clarify complex relations between different measures in integrated renovations. Energy performance certificate advisors do not often act as actors persuading the client to implement measures, although they list these measures in energy performance certificates.

• Responsible actors (decision-makers).

Practically, integrated renovation needs strong coordination and well-informed decision-making. We found that in the partner countries for the market of owner-occupied single-family houses, owner-occupiers are still often responsible for their choices despite having very limited knowledge of the technical issues involved in innovations. The decisions made by the homeowners depend heavily on the advisor they choose. Occasionally, an advisor such as an architect takes over (part of) the decision process. In the case of minor renovation work, the homeowner will often make a decision based on the advice of the contractors or craftsmen hired to carry out the renovation. In case of thorough renovation work, we found that the homeowner may hire a turnkey supplier or general building contractor to help make the right decisions. In Norway, emerging opportunities were detected for project managers as they were working directly for homeowners. One action to support the supply side would be to install a course on the specific topic of the project management of integrated renovations.

• Implementing actors (implementation).

In order to make an energy renovation effective, it is important that solutions are implemented appropriately. Although many enterprises claim to have some experience with deep or integrated renovation, a survey carried out in the framework of this project showed that a large majority of individual craftsmen still need to be educated on the specifics of deep renovation. There is shortage of training courses on this subject. However, all the countries studied have course material available that can be developed further in order to obtain more expertise in this field.

• Quality-assurance actors (confirmation).

The limited knowledge of implementing actors and the issue of consumer trust led to the concern that thorough renovations were perceived to need some form of quality assurance. Energy performance guarantees, avoiding thermal bridges and achieving high airtightness are particularly important. In the partner countries, there is currently no general use of a specific quality assurance mechanism for integrated energy renovations. All countries rely on the applicable legal warranty period. To some extent, voluntary labels are available in various countries. For example, the Belgian Passive House Platform offers a passive house certificate for renovated housing.

3. Networking events define opportunities and barriers

Further research focused on exploring opportunities for collaboration between actors from different categories as explained above. A research strategy was developed for detecting supply chain collaboration opportunities for advanced housing renovation, while at the same time reflecting on how to build up customer relationships to increase demand of energy renovations. The goal was to detect business opportunities and barriers from collaboration exercises between different supply side actor categories, and potential clients. As part of the One Stop Shop project, a specific networking methodology was developed which involved clustering innovative players to detect novel business models and reduce the fragmentation of the renovation process for single-family houses. Two networking events were organized.

The first one, entitled "Business Zoo", was held in Antwerp, Belgium on 18 April 2012. The event was attended by 88 professional participants from various countries, involving actors from the whole construction chain as well as potential customers. Inspired by the Business Zoo event in Antwerp in April, the Norwegian researchers designed and tested a four and half hour event on 19th of June in Nordfjordeid, located in Western Norway. This networking event relied more heavily on the regional situation, on energy audits already executed for home renovations and on the experiences of one Norwegian 'One Stop Shop' company which offers energy audits, project management of renovation of single family houses and training programs for energy efficient renovation. We note that related to these experiences, various (adapted) regional events in Europe will be held in 2013-2015 in the framework of a follow-up project.

The Business Zoo event aimed to inspire actors regarding novel forms of collaboration in the renovation chain in order to realise integrated sustainable housing renovation, using elevator pitches and problem discussions in small groups, as well as actor collaboration sessions and business model generation exercises. The questions addressed during the problem discussions included various important issues such as how to make the cost of renovation fully transparent, how to speed up the renovation of large stocks of post-war housing with faster construction methods, how to adapt energy performance certificates – and redefine the role of energy performance advisors – for integrated renovations, and so on. In further collaborative and highly coordinated knowledge pooling sessions, the participants were grouped into the actor categories mentioned above, and were asked to find a solution on renovating a particular house. In this exercise, the homeowner was given a central role in enforcing strict and ambitious demands, so that the supply side actors were forced to think from the client's perspective. We used a predefined 'animal gathering' canvas to facilitate this process and animal pictograms – such as gooses, crows, horses, tigers, beavers, hawk and gulls - to represent the characteristic feature of each category – respectively the client and informing, persuading, responsible, implementing, controlling and moderating actors. After one-to-one communication of the client with each actor category, the supplying actors were urged to take up the challenge of presenting a collaborative approach to convince the client. After this exercise, the previous case development was expanded to the volume market by developing new business models. Different groups developed specific integrated business models for deep and sustainable renovation, using a business model generation canvas (Osterwalder and Pigneur, 2010).

This "Business Zoo" methodology allowed various market players to identify collaboration opportunities and challenges with partners in their group. Furthermore, supply chain collaboration opportunities were explored between various renovation market players, such as architects, contractors, project managers, suppliers, do-it-yourself stores, owners, financers, non-profit organisations, city councils and communities. During the event, we detected that substantial innovation is still needed on the supply side, especially regarding collaboration between different craftsmen and experts. Suppliers such as contractors currently rarely offer integrated and/or sustainable renovation as a service or product. For realizing integrated renovation, usually collaboration was found with an actor who had previously shown experience in reference projects.

An important identified challenge was to unburden the client. In the growing market for deep renovation, homeowners can no longer be expected to coordinate the whole renovation process; to find all the information concerning deep renovation solutions and examples; to contact, contract and coordinate a range of individual craftsmen; to ensure quality while keeping costs and energy performance under control; and all the while managing the administrative burden and the uncertainty over financing the whole project. In order to prepare for a growing market, companies must be aware that the homeowners expect one single point of contact to take responsibility, act as project manager, and ensure quality and efficient, rapid execution.

The second event in Norway identified further opportunities and barriers when involving homeowners. Without the knowledge generated by a project management service company during a home-visit, the homeowner will probably not be able to discuss different solutions and describe his/her needs. Homeowners appeared to become more interested to increase their budgets as they learned more about specific issues such as energy performance and ventilation issues. In this event, one of the two homeowners was from the beginning interested in having a single contact point for managing the project, while the other meant initially that he could do the project management by himself. But as he realized the complexity he became more interested in hiring project management services. As local actors were hesitating to take on the whole responsibility, the One Stop Shop company was the most important actor in this process, since this enterprise could identify appropriate services and exchange experiences for optimal collaboration.

4. Guidelines for developing One Stop Shop business models

Next to these exercises in networking events, we established cooperation with pilot companies developing different types of business models. These models involve stakeholders from various levels in the value chain. The established supply chain collaboration mirrors the companies involved as well as the company in charge of the business. As such, different kinds of approaches to the One Stop Shop idea were documented in various countries: a “project management service” approach (Norway), a “consultant” approach (Belgium), an “energy service” approach (Denmark) and a “retail” approach (Finland). These cases were used to reflect and compose more general guidelines for developing One Stop Shop business models. These guidelines are now available (see: One Stop Shop, 2012). The guidelines define three consecutive steps to develop One Stop Shop pilot models.

4.1 First step – preparation for collaboration

First, a broad understanding of the competition arena in which the business model is to operate is needed. A combination of a PEST analysis and the Six Forces Model was found to be a good start. The PEST analysis is a tool for defining the most important Political, Economic, Social and Technological issues which influence the environment and framework for the business. The Six Forces Model is a market opportunities and threats analysis model, as an extension to Porter’s five forces model (Porter, 1980). Using game theory, Brandenburger and Nalebuff (1996) added the concept of complementors (also called "the

sixth force"), helping to explain the reasoning behind strategic alliances. The Six Forces model thus describes the actors playing in the competitive arena; customers, suppliers, competitors, potential new competitors, substitutes and complementary businesses. Complementary companies often turns out to be important collaboration partners or actors which somehow influence the market, e.g. banks giving lower mortgage interest to energy efficient renovation or enterprise networks dedicated to promoting highly energy-efficient housing. The PEST model and the Six Forces model then form the information basis for the SWOT analysis. The SWOT analysis describes a summary of the future business model's internal Strengths, Weaknesses, and external Opportunities and Threats, and forms the information foundation from which the business model is developing.

4.2 Second step – business canvas model

Based on this analysis, the company in charge of the future business collaboration is recommended to draw up a business model for the activity using A. Osterwalder & Y. Pigneur's (2010) "Business Model Canvas", consisting of nine analysis blocks which are defined in the following order: customer segment, value proposition, channels (communication, distribution and sales), customer relationship, revenue stream, key activities, key resources, key partners, and cost structure. These nine perspectives are used to discuss a full service or One Stop Shop concept for energy-efficient single-family home renovation.

4.3 Third step – strategic focus and implementation

In the final part of the guidelines special attention is given to clarifying important issues related to implementation of a One Stop Shop business model for the renovation of single-family homes.

Making strategic choices also includes being clear on what you are not going to do. A detected pitfall for companies is that they can make too many compromises in order to keep up good relations with various types of customers and supply chain collaboration partners. In order to implement the developed strategies a specific action plan is needed which defines progress planning, responsibilities of partners and needed resources (financial and human), as well as market segments.

It is very important that the various planners, project managers and craftsmen involved are updated on the subject of energy-efficient renovations and specifically on technical and collaboration issues crossing different skills. Therefore a plan for how to secure that the right competence is at right place and time must be defined. This includes also scheduling a training program for actors who need it.

We have experienced that there are some potential legal pitfalls when several actors are involved in renovating a private home. After buying a product or service, the consumer may return to the seller with complaints and claim replacement, repair or compensation. If a One Stop Shop responsible invoices the complete package it is this legal entity which also take on all responsibilities for all construction work and installations executed in the house. An

issue to be resolved beforehand is how to distribute the responsibilities among the involved actors. For example, the business model resulting from the second step in the guidelines for the company Bolig Enøk AS in Norway is illustrated in Table 1.

Table 1: Example of a business model development (Norway, Bolig Enøk AS)

<table>
<tr>
<td rowspan="2">Key partners

1. Building product supplier (service provider)
2. Contractors
3. Local retail stores
4. Various partners with expertise in building physics and energy and heating.</td>
<td>Key activities

1. Marketing
2. Building inspection and energy audit
3. Present report with recommendations and energy certificate
4. Project management
4.1 Help obtain approvals from local authorities
4.2 Tendering process
4.3 Regular contact with suppliers and homeowner
4.4 Quality assurance; both price levels and product/competence/ service by sub suppliers
4.5 Assist in filing of applications for subventions
4.6 Inspection when renovation is completed
5. Execution of renovation (by hired contractors)
6. Service/after sales</td>
<td rowspan="2">Value proposition

1. Provide knowledge of holistic renovation including potential extension of the house.
2. Personal visits to the homeowner
3. On site analysis
4. Technical analysis with recommend ations
5. Energy certificate
6. Project managemen t
7. Offer holistic renovation service</td>
<td>Customer relationship

1. Dedicated personal assistance. The Project Manager is the main (only) contact to the customer</td>
<td rowspan="2">Customer segments

1. Owners of single family houses from 60-80ies in selected areas.
2. Homeowne rs who have capacity to increase their mortgage loan</td>
</tr>
<tr>
<td>Key resources

1. Two Project Managers
2. Administration and marketing personnel in the company</td>
<td>Channels

1. Information in local newspaper
2. Information in House owner Associations magazine
3. Local community environment plans
4. Direct mail
5. Invitation to local information evenings
6. On site visit to the homeowner (ii-v)
7. Telephone (v)</td>
</tr>
<tr>
<td colspan="2">Cost structure

1. Salaries to Project Managers counts for majority of the costs. Therefore effective use of their hours is the most critical factor for profitability.
2. Travel costs
3. Marketing costs
4. Administration and support costs</td>
<td colspan="3">Revenue stream

1. Analysis and Energy Certificate: NOK 6.900 incl. VAT
2. Renovation: NOK 100.000-3.000.000 NOK incl. VAT</td>
</tr>
</table>

Bolig Enøk discovered that the liability towards a consumer lasts longer to a private consumer than between companies. As a consequence they realised that they would be held responsible for defects for a longer time than the sub suppliers' responsibilities towards Bolig Enøk. As legislations differ from country to country, each business model has to check out the realities in such cases and make agreements with the involved actors how such issues should be dealt with.

The One Stop Shop should clarify beforehand how each of the involved partners will assure quality of their work during the process, and how quality is assured when connected partners interact. A system and functions for construction and installation quality assurance during and after completion of the renovation must be a part of the One Stop Shop. The guidelines address important questions dealing with the quality assurance.

Pleased customers can be a major source of recommendation towards other potential clients. Business developers should think about how to use such experiences and peer-to-peer communication for market development. The guidelines recommend to evaluate and guarantee customer satisfaction and positive client communication. Evaluations of all projects will give important input to improvements of the service and how to promote it. The aggregated knowledge will also result in changing for instance marketing strategies as the market develops. Also "after-services" should be offered to maintain contact with customers. These may be periodical supervision of installations and maintenance which also means potential additional sales for the One Stop Shop company.

By following the three parts from the guidelines (One Stop Shop, 2012), enterprises in any country should be able to develop a One Stop Shop in an efficient way.

5. Conclusion

According to our findings, companies engaging in single-family home renovation are challenged to find supply chain collaboration, to collect the right information and to reorganize the supply chain to propose integrated project management services. Clients are becoming more demanding nowadays and they need to be informed properly and be convinced to engage in integrated renovation. Companies should identify and use customer values and choose for the best solution in the specific market segment of single-family home renovation. In the single-family housing renovation market, it appears that market-proof solutions are needed when it comes to alleviating project management. Enterprises should be aware of the high importance of unburdening the homeowner, avoiding physical obstruction, offering quality assurance, and helping in obtaining energy-related information, energy labels and financing. The current fragmentation – separate enterprises each doing a fraction of a supposedly integrated renovation - is perceived as an important barrier to the advanced energy renovation of single-family housing. Our research has found that renovation processes need to be reformulated and better collaboration structures need to be developed to unburden the client.

Collaboration by different actor categories would support the market development that is needed. The five steps in innovation-decision processes (information, persuasion, decision,

implementation, confirmation) provided an interesting basis for exploring supply chain collaboration opportunities. We related different actor categories to the homeowners' innovation-decision phase in the partner countries (Belgium, Norway, Denmark, Finland) and identified a need to develop supply chain collaboration between these actors. A particular challenge is to develop project management services, and to identify strong responsible actors who can inform, coordinate and control many less integrated actors. Education of implementing actors plays an important role in this framework. Ideally, innovators would jump into this gap in the market and set themselves up as project coordinators who can support the homeowner throughout the decision-making process.

To fully exploit supply chain collaboration opportunities, the innovator activities should serve as input for a strategic reflection. A direct opportunity to make innovator activities visible was found in the development of networking events and business models. Events that help the customer in identifying their real needs can eliminate the barrier of the difficulty for the homeowner to find appropriate actors. They can also serve as step towards increasing demand for integrated services by homeowners to which the companies should answer with integrated solutions, amongst which the One Stop Shop approach is one of the possibilities.

The One Stop Shop project resulted amongst other in an important reference book that can help companies to tap the important business potential of highly energy-efficient home renovation. The guidelines show how companies can change their business towards a systemic offer of highly energy-efficient home renovation, hereby specifically reaching single-family home-owners. The guidelines are based on experiences from different pilots and different sections have been systematically ordered and deployed according to modern theory of business development.

6. Outlook

As a follow-up of the ERANET-Eracobuild project, a new project, entitled 'Cohereno' will start in May 2013. This project will be funded in the framework of the programme Intelligent Energy Europe and involves partners from various European countries (Austria, Belgium, Germany, the Netherlands, Norway). The objective of the Cohereno project is to strengthen collaboration of enterprises in innovative business schemes for realizing nearly zero-energy building (nZEB) renovations in single-family owner-occupied houses. The project focuses on eliminating barriers for collaboration, providing enterprises guidance on how to collaborate and how to develop services for the different market segments. In this way single experiences of demonstration projects will be transformed to series of renovations in a volume market.

Examples of single-family house renovations in five partner countries are used to identify experienced actors. Their role within the renovation chain is mapped in a comprehensive publicly available list. Successful collaboration structures in the partner countries are identified. These are further explored in relation to the use for various market segments. Success factors and recommendations to eliminate barriers are highlighted and a presentation template for collaboration models is developed. The project will also show how

quality assurance mechanisms can cost-effectively be integrated in the business models to improve customer confidence.

In order to counter the fragmentation of market players on the supply side and to encourage collaboration along the supply-chain in all the partner countries further Business Collaboration Events will be organized in various European countries, inspired by the One Stop Shop networking events. The events will pave the way for the concrete uptake of new business models and furthermore they will be a starting point for a long term nZEB renovation network beyond the Cohereno project. This network will be dedicated to the widespread offer of integrated, collaborative services for nZEB housing renovation across Europe, increasing both quantity and quality of single family housing renovations.

The major outputs of the project will be:

- A presentation in a comprehensive recognized publicly available list of nZEB single-family house renovations in Austria, Belgium, Germany, the Netherlands and Norway with an identification of experienced actors and a mapping of their role within the renovation value chain

- An overview of structures for successful collaboration between contractors and other actors that are involved in delivering nZEB single-family housing renovation in the partner countries which will include customer segments related to the business models, success factors and key barriers and solutions for business collaboration and an executive summary with success factors and key barriers and solutions for European Contractor Federations

- Detailed recommendations on how to implement quality assurance in the various business models, specifically aimed at increasing consumer confidence

- The organisation, promotion, implementation and documentation of the two national Business Collaboration Events in two different regions in Austria, Belgium, Germany, the Netherlands and Norway, and the compilation of high potential models for collaborative nZEB renovations of owner-occupied single-family houses in these countries.

- The enabling of motivated supply actors to launch holistic services of nZEB renovation of single family houses and the establishing of about 20-25 new business collaborative models. A report on business models as examples of deep energy retrofitting for single family houses.

Acknowledgements

This paper summarizes findings of the ERANET-ERACOBUILD project entitled “One Stop Shop – From demonstration projects towards volume market: innovations for one stop shop in sustainable renovation” (1st September 2010 - 31st August 2012), supported by IWT - the Flemish agency for innovation by science and technology, Tekes and Nordic Innovation. It is presented in the framework of the project ‘Cohereno’, supported by the Intelligent Energy

Europe programme, coordinated by OTB Research Institute for the Built Environment, TU Delft (http://www.eaci-projects.eu/iee/page/Page.jsp?op=project_detail&prid=2597). The sole responsibility for the content of this publication lies with the authors. It does not necessarily reflect the opinion of the European Union. Neither the EACI nor the European Commission are responsible for any use that may be made of the information contained therein.

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Making use of knowledge on the construction site

Mats Persson[1]

Making use of knowledge on the construction site

Mistakes during the construction phase are very costly. Avoiding mistakes on the construction site and facilitating an efficient construction flow is recommended by many researches as a way of reducing construction costs. One way of dealing with this issue is by finding flaws and errors during the design phase. As buildings are increasingly complex with installation systems and demands for energy efficiency there is also an increasing demand for more knowledgeable personnel on the construction site. The construction personnel must comprehend how issues such as energy transfer, moist transfer, air-tightness, acoustic property, water protection etcetera is accomplished with efficient logistics, often in a lean construction environment. The different manufacturers and research generate much knowledge. In Sweden many attempts to accomplish systems for lessons learned and experience feedback have stranded due to the complex nature of the whole issue. Construction knowledge containers in the form of web-sites emerge both as company property and “publically available” sources.

This research investigates how the construction firms use knowledge management to be effective and competitive on the market. Through interviews and observations data has been collected to describe the strategy of Sweden’s three largest construction firms use knowledge management. Additionally a large regional construction firm and a smaller construction firm have been studied. Particular focus is on the construction site and how the workers on the construction sites are involved in the planning of work execution and how knowledge is made available in this process and how this influences the motivation and learning of the site organisation.

Keywords: Knowledge management, **work preparation**, **organising information**.

1. Lack of knowledge lead to mistakes

Studies of the effects of flaws and errors in the Swedish construction process indicate that these accounts for some 6% of the total production costs and that about 10% of working time is spent on correcting errors and reworking what has been done (Josephson & Hammarlund 1999). Portions of the errors were caused by deficiencies in the design work; such deficiencies include shortcomings in the knowledge available to those engaged in production. A considerable proportion of the errors can also be traced to difficulties caused

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by vagueness or imprecision in the instructions provided by the design team (Josephson & Saukkorpi 2005).

Construction firms are expected to conduct work at the construction site in accordance with agreed-upon drawings and specifications. The client expects this to be done in a professional manner, even if this is not explicitly expressed in the contract. The specifications and the contract are normally based on national standard reference frameworks. Basic workmanship and knowledge of the regulations applicable to building and construction work are essential pre-conditions for performing the work in accordance with the contract.

1.1 The knowledge situation on site

Those in charge of work at the site and others engaged in the practicalities of a construction project need adequate knowledge in order to carry out their work properly; moreover, they need to continuously update their working knowledge to keep abreast of the latest technologies (Persson & Bergh 2006). Typically, operatives on construction sites will receive at most some 4 hours of training a year, in contrast to their supervisors, who undergo about 40 hours of training a year. The education obtained in upper secondary school remains the most important component in the training of the majority of construction workers. When new methods and materials are developed, new knowledge is needed. In order to acquire the information needed at a construction site, the personnel (both management and operatives) should be provided with relevant information and be motivated to learn and generate such knowledge themselves (Persson & Bergh 2004, 2006).

Designers base their specifications on standard reference works and directions from suppliers, whereas site operatives (i.e., construction workers, craftsmen, etc.) almost never have direct access to information sources of this type. Any contact they do have with these sources is usually superficial, such as an introduction to such matters in upper secondary school (Persson & Bergh 2004). The individual's knowledge, then, is scarcely renewed although the standard reference framework may be updated continually. Knowledge concerning a task that has been completed can be of genuine help at a later time (positive feedback) and may result in a new and more effective approach to the task (Persson 2006).

In an effort to gain an understanding of how various tasks are actually performed by those who carry them out, 41 cases of task performance were studied (Persson & Bergh 2006). Compared a generic process model the results revealed that flows of information of the following types were usually absent:

- Information from a standard reference work being made available to the site operatives,

- Information from relevant legislation and building codes being made available to the site operatives,

- Information about labour safety regulations being made available to the site operatives, and

- Further education being provided for the site operatives.

1.2 Management of knowledge on site

The knowledge management of site operatives tends to be very much neglected (Larsson et al. 2005). As employment is in many cases contract/project based, many employers are not willing to invest in further training for the workers. This is further magnified by the nature of construction, with many specialised subcontractors constituting a temporary organisation on site (Persson 2006). Before starting any work, the site operatives and the site management usually discuss the planning and execution of the work (Persson & Bergh 2003). Although this could in principle lead to optimising of plans, sadly, the lack of adequate knowledge on the part of both workers and management could undermine efforts in this direction. According to project managers who were interviewed in a project performed in Uganda, the most important steps in improving productivity involve eliminating incompetence among supervisors and addressing the lack of knowledge and skills on the part of many workers (Alinaitwe 2006: see appendix III p 10).

The present system of knowledge management for the on-site personnel of construction companies (operatives, management, and supervisors) can be characterised by the following statements (Persson & Hansson 2008):

- The large numbers of errors occurring at construction sites (and the considerable costs that result) appear to be largely due to insufficient knowledge transfer on the part of the personnel involved.

- Information obtained from clients, designers, suppliers, and the contractor that could potentially further the knowledge development of the on-site personnel appears not to be well adapted to this purpose, or to be only partially suitable for it.

- A management function (process) supporting the system for knowledge development appears to be either poorly developed or missing entirely.

The flow of information to personnel at construction sites concerning how the tasks at hand can best be carried out is highly important for the development of knowledge of work procedures generally. With better knowledge of this sort, errors can be minimised or eliminated.

1.3 Aim, objectives, and methods

The aim of this paper is to investigate typical features of knowledge management systems for construction sites of both large and smaller construction firms and the construction sector.

2. Knowledge management system as support to the construction site

The knowledge transfer that takes place in a construction firm should be supported by a capable quality management system, as well as by the systems for cost estimating, time scheduling, and labour safety. The site operatives should possess sufficient knowledge to be able to demonstrate good workmanship, and to make effective use of contract documents, drawings, and specifications as the starting point for their work. They should also have the support of the site management and the firm's overall management system, being enabled to draw on lessons learned and knowledge accumulated.

The task of the knowledge management system is to direct, enhance, and coordinate knowledge development in the firm, using the relevant subsystems and ensuring that the knowledge needed to carry out the construction work is made readily available. A clear objective of the knowledge management system is to develop the knowledge of the staff in such a way that the conditions of each and every contract will be met and clients' requirements will be satisfied in an effective and professional way. Most construction firms are lacking effective approach to collecting and storing knowledge within the organisation, placing little emphasis on developing the competence of workers, however the attitude is slowly changing. The large numbers of errors made in construction work and the virtual lack of further training suggest that knowledge management, in whatever form it may be present, usually does not function well.

Individual site operatives should continually acquire new knowledge so as to maintain a satisfactory level of workmanship. A major part of the knowledge site operatives need to perform their tasks is obtained during their initial professional training and apprenticeship. Formal training provided after that is usually very limited. To be well prepared for the tasks they will perform, workers require ready access to further sources of knowledge, both general and project-specific. The following are certain important considerations pertaining to this:

- Drawings and specifications (in a form that the individual can readily comprehend) pertaining to the work at hand should be provided.

- A work execution plan (or detailed plan of the work to be done) should be made known, at the latest by the time the work gets underway.

- General descriptions of the work to be carried out should not only be accessible but also be easy to read and understand.

- There should be ample access to suppliers' instructions on how to assemble and use the materials and equipment involved.

- The laws and regulations that apply should be clear to everyone.

- Inspection routines should be clarified, and any checklist to be used for control purposes should be handed out to everyone.

The construction site knowledge management systems studied indicated the following problems for the individual site operative (Persson & Bergh 2004):

- Site operatives seldom attend planning sessions and toolbox talks regarding how work is to be carried out, even though they are the ones who perform the work.

- Only in exceptional cases do site operatives have the opportunity to read the specifications for the project they are involved in, or the relevant standard reference work.

- Site operatives rarely get to read the manufacturer's instructions.

- Drawings and specifications pertaining to work to be carried out often refer to standard documents or reference works or to instructions provided by suppliers. Such standard documents or reference works are usually not available at the work site.

- Construction workers are usually not trained to read standard documents or reference works. Although these may contain potentially useful instructions on how work is to be carried out, the instructions are often incomplete, out of date, or difficult to assimilate. The target groups for such documents are often designers and procurement personnel. Site operatives have little involvement with procurement and thus have limited access to these documents, and so such documents contribute little to the knowledge development of the workforce.

- Only in exceptional cases is a site operative encouraged or given the opportunity to reflect on, plan, or carry out the quality assurance work that is usually called for.

When looking at the resources used to do a project as according to Figure 1. The input to a project is the individuals and organisation of the construction firm, technology and equipment together with administrative procedures, checklists and templates. If these input resources are not present in the construction firm it has to be acquired from external sources.

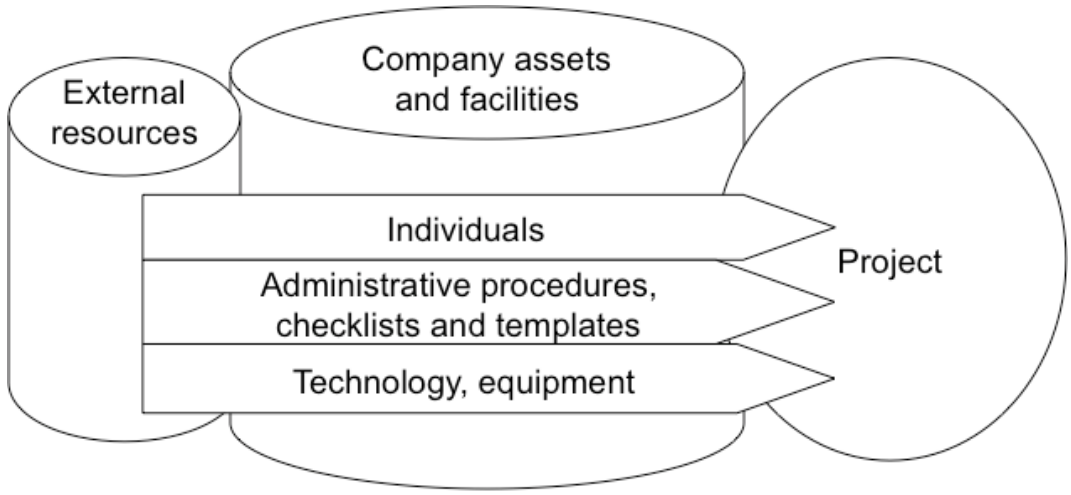

Figure 1: Company assets to accomplish a project.

The mismatch between subsystems and the lack of knowledge management can apply to different levels in an organisation. If one aims at changing practices in an entire construction firm, this must be undertaken at a variety of levels: individual – site – firm – national construction sector – international construction sector (Persson 2006).

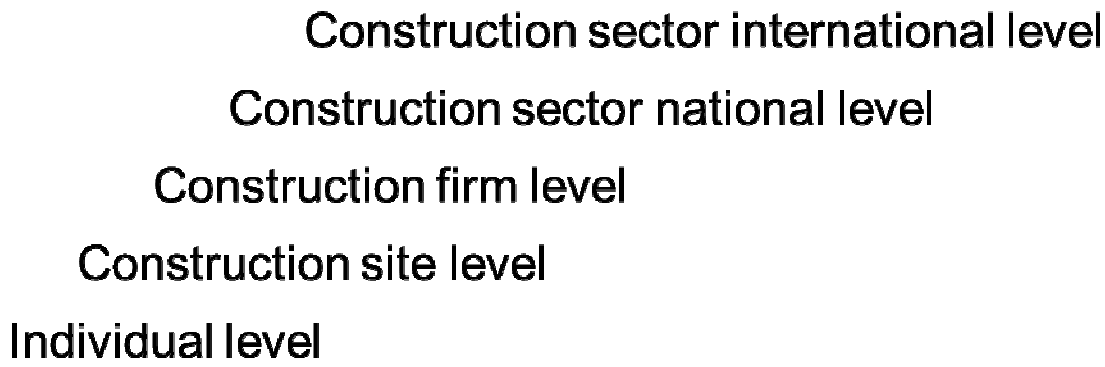

Figure 2: Levels for Knowledge management

The knowledge management of the sector and available information for personnel at the site is not well organised to facilitate a transfer from explicit to implicit knowledge according to the SECI model of Nonaka and Takeuchi (1995), as pictured in Figure 3. The bottom of the figure shows the process of socialisation (tacit → tacit); on the left is externalisation (tacit →explicit); at the top is combining of knowledge (explicit →explicit), and on the right side is the important process of internalisation (explicit → tacit). Enabling internalisation is the main objective of the development of http://www.ByggAi.se.

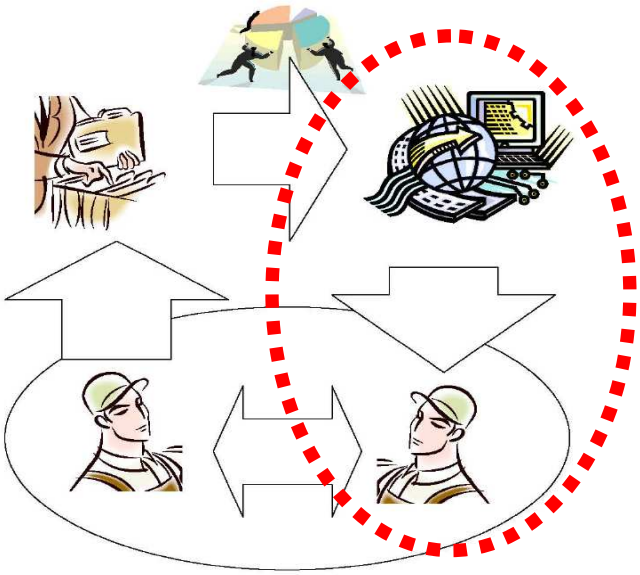

Figure 3: The SECI model of knowledge transfer with the process of internalisation highlighted (adapted from Nonaka & Takeuchi 1995)

3. Systems for improved knowledge management on construction sites

3.1 General system improvement

Various problems have been outlined concerning mismatches between subsystems within construction firms' knowledge management systems. There are various approaches that aim at suggesting, describing, or providing solutions to these problems. The Ratu file for planning construction (www.rakennustieto.fi) is one such attempt. This file is intended to improve the productivity, safety, and quality of construction work. Information regarding work procedures and work planning is collected at construction sites and is made available; information about safety in the workplace is provided, and quality assurance information is included. The file is available in a Finnish-language version only. In Denmark, knowledge about construction is gathered in a database (www.bygviden.dk). The program CITB Construction Skills is concerned with educational matters that apply to the entire construction industry (www.cskills.org).

3.2 Knowledge platform www.ByggAi.se

In Sweden an approach to making task-related information available as needed to those engaged in construction work has been developed in cooperation with various construction firms (Persson & Bergh 2006), the name of the system is *ByggAi.se*. The system has general site-use-adapted working instructions developed to transfer knowledge on site in a well-structured form. The basic information needed to carry out different types of work is readily available, with a focus on the needs of managers and operatives at a construction site. The working instructions contain information on personal safety, quality control, requirements, suggested tools and supplementary fixtures/materials, and illustrations and text describing suggested correct ways to carry out the work. The system makes information

available from health and safety systems, suppliers, standard reference works, and quality systems.

The instructions were designed in this way for the following reasons: The working instructions (WI) are general, meaning they can be used at most construction sites; this also means that when they are used they need to be supplemented with information specific to the project at hand. The WI's are site-use-adapted, meaning that they are adapted to the information requirements of the personnel conducting the work on site rather than the needs of purchasers, designers, etc.

During development a number of various methods for presentation of the WI's were investigated. Video, cartoons and written instructions were considered. A combination of pictures and short explanatory texts were chosen. The WI's are developed in PowerPoint and distributed in pdf-format. A format suitable for printing was selected and the pictures in the WI's turned out to serve as inspiration as they contain a lot of additional (surplus) information about the site and situation for the work. A reason for choosing pdf-format was the need to limit the size of files since at the time of development only few sites did have high-speed Internet access. Today a new format or alternatively database is investigated.

The development of the WI's was done in close cooperation with major construction firms in Sweden. The topics were selected among usual tasks on the construction site - work done on most sites. However a variety of topics were selected to include civil work as well as construction, rebuilding, demolition, HVAC and electrical installations, painting. Additionally there are a number of "informational" WI's developed to test the possibility to distribute information on working environment, protection against thefts, work in cold climate, transports on site etc.

The ByggAi system is available on the Internet at www.ByggAi.se. At this stage the Internet portal contains working instructions for 152 different tasks. For each set of instructions, the following main headings are used: Requirements, Preparations, Quality control, and Performance. The working instructions are available on the Internet portal in PDF format. A CD in PowerPoint format containing the working instructions, together with a template for those wanting to prepare their own working instructions, is also available.

3.3 The development of knowledge management in the Swedish construction sector

In Sweden around 300,000 employees work in the construction sector, which contribute to 8% of GNP. Investments are considered to be relatively low with difficulties to start new residential projects, however rebuilding is slowly increasing to the same level as new construction. The use of construction management software is slowly increasing in Sweden. On major construction sites the use of advanced software is spreading with utilisation of software for Virtual Design and Construction. Medium size and smaller firms adopt the use of iPad's and smartphones on construction sites in order to improve the distribution of information. This facilitates the distribution of information from the www.ByggAi.se web-site.

The ByggAi.se system has been well adopted by Swedish construction firms. The major contractors have designed their own internal knowledge management systems for their construction projects and link from their intranets to www.ByggAi.se. Smaller and medium-sized contractors use the system, as it is available on the Internet, or acquire the rights to use the information in their companies. Smaller contractors often say they would never be able to build such a system on their own. The system has recently been upgraded with a book on work preparation and teaching material and template available on the web.

The number of visits to the website is increasing. The number of visits per day has risen from 60 per day in 2009 to 149 in 2012. The first months of 2013 show a further increased number, now the average is above 320 visits per day. Positive feedback has been received from young engineers and also consultants such as architects. A couple of suggestions of needed corrections and clarifications have also been received.

The Swedish Contractors Federation has identified the need to improve knowledge management as a means to reduce errors and accidents on construction sites. They are now publishing a “Technical handbook for the construction site”. This handbook is divided in two parts. The first part contains information of what is well worth noticing when doing certain types of works. The second part contains information that is well worth knowing when doing construction project. The information of the handbook is connected to www.ByggAi.se with references and illustrations. It is also connected with references to the latest developments from research and development of techniques and tools. The handbook will be updated every year

4. Discussion and Conclusions

Currently there appear to be serious problems in the flow of information needed to provide adequate knowledge on how to perform tasks at construction sites. Inadequate knowledge leads to production problems on the construction site. Often, the same solution found for a problem concerning a given task at a particular site under a given set of conditions can also be applied at another site, even though conditions there may be different. There is thus a certain generality to the solutions suggested, which may basically apply throughout the construction sector.

The system – general site-use-adapted working instructions – ByggAi.se – thus addresses a wide variety of problems. Although ByggAi.se provides solutions to many problems, there is the question of the extent to which workers have access to it. Supervisory personnel at construction sites should either make computer facilities available to the personnel or make the instructions available to workers in a hard copy format.

Changing the way a given task is performed at construction sites within the entire construction sector as part of a movement for “continuous improvement” calls for a wide and open cooperation between those supplying information resources, contractors, clients, and others involved in the construction process. This also fits well with the analysing of construction activities being done in conjunction with lean construction.

From the SECI model it is important to acknowledge that the internalisation process is key. This has also been the focus of the research carried out to establish a platform that enables this process to start. The availability and ease-of-use factors are important, as is the need to avoid overloading the platform with information; rather, the idea is to make information readily available as it is needed ("Just what you need – when you need it"). The second most important factor in developing the platform is the combining process. This "background" work has been given highest priority as it is in the control of the platform developer (the internalisation process is practically beyond control).

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Project Governance Framework for Mega Construction Projects (MCPs) in China: Lessons from SHITH and SHCBD projects

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Peng Zhang[5]

Abstract

We analyse governance in two mega construction projects (MCPs): Shanghai Hongqiao Integrated Transportation Hub (SHITH) project and Shanghai Hongqiao central Business district (SHCBD). We suggest that the governance of mega construction projects in China needs the participation of construction headquarter and three coordination platforms, namely, design coordination platform, schedule platform and construction platform are necessary. This paper first analyses the current status and necessity of project governance in MCPs and review of project governance. Finally, we propose a theoretical project governance framework of MCPs in China. By understanding the importance of governance framework, it is hoped this will bring a signal for other MCPs in China to implement the similar method to ensure the efficiency and effective of construction.

Keywords: Mega construction projects; Project governance; Framework; SHITH project; SHCBD project.

1. Introduction

The rapid pace of modernization and the strong growth of the nation's economy have created a massive market for the construction industry in China over the last decades. With the introduction of a number of fiscal policies aimed at increasing investment in fixed assets and to accelerate the infrastructure development, an increasing number of high profile mega construction projects (MCPs), such as the Beijing National Stadium ('the Bird Nest') and the Beijing Olympics Project, and the Three Gorges Dam, have been undertaken or completed in the past ten years. These MCPs are characterized by large investment, great complexity, more stakeholders and extensive influence. Despite these achievements, the construction

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industry has been criticized for producing poor quality construction works, delay and cost overrun with low efficiency and effectiveness. Problems including evasion of the application of the procurement system, false contract transferal and illegal sub-letting are very common in the construction procurement in China, despite a series of government reform on the construction industry. While it is estimated that China's construction industry will account for nearly one-fifth of the global construction output within the decade, these problems would threaten the sustainable development of the nation's construction industry. With this in mind, it is important to probe a reasonable and effective tool to improve the project management and governance of the MCPs in China.

We start our analysis with a review of literature that has elaborated the concepts of mega construction projects, project governance and program governance, and more specifically, we review project governance framework literature. In the case study of this paper, we discuss the project governance work of the SHITH project and the SHCBD project and discuss the performance of their governance approach. Finally, we propose a theoretical project governance framework for MCPs in China.

2. Literature Review

2.1 Mega construction projects: the current status in China

MCPs are defined as a very large investment construction project, or aggregate of projects, characterized by magnified cost, extreme complexity, increased risk, lofty ideals, and high visibility, in a combination that represents a significant challenge to the stakeholders, a significant impact to the community and pushes the limit of construction experience. Flyvbjerg, et al.(1995) argued that the classification of mega-project should focus on the size of the task involved in developing, planning and managing projects of the large magnitude, which is more than US $22 million in term of investment. In the US, mega-project is defined as a major infrastructure projects that with a total contract sum more than USD $500 million or a project of a significant cost that attract a high level of public attention or political interest because of substantial direct and indirect impacts on the community, environment and budgets. Inkeri Ruuskaa(2011) defines a large project as a significant undertaking characterized by multiple organizations seeking success with different objectives, changing priorities of project objectives, and finally, the project being subject to the impacts of a wider socio-political environment. In China, MCPs are usually public works which are mainly invested by the government. The MCPs are usually multifunctional, colossal in size and scope, with a long life time, high invested and considerably uncertain.

With the size and complexity of MCPs gradually increases, the management of mega-projects is becoming more challenging, and it has been reported that many mega-projects in China were resulted in cost overrun, with regional development effects and environmental impacts often turning out very differently from the original planning (Aalonen, K. ,2008). While the Chinese construction industry has undergone a significant development over the last two decades owing to its strong economic growth and unprecedented urbanization plan, there exist many problems in the management and governance of the MCPs. Problems like cost overrun, late delivery, delay of payment, low efficiency, overstaffed organizations and/or

corruption have been repeatedly reported and stated. Government intervention, government corruption and poor public decision-making processes were identified as three most important risk factors for PPP projects in China. Administrative intervention from government along with serious local protectionism, an immature legal system, and corruption practices limit the transparency of the construction market in China. For example, the allocation of design and construction task of many construction works does not totally depend on a fair tendering approach, but influenced by local government. In addition, many construction practitioners in China believe that it is important to develop and maintain good relationship with the relevant authorities for winning construction works/tasks and smoothing approval process than improving their competitiveness with advanced management techniques. For these reasons, it has been argued that sweeping reforms of governance practice in construction or infrastructure projects is urgently needed.

2.2 Program governance and project governance

A large amount of literature is discussing about the term of governance and corporate governance. The former is often related to mechanisms or processes that affect to how either a single transaction or recurrent transacting is organized ex ante and carried out ex post between two or more actors, either within the boundaries of a single organization or between two or more organizations. Literature on institutional economics literature focuses, in particular, on governance structures required for carrying out economic exchanges, such as purchases of raw materials or purchases of complex projects. Furthermore, literature on corporate governance emphasizes various agency problems resulting from the separation of ownership from control that characterizes modern corporations.

Project governance is defined as the process of project decision-making within a framework, to ensure coherence between the realizing of organizational objectives and the processes and resources used in a project, thus enhancing a smooth running organization and profitability. Bekker and Steynde (2009) pointed out that project governance contains a set of management system, regulation, relationship, structure, framework which to provide decision supporting in order to realize the expected goal. Good project governance can cultivate a good operational environment and provide a strong institutional guarantee for project success. While the program governance is the process of developing, communicating, implementing, monitoring, and assuring the policies, procedures, organizational structures and practices associated with a given program (PMI, 2008). Both project and program governance stress on organizational structure, institution arrangement and management approach. But program governance ensures decision-making and delivery management activities are focused on achieving program goals in a consistent manner, addressing appropriate risks and fulfilling stakeholder requirements, and pay more attention to organization structure and institutional mechanism. Governance for programs is different from governance for projects, because the goal, scope and impact of a program is typically complex, such as multi-year timelines, competition between projects for scarce resources, diverse stakeholder requirements, inter-project and enterprise-level risks and issues. According to PMI, program governance provides an appropriate organizational structure and the policies and procedures necessary to support program delivery through formal program reviews'. Program governance is an effective management idea for program management

especially in organization management which should be applied throughout the program management life cycle. So program governance is not a new management idea that stems from program management they have the same goal but different approach. Program governance must provide additional benefits which cannot be gained through single project governance, While project governance mostly thrives on certainty.

2.3 A review of the project governance framework in construction field

To understand how a 'good' project governance could be achieved, it is important to understand the main components of the construction project management success. Collins and Baccarini (1996) proposed a logical framework method (LFM) to provide a detailed framework for defining and understanding the project success. The framework argued that both project management success and product success are main components of measuring project success. To achieve a project management success, it is important to ensure the project to meet the time, cost and quality objectives, to obtain the quality of the project management success, and to satisfy project stakeholders' needs with respect to the project management process. Based on the project transaction governance, Winch (2001) developed a conceptual framework for understanding the governance of transactions through the construction project lifecycle that combines the diverse perspectives of construction law, economics and management. In general, the conceptual framework specifies the projects could be governed in the vertical and horizontal dimensions. Vertical transaction governance relates to the supply of design services, which is initially for conceptual design and later for more specific design services related to aspects of facility functionality. Horizontal transaction governance relates to the employment relationship, and always involves market transactions for the supply of specialist skills and services. Miller and Hobbs (2005) have presented a framework for understanding governance in large complex projects and emphasized the dynamic, even unexpected nature of governance in large complex projects. According to Turner(1999),a functional hierarchical line management is a communication mechanism, but lack of innovation, inflexibility of management approach and focus of customers. He also proposed a versatile project-based organization should adopt network governance structure. Based on literature review of projects governance, the complexity of construction management needs the compelling of government, but also the program governance network sets the strategic direction, monitors levels of performance, especially profitability.

3. Methodology

In the process of building the project governance framework, this paper follows the following research steps. Firstly, the authors have a rich experience of construction for MCPs in China, and have contributed many MCPs in China, such as Guangzhou's Baiyun International Airport, SHITH, Shanghai Pudong Airport expansion projects, SHCBD, etc. The authors find that there exist many problems of project governance of MCPs in China after years of engineering practice. Meanwhile, in recent 10 years, the Chinese scholars further proved the lack and short points of project governance. Secondly, based on the existing project governance guidelines and standards, combining the characteristics of MCPs and unique feature of the project governance organization in China, the framework is built.

4. Two Cases

4.1 Shanghai Hongqiao Integrated Transportation Hub Case

4.1.1 Background information

The SHITH project, a major urban infrastructure, is the key projects of the “Eleventh Five-Year” outline in Shanghai, covering an area of 26.26 square kilometre. The whole project involves Hongqiao airport expansion project, high speed and inter-city railway system project (Hongqiao railway station), west traffic centre project, east traffic centre project, municipal comprehensive affiliation project, etc. It is the portal of Shanghai to Yangtze River Delta, with more than 700 billion RMB investment. The SHITH project is an open and complex system, the large scale, big investment and so on which made it more uncertain than the single project. But the schedule of this complex infrastructure project is less than three years, which calls on the high standard of management performance and project governance.

4.1.2 The main program actors

(1)The SHITH construction headquarter (CH) is established by Shanghai government in May, 2006, whose responsibility is general construction management task, i.e. the schedule coordination of different project investors.(2)Shanghai Rainbow Investment Corporation (SRTC) is a government investment development company, which is also established by Shanghai government in July, 2006. SRTC is also as the office of SHITH construction headquarter to coordinate various investment companies and undertake detail construction affairs. SHITH is a mega construction which consists of a number of investment subjects, so Shanghai Airport Authority (SAA) and City Investment Company are two other investment companies. (3)The hub is commissioned to two project management companies: Shanghai Airport Construction Headquarters (SA) and Shanghai Construction Management Company (SCM). The SA Construction Headquarters is mainly responsible for the management of the Traffic Centre part of the project, while the SCM Company take charge of the management of the comprehensive affiliation part of the project. (4)General design management mode is employed to the design management of SHITH. Shanghai Municipal Engineering Design Institute (SME) undertakes the design management of the entire region, while the Hua Dong Design and Research Institute (HD) are responsible for the Traffic Centre. In order to meet with the SME, the SHITH construction headquarters specially set up the general engineer’s office to undertake planning and design affairs.(5)There is no unified construction management subject for the construction management of the hub due to its complexity. For the Traffic Centre construction, general construction management mode is applied, and the Shanghai Construction Group Company (SGC) takes charge of the construction management of this part of the project.

4.1.3 Goals of the program and the objectives of project actors

The SHITH project is supposed to be finished before May, 2011 and provide service in the Shanghai world exposition. So the safety and schedule are at the top of all official priority lists.

4.1.4 Collaboration practices among actors

Complex multi-firm network embodies various roles and responsibilities. By Shanghai government delegates authority to the CH, CH is responsible for the general project governance task. It undertakes the missions, including formulating governance plan, preparing audit plan for the related municipal government department, establishing benefit realization plan for the investment company, making 'go' or 'no-go' decision for single project, providing authorization to main project management companies (i.e. SA Construction Headquarters and SCM Company). The investment companies are required to provide CH with the change request notification, milestone reports, project completion reports, including benefits realization reports. When the CH receives the reports and feedbacks from SRTC and other investment companies, the governance plan, audit plan, benefit realization plan will be updated and revised accordingly. The whole process is continuous from preparation stage to the final completion of the program and throughout the program life cycle. While SRTC is the office of CH, on one hand, the decision of CH can be carried out fast, but on the other hand, CH can't represent public welfare very well because of the benefit of SRTC in the traffic centre construction. Meantime, the authors' party' plays the role of schedule consultant and balance the schedule conflicts in order to guarantee SHITH finished in time. SME as the main design contractor is responsible for the CH to coordinate the conflicts among different design company in order to keep the goal alignment. Furthermore, the general construction contract confers SCG to control subcontractors and monitor that safety issues are properly dealt with.

4.2 Shanghai Hongqiao Central Business District (core the first phase) case

4.2.1 Background information

The SHCBD project is the key projects of the "Twelfth Five-Year" outline in Shanghai, covering an area of 86 square kilometres. The main functional area is 26 square kilometre. Besides, the first phase of development area is 1.4 square kilometre. And the first phase is in the development and construction process, and this paper will take the first phase as the example case. The whole project involves not only municipal infrastructure projects but also enterprise investment projects which makes it more complex. There exist conflicts between governmental will and enterprise behaviour which needs more coordination and balances.

4.2.2 The main program actors

(1)Shanghai Hongqiao Business District Management Committee (SHBDMC) is an agency of Shanghai government, undertaking the responsibility of the development of SHCBD. (2)Shanghai Rainbow Investment Corporation (SRTC) is still the main government investor, performing the governmental investment function. (3)Besides government investment company, there are many big real estate enterprise, such as, China Vanke limited corporation (Vanke), Longfor Properties (Longfor), Shui On land development corporation (Shui On), etc. (4)Meantime, there are many design companies and sub-contractor company in this project, but no main design management company and main construction contractor.

4.2.3 Goal of programs and objectives of the project actors

SHCBD is a new platform for international trade, the central business district of Yangtze River Delta and west centre of Shanghai, So the quality and schedule are the most important point. But, different investors have different purposes, for example real estate developers have business objectives, while the government has its public welfare.

4.2.4 Collaboration practices among actors

On July, 2010, Shanghai government delegate construction management committee (MC) established to coordinate and balance important construction problem in the CBD. Even if SHBDMC is also the agency of Shanghai government and SRTC is the governmental investment company. SHBDMC prioritizes quality and safety over the interests of STRC and other enterprise investors. Comparing with SHITH project, although they are both public sectors, there exists conflicts between them, i.e. MC pays more attention to serve the real estate developer while SRTC focus on infrastructure construction.

4.3 Progress of these two mega construction projects

The progress and outcomes in both projects are compared by the following issues: survey of budget, delays on schedule, quality control issues on concreting problems and quality control issues on other problems, collaboration among actors, and conflicts among actors. However, it should be noted that SHITH and SHCBD are proceeding in different phases. Although these two projects have some relativity, they have their own characteristics. The SHITH project appears to not only managerial challenge, but also technical, i.e. how to deal with the overlap joint of two different transportation infrastructures. Respectively speaking, the SHCBD does not face technical challenge, but how to deal the significant conflicts of interest between the public and private sector stakeholders are their crux.

4.3.1 Survey of budget

In SHITH project, the whole investment is 70 billion. And we can’t get much information of investment from outside media source. But we learn about STRC and SAA have investment surplus. And the investment of projects managed by SCM is basic balanced. So the most surplus is from SA construction headquarters.

In SHCBD project, the first phase also has investment surplus without detail data.

4.3.2 Delays on schedule

In SHITH, two major components for ensuring project success are (i) quality achievement according to the original requirement, and (ii) on-time project completion. In the SHITH Project, the Hongqiao T2 airport terminal project was completed in 12 days prior to the project completion date despite the tight construction schedule. The schedule accomplished rate of the Project reaches as high as 92%, which brings high economic benefits and social benefits. Also there is no major mistake taken place during the test operation.

In SHCBD, Until now no one land can be completed until 2014 in current status. As for infrastructure construction, the energy trench project and road engineering project are all scheduled to finish in 2012, and it will delay to 2013. because the advance speed is slow and the coordination capacity of MC is not enough, Shanghai government establish Shanghai Hongqiao Business District Construction Headquarter which has more authority just like SHITH construction headquarter and MC is as its office to deal with detail affairs.

4.3.3 Quality control issues, concreting problems

Because quality and safety issues are both key concern of CH, the quality control is successful in SHITH. While In SHCBD, the participation of land developer makes the quality control task is heavier than SHITH. And until now, there is no severe quality issue appeared.

5. Discussion

5.1 The role of construction headquarter Mega Construction Projects (MCPs) in China

Since 1958, construction headquarter mode appeared in China. As a temporary agency of local government, it's mainly responsible for the management and coordination of the public project, especially public infrastructure. MCPs can be viewed as a dynamic network of organizations that combines the resources, capabilities and knowledge of the participating actors to fulfilling the needs of the owner. As these objectives and expectations may conflict, large projects face several challenges not evident in the contexts of projects carried out by individual firms (Morris and Hough, 1987) (Flyvbjerg et al., 1995). In the SHITH, it contains 12 investment companies not to mention hundreds of design companies, supply units and so on. Both in the SHITH and the SHCBD, the projects interacts with the stakeholders which indirectly influence projects, such as relocation household who need to be paid for moving house. So it is necessary to have a party to coordinate and balance benefits between all stakeholders in the relative fair position. In China, there is no party can replace the function of construction headquarter. Usually, when the government becomes the major investment subject of the MCP, a 'CH' is developed to take charge of the whole development process for the public-funded project. The CH is a temporary organization which is accredited and guided by the related government departments, and will act as the project owner on behalf of the government. The main investment company usually commissions professional project management company to implement construction management and it mainly assumes the responsibility of supervising. The project management companies are in charge of the total management of the MCPs and to some extent play the role of owner project management. Fig 1 shows the project governance organization of MCPs in China.

In this mode, there exist many government agencies. So it's important to understand the project context of public sector. According to Pillai (1995), transparency and accountability are important in the public sector because the sector has a profound and pervasive effect on the lives of citizens and on the activities of the private sector. Transparency and debate to improve the analysis need to be implemented. Unaccountable decision making could

increase the danger of corruption. This includes the diversion of public resources, risk of costly project and project rejection.

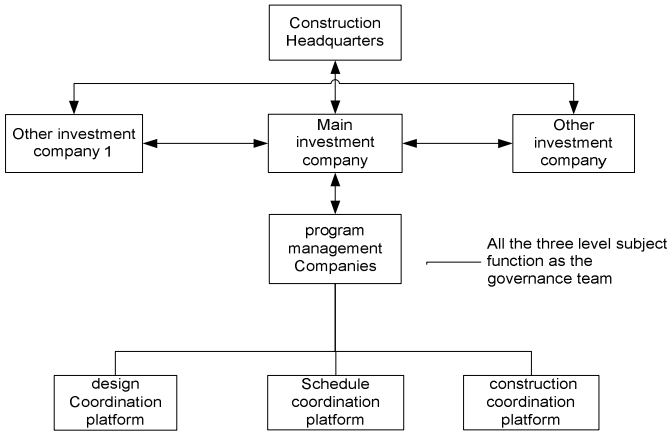

Fig. 1 The project governance organization for MCPs in China

Another potential impacts of public sector context is that no matter how strong professional advice may be for, or against, a project, and whatever the result of extensive use of rational methods, the final decision is a political one, such as SHITH and SHCBD. They have their political goals. It's important to recognize the importance of adapting project management method in the MCPs. The role of CH should be shift from a compelling coordinator to a decision maker with professional project advisor, ensuring effective service delivery. Meantime, by having effective and good project governance framework could assist transparency and accountability, trust and cooperation between top management.

5.2 The necessity of three coordination platforms

The governance in SHITH and SHCBD differed in the application of professional project management institute and three coordination platform, namely, design coordination platform, schedule platform, and construction platform.

Ineffective communication has been linked to poor performance (Inkeri Ruuskaa, 2011). In SHCBD, infrastructure projects and development land project have complex overlap relationships, i.e. the energy trench project needs to be finished before the first single building of development land of Shui On. And other nine developer's project schemes influence the stability of energy trench project. In order to avoid repeated construction and resource waste, the energy trench and underground pedestrian passage are supposed to be building at the same time. But these two projects are in the different phase. Because the lack of general design company, no one propose the rational and reasonable plan and arrangement of all single projects within the SHCBD. The project is unordered and inefficient and engineers are trapped in dealing with coordination affairs but not previewing problems.

The need to achieve goal alignment between the owner and the contractor, and to reduce the chance and benefit for opportunism by the client or contractor has been considered as the most significant issue when choosing a governance structure. Although CH can deal with

severe conflicts among different stakeholders, but there are also many detail construction conflicts which need to be coordinated. Therefore, the general design contractor and the general construction contractor will be selected through public bidding and tendering. The general design contractor will be responsible for the design management and also undertake the detailed project construction task. The general construction party is mainly responsible for managing and supervising the sub-contractors, monitoring the construction schedule and safety. The schedule coordination party is very often undertaken by professional advisor. A party “objectively” representing the interests of the mega construction project who could integrate and optimize schemes of all parties from initiation to handover is necessary.

5.3 The alignment between governance work and management work

Turner(1999) define the role of governance in a project is to set strategic direction, set and monitor levels of performance, especially profitability, provide finance, and control financial returns, provide technical expertise through centre of excellence, provide an audit function, and control risk exposure. However, governance work can deal with problems such as institutional arrangement, strategic direction and long-term goal of mega construction project. It is still necessary to achieve project success through project management approaches. How can the application of these two different approaches (management and strategic/ governance) work together to influence the performance of a project. Based on the research and the results of the case study analysis, it was discovered that there is a need to combine these two different approaches since the combination has the ability to enhance project’s performance. Clearly in SHITH and SHCBD projects, there are many project team behind three platforms which to achieve the short- term success of single project. Their goals’ alignment with mega construction is guaranteed by program management company and three coordination platforms.

6. Conclusion: towards a new project governance framework for mega construction projects (MCPs) in China

Three are less studies on universal theoretical project governance framework of MCPs. W inch(1999) proposed a 3C abstract project governance framework elaborating the relationship of controlling, conception and the construction. On this basis, the 4C framework and (1+3C) framework are built to demonstrate the function of client. According to Garland, the project governance framework must clearly show the decision making path which does not include the stakeholders directly in the decision making. Abu Hassim(2011) pointed that by implementing a project governance framework, problems in organizational can be hindered as the line of accountability is clearly defined. According to Yin(2009), program governance framework is composed by organization management level, institution management level and integrated management level. The literature review provides the theoretical basic of the project governance framework, elaborating the organization and institution management part in governance.

Based on literature review and the practices of MCPs in China, the program construction is influenced by not only internal factors, but also external factors. It is not an independent system. The external factors includes policy, economy, market and law environment which

all checks and balances the MCPs' project governance structure. The project and its performance are affected by complex external factors. Meanwhile, the MCPs inherent characteristics such as multifunction, colossal size, long-term, uncertainty and its organizational culture comprise the internal factors. The changes and influences from external and internal factors determine the framework is not invariable. It adjusts the inner organization and institution mode. But the main structure would not change much because the mode of MCPs in China would not change much in the MCPs duration mostly and only a stable governance structure can promise the steady management and advance. Fig 2 shows the pervasive governance structure for MCPs in China.

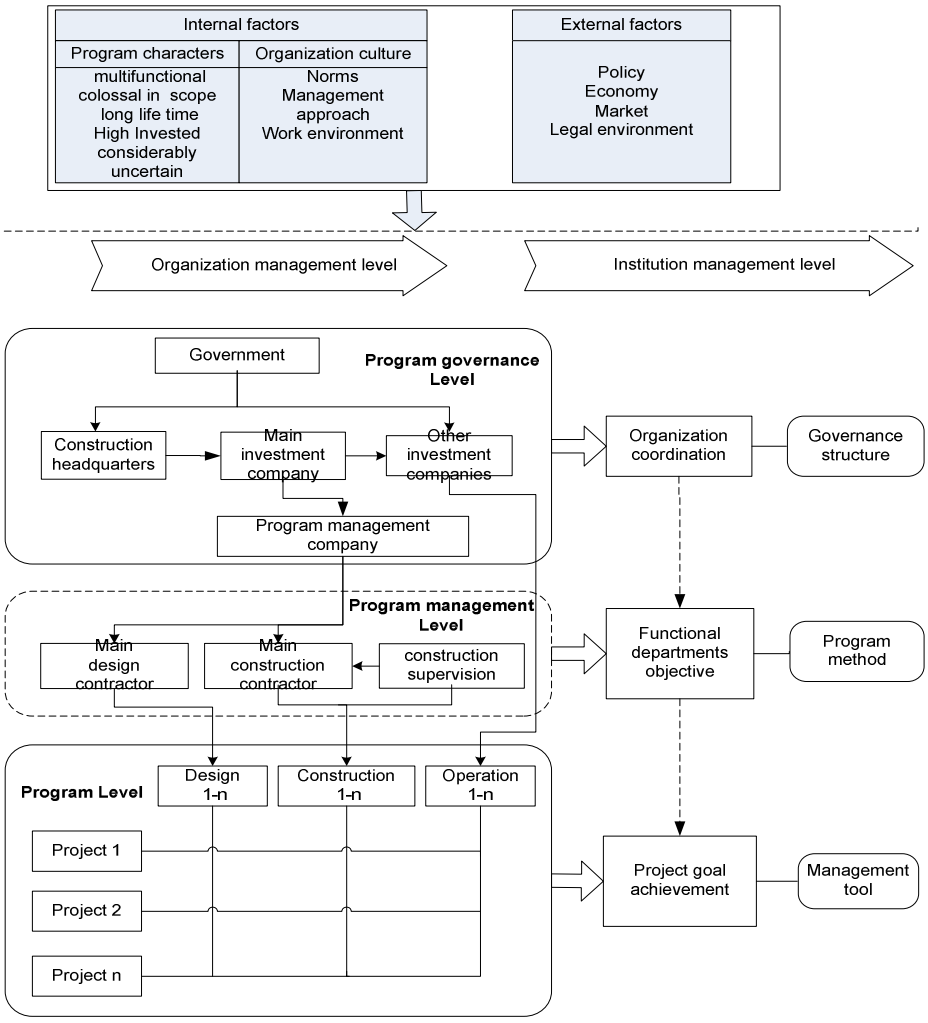

Fig. 2.Project governance framework for MCPs in China

As discussed above, the project governance team of the MCPs in China generally consists of three main subjects: (i) construction headquarter, (ii) investment companies, and (iii) program management company. The government first establishes a construction headquarters as a temporary organization of government which is responsible for MCPs' functional orientation and strategic scheme. And there is need to differ the function of CH from the main investment company.In this governance framework, on one hand, CH can gain more assistance from program management company, on the other hand, the supervision from the investment company should increase the responsibility and

accountability of public sector. And in this organization mode, it will realize the separation of the government function of investment, investment management and program management in order to avoid the occurrence of the government corruption.

CH and the main investment company are jointly take charge of the construction planning and management of the MCPs. The main investment company represents the government as an independent company for infrastructure investment. It assists construction headquarters to coordinate with other investment companies. The headquarter assists the main investment company to select professional program management agency to manage the MCPs through the public bidding and tendering, or by directly commissioning the main investment company as the program management subject. The program management subject will act as a link between the governance and program management. The program management company is responsible for the detailed management of the MCPs construction and in effect plays the role of owner's project management. The three level governance subjects select the general design contractor and the general construction contractor through public bidding and tendering. On the platform of design coordination platform, the design contractor is responsible for managing and conducting the design of the project. On the construction coordination platform, the general construction contractor is responsible for managing and supervising subcontractors, ensuring the safety of site, and monitoring the construction master schedule. And the schedule is often as the important focus of Chinese infrastructure construction. So a schedule platform is the progress consulting company will coordinate the progress issues among all construction and design firms and suppliers.

The project governance of MCPs in China includes the participation of government which makes its organizational structure different from other countries. On the way of the development and transition of construction industry, there are many program delivery failures caused by government corruption, government intervention and so on which can't be solved by traditional project management but project governance. By establishing a project governance framework involving the participation of government, investment companies, program management company, this could take the advantage of coercive power of government and monitoring power of investment companies. This is important as Chinese government needs to take the appropriate action to overcome numerous loopholes in the mega construction activities to ensure a more efficient and effective government investment.

7. Further Research

This paper focuses on project governance framework in the context of mega construction project with the participation of government which appears to be heading towards a new renaissance, in particular within the Chinese project area. This paper contributes to theoretical system in the governance of mega construction projects from organization management level and institutional environment level. We welcome further research that would further elaborate these novel findings of the governance in mega construction projects, with an emphasis on the complex supply network, various business approaches of the network actors, relationships, and the impacts of the complex institutional environments where the projects take place.

Further research on project governance in the context of mega construction projects is needed especially in four specific areas. First, this is a theoretical framework from a very small sample to draw conclusions, which limited the findings. Recent years, there have many mega construction projects in China. It's necessary to study their governance framework, governance organization and so on. Second, the literatures focus on qualitative research with less quantitative research. Further researches are also needed on the quantitative study of project performance implication of various governance frameworks.

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Post-occupancy Evaluation in Public Buildings

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Abstract

The increase in research devoted to performance evaluation of buildings in Brazil, coincides with the process of formalization of relations involving the history of the building, design, construction and maintenance of buildings. This process is the result of efforts to provide improvements in the supply chain of construction, with the incorporation of technological innovations, environmental comfort and devices for quality control. In Brazil, the contracting of services and public works is based on the law 8.666/93 between various aspects that highlights the importance of durability and the rationalization of public money. The durability of the built environment, compared to wear their equipment, facilities and maintenance needs, is a matter of great importance, especially in public buildings that are constructed to have long life. The present study aimed to identify key problems and pathologies of a public building in order to contribute to improved maintenance of the building, through the results and recommendations of this work. We conducted a case study of the building of the Rectory of Universidade Federal Fluminense - UFF, historical monument of great value to the city of Niterói, State of Rio de Janeiro. For this study, a survey was conducted of the various uses of the building throughout history, in conjunction with the Project developed a Post-Occupancy Evaluation which used instruments such as questionnaires and interviews with users of the building, quality assessments and Walk -through. These instruments have involved the technical, functional and environmental comfort with a focus on behavioral factors of the building and the degree of user satisfaction. As a contribution, this paper presents an array of recommendations to provide subsidies for the execution of maintenance works in the building, thus preserving the historical value of the public building.

Keywords: Post-Occupation Evaluation, maintenance of historical buildings, Walk-through assessment.

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1. Presentation Theme

The city of Niterói has detaque in the State of Rio de Janeiro due to development indices that make reference in key sectors such as education, health, quality of life and culture, the city grows apace gaining ground on the national scene.

In 1939 was built the Hotel Spa Casino Icarahy (figure 1) in the city of Niterói, state of Rio de Janeiro. In that same decade prevailed in the neighborhood Icaraí mansions, the palaces and buildings up to three floors.

According to the Municipal Bureau of Culture (2000), Casino Icarahy was the first skyscraper in the neighborhood and the attraction of the city during the 30s and 40s.

With the closing of gambling houses in Brazil in 1946, the building was sold and now operates as a hotel and restaurant. After the reform of 1952, came the Casino Theatre. Since 1967, the building was built by the Federal Government going to host the Rector of the Universidade Federal Fluminense (UFF), which occurs until the present day (figure 2).

Due to the great historical and cultural value to the city in October 1994, all the old Casino (main building, your garden and kills its slope) was listed, ie, the preservation of property ordered by the Board of Preservation Hall Niterói, based on Law No. 1.330/94. Thus, the visibility of the architectural ensemble was guaranteed.

The building stands out because it is located in the center of the terrain, with sharp separation front. Its facade is characterized by Art Deco style, with the use of geometrical shapes.

Currently the building is occupied with seven Pro Rectories performing activities of administration and advice to the Rector of the University, being distributed in the floors of the building.



Figures 1: Hotel Balneário Cassino Icarahy, 1939. (Prefeitura de Niterói, 1988)



Figure 2: Facade of the building currently. (Prefeitura de Niterói, 2010)

2. Objectives

Because it is a historical building, the building has undergone interventions with regard to their adaptation to new uses and also in regard to compensation.
The objective of this study is to evaluate the technical, functional, aesthetic and behavioral environment in use, in order both to users' opinion. Thus, diagnose strengths and weaknesses, defining the latter case, recommendations that may assist the university in future maintenance and performance of the built environment.

3. Methodology

The study emphasizes the identification and descriptive of significant flaws and positive aspects of the building of the Rectory, from the diagnosis of the same condition: technical, global, questionnaires and interviews with officials, particularly those of the Dean of Undergraduate (PROGRAD). The choice of PROGRAD happened because this is the Pro-rector who manages the academic life of the students of the UFF, since joining the expedition to the diploma. Moreover, the sector operates coordinating and supervising the activities developed in undergraduate teaching as well as various academic programs die.
In operational terms, the work was divided into three steps:
• Step 1: Survey - identify critical points, describe problems encountered, determining working methods and prepare research instruments [questionnaires, checklists and spreadsheets].
• 2nd Step: Diagnosis - characterize factors acting on the problem through technical evaluation, lift distribution and occupancy through low plants and field survey for deck building, analyzing the results of applying the tools of research, interviews and questionnaires.
• 3rd Step: Recommendations - perform critical analysis of results and recommendations for maintenance and future interventions.
The following are detailed procedures adopted in the implementation and results of each survey instrument.

4. Diagnosis of Conditions of Building

4.1 Evaluation Walk-Through

According to Castro (2004), analysis or Walkthrough Preliminary Analysis of the environment is the recognition and identification of problems and descriptive positive aspects thereof.
Ornstein; Romero (1992) said POE relies primarily on three types of evaluation: a functional - with emphasis on using the technique - with a focus on materials, building systems and building facilities, and behavioral - from observation and consideration of users.
In the case of the Rectory building assessment was performed by the technical team and representative of users (staff of the organization) who toured the building for the recognition of their physical and functional characteristics of the users and their activities. Surveys of operating conditions and condition of the building were recorded through photographs,

graphics existing bases and field notebook for notes on what was found.

Infiltrations
Infiltration is the main cause of mold and mildew stains from walls and the unhealthiness of the internal and external environments. In addition, lead to fungal growth, the decalcification of the concrete, cracking and peeling of the paint.

Floors
The floors of the balconies have insufficient trim, which causes the water from the rains and the air conditioners get accumulated, contributing further to the deterioration of the facade and the walls of the building board.
In the movement of fire stairs, floors vary floors. No standardization occurred in the coatings of the internal areas of the building, where they were observed: hydraulic tiles, wood laminates, parquet, slate, ceramic and rubbery.

Ceilings
The ceilings of the offices have recess in plaster, with matte white paint in good condition. On the roof of the fire escapes were applied in the slab itself paintings that need maintenance.
The lobby of the building features double height ceilings and recess, with indirect lighting in some areas that currently are intended for temporary exhibitions.

Corners and edges
Were observed edges and corners damaged areas of office due to mechanical shocks of furniture and equipment in general.

Window sills and balconies
The narrow width of the sills and running no inclination promote deterioration in the facades and allow water ingress by spans of some windows.
Regarding the balconies, it was found that the guardrails can not expel the water incident, well surpassing the transverse plane and causing sharp swearing. To prevent water from entering the rooms that have access to balconies, as an interim measure adopted by employees, fillets were placed on top of marble sills and toward the door, causing a gap in the passage leading to possible accidents and limit the disabled employees with special needs to balconies.

Frames
Some frames were repainted externally to the latest redesign of the front, but were not painted internally.
Some doors have screens that foster communication and integration of employees, and all, according to NBR 9050, are appropriate regarding the sizing.

Paving
There were no problems on the sidewalks outside the building and paving in the garden.
Only in the parking area there are problems of irregularities in paving the sidewalks due to the fact some cars in the same vouchers.

Garden
The garden outside the building is maintained by the gardening team, with good condition, despite it not present the original French style.

4.2 Evaluation of Quality and Environmental Comfort

Salgado (2004) says the quality assessment involves different aspects ranging from post-occupation This evaluation - focusing on the views of users about the performance of the building - even a purely technical assessment of the functioning of devices that allow the operation of a system building.
In this study, we evaluated issues relating to functionality, safety, suitability and comfort of environments.

Ventilation
The ventilation of the building happens artificially through wall air conditioning unit. In some sectors the distribution of the air conditioner is broken due to divisions that make up the environments. It was verified the lack of drains in the devices installed on the windows, which has caused stains on the facades. There is also air conditioning units installed in the internal partitions of the rooms, facing the circulation, causing the water swearing in the hallway that leads users to the stairs of the building, causing accidents (figure 3). The staircases feature windows that contribute to cross-ventilation (figure 4).



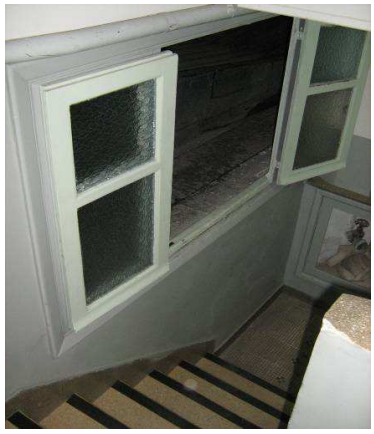


Figure 3 and 4: air conditioning installed and window on the stairs (Authors, 2010)

Effects of pollution
Pollution is one of the causes of spots in painting the facade of the building which is easily identified by the fact that the painting of the building be white in color.
According to Souza (2000), the air dust is transported and deposited on surfaces by wind, and the fine particles adhere better than coarse dust. The deposition of dust will be greater at the bottom of the constructions, due to the fact that the wind velocity increases with height, and yet, being intensified by the dust raised by traffic.
The air flow can be laminar or turbulent, depending on the wind speed and the obstacles,

has great influence on deposition of dust. The direction of raindrops falling on the facade depends on air flow at different levels. The rain showers are not usually sufficient to wash the dust and clean the walls, especially the lower parts. The drip of the rain is the main reason for pollution because it drags the dust, depositing it in a non-uniform.
The accumulation of dust is one of the causes of the frequent need to paint the facades, especially the front facing the public area.

Layout
We observed the following problems: lack of standardization of the mobile office rooms and circulation close, depending on the arrangement of the furniture, causing difficulty in the flow of employees (figure 5), especially those who have limited mobility. In some sectors were installed files sliders that favor the handling of documents.



Figure 5: circulation narrow (Authors, 2010)

Installations
We observed inadequate position taken (electric and telephone) in office rooms, causing the proliferation of wires and switches located behind the doors.
There are extensions made in the walls of the balconies, getting exposed to rainwater. It is also noticeable large amount of network wires and equipment (computers, stabilizers, printers, photocopier) and apparent loose in the halls. There were no problems regarding the functioning of the internet and plumbing.
The building has fire extinguishers in the hallways and in the lobby elevators. There are also fire hoses to access the escadas. There aren't antechamber and fire door on the stairs.

Lighting
No issues were identified regarding the distribution and luminance ratios of internal and external areas of the building. In offices were used fluorescent tubes, while in circulation areas, inlaid with CFLs. Some lamps in the office rooms are flickering or flashing light that is a physiological phenomenon that causes discomfort for visual users of the site.
The emergency luminaires in fire escapes remain in good condition.
In the lobby of the building lighting is indirect in some areas with plaster recess, favoring temporary exhibitions that occur in this area.

Security
The presence of security guards outside and inside the building as well as the receiving system and identification compulsory for visitors, function as efficient barrier to intrusion attempts.

Acoustics
Despite the building was located on a street with heavy traffic of cars and buses, the situation of the building is privileged over the ground by their remoteness front, which contributes to the comfort noise environments.

Signaling
The floors of the building have few signposts, which causes the discomfort of visitors.
We observed no signal in certain rooms and environments with plates that do not match your current usage.
There were no signs in case of accidents and risk maps.

Accessibility
There is only one ramp and handrail with no inclination to inadequate NBR 9050, which allows the passage of the garden to the corridor that leads to the elevator hall, cinema and theater. There were no ramps from the parking lot to the level of the garden paving. The existing elevators to meet the needs as vertical movement.

4.3 Level of Satisfaction of Users (Questionnaires)

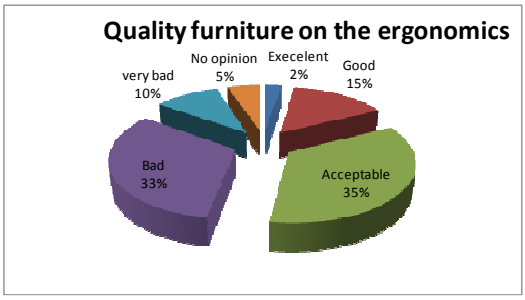
Preiser (1988), Ornstein, (1992), say the questionnaire POE enables the identification: functional aspects of the workplace, overall assessment of the building, the main qualities of the building and the level of user satisfaction.
Forty questionnaires were distributed, of which 100% returned answered. Table 1 shows the number of completed questionnaires divided by function categories and their respective percentages:

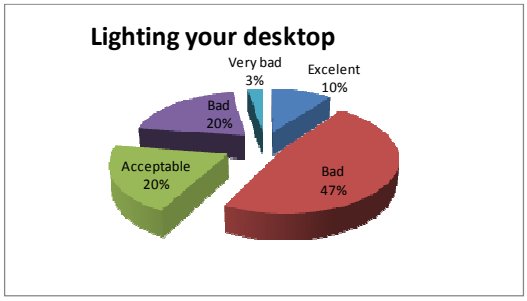
Table 1: Number of questionnaires, according role categories

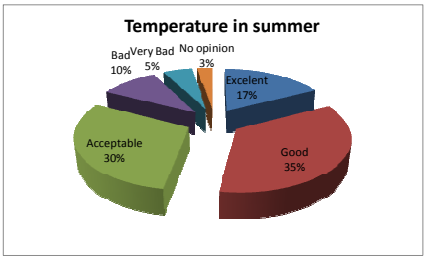
Variables	Frequency	Percentage
Employee	31	77,5
Trainee	02	5,0
Service Provider	07	17,5
Results	**40**	**100,0**

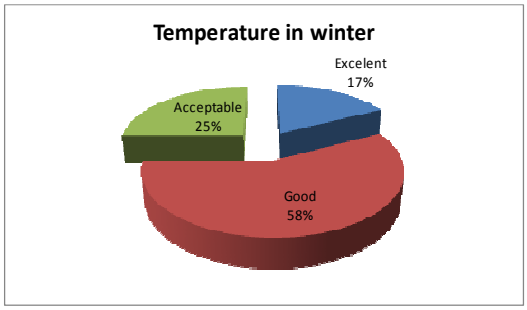
Most respondents were female (82.5%) while men accounted for 17.5%. Their ages ranged from 10.0% to less than 25 years, 17.5% for 25 to 40 years, 62.5% for 41-55 years and 10.0% for over 55 years. Most industry officials have long service with more than 10 years (55.5%) between 6 and 10 years (10.0%), between 1 and 5 years (25.0%) and less than 1 % 7.5 years.

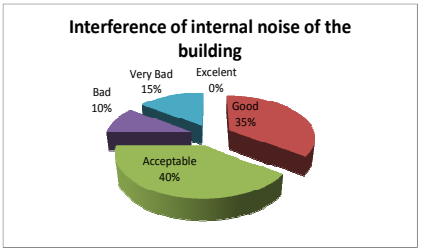
Feedback from users on the desktop

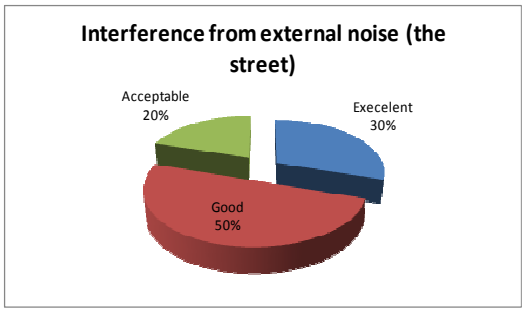


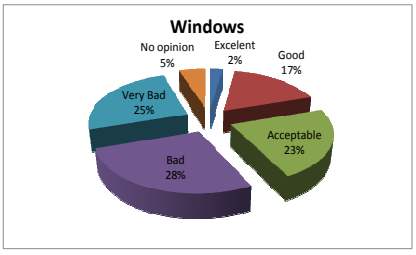


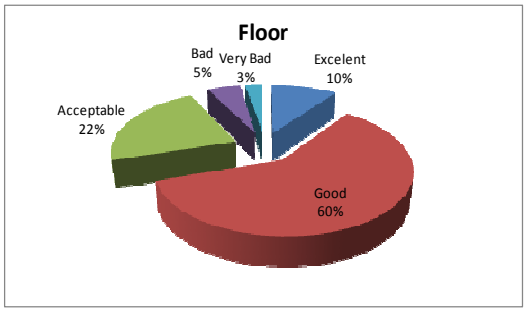








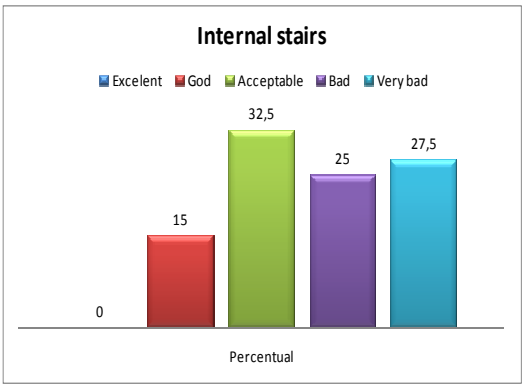


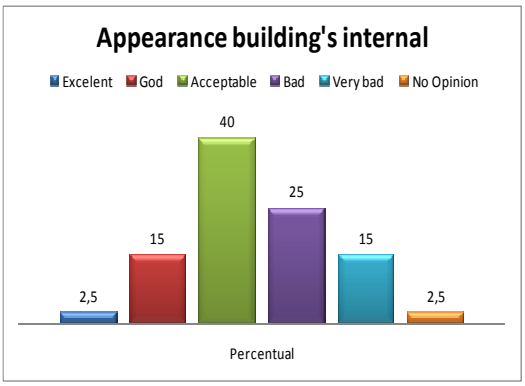


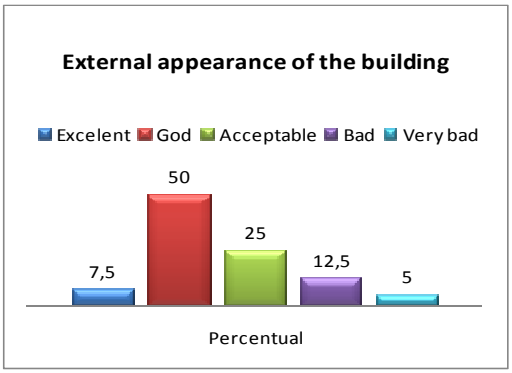
The graphs above show the level of user satisfaction in the workplace. Due to the lack of standardization of mobile and inappropriate choice as ergonomics, there is a dissatisfaction approximately 83% of respondents. Officials expressed satisfaction about the lighting, especially those who work in environments with a balcony, which allows the use of natural lighting and ventilation. In other environments fluorescent lamps meet the users and provide lower energy consumption. The temperature in summer causes dissatisfaction among users due to the difficulty of distributing the air conditioning system. In winter there is a significant use of natural ventilation as the building has large will enable cross ventilation. The external noises interfere less in the building because of the remoteness of the terrain front, but there is a lack of the use of materials that reduce the noise caused by internal users. Some

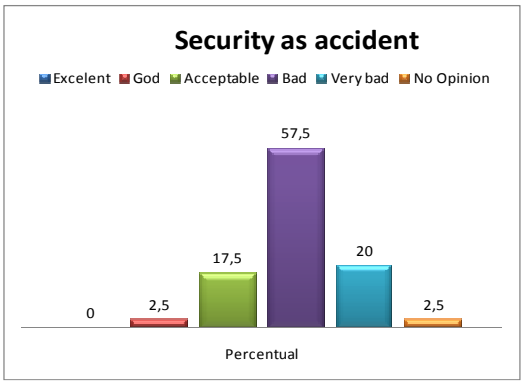
windows require maintenance and greater opening to allow air circulation. The floors are in good condition and in some cases needing replacement parts. The dissatisfaction of the users when the restrooms is related to the reuse of the building, since the existing toilets were constructed for hotel use and are not distributed according to actual need.

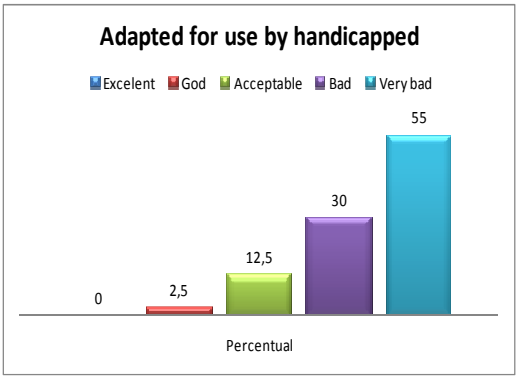
Opinions on building users

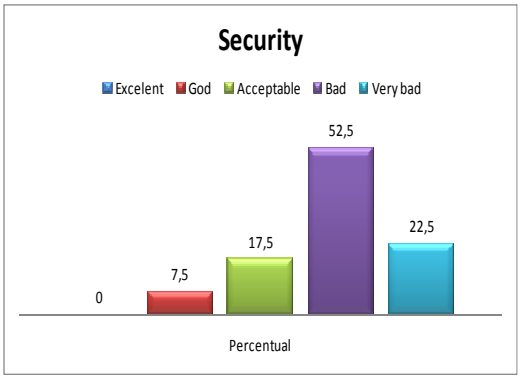












From the graphs it is possible to perceive the dissatisfaction of the users of the building as the signaling and safety as accidents, since the building does not present risk map and a few fire extinguishers. Due to the large influx of people into the building, there is a need to build new ramps and renovate existing ones to meet the special needs and handicapped. The stairs need emergency luminaires and more intense artificial lighting to prevent accidents. Most users satisfaction shows the external appearance of the building which has recently undergone renovations and dissatisfaction with the outward appearance for reasons explained above in evaluations Walk-Through, Quality and Environmental Comfort.

4.1 Considerations for the reuse of the building

In the case of the historic building that was the subject of adaptive reuses or retrofit (defined here as the modernization of the building without significant changes in its form and in its use), should be noted some peculiarities in the application of the approach. In the evaluation of reuses, special attention should be given to the relationship between the morphological structure pre-existing and the new intended use. Veloso (2007) said the area of conservation of heritage buildings, should be observed the suitability of the new program, since a single use (housing, for example) may suggest programs more or less suited to the pre-existing structure.

With regard to the building of the rectory was observed that the current use of an administrative building of the University, the program has very divergent from the original program intended for a hotel. With so many changes were needed inside the building and a large financial investment.

Another aspect to be considered, both in cases of reuse and retrofit, are the formal and stylistic characteristics that confer identity to the historic building, as a representative of an era. The essential features of such disfigurement is not located within modifying actions (often necessary) for the preservation and conservation of heritage, but as a renovation project any. On the other hand, it is permissible and even advisable, incorporating new construction technologies and new systems for building facilities in new interventions, in order to distinguish them from pre-existing and empower the old building to the performance of its new function, serving the needs of the present. The building of the rectory, despite various modifications and adjustments made internally but stayed with the features essential to the preservation of historic building.

5. Recommendations for building maintenance

After the analyzes in the building, so an array of recommendations to contribute to the maintenance project for the building.

RECOMMENDATIONS FOR BUILDING OF REGENTS OF THE UFF ITEMS RECOMMENDATIONS	
ITEMS	**RECOMMENDATIONS**
Infiltrations	Cleaning and replacing the drainage systems of the balconies.
	Deploy trim for stormwater runoff that are inductees in the balconies. Waterproofing of balconies.
	Replacing the existing blanket on the roof.
Floors	Standardization of the floors of the floors of the common areas of the building.
	Replacement of broken pottery on the stairs and passageways.
Ceilings	Painting the roofs of some stairs and circulation areas.
Corners and edges	Placement of metal or PVC profile at the corners for greater flow of furniture and equipment.
Sills and thresholds	Advancement into the masonry sill avoiding the appearance of damp stains and dirt on the facade.
	To avoid the deposition of dust and stains due to moisture, it is recommended that the sill highlight of cloth facade of at least 25mm, has a trim of about 8% to 10% and that its underside is provided with drip tray.
	Remove the fillets on the sills to prevent accidents.
Frames	Painting and exchange of hardware enabling opening of gaps and natural ventilation.

Paving	Leveling the paving of the parking lot and road signs prohibiting parking vehicles on sidewalks.
Ventilation	Placement of drains and replacement of existing filters of air conditioners.
	Installing central air system to better distribution in the room because the height of the partitions
Facades	Applying sealer and paint the facades general.
Layout	Review the layout as the design of internal circulations of rooms offices.
	Standardization of securities, installation of cabinets and sliding files.
Facilities	Installing taken near the equipment, changes in positioning of switches.
	Installation of pull boxes and raceways for conducting wireless network and equipment in general.
	Withdrawal of sockets and extensions exposed to the action of rain on the balconies.
Lighting	Replacing bulbs in offices that are flickering to prevent visual discomfort.
	Installation and exchange of signs that indicate the sectors and rooms according to the current usage.
	Instalação de placas de instrução em caso de acidentes e incêndio.
Accessibility	Adequacy of existing ramp with handrails and tilt according to NBR 9050.
	Construction of new ramp giving access to the garden from the parking lot.

There are currently experiencing some maintenance work, revision and adaptation of buildings and some of the recommendations are being met.

6. Conclusion

The After analyzing the problems identified in the building was the rectory, it was found that the cost to repair damage are much greater than the costs of preventive measures. Therefore, you must provide a consistent Maintenance Plan, which defines the frequency of inspections and preventive interventions, such as cleaning, unblocking drains, review of grouting, refinishing and other activities as needed. This plan should also take into account the natural aging of materials, maintenance standards required, the scale of priorities, financial availability and feedback from users.
The surveys should be conducted periodically and should be based on standardized lists (checklist), drawn from a screenplay logical inspection, considering the parts of greater importance. The surveys may be interleaved with visual inspections prepared, those that take place in some assays for measuring the condition of materials and structure.

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Acknowledgements

The authors thanks the financial support of CAPES (for doctorate scholarship) and CNPQ (Productivity Scholarship in Research).

A System Dynamics Modeling for Knowledge Management, Culture and Performance (KMCP): Case study in Indonesian Construction Firm

Mochamad Agung Wibowo and Rudi Waluyo

Abstract

In today's competitive world, knowledge is considered an essential source to improve performance of organizations. Thus, those organizations will be more successful that sustainably manage their knowledge assets through operational activities. The objectives of research are to develop model and to simulate knowledge management, culture and performance of construction firm using system dynamics. This research is an ongoing project and divided into four stages, i.e. develop conceptual model, obtaining data with interview and annual report of firm, develop causal loop diagram, stock flow diagram and simulation on model developed. Data analysis use system dynamics. The model developed is able to demonstrate the relationships between knowledge management, culture and performance to interact each other in the organization. It can be seen employee (staff) skill is growth up 7%, knowledge base is growth up 7% and costumer base is growth up 200%.

Keywords: **Knowledge management, culture, performance, construction firm, system dynamics**

1. Introduction

In knowledge based business era right now, knowledge is an important asset that used to compete in global business. Prijono (2008) said that knowledge management is a concept that has focus on management of knowledge, its process if it run well will be beneficial to business process and will improve firm performance (pp1-2).

Tahir et al. (2010) stated that a positive and significant firm culture influence knowledge management (pp1033-1034). Chen (2007) stated that a positive relationship between knowledge management and firm performance (pp260). Aluko (2003) stated that a positive relationship between firm culture and performance (pp176-177). The obtained results shows that firm culture and knowledge management influence performance of organizations. However, the previous research are a static models. The objectives of research are to develop model and to demonstrate knowledge management, culture and performance of construction firm using system dynamics. This is an ongoing research about relationship between knowledge management, culture and performance using system dynamics. The research model is developed using conceptual model, causal loop diagram and stock flow diagram. However, previous research are static models. The model developed is tested and simulated based on some phenomena.

2. Literature Review

2.1 Knowledge

Widayana (2005) defines that knowledge is an information that completed with relationship mode comprehension from information with individual and group experience. Combination of information, context and experience, looked is as a core competence of organization that can capture, share and utilize for business aspects (pp.9). Munir (2008) stated that in general knowledge is divided into tacit and explicit knowledge. Tacit knowledge is a human knowledge that can be an intuition, judgment, skill, experience, body language, values, belief and rule of thumb. It is very difficult to formulate, to communicate, or to share with other people. Explicit knowledge is a knowledge that can be expressed in words, numbers. It can be added, transferred, distributed and that given in systematic and formal way in data, knowledge formula, product specification, manuals and universal principles (pp.25-27).

2.2 Knowledge Management

Zuhal (2010) defines knowledge management (KM) is a term applied to techniques used for the systematic collection, transfer, security and management of information within organizations. Knowledge management is an organization way to manage knowledge, to create values and to improve competitive advantage or firm performance (pp.76-78). Seleim and Khalil (2007) stated that knowledge management have activities and we can call it knowledge management processes such as knowledge creation, knowledge acquisition, knowledge application, knowledge transfer and knowledge documentation (pp38-39).

2.3 Firm Culture

Suwarto and Koeshartono (2009) explain that culture has elements like assumptions, values, norms and behavioral. Firm culture are unity of people who have objective, beliefs and the same values. Firm culture are values system, beliefs, assumptions or universal norms that agreed and followed by employees, and used to behavioral standard and problem solving of organization. Firm culture are values systemic agreed, followed and believed in organization (pp2-5). In this paper corporate culture are values believed in firm to enable knowledge management processes and to improve performance. In addition, Lee and Choi (2003) stated that firm culture have values like collaboration, teamwork, trust, reward, recognition, and learning development (pp191-192).

2.4 Firm Performance

Lestari and Zulaikha (2007) define that firm performance is a level of achievement and show manager succeess. Performance refers to output and outcome of processes, products, and services that evaluated and compared with objective, standard, the past result and other organization (pp.15-17). Ellitan and Anatan (2009) stated that Performance is a level of organization to achieve business goal. It can be measured by profitability, finance, learning and growth (pp28-29).

2.5 System Dynamics

Susilastuti (2011) said that system dynamics (SD) was firstly introduced by Forrester as a method for modeling and analyzing the behaviour of complex social systems, particularly in an industrial context. It has been used to examine various social, economic, and environmental systems, where a holistic view is important, and feedback loops are critical to the understanding of the interrelationships (pp56-58). Sterman (2000) explains that system dynamics is an approach to understand the behavior of complex systems over time. It deals with internal feedback loops and time delays that affect the behavior of the entire system. What makes using system dynamics is different from other approaches to studying complex systems is the use of cause and effect diagrams and stock and flow diagram. These elements describe how even seemingly simple systems display baffling nonlinearity (pp41-43).

Georgiadis (2005) explains that the structure of a system in system dynamics methodology is exhibited by causal loop (influence) diagrams. The causal loop diagram captures the major feedback mechanisms. These mechanisms are either negative (balancing) or positive feedback (reinforcing) loops. A negative feedback loop exhibits a goal-seeking behavior: after a disturbance, the system seeks to return to an equilibrium situation. In a positive feedback loop an initial disturbance leads to further change, suggesting the presence of an unstable equilibrium. The Causal loop diagrams play two important roles in System Dynamics. First, during model development, they serve as preliminary sketches of causal hypotheses and second, they can simplify as a model representation. The structure of a dynamic system model contains stock (state) and flow (rate) variables. Stock variables are the accumulations (i.e. inventories), within the system, while flow variables represent the flows in the system (i.e. order rate), which are the byproduct of the decision-making process. The model structure and the interrelationships among the variables are represented by stock-flow diagrams. The mathematical mapping of a System Dynamics stock-flow diagram occurs by a system of differential equations, which is numerically solved by simulation. Nowadays, high-level graphical simulation programs (such as i-think, Stella, Vensim, and Powersim) support the analysis and study of these systems (pp353-354)

3. Research Methodology

This research which have done on one of big construction firm in Indonesia, began August-September 2012. This research uses system dynamics method and divided into 4 (four) stages. The first stage is literature review and developing conceptual model. Literature review has done to find research problem and then makes conceptual model that have got from literature study about firm culture, knowledge management and firm performance. Second stage are collecting data with interview and gathering annual reports of firm. Third stage is dynamics modeling. This stage has two activities i.e. developing causal loop diagram and developing stock flow diagram. Final stage is analysis, discussion and conclusion. Model of knowledge management, culture and performance are analysed by system dynamics. Results of simulation showed on table and figure form in order to make

easy to catch messages from this research. And the last activities are discussion and conclusion. All of study stages are shown at figure 1.

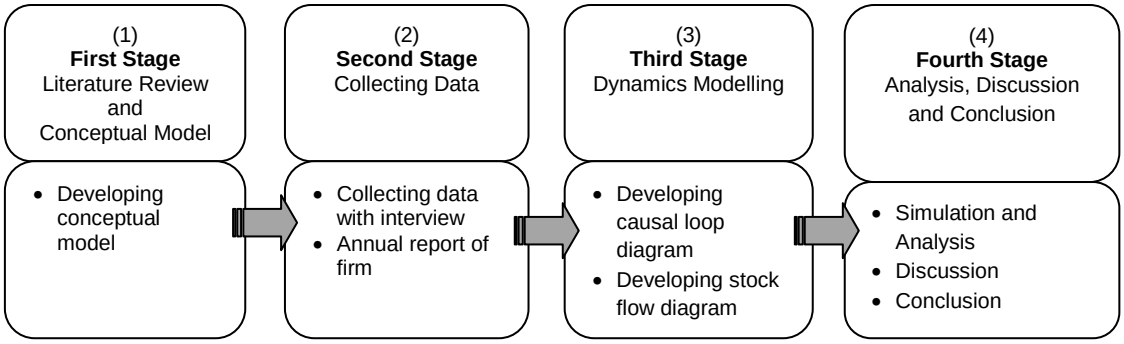

Figure 1. Study Stages

4. Modeling, Analysis and Discussion

4.1 Conceptual Model

Conceptual model of knowledge management culture and performance of construction firm have been gotten by literature study of relationship between firm culture, knowledge management and firm performance. Tahir et al. (2010) stated that a positive and significant firm culture influence knowledge management (pp1033-1034). Chen (2007) stated that a positive relationship between knowledge management and firm performance (pp260). Aluko (2003) stated that a positive relationship between firm culture and performance (pp176-177). Figure 2. displays a conceptual model of knowledge management culture and performance (KMCP).

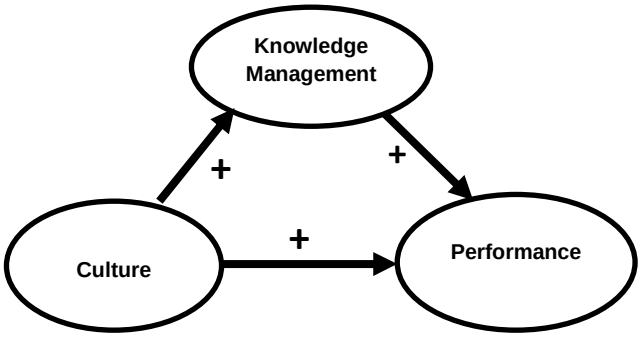

Figure 2. Conceptual Model of Knowledge Management Culture and Performance

4.2 Causal Loop Diagram of Knowledge Management Culture and Performance (CLD-KMCP)

Causal Loop diagrams are used to capture mental models and represent interdependencies and feedback processes in a system. All dynamics arise from the interaction of just two types of feedback loops, i.e. positive loops tend to reinforce or amplify whatever occurring events in the system and negative loops tend to balancing system. The diagram in Figure 3 presents the essential components and interactions in the model of knowledge management culture and performance construction firm.

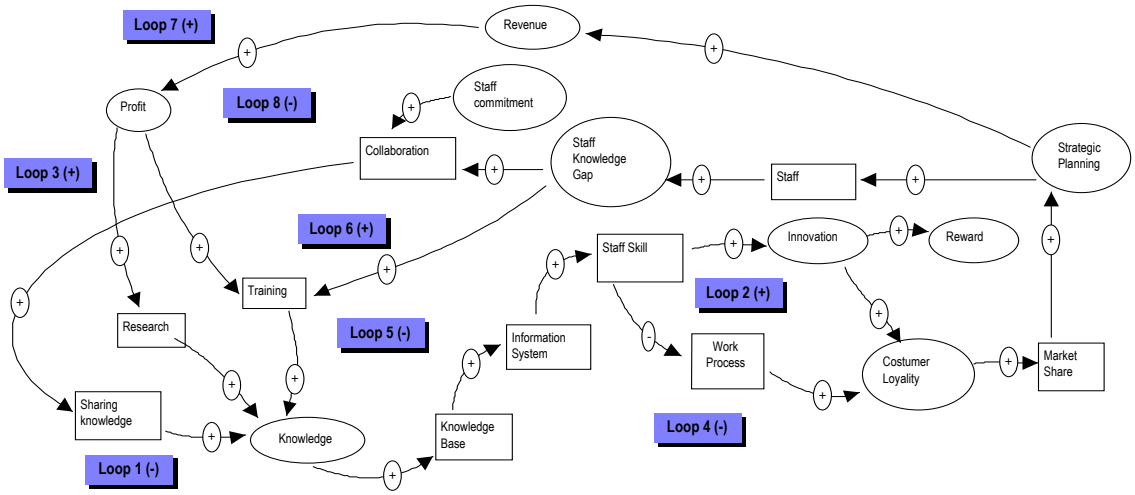

Figure 3. Causal Loop Diagram Knowledge Management, Culture and Performance in Construction Firm

Based on figure 3 causal loop diagram (CLD) knowledge management, culture and firm performance and then developing loop structure, i.e.

a. Loop 1 (-) consists of sharing knowledge - knowledge - knowledge base - information system - staff skill - work process - costumer satisfaction - market share - strategic planning - staff - gap of staff knowledge - collaboration to add knowledge - sharing knowledge;
b. Loop 2 (+) consists of sharing knowledge - knowledge - knowledge base - information system - staff skill - innovation - costumer satisfaction - market share - strategic planning - staff - gap of staff knowledge - collaboration to add knowledge - sharing knowledge;
c. Loop 3 (+) consists of research - knowledge - knowledge base - information system - staff skill - innovation - costumer satisfaction - market share - strategic planning - revenue - profit - research;
d. Loop 4 (-) consists of research - knowledge - knowledge base - information system - staff skill - work process - costumer satisfaction - market share - strategic planning - revenue - profit - research;
e. Loop 5 (-) consists of training - knowledge - knowledge base - information system - staff skill - work process - costumer satisfaction - market share - strategic planning - staff - gap of staff knowledge - collaboration to add knowledge - training;

f. Loop 6 (+) consists of training - knowledge - knowledge base - information system - staff skill - innovation - costumer satisfaction - market share - strategic planning - staff - gap of staff knowledge - training;
g. Loop 7 (+) consists of training - knowledge - knowledge base - information system - staff skill - innovation - costumer satisfaction - market share - strategic planning - revenue - profit - training;
h. Loop 8 (-) consists of training - knowledge - knowledge base - information system - staff skill - work process - costumer satisfaction - market share - strategic planning - revenue - profit - training.

In general, causal loop diagram represents four reinforcing loop and four balancing loopss. System has reinforcing and balancing interaction and if one of the sub systems is uncontrolled, feedback system will happen in order to balancing and reinforcing elements inside the systems.

4.3 Stock Flow Diagram of Knowledge Management Culture and Performance (SFD-KMCP)

The stock and flow model presented below is based on the causal loop diagram in the previous section. A selection of variables from the causal loop diagram was translated into stocks, along with the corresponding relationships. The variables selected were chosen according to their relevance with regard to stock and flow systems, and their potential influence on firm performance. Stock flow diagram of knowledge management, culture and performance can be seen on figure 3.

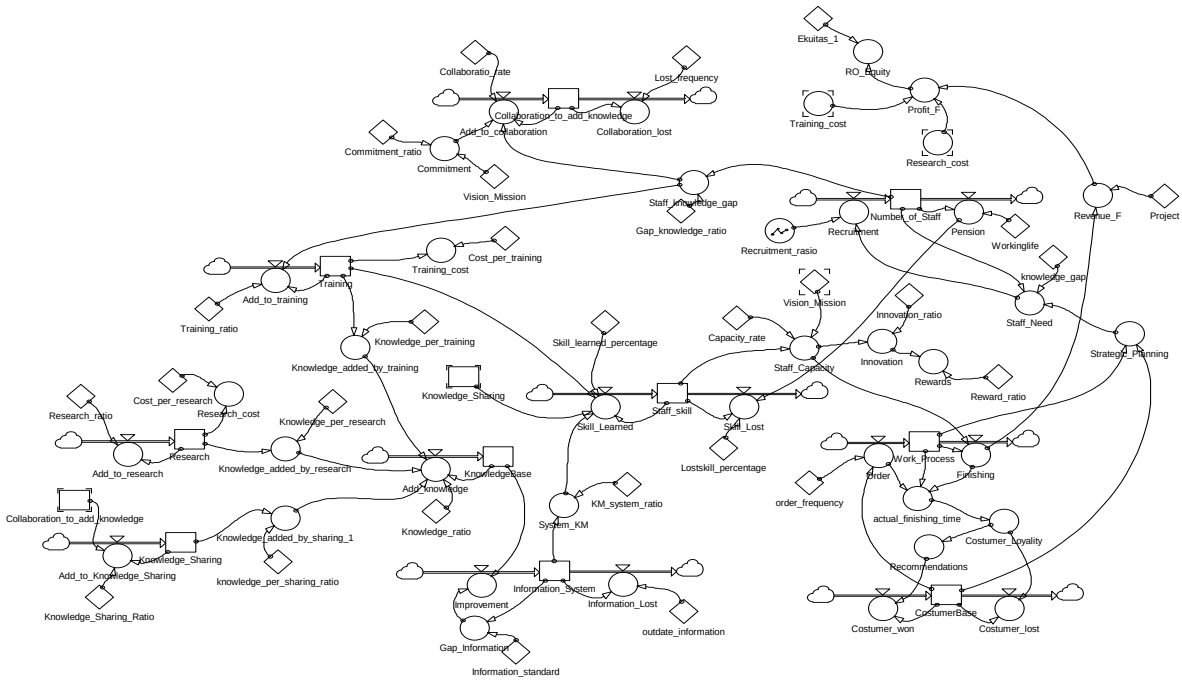

Figure 4. Stock Flow Diagram Knowledge Management, Culture and Performance in Construction Firm

Stock flow diagram (SFD) on figure 4 explain that knowledge management, culture and firm performance is a dynamic modeling and have dynamic connection each other.

4.4 Simulation of Dynamic Model of Knowledge Management Culture and Performance

Figure 4 shows that dynamics model of knowledge management culture and performance consist of ten sub system i.e. collaboration to add knowledge, training, research, knowledge sharing, knowledge base, information system, costumer base, work process, number of staffs (employees), employees (staffs) skill. Based on conceptual model of KMCP and then ten sub system categorized into three variables and showed on figure 5. Simulation of model represents dynamic change and is showed in time graph and time table. Results of simulation can be explained through three sub system, i.e. employee skill is representative of culture, knowledge base is representative of knowledge management, costumer base is representative of performance.

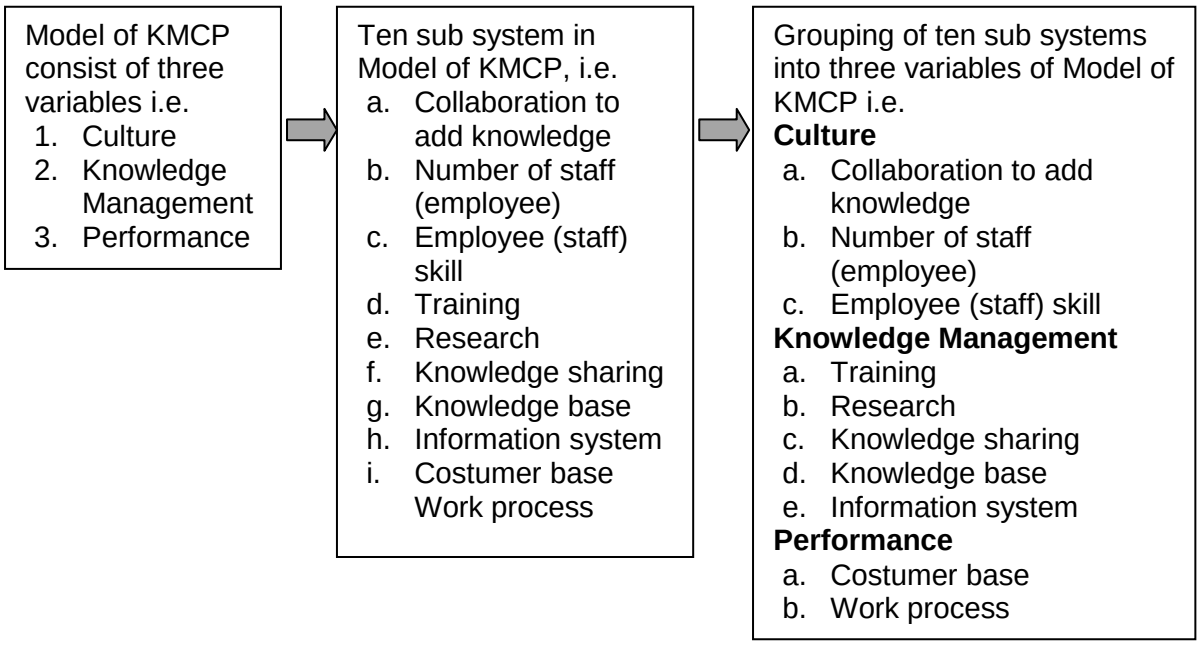

Figure 5. Grouping of Sub System into Variables of Model of Knowledge Management, Culture and Performance in Construction Firm

4.4.1 Employee Skill Sub System

Based on figure 4 can be explained that staff skill sub system comprises with staff skill element as stock variable that gets inflow from skill learned and outflow from lost skill. Skill learned got information from skill learned percentage, knowledge sharing, system knowledge management and staff skill. Skill lost got information from staff skill, lost skill percentage and pension. Result of simulation of dynamic model presented on table 1 and figure 5.

Table 1. Simulation of Employee and Add to Skill

Year	Staff_Skill	Skill_Learned
0	1000000	410671
1	1080671	442939
2	1166989	477467
3	1259349	514411
4	1358175	553941
5	1463918	596238
6	1577063	641496
7	1698129	689922
8	1827669	741738
9	1966276	797182
10	2114587	856506

Figure 6. Simulation Graph of Employee and Add to Skill

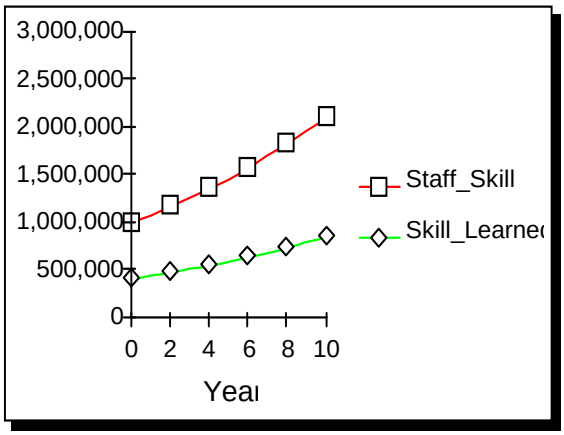

Table 1 and graph 6 shows that staff skill and skill learned growth up significantly from first year until tenth year. Staff skill and skill learned are growth up 7% average every year.

4.4.2 Knowledge Base Sub System

Figure 4 shows that knowledge base sub system comprises with knowledge base element as stock variable that got inflow from add to knowledge. Add to knowledge got information from knowledge added by sharing, research, sharing, knowledge base and knowledge ratio. Result of simulation of dynamic model is presented on table 2 and figure 7.

Table 2. Simulation of Knowledge Base

Year	Knowledge_Base1	Add_to_knowledge
0	50000	30418
1	80418	36502
2	116920	43802
3	160722	52562
4	213284	63075
5	276359	75690
6	352048	90828
7	442876	108993
8	551869	130792
9	682661	156950
10	839611	188340

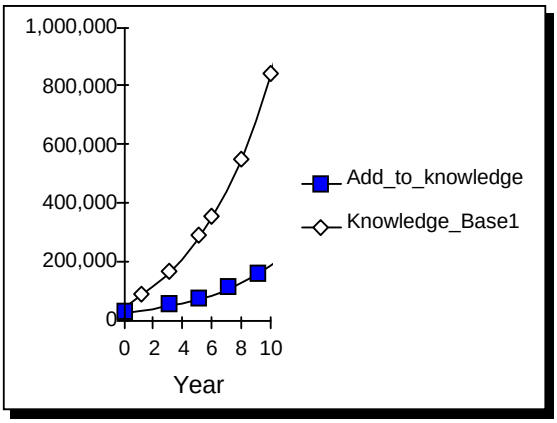

Figure 7. Simulation Graph of Knowledge Base

Based on table 2 and graph 6 can be explained that knowledge base and add to knowledge growth up significantly from first year until tenth year. Knowledge base and add to knowledge are growth up 7% average every year.

4.4.3 Costumer Base Sub System

Based on figure 4 can be explained that costumer base sub system comprises with costumer base element as stock variable that got inflow from costumer won and outflow from costumer lost. Costumer won got information from costumer base and recommendation, costumer lost got information from costumer base and costumer loyalty. Result of simulation of dynamic model presented on table 3 and figure 8.

Table 3. Simulation of Costumer Base

Year	Costumer_Base
0	20,000.00
1	60,000.00
2	180,000.00
3	540,000.00
4	1,620,000.00
5	4,860,000.00
6	14,580,000.00
7	43,740,000.00
8	131,220,000.0
9	393,660,000.0
10	1,180,980,000

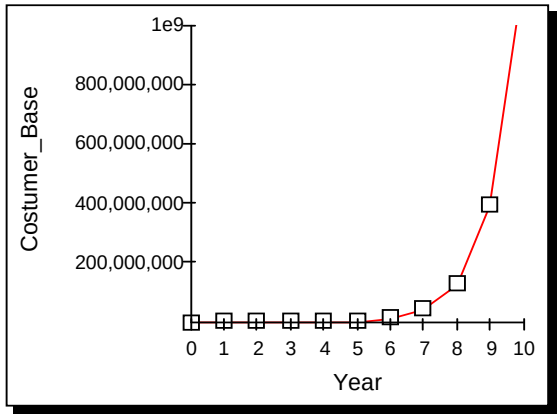

Figure 8. Simulation Graph of Costumer Base

Table 3 and graph 8 presents that costumer base growth up significantly from first year until tenth year. Costumer base is growth up 200% average every year.

4.5 Discussion

The simulation results contribute to the understanding of the dynamics of the system of knowledge management, culture and performance in construction firm. Resulting from the positive effect of culture and knowledge management rises within the simulation time of employee (staff) skill in 10 years. The simulation results show that staff skill rises significantly 7% in average every year. Positive relationship between knowledge management and performance proved by simulation results of costumer base that show rises significantly 200% average every year. And simulation result of knowledge base show rises significantly 7% average every year.

Result of this research support some previous research, i.e. Tahir et al. (2010) stated that a positive and significant firm culture influence knowledge management (pp1033-1034). Chen (2007) defined that a positive relationship between knowledge management and firm performance (pp260). Aluko (2003) stated that a positive relationship between firm culture and performance (pp176-177).

5. Conclusion

The objectives of research are to develop model and to demonstrate knowledge management, culture and performance of construction firm by using system dynamics. By employing the system dynamic simulation tools, diagrams illustrating causal loops and stock and flows have been presented with the intention to demonstrate the different variables and how they affect each other. The model suggested in this research demonstrates the relationships between knowledge management, culture and performance can give improvement. It can be seen from results of employee (staff) skill is growth up 7%, knowledge base is growth up 7% and costumer base is growth up 200%.

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Vegetative (Green) roofs in urban areas for the improvement of the outdoor and indoor comfort

Maeva Sabre[1], Rémi Bouchié[2], Assaad Zoughaib[3]

ABSTRACT

The need for cooling buildings for the comfort of inhabitants has an impact on urban heat island phenomenon and also on the energy consumption of buildings. Vegetation can be considered as a renewable heat sink for cooling purposes. Vegetative (Green) roofs have always been presented as an efficient solution to reduce the energy consumption. But few experimental studies exist, too limited and too specific. The energy saving by Vegetative (Green) roofs has to be assessed for implementation in the French building thermal rule (RT2012). Because Vegetative (Green) roof is part of the building envelope, its capacity to dissipate energy through evapotranspiration can be a solution especially during summer season and heat waves, in association with watering devices. The assessment of the evapotranspiration due to Vegetative (Green) roofs is important for the evaluation of the latent heat flux, part of the surface energy balance that influences the urban microclimate. Experimental studies have been conducted in order to assess the actual evapotranspiration of several Vegetative (Green) roof platforms and to propose a simplified model for the thermal rule. This paper presents reserved results. On the one hand, it confirms the importance of vegetation as a very promising approach. The thickness and the vegetation type improve the evapotranspiration of Vegetative (Green) roofs. On the other hand, at the building scale, it seems that other parameters are more influential on the cooling consumption, e.g., glass surfaces. But in both cases the water supply is important.

Keywords: Vegetative (Green) roofs, Urban Heat Island, Thermal Performance, Field measurements, France.

1. Introduction

The concentration and expansion of urbanized areas induce the Urban Heat Island (UHI) phenomenon. It occurs mainly during summer periods, increases air temperature on urban areas and could generate increased energy consumption due to air conditioning requirements, and hence, could also contribute to global warming. To achieve this objective,

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a solution could be reflecting solar radiation by using high reflective roofs known as “cool roofs” which can reduce heat flux through to roof in summer. Authors' show that the efficiency of these cool roofs decreases when the roof is insulated (Desjarlais et *al*., 2007). Vegetative (Green) roofs in urban areas could be an opportunity to reduce the UHI effects by increasing the evapotranspiration of water (Mentes et *al.*, 2006; Dimoudi and Nikolopoulou, 2003; Wong et *al.*, 2003; Bass et *al.*, 2002; Rosenfeld et *al.*, 1998; Von Stülpnagel et *al.*, 1990). Indeed, Vegetative (Green) roofs allow a reduction of the surface temperature amplitude with the modification of the surface albedo (Susca et *al.*, 2011; Akbari and Konopacki, 2005). Moreover, Vegetative (Green) roofs can also enhance the insulation in the buildings, and act as an efficient barrier against solar radiation permitting to reduce energy consumption from air conditioning and improve thermal comfort (Alexandri, 2007; Lazzarin et al, 2005; Niachou et al, 2001; Zinzi and Agnoli, 2011, Liu et al, 2003).

Many authors pointed out that vegetation contributes to the reduction of the outflow volumes at the annual scale due to evapotranspiration (Gregoire and Clausen, 2011; Palla et al. 2010; Stovin 2010; Bengtsson 2005, Köehler 2005). Only a few studies quantified the actual evapotranspiration (AET) by experimental measurements (Gregoire and Clausen, 2011; MacIvor and Lundholm, 2011). Few studies calculate the AET from numerical modeling (Metselaar, 2012; Hilten et al., 2008). Temperature reductions at the Vegetative (Green) roof surface compared to classical roof were shown in many studies (Jaffal et al., 2012; Susca et al., 2011; Teemusk and Mander, 2009; DeNardo et al., 2005; Wong et al., 2003). The main purpose of this study is to quantify and qualify the evapotranspiration with experiments.

Since the publication of the 2000 thermal French rule (RT2000), Vegetative (Green) roofs have been presented as an efficient solution to reduce the energy consumption but neither experiments nor models have been proposed to support this. To assess thermal behavior of Vegetative (Green) roofs in the new RT2012 French thermal rule, an experiment has been done to quantify and qualify those solar thermal fluxes through roofs.

2. Material and methods

2.1 Experimental Vegetative (Green) roofs structure

2.1.1 Nantes experiment

Six experimental Vegetative (Green) roofs (see Table 1) with overall dimensions of 1500 mm x 1500 mm were constructed by CSTB (Nantes, France). All platforms were built on wooden support and protective paint coating was used. Experimental roofs were constructed by following the French rules in roof construction. The wood support was recovered with a commercial bituminous vapour barrier (5 mm). The insulation layer was made using polystyrene blocks of 60 mm high. PVC membrane of 5 mm high was used for waterproofing. The discharge outlet was done with a PVC tube of 30 mm diameter placed at one corner of the roof platform (120 mm from the borders).

Table 1: Experimental roofs in Nantes

Roof number	Media thick (mm)	Vegetation
1	80	No
2	120	No
3	80	Sedum *album*
4	120	Sedum *album*
5	120	Festuca *glauca*
6	120	Dianthus *deltoïdes*

Experimental roofs were placed on a path with a slope of 1.5° at CSTB site in Nantes, France (see Figure 1). A meteorological (weather) station (MET) records the air temperature, the relative humidity of air, atmospheric air pressure, global and net radiation, wind speed and its direction at one minute frequency (see Figure 2) and at the same time to characterize the rainfall, a rain gauge and a Parcivel Disdrometre are also installed. All mean data are recorded every 10 minutes on a data logger (CR3000, Campbell Scientifics).

Commercial extensive Vegetative (Green) roof media were used (Star Forges, France). The growing media was composed of 70% minerals materials and 30% organic matter. The minerals were a mixture of pumice stones of 3/20 mm calibrate, Pozzolana of 3/7 and 7/15 mm calibrates. The organic matters contained composted bark of maritime pine, black peat with 3/20 mm calibrate and blond peat with 3/20 mm.

The plants commonly used in Vegetative (Green) roof are variety of succulent plants. Their metabolisms allow the plants to be more resistant in dry period. As a result, they are the most appropriate for Vegetative (Green) roofs (Emilsson, 2008). The CRITT Horticole, a French association which is helping the research and development of Vegetative (Green) roofs in France has tested several plants in a roof environment. Three species of plants have been selected with its help. The first plant variety is *Sedum album*. The second variety of selected plants is *Festuca glauca*. Both varieties are commonly used in Vegetative (Green) roofs. The third variety of plants is *Dianthus deltoids*. This species has never been used for Vegetative (Green) roofs; it's a perennial plant, aesthetically interesting with a large flowering period from June to September.



Figure 1: Experimental Vegetative (Green) roofs in Nantes, France.



Figure 2: Meteorological station in CSTB Nantes, France.

Rainfall flowing from experimental roofs is discharged to a tipping bucket mechanism. Two temperatures probes are placed in the middle and on the surface of the growing media. Four water content probes (Figure 3), based on domain frequency response are used for estimating volumetric water content inside the growing media.

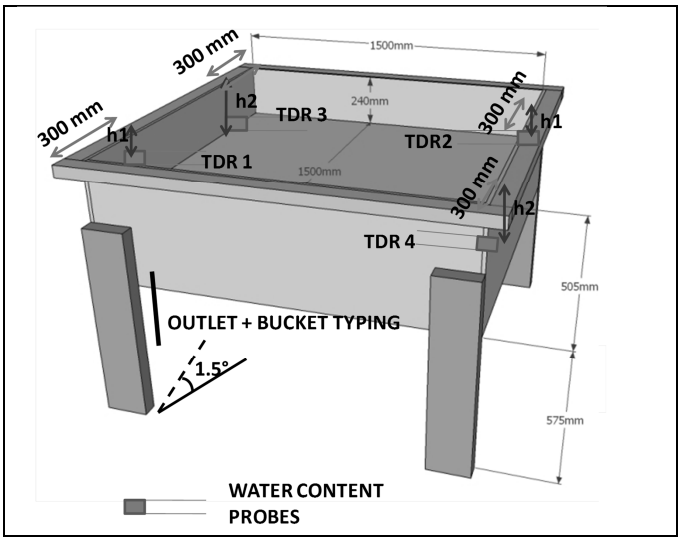

Figure 3: CS616 water content probes location.

The water volumetric probes are calibrated using the method of Rüdiger et al. (2010). The average volumetric water content is calculated from the average value of four probes.

2.1.2 Champs/Marne experiment

The main objective was to study the thermal fluxes through the roofs, with and without Vegetative (Green) roof configuration during summer season to determine energy consumption. For that, three platforms (2000x2000mm) representing different Vegetative (Green) roofs were built: a semi-intensive (A) and an extensive (B) Vegetative (Green) roof with a concrete structure (heavy roof) and an extensive Vegetative (Green) roof (E) with a steel structure (light roof) plus two reference platforms without Vegetative (Green) roof configuration, one with a steel structure (D) and the other with a concrete structure (C) (see Figure 4). The different layers are described in Figure 5.

With theses thermal fluxes through the roofs, all boundary conditions are measured, such as external temperature, solar flux and rain, in order to validate a thermal model which has been developed.



Figure 4: Experimental Vegetative (Green) roofs in Champs/Marne, France.

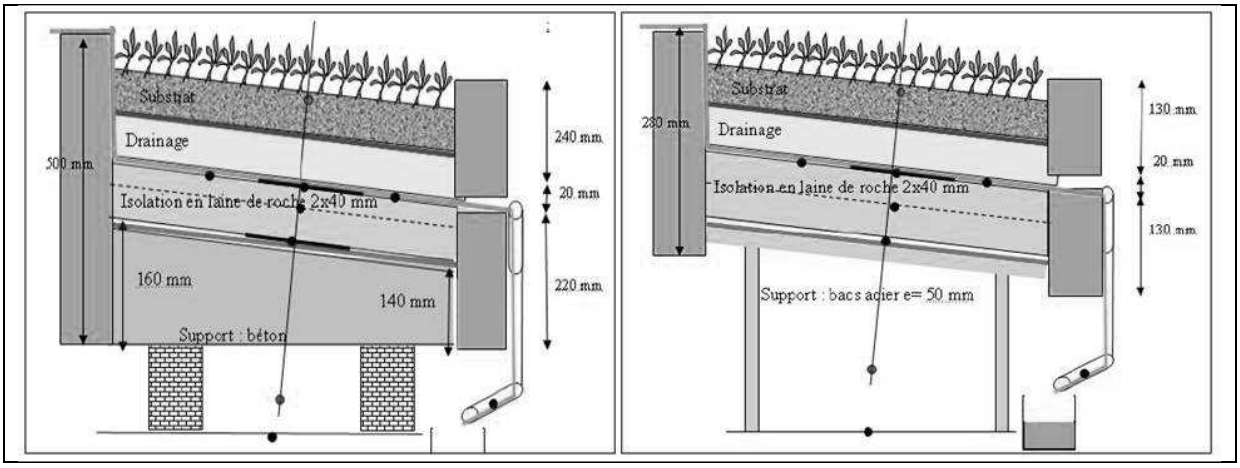

Figure 5: Scheme of experimental Vegetative (Green) roofs in Champs/Marne, France (left: semi-extensive with heavy structure; right: extensive with light structure).

2.2 Evapotranspiration calculation

Actual Evapotranspiration (AET) in mm was calculated from daily water balance through the following equation:

$$\boldsymbol{AET = P - R - L.\Delta\theta.\rho_b/\rho_w} \qquad (1)$$

where P is the daily cumulated precipitation (mm), R is the daily cumulated runoff (mm), L is the thickness of the growing media (mm), ρ_b and ρ_w are respectively the bulk density of the growing media and the mean density of water (g.cm^{-3}) and $\Delta\theta$ is the daily variation of volumetric water content (-). Cumulated AET (CumAET) for the monitoring period corresponds to the sum of daily cumulated runoff.

The evapotranspiration (ET) is calculated from hourly energy balance using the Penman-Monteith equation (it needs a relatively large number of input parameters, which is inconvenient in many applications):

$$ET = \frac{1}{\lambda}\frac{\Delta(R_n - G) + \rho_a c_p \frac{(e_s - e_a)}{r_a}}{\Delta + \gamma\left(1 + \frac{r_s}{r_a}\right)} \qquad (2)$$

where Δ (kPa.°C^{-1}) is Clausius-Clapeyron relation, R_n (MJ.m^{-2}.h^{-1}) is the net radiation, G (MJ.m^{-2}.h^{-1}) is the sensible heat flux into the soil, ρ_a (kg.m^{-3}) is the mean air density at constant pressure, c_p (MJ.kg^{-1}.°C^{-1}) is the specific heat of the air, e_s and e_a (kPa) are respectively the saturation and actual vapour pressure of the air, r_a (s.m^{-1}) is the aerodynamic resistance, r_s (s.m^{-1}) is the bulk surface resistance, γ (kPa.°C^{-1}) is the

psychometric constant and λ (MJ.kg^{-1}) is the latent heat of vaporization. The daily ET is the sum of hourly ET.

All the parameters needed for the calculation have been directly measured where possible or from the literature. The hydrological performance of experimental roofs is analyzed with regards to the variables affecting Vegetative (Green) roof behaviour, including: media type, growing media thickness, presence of vegetation cover, vegetation type, evolution of the vegetation cover and category of rain.

2.3 The French thermal rule for building code

The French thermal regulation (RT 2012) is based on a simplified RC thermal modelling described in the European standard EN 13790. In this model, opaque building components are described with two parameters: its thermal transmission coefficient Up (W/m².K)) and its solar factor Sp (-). The thermal transmission represents the insulation ability of the component and is important to avoid thermal loss in winter conditions. The solar factor represent the ability of the component to transmit solar flux into the building: the solar factor is the ratio between thermal flux going through the component and solar incident flux, with the same ambient temperature on both sides of the component.

For opaque components, the solar factor can be deducted from the following equation:

$$S_p = \alpha_e \frac{U_p}{h_e} \quad (3)$$

where α_e is the absorption coefficient of the external side of the component, strongly linked to their colour (the whiter the colour is, the lower α_e is), h_e is the thermal superficial transfer coefficient of the external side, linked with wind speed and thermal emissivity and Up is the thermal transmission coefficient.

This formula does not consider evapotranspiration aspect and the goal is to correct it for Vegetative (Green) roofs applications.

3. Results

3.1.1 Hydrological performances

The results for Nantes experiment presented here correspond to the period from 1st July 2011 to 30th September 2011. The monthly mean temperature, rain, relative humidity, wind

speed and net radiation for 2011 summer period are shown in Table 2. The characteristics of the rain during the study period are illustrated in Figure 6.

Table 2: Experimental roofs in Nantes

2011	July	Aug	Sept
T(°C)	18.0	18.5	17.6
Rain (mm)	70	125	43
Hr (%)	68	75	77
U (m/s)	1.9	1.6	1.5
Rn (W/m²)	358	367	356

The daily mean temperature for the studied period was 18.1 ± 2.2 °C. The maximum temperature recorded was 30.9 °C and the minimum was 7.2 °C over this summer season. The cumulated rainfall amount was 238 mm for the same period. In comparison from July to September, for Nantes from 1971 to 2000, the mean air temperature was 18.5 °C and mean cumulated rainfall was 156 mm (Meteo France, 2009). The measured air temperatures are consistent, but the amount of precipitation is higher in comparison to the previous years. Rain events are considered when rain intensity is higher than 0.2 mm/h and the end of a rain event is considered when no rain is recorded after one hour. A total of 62 rain events were recorded during this period – 35 events were classified as light (<2 mm), 16 as medium (2-6 mm) and 11 as heavy (>6 mm) rain events.

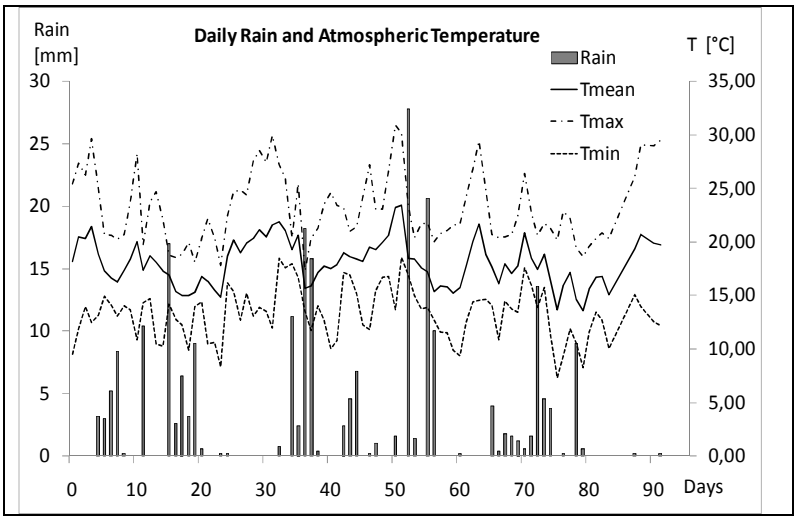

Figure 6: Daily precipitation (mm), mean, max, min daily temperatures (°C) (day 0 = July 1st 2011; day 92= September 30th 2011) from the MET station of the CSTB site.

Cumulated AET calculated from water balance (equation 1) is shown in Table 3.

Table 3: Cumulated AET in Nantes

Roof number	Cumulated AET (mm)
1	115*
2	160
3	180
4	203
5	202
6	216

**The tipping bucket mechanism of roof n°1 started recording data from the 30th July 2011. This explains the lower value for AET of roof n°1 in comparison with the others roofs.*

CumAET from roofs with bare surface (roof n°1 and n°2) is lower than those of roofs with vegetation cover (roof n°3 vs. 4). This is mainly due to the benefits of transpiration of the vegetation. Roofs with greater thickness of growing media have higher values of CumAET (roof 3 vs. 4, 5 and 6). The vegetation specie also has an impact on the value of CumAET. In this case, CumAET for *Dianthus deltoïdes* (roof n°6) is higher than the ones of *Sedum album* or *Festuca glauca* (roof n° 4 and n°5, respectively).

Reference ETo for grass and crop ETc for Sedum roof n°4 were calculated through equation 2. The correlation between ETo and ETc defines the crop coefficient K_c for sedum as estimated to 0.71 ($K_c = ETc/ETo$). Cumulated ETo and ETc are respectively 324 mm and 232 mm.

3.1.2 Thermal performances

The results for Champs experiment presented here correspond to two months – August and September 2009. Compared to the bare surface platform, the main result is a significant decrease of the fluxes through the Vegetative (Green) roofs, when they are wet. As an example, see below (Figure 7) the incident solar flux and the thermal flux through the light structure, with and without extensive vegetation.

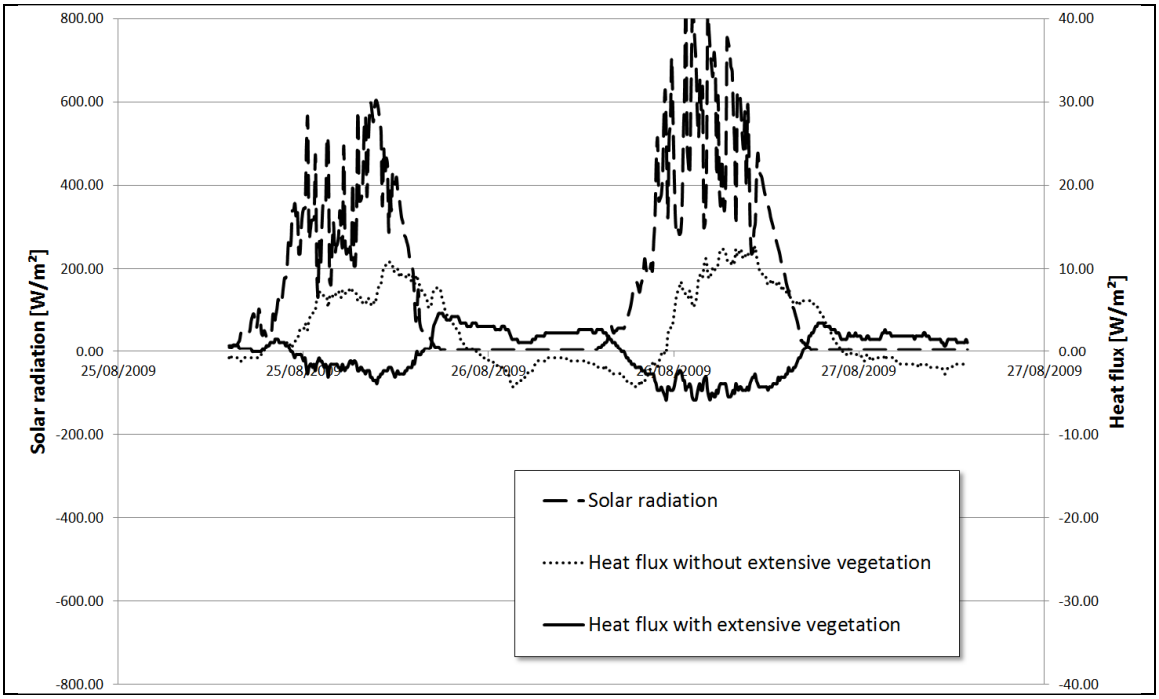

Figure 7: Platforms D and E radiation and fluxes form 25-27 of august 2009.

A thermal model was developed and validated with these experiments (Besbes et al, 2012). Using this model, influent parameters has been shown. A wet Vegetative (Green) roof can absorb a large amount of solar incident flux by evapotranspiration. When the Vegetative (Green) roof is dry, the solar incident flux is not absorbed but is limited by the mask effect of the plants. In all cases, thermal insulation of the roof is important to limit thermal flux through the component. A simple formula has been validated to describe the solar factor of a Vegetative (Green) roof:

$$S_{p,GR} = \alpha_{e,GR} \frac{U_p}{h_e} \cdot (100 - \Delta t_{wet}) \qquad (4)$$

where $\alpha_{e,GR}$ is the equivalent absorption coefficient which has been assessed by simulation, and Δt_{wet} is the percentage of time during which the Vegetative (Green) roof is wet in summer season, assessed by simulation and for the French meteorological climates.

This solar factor has been used then to simulate the summer thermal behaviour of an entire building. Despite a strong ability to limit solar flux transmission through the roof, the effect of the Vegetative (Green) roof on the global energy consumption of the building is quite limited. A lot of parameters have more influences on the thermal behaviour and energy consumption of an entire building, such as:

- Numbers of windows: solar factors of windows are higher than solar factors of opaque components

- Insulation of the building: the effect of Vegetative (Green) roofs will be lower on well insulated buildings

- Surface ratio between roof and other walls: for a collective dwelling, the thermal effect of the Vegetative (Green) roof will be efficient only for the last floor

- Climate: if the limitation of solar flux transmission provided by Vegetative (Green) roofs reduces energy consumption for cooling in summer, it increases the energy consumption for heating in winter and a Vegetative (Green) roof could has no effect on annual energy consumption in cold climate.

4. Conclusion

These studies point out the role of Vegetative (Green) roofs with regards to their hydrological and energy mitigation performance. However, using Vegetative (Green) roofs with a very low growing media thickness is debatable because it could prevent satisfactory vegetation growth. Another point concerns the maintenance of those systems, because well-maintained vegetation seems to be necessary to ensure steady storm water mitigation and to keep high evapotranspiration rates for better performances. The requirement of watering or irrigation seems to be mandatory, which may decrease their global environmental benefits (unless grey water is used).

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Acknowledgements

This study was conducted thanks to the support of the VegDUD project, partially funded by the French National Agency for Research, and to the support of two French Institutes (ADEME and DHUP) and a French manufacturer association (the ADIVET).

The Euro Crisis and the German Construction Industry

Horst Brezinski[1], Katrin Brömer[2]

Abstract

The international financial crisis of 2007/2008 led to a drop of the key interest rate, set by the European Central Bank, from 4.25 % in 2008 to 1.0 % in 2009. Due to the Euro crisis, which followed the international financial crisis, the European key interest rate was lowered even further to 0.75 % in June 2012. These actions were taken to revive the European economy and to assist the struggling states and financial institutions. This led to an enormous increase in the liquidity of banks and a growth in the quantity of money, which ultimately led to increasing expectations about the future inflationary process. Following the traditional transmission mechanism of an increase in the quantity of money, the impact on the construction industry was not astonishing. Residential construction activities in Germany increased – a so-called "escape into concrete gold".

This effect can be considered an indirectly financed stimulus program for the German construction industry. Whether it can only be observed in Germany or also in the other financially stable EU economies will be investigated in this paper. Moreover, the structural effects on the German construction industry will be examined. Finally, it will be analyzed, whether the construction industry can be considered a winner of the Euro crisis or not.

Keywords: construction industry, Germany, Euro crisis, residential construction, monetary policy

1. Introduction

Beyond others, two major factors caused the crisis of 2007: rising house prices due to an expansive monetary policy leading to low interest rates in the U.S. and a failure in the governance of banks worldwide causing a housing price bubble. There have been several price bubbles in the US housing market in the last decades (see Reinhart and Rogoff, 2009) yet this bubble with a dramatic increase in housing prices happened to be the largest in the history of the United States. The Case-Shiller Index pictures the changes in the price level of the U.S. Housing Market (see Figure 1).

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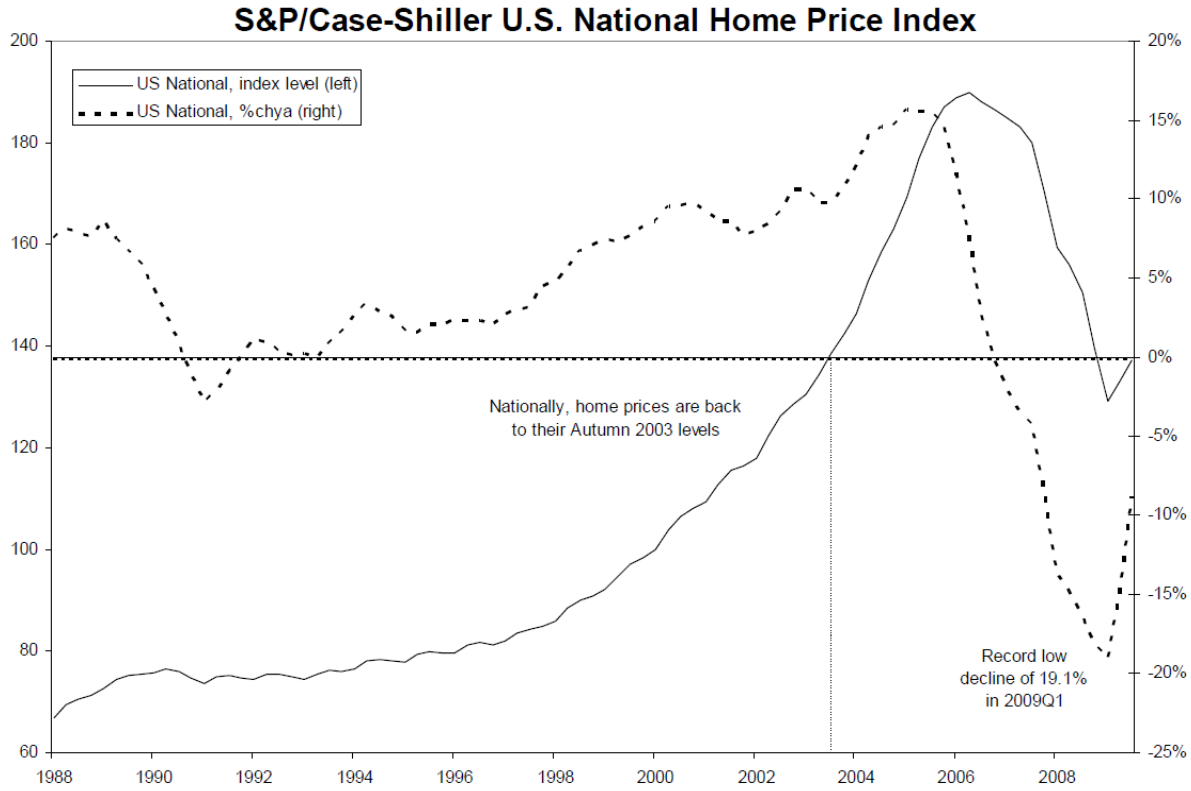

Figure 1 Development of the S&P/Case-Shiller U.S. National Home Price Index from 1988 to 2009 (Standard & Poor's, 2009, p. 2)

The so called subprime-crisis has triggered the Euro crisis which is having large impacts on the European economies. The European Central Bank (ECB) reacted on the crisis by lowering the already low interest rates even further.

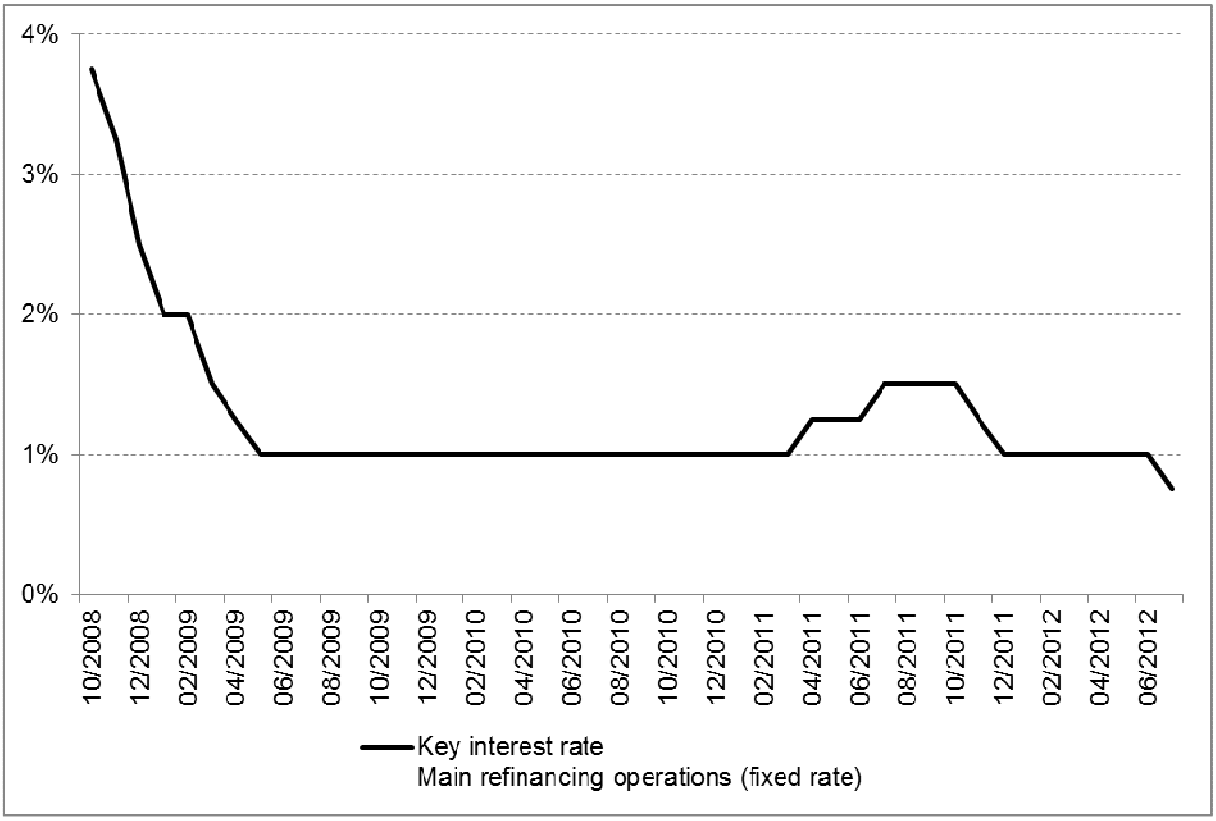

Figure 2 Development of the key interest rate (Main refinancing operations) from 2008 to 2012 (European Central Bank, 2012)

The European Key Interest rate has never been higher than 4.75 % (as for main refinancing operations). Between 2008 and 2009 it has been lowered from over 4 % to 1 %. The first signs of recovery triggered the ECB to slowly higher interest rates in order to prevent inflation. As it became apparent that the Euro crisis was significantly more serious, the interest rates were lowered again to nowadays a mere 0.75 %.

While many European countries struggle with the crisis, in some European countries the historically low interest rates were of interest for individuals especially when lending money. Combined with the fear of inflation a so-called “escape into concrete gold” or into other material assets such as gold began pushing the residential construction sector amongst others. The demand for private housing, especially condominiums in metropolitan areas, in economically stable countries like Germany rose (see Dorffmeister, 2012a, p.42).

Following the two governmental stimulus programs in the years 2008 and 2009 (see Brezinski and Brömer, 2012) the situation described above can be considered an indirectly financed stimulus program for the German construction industry. In contrast to Germany, not all European countries of the Euro-zone are benefitting from the crisis.

2. The effects of the Crisis on the German construction sectors

The subprime-crisis developed from a US-crisis into a world economic crisis followed by a Euro crisis which did not spare out the German construction sector. Yet, as the general construction business cycle is known as lagging behind by about one year compared to the

business cycle of the overall economy and due to the stimulus programs which the German government implemented, the downward effects were not as drastic as in other industries.

Split up into the three sectors - residential construction, commercial construction and public construction - Figure 3 shows the development of the construction investments in Germany from 2005 to 2011.

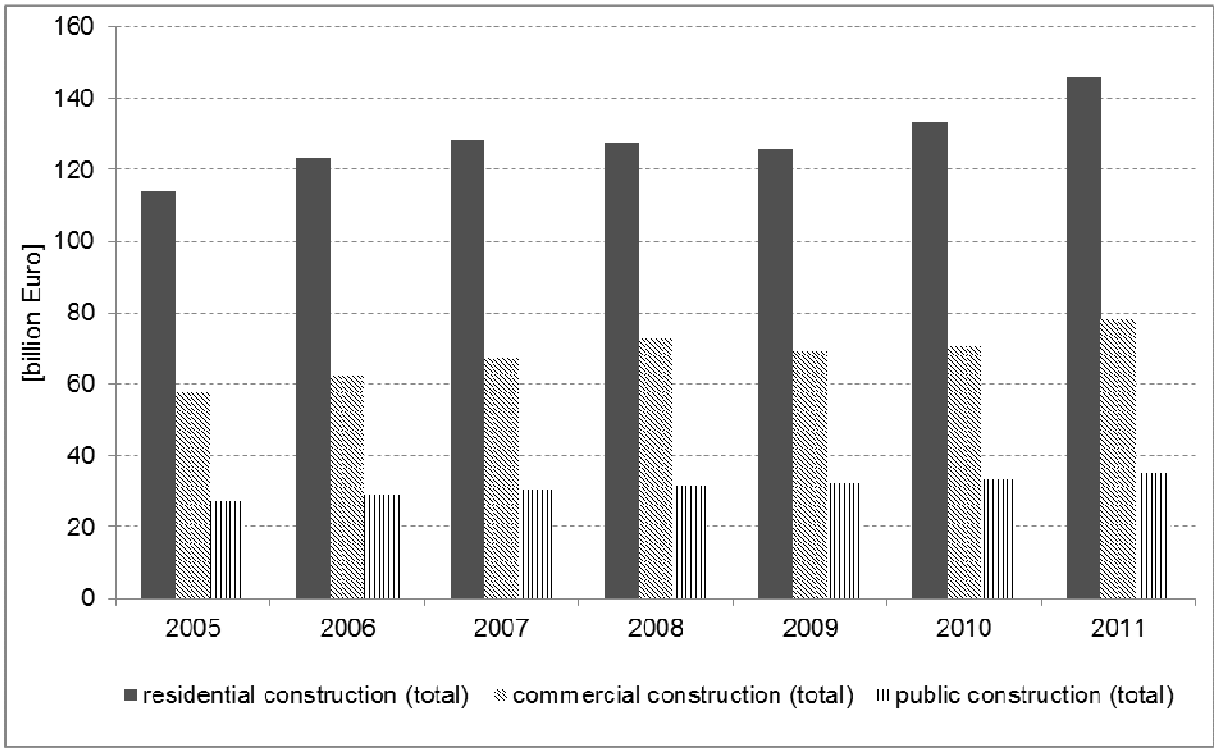

Figure 3 Construction investments of the sectors residential, commercial and public construction in nominal prices (Statistisches Bundesamt, 2012)

Residential construction investments are made mostly by private individuals. Public residential construction constitutes only an insignificant share in governmental expenditures. It becomes obvious that residential construction investments contribute the largest part to the total construction investments (see Figure 3). Generally rising from 2005 on, the sector showed a slight decrease of investments in 2009, followed by large increases in the years 2010 and 2011. Quarterly figures for the first half of 2012 show a further growth of residential construction investments.

Commercial construction had a negative growth in 2009 and recovered slowly in 2010. In 2011 the investments of companies in construction climbed up to the highest value of the last ten years.

Public investments include all areas of civil engineering and public housing. However, government investments for residential purposes have been very low compared to the public construction in total, hardly exceeding 2 % of the overall public construction investments in the last decade. Public construction investments in total have been rising during the crisis due to the large stimulus programs which still positively affect the 2011 numbers.

A more detailed picture can be drawn from the changes in the total order value (see Figure 4). The demand for residential construction has been fairly constant until 2009. Since then, the order value is booming. A boom can also be seen in commercial construction whereas public construction has been decreasing since that year.

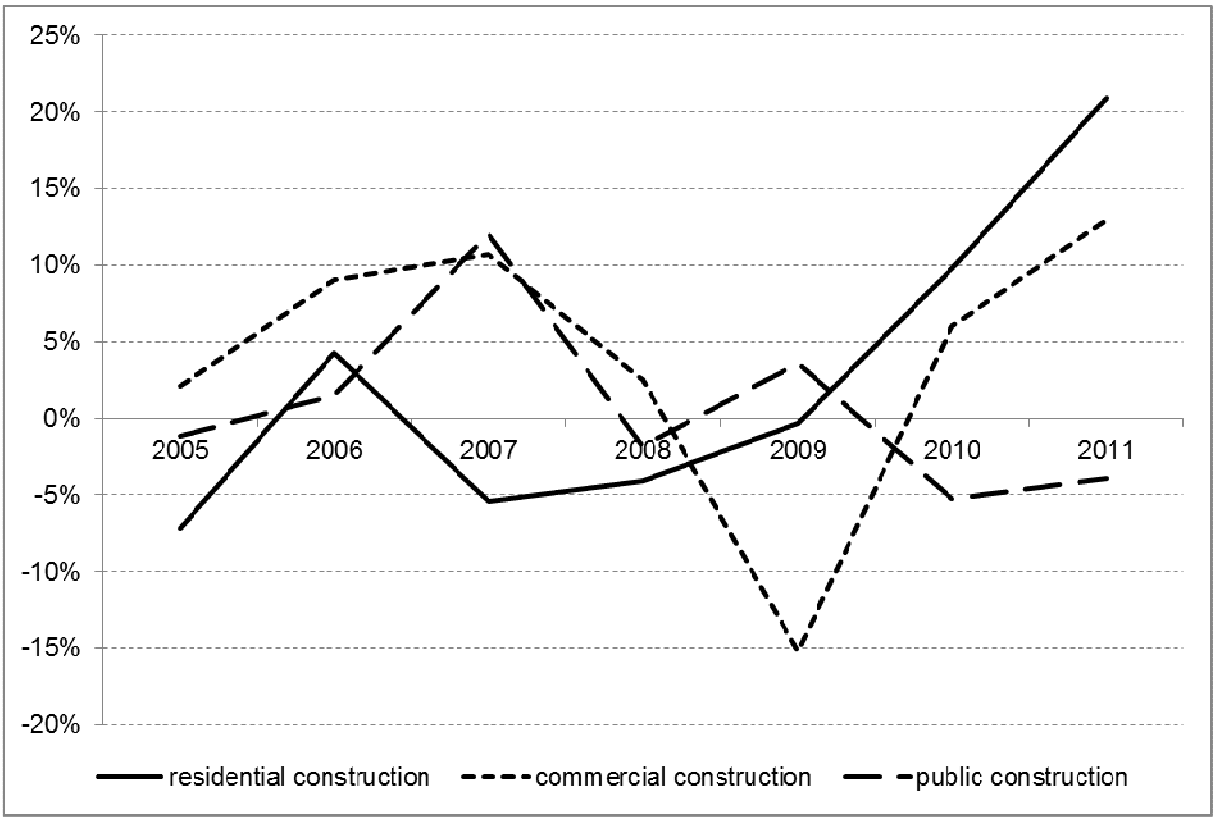

Figure 4 changes in total order value (main construction industry, companies with 20 or more employees) of the sectors residential, commercial and public construction (Database ELVIRA)

Overall, the two sectors, residential and commercial construction, have been affected by the crisis, especially in 2009. Yet, looking at the investments, all three sectors show a rising trend from 2010 on whereas the order value of public construction is already decreasing from 2009 on due to the end of the stimulus programs. Particularly residential construction made a large saltus upwards whereas public construction is expected to fall in the future due to the phase-out of the stimulus programs. There may be a tendency in the future that construction companies allocate their resources to meet predominantly the increased private demand.

3. Residential Construction in Germany

After the German reunification the construction sector experienced a large increase in demand as the East German housing and infrastructure were poor and ailing. In 1995, saturation was reached and the residential construction investments stayed at a stable level until 1999. Since then (see Figure 5), investments decreased by more than 20 % within 5 years. The short upswing in 2006 was then once more followed by a decrease causing a

backlog for housing in the country. From 2009 on, residential construction is developing very positively.

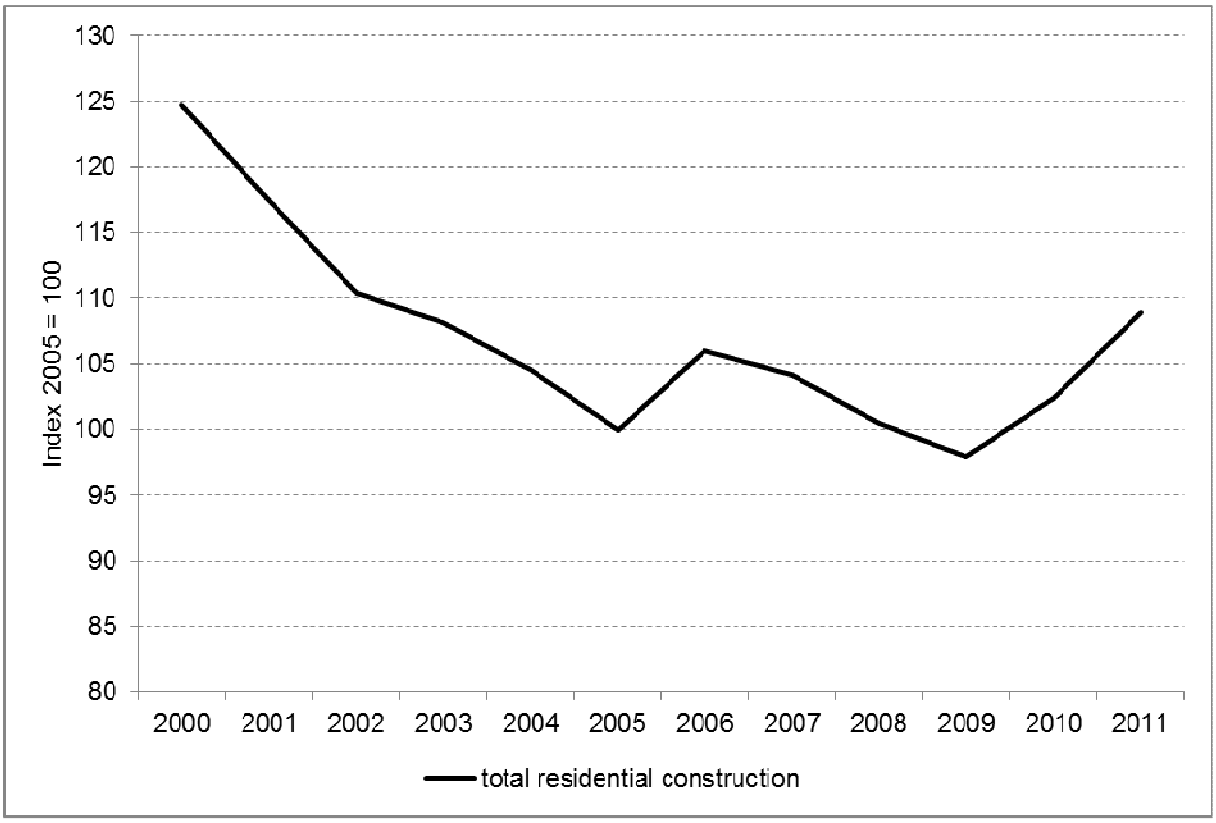

Figure 5 Total residential construction investments in Germany (chained index, 2005 = 100) (Statistisches Bundesamt, 2012)

Apart from the revival of demand for newly built houses and condominiums, the real estate market is also prosperous in Germany. As for construction work, the demand is not equally distributed over the country, but rather focussed on metropolitan areas (Bundesinstitut für Bau, Stadt- und Raumforschung, 2012). In Germany, a large private rental market exists apart from social housing provided by the state so that generally there is no urgent need in building own houses. Furthermore, the German tax system does not advantage private residential construction continuously, even though there have been temporary privileges in the past. In contrast, property taxes exist as well as high transaction costs. Even though the German house prices seem to be more stable than in other countries due to institutional differences (see Muellbauer, 1994, p. 246) and other factors (for more detail, see Kholodilin et al., 2008), house prices have been rising within the last months due to the large demand.

In general, the development of real estate prices depends on the rising of the real disposable per-capita income, the population growth, the long-term real interest rate, the degree of urbanization (Kholodilin et al., 2008) and real income expectations. In Germany, the population growth is negative, the average economic growth is slow compared to other nations and the real estate credit market is relatively non-elastic – all factors, that slow down the rise of real estate prices.

The increase in demand for newly built houses and existing property accompanied by rising real estate prices in metropolitan areas raises the question if a new housing bubble builds up in Germany. According to Kholodilin (2012) there is a threat of a speculative housing bubble looking at the real estate market e.g. in Berlin, but as of today, no housing bubble exists (similar options are shared by Bundesinstitut für Bau, Stadt-und Raumforschung, 2012 and others).

4. Residential construction in other European countries

Generally speaking, there are different factors influencing the residential construction sector: available and expected real income, financing conditions, the situation on the labour market, demographical effects, housing prices and others (see Dorffmeister, 2012a, p. 43).

The Euro crisis had large negative effects on the European construction sector, especially residential construction. Amongst others, many South European countries, especially Spain, suffered from the dramatic drops in residential construction sector, due to a bursting housing bubble which had its peak during the residential construction boom in 2007. Private households in these financially strongly hit countries refuse to make large property investments due to uncertain economic developments or simply because of lacking financial possibilities. Vacancies and decrease of prices for real estate burden the situation even further.

In contrast, some North and Central European countries find themselves in a totally different situation. Economically stable and financially solid countries such as Norway, Finland, Poland, Switzerland and Germany might be seen as winners of the crisis (Dorffmeister, 2012a). Not just private households invest their money within their home countries, e.g. in “concrete gold”. Moreover, foreign capital investors transfer their money from South Europe to stable Central and North European countries. Due to the fear of inflation, investments in material assets like construction and real estate are favored.

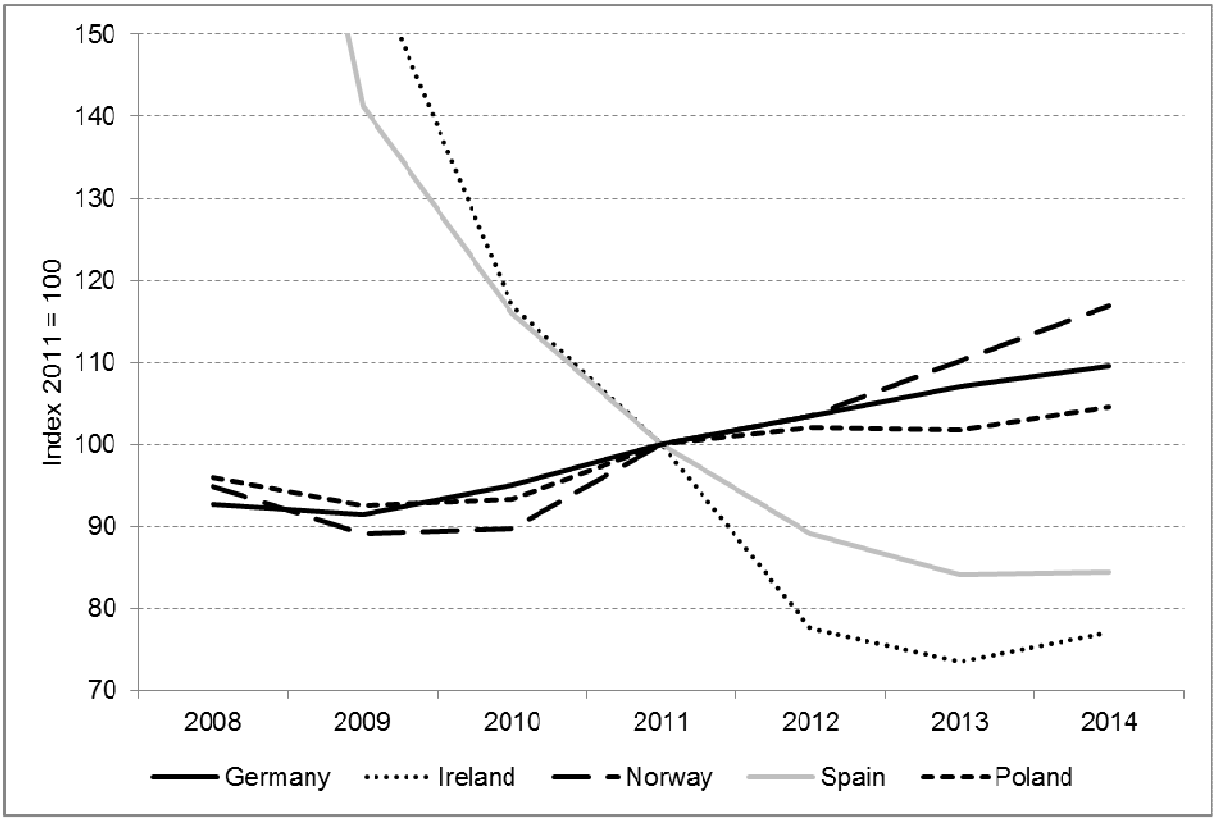

Figure 6 Development of residential construction volume in selected European Countries (Index 2011 = 100, prices of 2011) (Euroconstruct, June 2012)

Figure 6 shows the development of the residential construction volume for selected European countries until 2010 and the estimates by Euroconstruct for the next years. Ahead of the crisis, Spain and Ireland had high construction volumes in the residential construction sector, resulting in housing bubbles which busted in 2007/8. As for the future, Spain and Ireland are expected to need another couple of years to reach a steady, yet much lower level in the residential construction sector.

The residential construction sector of Germany, Norway and Poland only had minor decreases during the crisis. From 2010 on, this sector in all three nations increased in prosperity and is expected to keep rising or stabilizing respectively within the next years. The initial situation of these countries was different from those in Spain or Ireland. The European residential construction boom (see Dorffmeister and Gluch, 2011a, p. 37) which ended in 2007 was stimulated by a prosperous economy, high inflation rates, low interest rates, rising housing prices and easy credit initiation. It did not spread equally over Europe – south European countries were particularly affected whereas the situation in e.g. Germany was much more retained. The German residential construction sector was not overheated compared to e.g. Spain: more than one third of the 1.5 million newly build condominiums in 2007 were built in Spain (see Gluch and Dorffmeister, 2011, p. 28). Instead, a backlog in housing construction exists in Germany due to the long recession in the sector after the German reunification.

How long the period of recovery of the European construction sector will be, cannot be predicted as it is dependent on the development of the public debt crisis. According to

estimations of the Euroconstruct summer conference, it might take another couple of years until the European economy returns to growth (see Dorffmeister, 2012b, p. 35). In times of austerity measures resulting in cuts of wages, subsidies and investments, only particular branches might recover.

5. Conclusion

The Euro crisis which followed the global financial and economic crisis had large effects on the construction industries in many European countries. The different impacts on the German construction sector, in particular the residential construction sector, were investigated in this paper. Furthermore, the situation in other European countries was considered as well.

The overall German construction industry has been affected by the crisis, especially in 2009 except for the public construction sector, which profited from the government's stimulus programs. However, the declines of investments and order values were not as drastic as in other countries and recovery began in 2009 already. Although public construction investments are expected to decrease in the future, particularly residential construction has made a large saltus upwards and is expected to rise even further. The positive development in Germany might be due to the long recession, which the residential construction sector went through in the last decade. So far, a new housing price bubble in Germany has not been predicted.

Even though the basic conditions such as interest rates in Europe were the same at the beginning of the crisis, the initial situation in each country was different. The starting point of the international financial crisis was also the end of a European residential construction boom which on the contrary did not capture all countries. The residential construction sector developed very differently in the various European countries. In some North and Central European nations with economic and financial stability e.g. Germany, Poland or Norway, the sector had the possibility to profit from the crisis. In these countries, the fear of inflation is worse than the expectation of lower incomes whereas negative income expectations are the main reason for the downward development in many south European countries, but also Ireland for example, which have experienced a deep recession in the residential construction sector.

The scope of this paper only allows a short insight to the development of the German construction industry, particularly residential construction. Further research should be done in order to econometrically demonstrate the relations between the different factors relating the Euro crisis and the construction sectors.

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Hanger bolts and solar fasteners in sandwich panels

Helmut Krüger[1], Thomas Ummenhofer[2], Daniel C. Ruff[3]

Abstract

For the energetic use of sunlit roofs, photovoltaic and solar thermal elements are mounted using different fastening systems on existing roof surfaces. For the installation on trapezoidal profiles or sandwich panels, hanger bolts and solar fasteners belong to the most prevalent fastening systems. For the structural analysis of these systems, however, only insufficient design approaches are available until up to date. Especially for the application on roofs covered with sandwich panels no design criteria is available at the present. The introduction of roof parallel loads from roof shear, wind and snow into the substructure can be specified as pressing problem. Within the scope of a research project sponsored by the DIBt (German Institute for Building Technology) design criteria for hanger bolts and solar fasteners in sandwich panels with a plastic foam core were developed. When roof parallel forces are applied to the fastener the fastener is supported by the sandwich panels' surface sheet. For that reason the load bearing capacity of thin steel sheets with a thickness from 0.38 mm to 0.56 mm for different diameters of hanger bolts or solar fasteners is determined. Beside the local hole load bearing capacity of the sandwich panel the load bearing capacity of the whole upper flange is from major interest. Performed tests show that an overloading of the upper flange results in cracks in the core material combined with a separation of the core material and the surface sheet. Because of the various designs and materials of sandwich panels the definition of a universal load bearing capacity is not possible. But when respecting some boundary condition relating to the material properties and the shape of the sandwich panel a conservative value of 0.70 kN can be used. Beside the already developed design approaches there are still open questions for further investigations. Among others this includes the mentioned load bearing capacity of the upper flange and the load bearing capacity for cyclic stresses.

Keywords: sandwich panel, hanger bolt, solar fastener

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1. Introduction

Worldwide national governments, companies but also private households get involved in pushing forward the global need for sustainable and regenerative energy production. Therefore hydro-electric power plants, onshore and offshore wind power parks and solar collectors are installed everywhere the boundary conditions are matching. Because of the rapid progress of the development of new systems, sometimes the performance of single components is only analysed insufficiently. Especially the fastening of photovoltaic systems on industrial buildings is rarely investigated up to date. These industrial buildings, often covered with trapezoidal profiles or sandwich panels, provide huge sunlit areas. For the mounting of photovoltaic components hanger bolts and solar fasteners belong to the most prevalent fastening systems. But neither for the use in trapezoidal profiles nor for the use in sandwich panels sufficient design rules are available. Although for trapezoidal profiles some approaches are developed, for sandwich panels no design criteria is available up to now. Especially the introduction of transverse forces into the substructure resulting from roof shear forces, wind and snow can be regarded as a pressing problem. For this purpose the paper at hand deals with newly developed design approaches for determining the load bearing capacity of hanger bolts and solar fasteners in sandwich panels.

Hanger bolts are dowel type fasteners with a metric thread at one end and a threat for metal screws or wood screws at the other end. Usually they are made of stainless steel with a total length from 100 mm up to 400 mm. The diameter varies between 8.0 mm and 12.0 mm. A common hanger bolt with a plain centre is shown in figure 1.

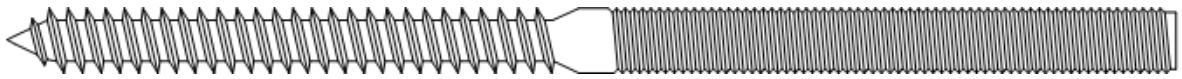

Figure 1: Hanger bolt

Solar fasteners are a further development of hanger bolts especially designed for the application on trapezoidal profiles or sandwich panels. They differ only in an additional hexagon located in between of both threats. This hexagon is, in contrast to a nut, immovable and improves the assembly of the fastener. A common solar fastener is shown in figure 2.

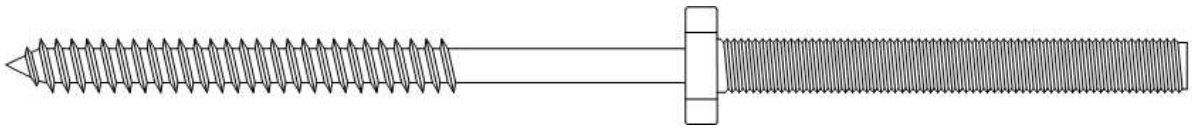

Figure 2: Solar fastener

For installing the fastener on trapezoidal profiles or sandwich panels the surface sheet and the substructure are predrilled first. Subsequently the fastener combined with a sealing is screwed into the substructure. For fixing any kind of installation normally an additional predrilled metal sheet is mounted in the area of the metric thread. A typical situation of installation of a solar fastener in a sandwich panel is shown in figure 3.

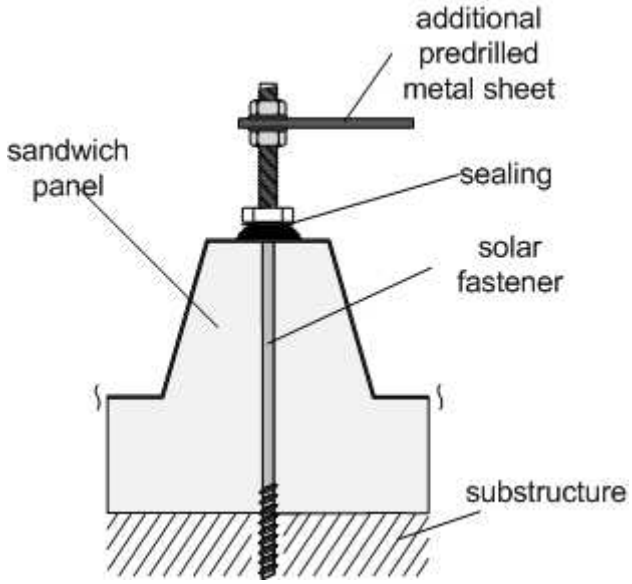

Figure 3: Typical installation situation of a solar fastener in sandwich panels

Beside the load bearing capacity of the fastener itself, the resistance of the sandwich panel is of major interest, because roof parallel forces may cause a crack in the core material or a separation of the surface sheet and core material. That is why the verification procedure for hanger bolts and solar fastener in sandwich panels has to be separated into two sub steps:

- The verification of sufficient load bearing capacity of the fastener. This includes the local hole bearing capacity of the surface sheet of the sandwich panel.
- The verification of sufficient transverse load bearing capacity of the sandwich panel

2. Local load bearing capacity of the fastener

2.1 Mechanical model

For determining the load bearing capacity of hanger bolts and solar fasteners in sandwich panels first a practical simplified mechanical model is required. This model has to include the partially clamping of the fastener inside the substructure and the resilience resistance of the local hole in the sandwich elements' surface sheet. These boundary conditions and the external loads F_E and V_E lead to the mechanical model a shown in figure 4. The external load F_E, representing the dead load of the solar installation and snow load, is normally applied eccentrically. This is taken into account by an additional bending moment M_E. For calculating the resulting support reactions F_b, $F_{a,h}$ and M_a the mechanical properties of the fastener and the spring stiffness C_a and F_b are required. In many situations, especially when using slender shaped fasteners, the influence of the spring C_a is neglect able. This leads to the simplified model b also shown in figure 4. The only unknown component for determining the load bearing capacity, assuming the material properties and the shape of the fastener are known, is the local resistance of the outer surface sheet of the sandwich panel $F_{b,R}$.

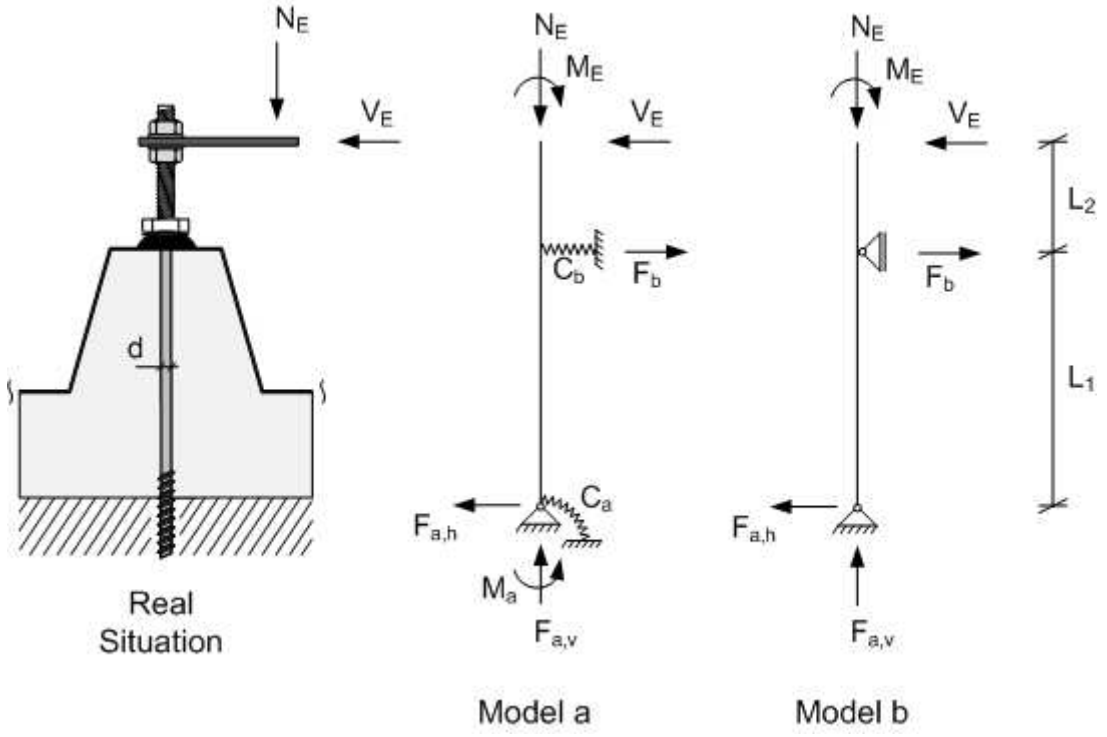

Figure 4: Mechanical model

2.2 Local hole resistance of the sandwich panels' surface sheet

When using model b according to figure 4, the major value for determining the load bearing capacity of the fastener is the local hole resistance $F_{R,b}$ of the sandwich panels' surface sheet. Because this value cannot be calculated, it is determined on the basis of tests performed. The chosen test set up is shown in figure 5. Metal sheets with a size of 120 mm x 120 mm x t were clamped into a circular shaped metal frame with an inner radius of 40 mm. The solar fasteners were screwed into a predrilled hole in the middle of the sheets. The diameter of the hole was similar to the diameter d of the solar fastener (see Fig. 4). The thicknesses of the sheets amounted to 0.38 mm, 0.49 mm or 0.60 mm. The diameter of the solar fastener was determined to 7.0 mm or 9.0 mm. The chosen sizes represent the most common designs for sandwich panels and solar fasteners. During the test, the solar fastener was continuously pushed through the hole until the metal sheet was destroyed. A representative force – deformation – diagram is added to figure 5. During the test, the linear elastic load bearing capacity is normally achieved at a deformation of $w \leq 1.0$ mm. The maximum value of the local hole resistance is normally achieved at $2.5 \text{ mm} \leq w \leq 4.0$ mm. Seven test series with a total of 85 single tests were performed. All holes were predrilled in realistic, not laboratory, conditions. That means they were predrilled using a regular hand drilling machine. This is important, because the local hole resistance is strongly depended on the quality of the predrilled holes.

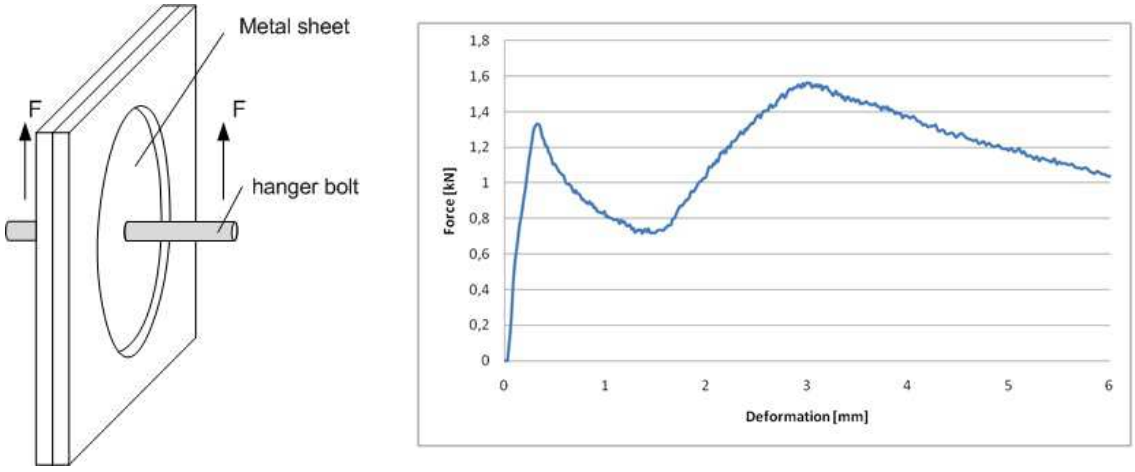

Figure 5: Test set up and characteristic force – deformation diagram

The measured mean values of the local hole resistance (maximum values) F_{mean}, the measured mean values of the deformation at maximum force W_{Fmean} , the mean values of the sheet thickness t, the mean values of the tensile strength of the surface sheets σ_s and the determined variance of the maximum forces for each test series V_x are shown in table 1.

Table 1: Test results

Series	1	2	3	4	5	6	7
Diameter of the fastener [mm]	7.0	7.0	7.0	9.0	9.0	9.0	11.0
Thickness of the sheet [mm]	0.38	0.49	0.56	0.38	0.49	0.56	0.38
F_{mean} [kN]	1,18	1,80	2,28	1,27	1,78	2,51	1,47
V_x [-]	0,051	0,050	0,044	0,070	0,078	0,063	0,110
W_{Fmean} [mm]	3,28	3,79	4,15	3,86	4,10	5,07	4,40
σ_S [MPa]	390	405	375	390	405	375	390

A statistical analysis of each test series leads to characteristic $F_{R,b,k}$ values for the local hole resistance. To ensure the comparability of the measured test results the values are normalised to a tensile strength of the surface sheet of 360 MPa. The 5% percentile value with a confidence level of 75% using Gauss distribution is calculated to

$$F_{R,b,k} = (F_{mean} - F_{mean} * V_x * 1{,}64) * 360\ MPa / \sigma_s$$

The characteristic values $F_{R,b,k}$ are shown in table 2. These values do not include any kind of safety factor, neither for the resistance nor for the applied forces. A minimum tensile strength of the surface sheet of 360 MPa is required.

Table 2: Characteristic values

Diameter of the fastener [mm]	7.0	7.0	7.0	9.0	9.0	9.0	11.0
Thickness of the sheet [mm]	0.38	0.49	0.56	0.38	0.49	0.56	0.38
$F_{R,b,k}$ [kN]	1,09	1,67	2,12	1,14	1,57	2,26	1,23

2.3 Tension resistance of the fastener

The tension resistance $F_{R,a,v}$ is depended on the substructure the fastener is screwed into. For wooden substructures the load bearing capacity can be calculated, for example according to DIN EN 1995-1-1. There are some restrictions regarding the thread, but usually they do not affect hanger bolts and solar fasteners. For steel structures a development method is described in “Statistische Auszugtragfähigkeit gewindeformender Schrauben in Metallonstruktionen” by Roderich Hettmann (2006).

2.4 Stability of the fastener

The pressure resistance of the connection to the substructure is identical to its tension resistance. Additionally the stability of the fastener has to be taken into account. For that reason a calculation using second order theory is required. The factor α can be determined by

$$\alpha = 1 / (1 - N_E/N_{ki})$$

with

$N_{ki} = (\pi^3*E*d^4) / (64*(\beta_1*L_1)^2)$

N_E value of the applied pressure load
d Minimum diameter of the fastener
E elastic modulus of the fastener (normally 170000 MPa for non corrosive steal)
β_1 buckling coefficient
= $0.7 + 1.85 * L_2 / L_1$ for wooden substructures or thick steel structures
= $1.0 + 1.87 * L_2 / L_1$ for thin steel structures

The factor α considers the shape of the fastener and the clamping of the connection to the substructure. But in addition the misalignment of the fastener has to be taken into account by applying and additional bending moment $M_{E,add}$

$$M_{E,add} = N_E * L_1 * \arctan (W_{F,mean} / L_1)$$

2.5 Temperature indicated imposed deformation

The thermal movement, especially when using deflection resistant fasteners, is partly blocked by the fasteners. This results in local hole forces that are significantly higher than the determined hole resistances $F_{R,b,k}$. For that reason it has to be ensured, that the thermal movements do not exceed the maximal values $W_{F,k}$.

3. Load bearing capacity of sandwich panels

Beside the local hole bearing capacity of the surface sheet, also the load bearing capacity of the panels' upper flange is of major interest. Roof parallel forces being applied in direction of the span of the panel are not critical and therefore not further investigated. Roof parallel forces that are applied transverse to the panels' direction of span lead to stresses the panel is not constructed for. As illustrated in figure 6 they may cause cracks in the core material or a separation of the surface sheet from the core material.

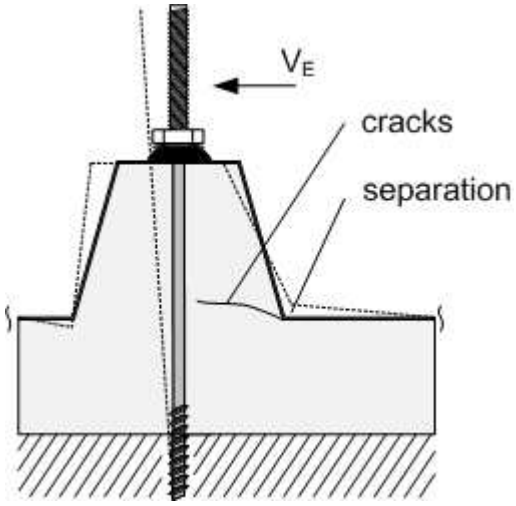

Figure 6: Damage to the sandwich panel caused by roof parallel forces

To analyse the behaviour of the sandwich panel large component tests with 1 m x 2 m sized sandwich panels as well as tests with cut outs were performed. For the tests sandwich panels with plastic foam core and layer sheets made of steel were used. The tests revealed, that the mentioned failure modes are not just theoretically and have to be investigated in detail. The major problems for determining a universal load bearing capacity are the anisotropic material properties and different production methods for sandwich panels. Nevertheless a statement on the basis of the performed tests for a specified group of panels is possible. When the tensile strength of the connection between core material and surface sheet is at least 0.06 N/mm^2, the shear strength of the core material is at least 0.10 N/mm^2 and a minimum thickness of the surface sheet of 0.45 mm a value of 0.70 kN for the load bearing capacity $V_{R,panel}$ can be used. This value requires that the hanger bolts or solar fasteners are not mounted at the edge areas of the panel. The maximum height of the upper flange is limited to a value of 45 mm with a minimum width of the upper flange of 23 mm.

4. Conclusion and Outlook

The presented approaches and values can be used for determining the load bearing capacity of hanger bolts and solar fasteners in sandwich panels. The local hole resistance is given for the most common thicknesses of surface sheets and diameters of hanger bolts or solar fasteners. For the load bearing capacity of the sandwich panel a value of 0.70 kN is presented. As this is just a conservatively determined value that matches many panels this

value can probably increased with the help of further investigations. Also surface sheets with a thickness of more than 0.60 mm have to be part of further studies to exploit the full capacity of modern industrial fabricated sandwich panels. One futher aspect, that is still not known in detail, is the long term performance of the local hole resistance. Because of thermal movements the holes are stressed continuously and small, slowly growing cracks, may occur a reduction in load bearing capacity.

This research project has received financial support from the DIBt (German Institute for Building Technology). We express our sincere gratitude for this support.

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CONSTRUCTION WASTE MANAGEMENT SYSTEM: A CASE STUDY IN A CONSTRUCTION PROJECT IN CHILE

Juan Camilo Aldana[1], Alfredo Serpell[2].

ABSTRACT

Construction waste forms the majority of waste disposed in landfills. It originates from various sources and is produced throughout the duration of the construction projects. The Chilean Chamber of Construction has taken actions to reduce waste generation through mechanisms such as the Clean Production Agreement and the Guide to Good Environmental Practices, among others. However, they have had poor results in terms of reducing the rate of waste generation. For this reason, it is important to view construction waste management as a series of procedures to improve production methods and not just as a process of classification, collection and disposal of waste. This article describes a waste management system (WMS) at a construction operations level and the results of its implementation during the execution of the structural work on a real project. While the procedures that make up the WMS were the result of a series of interviews with construction experts, some of the support elements necessary for its implementation in the field were the authors' own developments. The results show a high participation and involvement of all who took part in the project. The implementation of the WMS raised awareness towards waste minimization and its effectiveness was demonstrated by the amount of waste reduction achieved. Preliminary findings indicate that some of the most important components for a good performance of the WMS are staff training, leadership by the project manager and control through the partial measuring of the performance of its components.

Keywords: system, management, waste, construction, case study.

1. INTRODUCTION

Construction is the industry that generates the greatest quantity of solid waste in the world (Xiao-shuang, et al., 2010; Spoerri et al., 2009; Kourmpanis et al., 2008, Deng et al., 2008 and Wang et al., 2004). With the current population growth rate, the demand for construction will continue to rise, thereby causing a significant increase in the rate of waste generation.

According to Chile's Environment Ministry (2010), 5 million tonnes of construction waste are generated annually. According to the Chilean Chamber of Construction, building permits in

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2011 increased by 55% in comparison to 2010, in a year which saw the highest number since 1992 (Report Mach-35, April 2012). In many cases the waste produced by this construction is being taken to illegal landfills located mainly in poorer peripheral neighborhoods in the metropolitan area, generating increasingly greater environmental and social impacts. In January 2010, the Ministry of Health recorded more than 70 illegal dumps in the metropolitan region of Chile alone, not counting all of the micro landfills. The vast majority of these are located in peripheral municipalities of Santiago where there are scarce resources for control and management.

Construction waste comes from various sources involved in the execution of building projects (Shen et al., 2004). Waste management on site is becoming an important part of the construction process (Wimalasena et al., 2010). In the construction phase, specific plans have been put forth for waste management, such as those proposed by McDonald and Smithers (1998). Additionally, McGrath (2001) developed a project called SMARTWaste, Chen et al. (2002) used barcode technology and Shen et al. (2004) employed the Waste Management Mapping Model (WMMM). Furthermore, Cha et al. (2009) have proposed utilizing the Waste Management Performance Assessment Tool (WMPAT) to assess waste management in advance from four perspectives: labor, equipment and materials, construction methods and management practices. However, a WMS is not currently available for construction operations that incorporate management actions for waste that has already been generated or for the management hierarchy of waste avoidance, reduction, reuse and recycling, as proposed by Deng et al. (2008), Shen et al. (2004) and Kartam et al. (2004). Therefore, in this study a WMS to support construction operations has been developed and implemented in a construction project of a Chilean company.

This article describes a WMS for a construction project in Chile, at a construction operations level, with all of the involved processes, activities and records. The results of the WMS implementation are also shown to demonstrate its benefits in terms of reducing the amount of waste its contribution to economic utility of the project.

2. PREVIOUS RESEARCH

The literature review focused on three major topics: waste management plans and case studies, manuals of good waste management practices and public initiatives in Chile developed for construction waste. The following chapter describes the findings in each of these cases.

2.1 Waste management plans and case studies

McDonald and Smithers (1998) implemented a waste management plan for the construction site of a two floor building with a floor space of 10,600 m^2. The plan's objectives were to reduce, reuse and/or recycle waste. The main strategies used to achieve the objectives were: to prepare an inventory of wasted materials and to asses their potential for reuse and recycling, to evaluate the costs of waste disposal, to develop a practical method for the collection of waste and to use recycled materials in temporary work. Although waste

reduction costs were estimated, the only the management operations studied were those concerning the handling of waste. Additionally, specific practices implemented in the project, such as the use of cranes, workers, trucks, and waste handling facilitators, among other details, were not explained.

McGrath (2001) proposed a using piece of software called SMARTWaste (Site Methodology to Audit, Reduce and Target Waste). Its purpose is to identify sources of waste generation and quantify the amounts generated. The system is based on collecting information by periodically analyzing waste disposal containers. It analyses the possible causes of waste generation by entering information such as type, size and quantity of waste, as well as the location it was collected, among other data. SMARTWaste requires a person on site once or twice a week, whose task is to collect the details of waste generation and to talk with workers and project managers to determine the origin of this waste. The implementation costs and efficiency of the plan with regards to the reduction of waste were not evaluated.

Chen et al., (2002) presents a rewards program based on giving incentives to building site workers (IRP - Reward Incentive Program). It uses a bar code system to identify materials and obtain real time information on the amount of material exchanged between the warehouse and the workers. In this way the consumption of each type of material is controlled and it can be identified whether a material has been either saved or consumed excessively. Workers can then be rewarded according to the quantities and values of the materials they have saved when carrying out their work. Although this incentive program is able to reduce the amount of material consumed, it does not identify which waste management procedures have been implemented by the workers, nor does it calculate the economic benefit of this reduction.

Shen et al., (2004) propose using a program known as the WMMM, which was employed to implement good waste handling practices in Hong Kong. The proposed model focuses on strategies to deal with waste on construction sites once it has been generated. The idea is to reduce costs by minimizing and simplifying handling processes, cutting back on staff (by using mechanical waste handling methods) and abolishing the double handling of waste products, among other strategies (Shen et al., 2004). While this model proposes specific action to minimize the generation of waste at the handling stage, it does not quantify the economic impact of such action.

Cha et al. (2009) propose employing the WMPAT. This is an application developed using Excel and Visual Basic to facilitate the evaluation process of waste management in projects concerning labor, materials and equipment, methods of construction and management practices. The WMPAT gives a total index that indicates the level of performance of the project in terms of waste management (Cha et al, 2009). This index has been classified into four levels: excellent, good, fair and poor. For example, for a project classified as “poor” waste management is of little importance to the workers and they have little training in this area. In terms of materials, the recycling of materials is rarely implemented. Regarding building methods, little effort is made on the site to decrease waste. Finally, from a management perspective, there is no incentive for waste reduction. While the WMPAT is a

tool that evaluates the performance of waste management, it does not evaluate each factor influencing the economic impact of construction waste.

2.2 Manuals of Good Environmental Practices

The United States Environmental Protection Agency (EPA) has proposed strategies and practices to reduce construction waste and demolition debris from buildings. It has published the results of a series of cases where there is an emphasis on cost/benefit and has made suggestions for the use of such results in other projects. One strategy is to educate contractors and workers in material recovery techniques. Another is to make subcontractors responsible for the recovery of materials through the inclusion of contractual clauses which can be paid only after it has been certified that the outsourcer has made efforts to recover materials. Finally, incentives are provided for the recovery of materials.

The Master Builders Association of Victoria and Ecorecycle Victoria, also in the United States of America (2004), have published a brochure to provide guidance to reduce waste. They propose six ways to work smarter, to reduce waste and to save money. These are: (1) To prepare a waste management plan, (2) to design and order only what you need, (3) to use pre-manufactured products, (4) to work together with other builders to recycle, (5) to provide waste recipients, and (6) to separate waste for recycling. Additionally, they provide a template to check each of the above components before, during and after construction.

Laquatra and Pierce (2002) propose using spreadsheets to audit waste. These will help control the disposal of waste by volume and by weight, identify companies that recycle specific materials and their costs, calculate the rate of waste generation per material, register the organizations involved in waste recycling, register identify the current costs of waste disposal, and take note of other important observations.

The Chilean Chamber of Construction, specifically the Commission on Sustainable Development, has prepared a guide to good construction practices that is especially oriented towards the erection of buildings. It proposes mitigation measures to moderate the following effects that may be generated by construction activities: air emissions, noise, waste and complaints by neighbors (Chilean Chamber of Construction, 2010). Regarding the waste issue alone, there are 13 mitigation measures that have been proposed for building constructions. Only 5 of these aim to prevent the generation of waste, while the others focus on its handling once generated. However, these measures are only outlined. Some are generic and it is not shown in detail how they would be executed. Each requires operational planning for its proper implementation in the field.

2.3 Public initiatives in Chile

On 28 January 2000, the construction sector’s Clean Production Agreement (CPA) for the metropolitan region of Chile was signed. It came into effect on May 1 of that year and ended on April 30 2002, adhering to the 34 construction company members of the Chilean Chamber of Construction. The CPA’s study of the environmental and economic impact

determined that the goals of the CPA in relation to solid waste had not been completely accomplished. However, it did show that average waste generation was reduced by 20% through the use and acquisition of standardized or precast products and the reuse of excavation waste as fillers in other building work. The study also determined that it is not possible to say whether this reduction is due to the CPA or not because the total construction area developed by the companies who signed the agreement in 1999 (the year of the initial signing of the agreement) and 2005 (when the study of the environmental and economic impact of the agreement took place) is not known. This is due to the fact that companies tend to treat such data as confidential information. Therefore, the true effectiveness of waste management in construction projects cannot be identified. Secondly, other good environmental practices that would indicate how to avoid, reduce, reuse and/or recycle waste before it ends in a landfill were not incorporated.

3. FRAMEWORK AND METHODOLOGY

The generation and management of waste in a project are closely related to production processes and support activities (procurement management, quality control system, material control and cost control, among others.). Previously, when thinking about procedures to reduce waste and emissions from certain activities, the first thing that was focused on were tactics like the replacement of materials and equipment. The possibility of reducing waste by implementing simple and inexpensive measures to improve operations management in a project had not been considered. For this reason, in this study a WMS was designed that proposes some changes to the traditional patterns of management operations and also articulates some of the activities that support the implementation of a project. In this way it is hoped that the generation of waste can be reduced and environmental and economic benefits for construction projects can be obtained.

Based on the list of the sources and causes of waste generation and the procedures and/or waste management strategies proposed by Aldana et al., (2011), a list of 33 measures was generated that can be implemented in construction projects and contribute to the reduction of waste. Additionally, by reviewing the literature regarding materials wasted in construction projects, a list of 34 waste materials was obtained. Subsequently, interviews were given to 11 professionals from 6 construction and real estate companies. These people were asked which 10 procedures and/or strategies they considered most relevant to implement in a construction project that would contribute to a reduction of waste. Finally, they were asked which 5 materials are wasted the most on such projects. The professionals surveyed consisted of builders (7) and civil engineers (4) who have an average of 19 years experience in the industry and who currently hold the following positions: technical manager (1), project manager (2), site manager (6), construction manager (1) and technical inspector (1).

After an analysis of 123 publications on construction waste management, it was found that only 26 of them talk about waste management procedures and/or strategies. Based on this, a ranking was performed taking the frequency that these strategies were mentioned in the literature (see Table 1) as a parameter. This frequency ranking was taken from Aldana and Serpell (2012).

Table 1. Waste management procedures and/or strategies most cited in the literature.

Procedures and/or strategies	Number of citations
Sorting waste at construction sites, assigning locations and recipients for each type.	9
Use of precast materials.	8
Training and educating staff on management tools and on-site waste management.	8
Buying and ordering materials efficiently.	7
Establishing centralized cutting areas to identify parts that can be reused.	4
Storing materials in good condition.	4
Making orders and receiving deliveries in good time	4
Encouraging subcontractors and workers to save materials.	3
Requiring the reuse of materials to be stated in contracts, demanding the amount of waste to be recorded and the generated levels to be reported as the construction process is carried out, requiring materials to be ordered with the correct sizes by adequately reviewing supplier catalogs, changing the design of construction processes, using metal formwork.	2
Cutting steel in the factory not on site, using modern technologies, committing workers to use good material handling, requiring subcontractors to purchase their own materials, maintaining machinery and equipment, handling materials correctly, reviewing materials when workers arrive on site and returning deteriorated materials to the supplier, preparing transport systems suitable for each material, unloading materials at their final site and avoiding stacking and double handling, locating warehouses near the construction site, limiting the quantity of stockpiled materials to avoid excess inventory, returning material packaging to suppliers for reuse, negotiating the return of unused materials with suppliers, avoiding suppliers that over package materials, providing recipients that separate trash (food, drink containers, etc.), carrying out material inventories as planned, buying materials that have reusable packaging, using technologies that generate little waste, using materials before their expiry dates, requiring subcontracts to dispose of their own waste.	1

After analyzing the results of the interviews and the ranking in the literature, it was possible to conclude that of the 14 procedures most frequently listed in the literature, 12 of them were selected by experts in the interviews. An analysis was also done considering the specific influence of the experts' responses, leading to the conclusion that of the 15 procedures most mentioned in the literature, 12 were selected by experts. Finally, an incremental revision of the interviews was carried out to verify the stability of the answers and to determine whether more interviews were needed to select the procedures that would be the basis of the WMS. It was concluded that of the 15 procedures mentioned in the literature, between 10 and 13 were selected by respondents in all the iterations analyzed. Therefore, it was decided to take the procedures identified by the experts as a reference point for planning the WMS. The results of the survey yielded the following order of importance of waste management actions:

(1) committing workers to use good material handling, (2) encouraging subcontractors and workers to save materials, (3) training and educating staff about management tools and waste management, (4) sorting waste on site by assigning locations and recipients for each type, (5) buying and ordering materials efficiently, (6) using precast materials, (7) establishing centralized cutting areas to identify parts that can be reused, (8) handling materials correctly, (9) providing garbage containers, (10) cutting steel in the factory rather than on site, (11) recording the amount of waste and reporting generated levels as the construction process progresses, (12) requesting appropriately sized materials through the study of supplier catalogs, (13) using metal formwork, (14) changing the designs of construction processes, and (15) using modern technologies and those that generate little waste.

Based on the 15 procedures selected, aspects that were applied at the operational level required for their successful implementation in the field were reviewed. This included taking a performance measurement for the WMS implementation to control its execution in the field, as proposed by Aldana et al., (2011). Finally, once the system had been designed, verification of the project support activities was carried out (quality control system, procurement system, cost control system, etc.) to see which were common to the WMS. In this way, the same work was not done twice and information was not over-recorded.

The WMS was validated by the technical manager of the construction company who provided the building project and two project managers for the case study. The particularities of the project and restrictions made by the person in charge resulted in minor changes to some records and the incorporation and/or elimination of some of the proposed procedures.

According to Aldana and Serpell (2012), the construction waste most widely reported in the literature is: concrete, wood, brick, plastic, metal, steel, and gypsum board. According to the interviews with the experts, the most frequently generated waste is: concrete, wood, steel and gypsum board. Based on this, the materials selected for the implementation of the WMS were those reported by both the experts and the literature, and which are present during the structural stage of the project.

4. FINDINGS

An overview of the case study project, the WMS, some specific aspects of the WMS process, a performance measurement of the WMS implementation, and the effectiveness of the WMS are presented below.

4.1 Overview of the case study project

The case study project chosen for the WMS implementation was the construction of a pre-school with a building area of 12,603 m^3. The structure is of reinforced concrete, with foundations and roof beams in concrete runs and vegetation cover. To measure the effectiveness of the project, the WMS was divided into four areas, each having the same

distribution. Rhythmic planning was used. In zone 1 the amount of waste was measured without having implemented the WMS. In zone 2 the deployment had already begun and served as a transition for zones 3 and 4 where the effectiveness of the WMS was measured once implemented.

4.2 Waste Management System

The 15 measures selected for the WMS were grouped into the following ten processes: (1) 3D modeling, (2) training, (3) efficient purchasing of materials, (4) steel prefabrication, (5) materials handling, (6) donating materials, (7) rewarding workers, (8) recycling time, (9) material storage areas, and (10) recording and reporting residue levels. Each process was planned in such a way that all the elements necessary for proper execution and implementation in the field were developed. This included a flowchart, forms, records and supporting documents.

4.3 Description of the WMS processes

The following section will explain some of the processes that generated the most significant WMS changes at an operational level when compared to how the company was run before.

4.3.1 Efficient purchase of materials

Before implementing the WMS, products offered by the material suppliers were verified by reviewing their catalogs. Through measurements in the plans of the amount of material theoretically needed for each activity and considering the supplier's recommended performance, the amount of material required was calculated. This is a procedure known as scaling. Previous to scaling, providers were consulted on the possibility of producing materials that specifically fit the project to avoid excess waste in the cuts. After finding out the dimensions made available by the manufacturers, optimization of the material was performed through the use of the appropriate software (Length Cutting Optimization 2D and 1D). Subsequently, modulation plans were generated of the activities that required the material studied. In this way, materials and cuts could be optimized. The plans indicated to the fitters how to make the cuts and where the materials should be installed. Finally, a cost analysis was carried out to compare buying materials with standard sizes with those cut to project specifications.

4.3.2 Waste control

Before implementing the WMS, the number of waste trucks leaving the site were counted in order to obtain the total waste volume. The goal was to create a methodology for measuring the amounts of materials wasted daily in project activities and to deliver information for decision-making without having to wait a considerable time. This helped control productivity and the performance of the materials.

After the implementation of the WMS, a material control table was designed (see Table 2) based on the scaling obtained after developing the modulation plans. Table 2 shows the quantity of each material to be delivered to locations in each of the preschool areas. Later, the store manager recorded the amount of each material received, following the inspection protocols of these materials. The delivery of materials to the workers was allowed only through permission slips given by the site managers. When the requested quantity exceeded the amount permitted by the control table, a warning was generated and a message was sent to the project manager to report on what had happened and initiate a procedure to identify the reason an excess amount of material had been requested.

Table 2. Example of material control box

Zone	Compound	Material	Materials stored			
			Unit	Amount allowed to be delivered (A)	Quantity delivered to workers (B)	Difference (A-B)

Finally, in order to maintain control over the volume of waste of each material for each location, the site managers carried a notebook where they recorded day by day activities with their respective units of measurement (see Table 3). In this way, by looking at the amount of material delivered and the amount used, it was possible to accurately find out the quantity of waste generated at each location and for each activity.

Table 3. Example of notebook of measurements

Compound:					
Activity					
Measuring unit:					
Measurement date	Length (m)	Width (m)	Height (m)	Total	Observations

4.4 Performance measurement of the WMS implementation

To evaluate the performance of the WMS implementation, a weekly indicator was used based on that proposed by Aldana et al., (2011). This evaluation consisted of a weekly visit to the project to find out where there was compliance with each of the control variables of the WMS processes. The structural work stage of the project lasted 14 weeks, in which time an

average of 50% of the WMS implementation was achieved, with a maximum of 60% in week 6 and a minimum of 17% in week 10.

4.5 WMS effectiveness

Below are the results of the measurements of material waste in the structural work stage.

Table 4. Level of material waste in the structural work stage

Material	Waste (%)		
	Without WMS implementation (Zone 1)	With WMS implementation (Zone 3)	With WMS implementation (Zone 4)
Concrete	10	9	8
Steel	10	8	7
Wood	15	11	9

5. DISCUSSION AND CONCLUSION

Implementing the WMS required cultural and behavioral changes for workers and professionals that were part of project. Initially some resistance to the changes that were implemented was shown by certain participants. However, following procedures such as training and incentives, and after the support of the senior management of the company and project managers, this changed and a high degree of worker motivation was generated. Behavioral changes were especially apparent in the carpenters. This was due to the implementation of wood recycling collection centers, where before removing material from the stores, workers went to the collection centers to select materials that could be reused.

The integration of the WMS with processes such as cost control, procurement management and quality control were instrumental in its implementation. This is because overly long records with unnecessary information did not have to be generated. Therefore, people did not have a negative disposition towards the WMS and in return a more useful information was obtained. This helped decision making and led to improvements in construction operations.

When measuring the performance of the WMS implementation, a maximum and a minimum were presented. The maximum was due to motivational factors that coincided with system processes, thereby resulting in a proper WMS implementation. The minimum coincides with activities that were more difficult to execute and with problems of labor shortage where new workers had to be incorporated, trained and taught the WMS principals.

As a result of the implementation of the WMS, savings of approximately US $ 400,000 were achieved. This figure consists of savings on materials, with an approximate value of US $

300,000, and savings on waste collection and removal, with an approximate value of US $ 100,000. It should be noted that the project budget was US $ 4 million.

ACKNOWLEDGEMENTS

The authors wish to thank the AXIS Construction Development Company S.A for providing a project with which to implement the WMS. Also, gratitude is given to all participants of the project (about 200 workers) for their good reception and hospitality.

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Defining the Domains for Research into Clients

David Boyd[1]

Abstract

Research into construction clients is in its infancy. Construction clients are multifarious and internally complex thus it is extremely difficult to present an overarching model of their world. This difficulty prevents research into improving the response of the industry to clients and into helping clients be more successful clients. This paper will explore the generic feature of clients as displayed by their relationship with four domains. Clients only become clients when they initiate or maintain facilities. These facilities have the effect that client's desire but involve interaction with the other domains. One domain is internal to the client and involves the facilities users. The other three are external to the client. Two are independent namely the social/business environment and the regulatory environment. These external dimensions both drive the client's purpose but also limit what the client is capable or allowed to do. The final domain involves the construction industry which is contracted to the client to act for them but in so doing the client has dependency on them. This four domain model will be used to explain clients concerns and these will be presented through four viewpoints: operations, economics, social structure and experiential. The presentation of this model will show what research needs to be undertaken to better address client needs.

Keywords: clients, research, model.

1. Introduction

As Boyd and Chinyio (2006) state 'building is not about building but about organisational development' for the client. The concept of a construction client is not well defined as it is only given meaning by the client's actions associated with initiating building or operating a physical facility. Clients do not immediately associate themselves with this term as it is the business or service that they are providing that gives them identity and consumes their attention. They use a facility as a means for conducting the business or service; thus, the facility is a tool or a technology for meeting a purpose and this gives it a secondary interest to the client. The facility then may be a constraint on the client, and the client may prefer not to have it, or a positive opportunity for enhancing their purpose. As the facility is secondary to clients' purposes, what success means, as regards a facility, is bound up with the clients' success as a business or service.

The complexity of clients is made worse by the fact that although the term is unitary, almost all construction clients are organisations. In order to operate, organisations divide themselves into

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internal functional divisions with differing activities. These divisions have their own problems and the client has to coordinate the differences. The divisions also have different relationships with the environment in which the client operates.

Defining a research domain for clients requires putting the client's purpose central to research. Such a placing is contrary to other work in which construction clients appear. What this other work does, is consider how other stakeholders see clients from their world. Construction management research on clients see clients as a problem for the operation of the construction industry (e.g. (Cherns and Bryant 1984). Work on planning see clients as something that need to be stopped in order to advance the public realm (e.g. (Healey 1991). Work on architecture focuses on their ability to provide an aesthetic environment for clients e.g. (Cuff 1992), (Hays 2000). Work on real estate sees clients as providers of work for consultants (Fisher and Collins 1997) or the funders of property (Isaac 1996). Work on Facilities management sees owners as providers of facilities (McGregor and Then 1999). Business and management research seldom see facilities as worthy of mention but concentrates on the business operations or service operations (Huczynski and Buchanan 2007); thus, does not provide a solution to defining the domain for research. Any research on clients must be cognisant of these views but must search out the clients' perspective.

This paper aims to define the domain for research into clients by creating a composite model of any clients' environment. The paper adopts critical discourse method (Weiss and Wodak 2003) using literature surrounding clients to explore the generic feature of clients as displayed by their relationship with four research domains as shown in Figure 1.

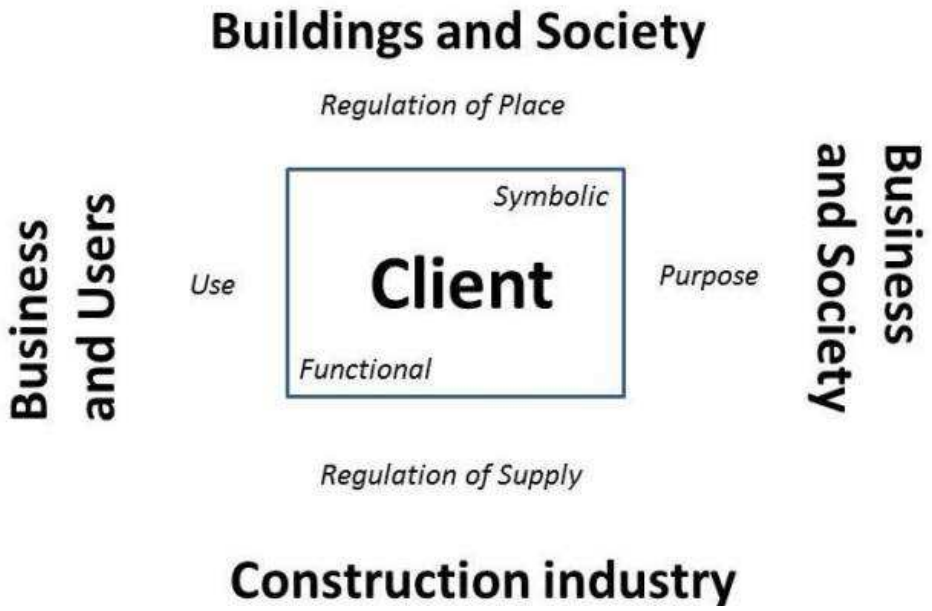

Figure 1. The Domains of Client Activity

The domains arise through the clients being defined by their facilities. These facilities contribute to the client's purpose but involve interaction with the domains. The first domain is the social/business environment in which the client fulfils their purpose. The second domain is internal to the client and involves the facility users who fulfil the clients' purpose. The third

domain is the regulatory environment which limits what the client is allowed to do as regards their facility. The final domain involves the construction industry which is contracted to the client to act for them but in so doing the client has dependency on them. These domains will be explored through four client viewpoints about them: operations, economics, structure and experiences. The presentation of this model will show what research needs to be undertaken to address better the needs of clients.

2. A Model of the Domains of Research into Clients

Clients exist as a business within the wider environment of businesses and society. Clients can be distinguished by the nature of their business and the constitution of their organisation principally whether they are public (McKevitt and Lawton 1994) or private enterprises (Wilson 1948). In different places in the world, different businesses are undertaken under different constitutions depending on the governance arrangement of the country and the prevailing political disposition (Bell and Hindmoor 2009). All clients have to experience a desire to building which they see as developing their organisation for or within this environment of business and society. This development might be simply to increase capacity of production or service, it might be to undertake a new activity or it might be to improve an already performing activity. In all cases it is this sense of achievement within the environment of business and society which drives them as a business and ultimately what drives them to building. This environment also defines the way economics of the client activity is calculated and also the economics of building (Warren 1993) making this an important viewpoint. This is sometimes confused as building itself adds assets to a client (Isaac 1996) inducing the client to view this as a driver to build and this may interfere with the functional reason for building. Thus, building is not just a cost but possibly an economic multiplier though it is a less fluid asset than money or stocks.

In undertaking this organisational purpose then the building is a framework that is populated and activated by users who fulfil the clients. Thus, the way the building contributes to the business through users is critical (Evans, Haryott et al. 2004, Saxon 2005). The difference between clients and users needs to be careful acknowledged and their relationship better understood. The Client may have a very functional attitude to what the building is doing but the users experience it in a much more physical and emotional manner. Thus, the client might be interested in how productive the building allows users to be, whereas the users may be more interested in the way they identify with the building and what it does for them.

The clients building aspiration fits within not just the business environment but also the building/land and social environment. This is in most countries set within a regulatory policy framework (Baldwin and Cave 1999) which works outside (and often against) the business environment (Morphet 2011). It is here that the long term meaning of the building is controlled and how it fits within the spatial development of society. This is a complex interaction as individual clients see this as a cost and constraint but they benefit in the longer term sustainability of the built and natural environment. Indeed, the registration of land and property provides value for these within the national political economy.

Finally, the clients building aspiration is delivered via the construction industry (Cherns and Bryant 1984). Clients experience the reliance on professional skills to meet their objectives; however they are always questioning these and trying to demand more. The construction industry's operations are reasonably well researched however the relationship with the client is seen through a supply and demand model. Such models do not acknowledge the contradictory interactions between clients and the industry which need to be researched in a lot more detail. The fragmentation of the industry is also evident and difficult for the client to comprehend; for example, the way design is separated from construction being the most fundamental. There is a strong legal framework in this relationship and this is set within business and societies wider interactions. Thus, changes to the way buildings are procured, particularly in the public sector, seem to dominate operations with the assumption that once these are sorted out, it is easy to design and build. In this new relationship with clients, there is a growing expectation that the client uses their power to develop the industry and to develop the technology of the industry. This new dimension is confusing for clients who are used to a more conventional supplier purchaser arrangement. Again, clients only receive benefits in the long term from such initiatives rather than on an individual project, thus they are difficult to evaluate. Similar pressures come from an expectation to support the local community and local workforce during construction which again affects the ability to judge value from investment.

The domains identify groups surrounding clients that influence what the client does but these groups have different needs and ways of working. This complexity can be confusing to clients but it also, means that it is difficult to have a single overarching theory of client situations. If a single model of clients was considered viable then there would need to be a single model of the built environment (for example (Lorch 2003, Koskela 2008). Boyd (2007) discusses the difficulties of undertaking such a task and demonstrates the contradictions inherent in trying to achieve this conceptualisation. These contradictions involve both thinking about the situation but also in the practice of acting in the situation. The desire for unity of view comes from a rationalist perspective which concentrates on a single correct view of a situation most often concentrating on functionality and efficiency (Hislop 2009). This aligns with classical economic theories both in terms of money and now in terms of resources and sustainability but it is only one view. The basic notion that buildings are merely concerned with shelter or functional activity is limited. The significance (Beynon-Davies 2011) of buildings is the meaning they have for clients' and those around them. This meaning of buildings in relation to clients and the domains is more complex to understand as clients purpose can be both functional and symbolic (Zukin 1996). Thus the variety of aspects necessary to achieve a successful building is multifarious and these aspects interact to provide an overall impact which is continually being reformed. Also, it is possible to have poorly fulfilled physical aspects being acceptable because of well fulfilled symbolic aspects, but this is seen differently in each domain as well as changing over time.

In order to research these complex, interdependent and dynamic issues of clients across the domains, it is necessary to view the domains from different viewpoints. These viewpoints are shown in Figure 2 in relation to the domains and can be regarded as different ways of knowing in the client situation and have a character similar to Morgan's (2006) metaphors of organisations. Firstly, operations focuses on the processes that are set for the client engagement with the domains. These are pressurised by the client's desire for business and

building change which are the objectives of engaging with construction, Secondly economics presents the flows of resources and information between the domains for the purposes of the client and evaluates the success of this. Thirdly, the social structure defines the client identity in relation to other parties and is also associated with various influences that the client has and is affected by. Finally the experiential system defines how the client experiences activity in the domains; it is important as it determines the emotional feeling of the client and how others regard them.

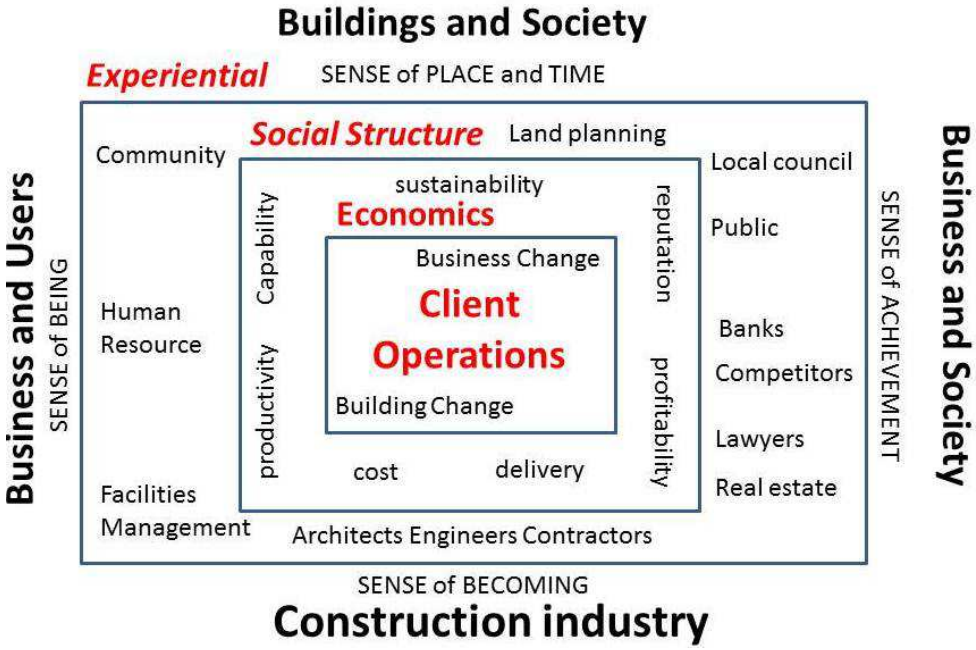

Figure 2.The Viewpoints of Clients

3. The Operation of Clients

The operational processes of clients was the focus of the work of Boyd and Chinyio (2006). They created a composite model of clients operations so that the construction industry could understand clients actions. What clients desired from a building is added value to their business/ service. During construction, the client's business as well as the building change and this duality gets embedded in the objectives of construction, Boyd and Chinyio's (2006) model is a system dynamics model (Flood and Carson 1993) using a theory of whole system constraints (Goldratt, Schragenheim et al. 2000) both externally to the situation as in contingency theory (Huczynski and Buchanan 2007) and internally due to the constitution of the organisation (Goldratt, Schragenheim et al. 2000). There are also psycho-dynamic aspects (French and Vince 1999) due to the organisational and individual change such that organisational development is complex and uncertain (Stacey 2011) Thus, success for the client means to be satisfied: in the building, as an organisation, and as people. Boyd and Chinyio (2006) used their model to look at the operations of six clients demonstrating its ability to draw out the particular features that would be required for success for these clients.

The operation of the ‘regulation of place’ is undertaken through the planning system which is constituted in national governance (Cullingworth and Nadin 2006). Clients only occasionally act in this domain. This domain puts many conditions on clients about where and what can be built. However, there is an operating tension between the economic advantages of a successful client and the maintenance of the significance of place (Schneekloth and Shibley 1995). This is also discussed under economics as it influences the flow of resources within a location and about social structural in the way that power and influence act in the location. In addition, the symbolic nature of a building can provide the inspiration for others to build; thus, the building is the symbol of the start of development or re-development. This creation of the wider public realm: involving buildings, public space and infrastructure, is part of the symbolic economy (Zukin 1996). This public realm can only be a minor interest to clients who may criticise it for being too costly. On the other hand, there are other stakeholders who criticise planning as failing to preserve heritage or the ecology (Flyvbjerg 1998, Priemus, Flyvbjerg et al. 2008) against the client. These debates and tensions span social and spatial scales through their symbolic and physical significance but also change over time.

The ‘regulation of supply’ is to some extent much simpler as it is represented by the built environment industry. Again most clients only act in this domain occasionally. This has well recognised operations in terms of roles and processes (Winch 1996). However, as Groak (1994) shows, there is no coherence as an industry but merely a collection of projects. What the client can get produced in what time scale and by what means is set within this constraint (Winch 2010). It is problematic as everything is possible if enough resources can be brought to bear on a project; the relationship between what is possible and what is practicable is unclear. Thus, in these complex operations, it is possible for the clients to feel that the industry is inadequate and indeed it is backward (Woudhuysen and Abley 2004) and there is always the desire to find another construction supplier who can do what the client wants.

That the vertical axis involves constraints is annoying to clients but the horizontal axis is the motivation to see this through to meet their business purpose. The ‘*purpose’* of building aligns to this motivation through an explicit formal statement, such as a brief; however, there is often an undeclared, but tacitly understood, aim that fulfils other purposes (such as status) (Boyd and Chinyio 2006). The formal purpose leads operations to be driven by financial analyses and economics. Further, buildings that are owned by a client are part of the fixed assets of an organisation (Peterson 2002) and this can add to the confusion of purpose. However, some clients have social purposes which adopt a business approach through usage and social accounting (NEF 2007). As buildings involve use in the future these analyses are somewhat speculative but often buildings are not just designed for an immediately perceived use but also a notional expansion in use which is even more speculative. The tacit purpose are often symbolic aspects which are complex because they can be justified by manipulating arguments in the business and social arenas (Boyd and Danks 2000). What is key about both the business and social purpose is that operations are framed within a wider social world of business or public service and cannot be detached.

The final domain of operational interaction for the client is with the building user (Vischer 2008). The purpose of the building also defines the user. Users can be customers or suppliers or employees of the business or service. Users may also be more tangentially associated with the

building as observers or neighbours. Users make use of the building for their purpose which is most often the client's purpose (Rubin, Elder et al. 1980) (Vischer 2008). Complex buildings, like hospitals, have building operations that are social and technical to fulfil the purpose of health provision. Their primary users for their function are patients and medical staff so that patients enter and are transformed by these staff to exit with improved health. However, surrounding this are family and friends on the patients side and numerous ancillary staff, professions and administrators that support the facility operation. The scale of this, and the scale of the building, means that these need management to coordinate and plan the enterprise; this management becomes a surrogate client for the building function. Finally the building is a technology in itself which requires managing and maintaining and such functions as facilities and estate management become part of the client operation (Alexander 1996, Kyle, Baird et al. 1999, Deakin 2004).

4. Clients as economic systems.

Economics considers the institutions and consumers that combine to produce, distribute, regulate entities that are desirable and scarce in society (Gillespie 2010). This involves determining and connecting the flows of resources and information that operate within social structural relationships that define societies and define organisations. The garnering of resources to accomplish buildings is a key economic task which is greatly influenced by the client's position in the world (Warren 1993, Ruddock 2008). Buildings involve significant resources and therefore command great economic attention. This movement of resources to building is also significant as it is a decision to not use the resources for something else. Thus the priorities that are made on what to spend resources, for example, symbolic aspects, creates a tension as they are not spent on e.g. social aspects. Buildings are large and so involve a large number of resources and so the tensions are large thus the social emotion attached to buildings is large; the larger the building the greater the tension. However, the symbolic aspects can be scale (e.g. a purpose to have the tallest building in the world) thus the economics of such priorities is difficult to account.

As regards the 'regulation of place' domain, the placing of building in its spatial and social context is an economic activity (Morphet 2011). There is a dilemma for regulation between advancing economic development and retaining spatial conservation. The ownership of land as an economic asset does not allow the client to do what they like thus this regulation can reduce value. Further, society gives itself through parliament the authority to dictate to the client what they can build and for what purpose; again limiting the economic advantages. The tension that surrounds building, especially in denser social settings, increases as others become swept into the physical and symbolic development. A growing issue in this domain is the delivery of sustainability through promoting values on conserving space, ecology, resources, plus avoiding pollution and social decay (O'Neill, Holland et al. 2008).

In the business domain, the client may seek financial resources to realise their purpose. One aspect of economic value is a client's relationship provided by property rights determines their ability to command the use of property and to accumulate the benefits of this over extended time. Different forms of property ownership exist (e.g. capitalist and socialist) but nuances in the duties and constraints on this ownership are found in different national systems. All societies

have some form of public ownership such that many of the aspects of infrastructure and governance are performed within public settings.

In the supply domain, the bringing together of resources to accomplish a project is limited by the availability of materials, plant, organisations, and individual skills. Clients induce a flow of physical and symbolic resources to bring about a building project. But through their action, clients may also create these and deplete them. Indeed buildings themselves are a type of storage of resources with this being acknowledge in the term capital asset (Ruddock 2008). The creation of a building in a location is part of its economic development thus it provides jobs and business opportunities and further afield can support a supply chain and innovation (Gann 2000). Many economic discussions in the supply domain focus on efficiency; however, clients are mainly interested in costs viewing other discussions as 'someone else's problem'. The difficulty, however, is that procurement arrangements that only focus on cost produce a confrontational and dishonest response to activity such that additional costs are generated through avoiding or not managing the consequences. Clients who wants something different or even innovative are constrained by the norms of the economic framework in which they are working (Ive and Gruneberg 2000). The clients role in stimulating innovation is clear to Brandon and Lu (2009) as the industry is unwilling to take on the risk of novelty (Woudhuysen and Abley 2004). However change and innovation is also central to new practices (Akintoye, Goulding et al. 2012) and to sustainability and green buildings (Halliday 2012)

In the user domain, the value of building relates to its support of the purposeful activity. Work by Evans et al (2004) postulates the ratio 1:5:200 where 1 is the design cost, 5 the construction cost and 200 is the operating cost. This suggests that it is valuable to spend money on design to get benefits in operations. Other work by Macmillan et al (2002) draws out the intangible advantages of buildings and tries to connect value to them.

5. Clients as social structures

Clients themselves are entities that have social identity (White 1992). They are surrounded by competitors, suppliers, their clients, and regulators which help to form this identity. The social structure view sees clients, once identified as such, behaving to their identification. Similarly the other actors and institutions behave in this normalising way. This is critical for appreciating change in that a single new action does not constitute change; it is only when the norm changes that a social change has occurred. The roles surrounding clients includes regulatory officials, real estate, banking and finance, lawyers, local government officers, human resource managers and an array of construction professionals. These require the client to operate differently with each stakeholder who may have different priorities and different economic perspectives.

These patterns of social arrangements can be linked to actions of individuals however they are often discussed in a macro scale where the power of various institutions and social groups determine what it is possible to do and even think in society (see (Mintz and Schwartz 1985) for a discussion of US business). Owning, occupying and operating buildings continues to be a key aspect of society. The identity of clients in this gives them power and authority in many aspects of social life (Healey 1991). Power is distributed in different ways; some of it is rational

regulatory power other is emotive symbolic power (Flyvbjerg 1998).This clearly interacts with an economic view but is more concerned with influence rather than on the flow of goods and services. The clients identity, particularly if a private business, emphasises the rights of self-determination, competition, enterprise, personal merit, duty and historical position (Morrison 2011).

The client's business places its users into a social structure (Huczynski and Buchanan 2007). The larger the client organisation the more formal, and bureaucratic, arrangements that prevails. This structure gives the identity to the people and provides a formal reporting and reward mechanisms; thus employees will have a contract and also be protected by employment legislation. However, it does differentiate different divisions in the client which begin to operate with their own goals and establish their own power. Corporate clients struggle to maintain a single identity internally and a common integrated purpose. These different divisions relate differently to the external structures and in particular to the different roles surrounding building. As building involves organisational development in the client then it requires a change in client business structures; thus places a tension within the client. The complexity of the client system means that change occurs not just through goal driven action (design) but as a negotiation of meaning and power (Gabbard and Beaulieu 2005) between the different divisions (Wenger 1998). Thus, change occurs differently in the different client divisions and so the success of building is different in the different divisions.

6. Clients as Experiential Systems

An experiential view determines how the client engages with the social and physical world and how this influences client behaviour (Heron and Reason 1997). Clients themselves and the surrounding actors are all engaged in this experiential activity and it is the way that the different experiential systems contribute to each other's experience that creates outcome. This experience is set by the social structures, the economic values that have priority and the forms of operation that are conducted in the business and in the task of building.

Of particular interest is the way each makes sense (Weick 2001) of the situation that each finds themselves in. Sensemaking is the active way of knowing (Weick 2001) but also contributes to the way explanations are constructed for actions and outcomes. It can be seen as the stories organisations tell about their activities (Snowden 2002). The sharing of these stories is one aspect of creating identity in organisations (Armstrong and French 2005). Unlike more deterministic and objective views of organisations (such as economics) which focus on accuracy, sensemaking focuses on plausibility (the best explanation). What drives these best explanations is key to appreciating clients and the surrounding organisations. Inside each domain the explanations appear 'common sense' (Tsoukas 1994) however to external views they may be annoying or erroneous. Weick's (2001) view is that organisation seek to remove 'equivocality' so that they only have a single view thus de-legitimising the views of other organisational systems.

The client as building initiator is driven by 'a sense of achievement' in the business/ social world. This sets up aspirations for what can be and should be. Building then is driven by this sense of achievement and the relationship with all around is dictated by their response to this.

The regulatory system is characterised by its desire to achieve ‘a sense of time and place’ (Schama 1995). Regulation is often presented as upholding the view of the wider society; however, this is experienced negatively by the client as a constraint on their actions. The users in the client organisation are driven by ‘a sense of being’ as often work defines peoples’ existence. Building can aspire to improve the sense of being and as such can be supported and celebrated by most. However, there is a tension as the client’s sense of achievement seeks to increase productivity or service quality through the user as a result of building. The construction industry offers the experience of ‘a sense of becoming’. Its key feature is that it is changing the client’s world (Boddy and Buchanan 1992) and so its rhetoric of improvement (Green 2011).

7. Conclusion

This paper has shown one route to conceptualising client, accepting that a unified conception is not possible. Clients are too multifarious and their relationships are not fixed for any meaningful attempt at a single overarching theory or domain. What is required are multiple views and a way of integrating these views. Such research into clients must collect these multiple views and case studies from practice provide the best vehicle for this. These views can then be interpreted through the frameworks presented in figures 1 and 2. This helps to integrate the views and to provide a language to discuss the various actions of clients.

It is only recently that the significance of the role of clients in the building process has been recognised. Previously, the complexity of building itself and the spatial significance have dominated thought. Clients have merely been seen as external to the process; paying for it, initiating it and sometimes being problematic for the industry. Clients must be seen as an industry in themselves. The approach using multiple views presented here will allow research into clients to commence which will assist clients in performing better for themselves and also for the construction industry to respond in a more supportive way.

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Value Driven Briefing Process using ICT

Charlotte Bruun[1], Peter Johansson[2]

Value Driven Briefing Process using ICT

The way briefing is prepared in conjunction with building projects is crucial to the project's adherence to the client's intentions. It is through the brief that the values expected are documented and transferred. However, international research has for a long time pointed out the briefing stage as a constantly recurring problem area for the construction sector.

The aim of this research is to achieve a more value-driven building process by the use of ICT. The objective of this study is to improve the briefing phase using ICT.

To reach this objective the following questions will be addressed:
Q1: What values are defined in the briefing process?
Q2: What values were created by the use of ICT?
Q3: How could ICT be developed to further support a value-driven briefing process?

To answer these questions three case studies were used. One of the case studies concerning a building for culture and music is presented here. The ICT tool Program of Technical Standard (PTS 2012) was used to support the briefing process in the building project studied. In the case study three questions were answered:

What functionalities in PTS support the briefing process?
How did the use of PTS influence the process?
What values were created by the use of PTS?

The result of the studies shows that using ICT to support the briefing process has many valuable advantages. The use of ICT-support in the briefing process makes the process more efficient. PTS facilitates information transfer and consistency of standard.

Keywords: Client, Briefing, Values, ICT support.

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1. Introduction

A building should create value for all the parties involved, both those who ordered the building, owns it and maintain it, but also those who use the building. The building sector is mainly focused on reducing the initial (investment) costs, rather than applying any comprehensive approaches for optimizing total facility life cycle values for the benefit of owners, users, the environment and the society. This is partly due to lack of models, methods and tools for total life cycle value management. The client, in his role as manager for the product development process should gather and transfer information about all requirements and values of the product, the building, and manage the development process toward fulfilling these requirements and receiving the values. This process is often called briefing. Briefing can be considered almost synonymous with concepts of “Architectural Programming” as used in North America (Kelly and Duerk 2002) and “Scope Management” as used in Australia (Peakman 2008). Presently, the terminology describing various types of briefing is inconsistent and different terms are used by different professions and for different project types in construction (Chung et al. 2009).

In order to achieve premises the client can chose between different briefing methods when a new building are planned. Regardless of the method chosen, one success factor of a building project is the way that requirements from the client is transformed and communicated to the contractor (Ryd 2004; Pemsel et al 2010). This process can be supported by ICT tools.

The briefing process is an iterative process in which the client’s requirements and values will be absorbed into both the brief and the design phase. One success factor of a building project is the understanding of end-users needs and the communication of the clients requirements to the contractor (Kelly et al. 2005). Understanding the requirements and the ability to communicate them are a success factor for the building project and leads to more satisfied and less critical clients and end-users (Pemsel et al. 2010). There are many different methods to understand and communicate the requirements of the end-user (Malmqvist and Ryd 2006), some of which are supported by ICT. There have been some reviews of ICT applications in briefing, e.g. (Ryd 2003, Chung et al. 2009) but these reviews have been focused on research prototypes more that the software’s used in practice. There is a lack in the literature of how ICT-support is used for briefing in practice and the values coming from this use. This knowledge is vital as a foundation for further development of ICT-support for briefing. In Sweden there are two systems that are widely used in practice: dRofus (Nosyko 2012) and Program of Technical Standard (PTS 2012). PTS is used by more than half of the Real Estate organisations of County Council in Sweden in the early stages of the building process, and therefore chosen as a case study in this study.

2. Aim and Research questions

The **aim** of the research project, where the study presented here is a part, is to achieve a more value-driven building process by the use of ICT.

To fulfill this aim three main **research questions** were formulated:
Q1: How is ICT used today in a value-driven briefing process?
Q2: What values are given by using ICT-support in the briefing process?
Q3: How could ICT be developed to further support a value-driven process?
In this paper question Q1 and Q2 will be in focus but answering these two questions will also bring forth some information concerning Q3.

To answer the questions above three case studies were used. Three ongoing building project were studied; two healthcare buildings and one building for culture and music. These case-studies were performed as a part of the Eracobuild project "Value Driven Procurement in Building and Real Estate" (ValPro 2012) to develop a holistic value model for the facility life cycle.

In this paper we focus on one of the case studies concerning the planning and production of a building for culture and music. The ICT tool PTS (2012) was used to support the briefing process in this project.

3. Case study: Spira, the Culture centre in Jönköping

Spira, the Culture centre in Jönköping has a total area of 14 000 square meters and the client is Landstingsfastigheter in Jönköping (The Real Estate Organisation of the County Council). The type of contract that has been used is a turnkey contract and the contractor was PEAB. The budget was 34 million Euro and the final bill ended up at 48,5 million Euro (41,2 million Euro for the land and the construction of the building, and 7,3 million for interior, equipment, and artistic decoration). The construction process started in June 2008 and the opening was on 11 November 2011. When constructing this new building, the ICT tool PTS(2012) was used to support the briefing process.

3.1 Case owner

The County Councils most important task is health care. But the County Council in Jönköping is also responsible for theatre and culture activities, called Smålands Musik & Teater. The working environment for the staff of Smålands Musik & Teater was condemned by the Work Environment Authority in Sweden and therefore a new building was planned.

3.2 Objectives and research questions for the case study

The objective of this case study is to investigate the use of PTS in the building process concerning a building used for activities other than medical service. This case study creates an opportunity to gather valuable knowledge for the development of PTS in a general manner. Medical premises have until now been the main focus for PTS but in this case the ICT support has been used during the construction of a culture centre.

To reach the objective the following questions were focused in the case study:
CSQ1) What functionalities in PTS support the briefing process?
CSQ2) How did the use of PTS influence the process?

CSQ3) What values were created by the use of PTS?
The two first questions, CSQ1 and CSQ2, will mainly answer research question Q1.
The third question, CSQ3, will mainly answer research question Q2.

3.3 Method and research realization

An illustrative case study, is primarily descriptive (Hyvärinen and Mäkeläinen 2010), and seemed the right choice for this case study, which seeks to identify and describe how PTS was used in the building process of a hospital building.

Three different techniques for collecting data were used in this case study:
1) Workshops
2) Document study
3) Semi-structured interviews

A summary of techniques used for collecting data and how they are related to the research questions are presented in Table 1.

Table 1: Techniques used for collecting data related to the research questions.

Research question	Technique	Analyse Method
CSQ1 What functionalities in PTS support the briefing process?	Workshops, Document study	Descriptive
CSQ2. How did the use of PTS influence the process?	Workshops Semi-structured interviews	Descriptive Content analysis
CSQ3. What values were created by the use of PTS?	Workshops Semi-structured interviews	Descriptive Content analysis

3.3.1 Workshops

The workshops were carried out with staff from Landstingsfastigheter, acting in a double role as both client and case owner. In the group there were professionals that have a decision-making role at Landstingsfastigheter and people who use PTS on a daily basis.

Two workshop-series were carried out in this research and the aims of the workshops were to:

1. identify the briefing process and establish a description of how and when PTS was used during the early stages in the building process. This should give data to answer research question CSQ1 and CSQ2.

2. establish a description on the values of using PTS. This should give data to answer research question CSQ3.

3.3.2 Document study

Written sources such as administrative documents, newspapers, websites, letters and other internal documents can be used and be relevant to a case study (Yin 2009). However, one should be aware that these types of documents and information are not always correct and they can also contain some bias, and therefore should be used with caution.

In this case study websites and internal reports were used for collecting information about ICT tools, project description etc.

3.3.3 Interviews

Personal and semi-structured interviews were conducted with selected respondents, to study their experiences, thoughts and expectations or perceived effects and problems associated with the use of ICT support in the process.

Responses from those who work for the client (those who purchase the building project) will be compared with the replies from those who carry out (develop) the building project. Therefore project participants from both the client and the current contractor were asked to participate in the study.

The project manager was given opportunity to recommend which representatives from the tenant could participate in the interviews because they had the knowledge on who participated in the early stages.

4. Results

A summary of the results from the document study, workshops-series and interviews is presented below. The result is presented divided by the research questions. The citations used from the interviews below are translated from Swedish into English by the first author.

4.1 What functionalities in PTS support the briefing process? (CSQ1)

As a result of the document study a description of the ICT support PTS was made.

Landstingsfastigheter has developed PTS as an ICT-based management system for controlling and supporting its building process. PTS is a knowledge database containing best practice and specific knowledge about how the building of premises for healthcare should be carried out.

"Program of Technical Standard aims to strengthen the client's role through active assumption of responsibility, acting correctly from the start, involving clear instructions, good solutions that can be reused and guidelines that set value related goals." (Landstingsfastigheter i Jönköping 2010)

PTS was developed back in the early seventies when two of the County council's hospitals were planned. Today it is a web-based software that can be used if a computer has a connection to the Internet.

Ten of the twenty Real Estate organisations of County Councils in Sweden use and are part-owners of PTS. Each part-owner has one representative person on the PTS board (Landstingsfastigheter i Jönköping 2011). The PTS board makes the overall strategic decisions about the ICT software e.g. how and when the IT-system should be developed. Program of Technical Standard is regularly updated e.g. after collecting experience from the client, contractor and tenants when a construction projects has ended (Landstingsfastigheter i Jönköping 2010). The requirements and information in PTS are also updated if the healthcare providers (the tenants) change their workflows or introduce a new treatment method that affects the requirements of the premises.

4.1.1 Use of Guidelines, Technical Program and Standard rooms

PTS contains guidelines which set the overall values and requirements for standards in premises for healthcare. Guidelines such as acoustics, fire prevention, environmental requirements, hygiene and accessibility (disability) are specified in PTS (Landstingsfastigheter i Jönköping 2010).



Figure 1: Snapshot of guidelines in PTS.

In PTS there is a module called, Tekniska Programmet (TP) where clarifying and more specified requirements for building regulations and legislation and Sweden's law for health- and medical care are stated (Landstingsfastigheter i Jönköping 2010).

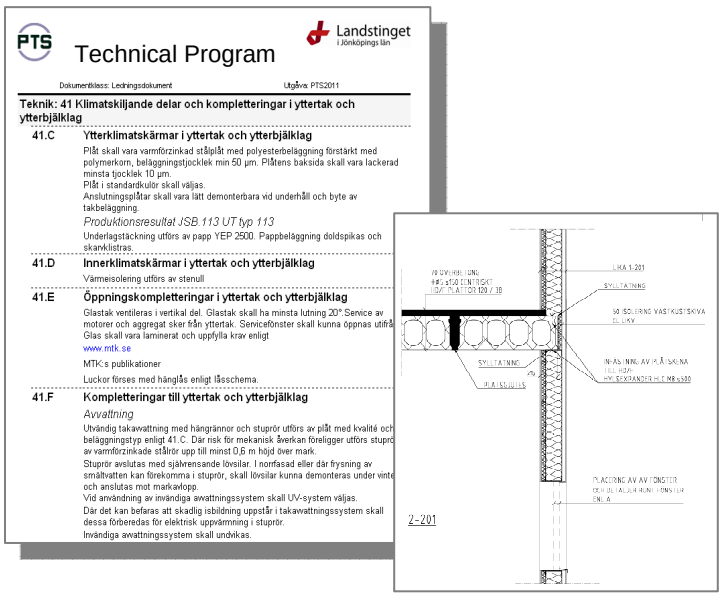

Figure 2: Snapshot of a report from the Technical Program in PTS.

PTS also contains standard rooms that are good examples of solutions for premises for the County Council. The standard rooms contain requirements for a room such as interior equipment and functional-requirements. The standard rooms are also visualised, as 3D-images, which are used in discussions about solutions with the tenants. It is valuable for the County Council that premises are general and flexible so they can be used for different purposes. Therefore the standard rooms in PTS are used as a base when building project in the county are planned (Landstingsfastigheter i Jönköping 2010).

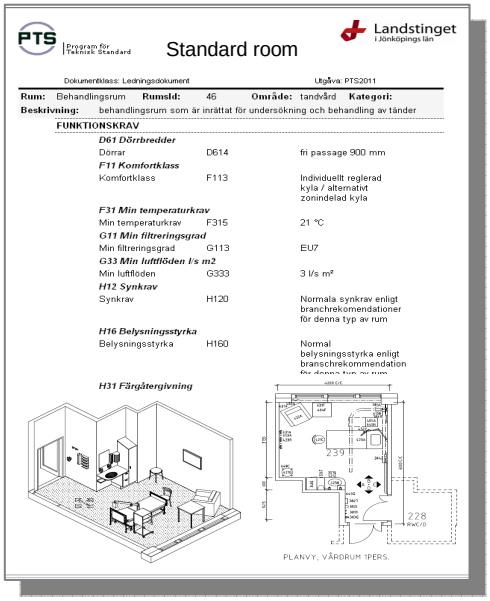

Figure 3: Examples of use of Standard rooms in PTS.

4.2 How did the use of PTS influence the process? (CSQ2)

During two workshops-series the early stages in the process was identified and a description was conducted on how the software PTS was used in these steps.

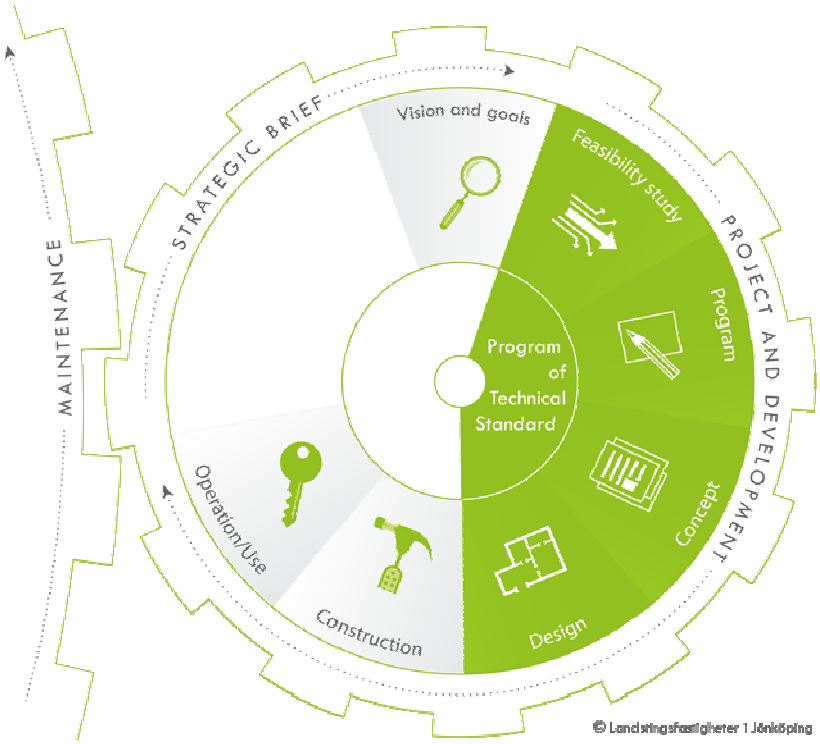

Figure 4: The building process and the use of Program of Technical Standard.

PTS is used during the feasibility study, the program, the concept and the design phase in the building process (figure 5). The use of the software in the different stages is presented below.

The first phase when PTS is used, is in the **feasibility study**. The standard rooms in PTS are studied and discussed during workshops with the tenants, e.g. when discussing the tenants processes and workflows, function and size of the room etc. PTS also supports an early calculation of area, costs and the establishing of the technical brief. In this phase PTS is used by the client (facility planner, project manager) and by the architect/developer.

In the **program** phase, PTS supports a careful planning of the new premises. The FP module (FunktionsProgrammet) in PTS is being used to develop the functional brief of the premises. The brief contains a list of all needed rooms and the requirements for each room. This information is documented in room data sheets (East and Nisbet 2011), in Swedish called RumsFunktionsProgram, RFP. The RFP contains detailed information on interior requirements such as equipment and what functions the rooms should possess. To establish the RFP the standard rooms in PTS are being used and discussions are held in workshops with the tenants. The results from the earlier phase (feasibility study) support this phase and PTS is used by the client (facility planner, project manager) and by the architect in this phase.

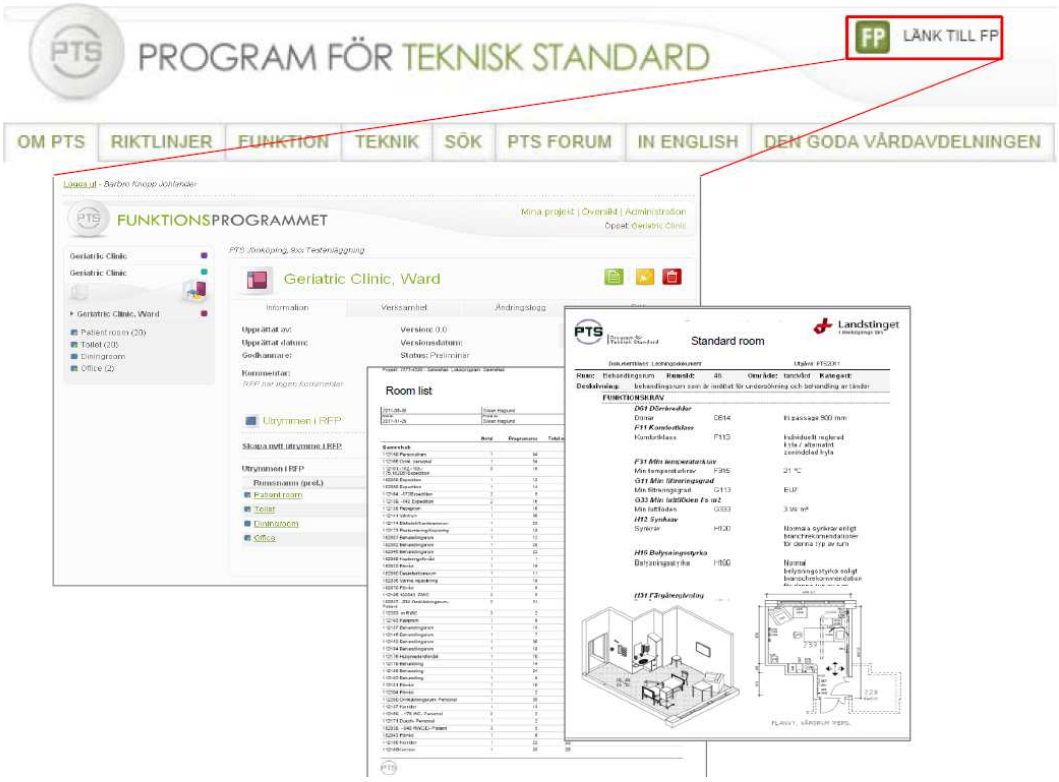

Figure 5: The use of PTS in the program phase developing Room list with connection to the standard rooms.

The TP module in PTS is used in the **concept phase**. TP is used for developing specifications for the technical brief, such as the frame system, materials, building systems etc. Users of this module are staff from the client when they are conducting tendering. But the contractor and entrepreneurs also use this module when procuring materials for the building project.

The project of building 36 is a hospital building and an ordinary building project for this client. The result from the case study shows that PTS has been used according to recommended use

4.3 What values were created by the use of PTS? (CSQ3)

During the workshops held with the client organization Landstingsfastigheter, discussions were held on what values the use of PTS gives. Thirteen (13) values were identified. For more information about these values see (Bruun at al. 2012).

When comparing these thirteen values of using PTS, with the result from the interviews, the results showed similarities. Three expected values could be connected to answers from respondents from the interviews:
Using PTS facilitates communication and information transfer
Using PTS an enables efficient process.
Using PTS enables getting consistency of standard
Those combined values of using PTS are described below.

4.3.1 Using PTS facilitates communicating and information transfer

The developer can benefit from using PTS especially when communicating and transfering information about the requirement of interior and the function of the premises.

"I think it's very important that there is a brief, that is, a RFP that you can follow. There are projects where there isn't always a room program, and the house will be a little bit like what the discussions decide. And that's fine, as long as everyone is in the process. But we work with quite a long process, so people disappear and you stop and .. . all of a sudden, someone is wondering why it is like this, or why that room or that function disappeared... It's difficult; it is not everybody that... it is difficult to get the answer back then, therefore it is good that there is a direct room program. " (Architect, 2011-09-27)

To get essential information about the requirements specified in a structured and easy way to follow, is important for the developer and the final outcome.

"The more information we get, the easier it is for the architect to carry out the work well." (Architect, 2011-09-27)

PTS is also supporting the way in which fear and negative attitudes from e.g. the tenant can be handled.

"The tenants are terrified that their workspace won't be perfect when they move in. They all want much bigger rooms because they are so cramped where they are now. Then you try to tell them that they won't necessarily be so cramped with different planning and different furniture. So I think that this is another fear of theirs and I think the standard room in PTS is a very good tool which you can use to show them what their space will be like." (Facility Planner, 2011-08-18)

4.3.2 Using PTS enables an efficient process

The result from the interviews shows that using PTS enables an efficient process i.e. less time will be spent for the client in the briefing process when using PTS.

"Normally using PTS ensures that we will arrive at a solution faster - we don't discuss things back and forth over a long period of time." (Project Manager, 2011-08-16)

Although it was a different building to construct and the requirements were more specific than the client was used to, the project manager believes that the use of PTS did add value to the process, especially in the contact and discussions with the tenant about their needs and requirements.

"The advantage of using PTS is that we have defined specifications and requirements and we know how our premises should be built and equipped. It is also an advantage to use PTS when dealing with tenants from another organization than the healthcare. This tenant is a very special type of tenant with very special requirements. PTS has helped the facility planners to guide them towards the standards already defined in PTS… as much as they could anyway." (Project Manager, 2011-08-16).

4.3.3 Using PTS enables getting consistency of standard

The results show that using PTS will have some benefits, even if the ICT tool is developed for health care premises and not for premises such as, in this case, music and theatre. Using the software and its requirements enables control and the possibility of achieving a level of standards in the county's premises.

"Actually, PTS is a base to build on ... we avoid having to investigate things for each new project, and we have a standard for how the county council wants to build. PTS is in fact a standard. It helps us to avoid discussions for each project: how big must the rooms be? What should they contain? And already in the early stages you know where the technology in the house must be. [...] And you don't need to go out to each workgroup with the tenant and discuss how big the room must be, because it is a template, a standard. I think it helps me tremendously." (Facility Planner, 2011-09-05)

5. Conclusion

In this paper we focus on how ICT-support is used for briefing in practice. The use of the ICT tool Program of Technical Standard (PTS) has been studied. PTS is used in the early stages of the building process to support the briefing process by more than half of the Real Estate organisations of County Councils in Sweden. The findings in this paper are based on a case study concerning the planning and production of a healthcare building.

PTS is a knowledge database containing best practice and specific knowledge and the ICT support is valuable to use in the feasibility, concept and design process. It is valuable for all parties involved in the process. The case study gave the following values using PTS:

- Enabling the capturing of requirements.
- Facilitating communication and information transfer.
- Enabling consistency of standard.

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Assessment of adaptation strategies to climate change impacts in a big city: the case of Paris

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Abstract

The EPICEA project is a joint collaboration between the City of Paris, the French Meteorological Office (Meteo-France) and the French Scientific and Technical Centre for Building (CSTB). The general objective is to quantify the impact of climate change in Paris city as well as the influence of the built environment on urban climate. The project addresses three subjects: (1) the long-term evolution of the Parisian urban climate in a changing climate; (2) a sharp analysis of the 2003 heat-wave and (3) the interactions between the characteristics of the built environment and the urban climate. Numerical models describing heat and mass transfer between the urban area and the atmosphere were used. For subject (2), a fine scale description (250m x 250m) of the area was chosen to allow a precise definition of the physical properties of the built environment which rule the urban energy balance (thermal mass, radiative properties of roofs, walls and streets cover, green areas ...). A comparison with recorded meteorological data demonstrated the robustness of this simulation which was then chosen as a reference situation. This reference situation helped assessing the impact on the heat wave intensity and other meteorological parameters of modifications of the built environment. Several scenarios were elaborated: “shining Paris” (increased albedo of surfaces), “greener Paris” (increase of green surfaces), “watered Paris” (water on the street surfaces). Simulations were run for each of the scenarios using the same numerical environment than for the reference situation. Differences in results reflect the impacts of the modified characteristics of the built environment. This paper presents these results which confirm the importance of (watered) vegetation as a very influent factor. The impact of other factors such as high albedo surfaces and water is also tangible. These results are analysed in an economic perspective taking investment and maintenance conditions into consideration.

Keywords: urban-heat-island, adaptation, heat-wave

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1. Introduction

An urban area is a very complex dynamic structure that supports a great number of social, economic, symbolic and technical functions. The share of world population living in urban areas was 13% in 1900, a bit less than 30% in 1950, close to 50% in 2005 and is expected to reach 60% in 2030 (UN, 2005). This trend now concerns all countries. The number of both large cities (population ranging from 5 million to 10 million) and mega-cities (with at least 10 million) is expected to increase in the near future: numbers should jump respectively from 40 to 59 and from 23 to 37 between 2011 and 2025 (UN 2011). Originally, urban areas developed from a natural environment experiencing local climate. The concentration of a huge mass of construction material on a relatively small area as well as the presence of multiple sources of energy (e.g. heating/cooling of buildings, traffic of vehicles, production activities) modified the local urban climate. This evolution of local climate mainly results from the modification of the exchange of energy with the atmosphere. The urban-heat-island (UHI) phenomenon is one of these modifications that has for long been described and documented (OKE 1988). The building fabric, the topography of the urban tissue, bare ground surfaces, green and blue areas embedded in the urban tissue, wide and narrow streets with or without trees along are some of the parameters that participate in UHI development.

The on-going growth of the urban population and the concomitant climate change perspectives create an unprecedented context. Global warming is already observed (IPCC 2007) and will very likely become particularly significant beyond 2070. Heat waves comparable to or even more intense than the August 2003 event could concern Western Europe every other year from 2070. The conjunction of both urban growth and more intense and frequent heat-waves triggers reflection on how to cope with future climatic situations. Moreover, the time scale of urban interventions is several decades so that decisions should be prepared from now in order adaptation measures to be timely implemented and operative by the end of the century.

The aim of the EPICEA project (French acronym for “pluridisciplinary study of the impacts of climate change at the scale of Paris region”) is to address such issues and to provide scientific background to decisions. This project results from a joint effort of Meteo-France and the French Scientific and Technical Centre for Building (CSTB). It was launched in 2008 and funded by the City of Paris.

2. Objective and methodology

2.1 Objective

As in many cities in Europe in August 2003, as well as in other country during past intense heat-waves (e.g. in Chicago and Philadelphia in 1995, (Kahn-Thornbrugh 2001)), a high number of extra fatalities was recorded in the city of Paris. Between August 1 and August 20, 1 910 deaths were recorded whilst the statistical number during the same period was expected to be 843.1 (Hémon, Jougla 2003). These figures reflect the vulnerability of the population exposed to extreme temperature during long periods. These extreme

temperatures result first from the temporary meteorological conditions at a regional scale and are increased in urban areas due to the UHI effect.

The general objective of EPICEA is to address the evolution of the Parisian urban climate within the context of climate change with a particular focus on temperatures as a main driver of observed heat-wave related extra fatalities. The project does not directly address the vulnerability of persons but as the link between extreme urban temperatures and extra fatalities is qualitatively established, we will use the expression “vulnerability of the city” (to heat-waves) as a shortcut.

2.2 Coupling atmospheric and urban area systems

The description of the energy exchange between the atmosphere and the urban area is essential to explain observed climate and to anticipate the effects of future global climate on local urban climate. Several numerical models developed by Météo-France were used during the EPICEA project.

The French Meso-NH atmospheric simulation system (Lafore et al. 1998) is designed as a research tool for small and meso-scale atmospheric processes. The dynamics of the model is based on the non-hydrostatism hypothesis and the anelastic approximation. The physical part of the model consists in the parameterization of microphysics, convection, turbulence, radiation and surface. Surface treatment is externalised and specific surface schemes are coupled with the atmospheric model: the Town Energy Balance (TEB) scheme for the urban part (Masson 2000), the ISBA scheme for the vegetation (Noilhan, Planton 1989), and two other specific schemes for lakes, sea and oceans.

The TEB scheme is designed according to the canyon approach (figure 1). Walls (w), flat roofs (R) and streets (r) are described by layers of construction materials. Liquid water (W) or snow (W_{snow}) can be accumulated on roofs and streets. The temperature (T) of the different layers is calculated using the laws of heat transfer. The TEB scheme was upgraded during the project so as to integrate low growing vegetation in the streets (Lemonsu 2010). Topographic data as well as data referring to the building fabric reflect the characteristics of the Parisian urban area.

A main driver of the UHI phenomenon is the thermal inertia of the urban area as a whole. The TEB scheme is then designed to well represent heat exchanges at the urban/quarter scale. Recent upgrade allows a better representation of building physics but the initial design proved to be accurate enough to simulate the observed UHI effects at the scale of urban areas (Masson et al. 2002).

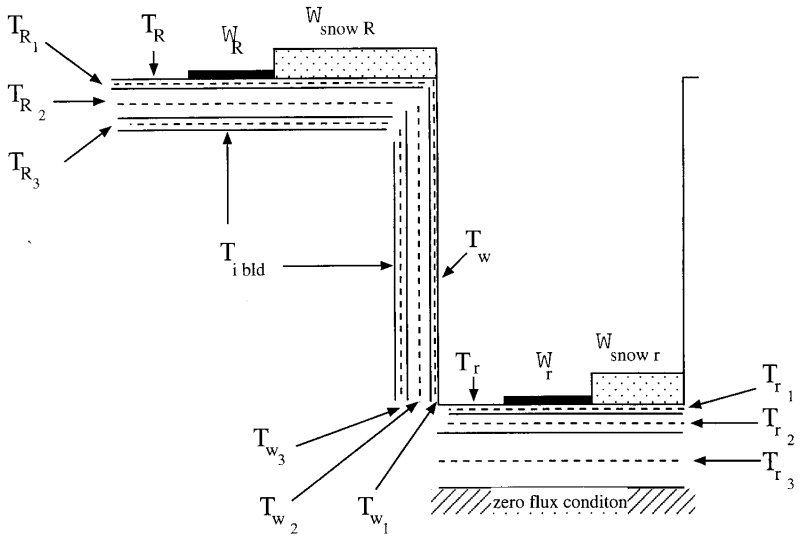

Figure 1: the TEB canyon street (adapted from Masson 2000)

2.3 A three-fold approach

A three-fold approach was followed so as to achieve the previously exposed general objective of EPICEA: part 1) investigation of the long-term evolution of the Parisian urban climate under global climate change; part 2) detailed simulation of the August 2003 heat wave as an example of extreme meteorological event that is likely to become more frequent in the future; part 3) exploration of the impact on local urban climate of adaptation measures aiming to influence the intensity of the UHI in future climate. The following subsections provide a brief overview of the context of the simulations for each of the three aspects as well as some results. More detailed results of part 3 are presented in section 3.

2.3.1 Paris city in a future climate

The objective of this first part is to simulate the impact of climate change by comparing the urban system response in two different climatic contexts: one in the recent past, one in the future. Our methodology relies on simulations over long-time periods using the same surface model (i.e. the characteristics of the city remain unchanged).

The surface model is forced by meteorological conditions derived from an analysis system called SAFRAN (Durand et al. 1993) and validated over France (Quintana Segui et al. 2007). It is a spatial and temporal interpolator which gives analyses of meteorological variables (temperature, humidity, wind, precipitation, pressure, and solar and atmospheric radiation) on a 8km*8km grid over France with an one hour resolution, using CORINE Land Cover (Heymann et al. 1993) and associated parameters from the ECOCLIMAP (Masson et al. 2003) database. Our simulations are run on a 48km*48km grid with the city of Paris in its center. The spatial resolution is 1km.

Simulations of past/present climate of the city of Paris start on 01/08/1970 to end on 31/07/2007. Simulations of the future climate for the period 2046-2065 were run using ARPEGE-Climat, the French global climate model developed by Météo-France. Emission scenarios A2 and A1B produced by IPCC in its Special Report on Emission Scenarios (IPCC 2007) were considered. Meteorological forcing for each scenario was issued from downscaling techniques used in the RExHySS project (Ducharne et al. 2009).

Simulation results highlight a significant increase of the outdoor temperature (between 2 to 4 °C) which depends on the urban density (central city, suburb, countryside) (table 1) as well as a clear trend towards milder winters and much hotter summers by the end of the 21st century.

Table 1: present and future minimum / maximum annual average temperatures 2m above ground according to IPCC SRES A1B and A2

		Urban area		Near suburb		Rural	
		T_{MIN}	T_{MAX}	T_{MIN}	T_{MAX}	T_{MIN}	T_{MAX}
Present (1971-2006)		9,4	15,8	8,0	15,5	6,9	14,6
Future (2072-2098)	A1B	11,8	18,7	10,3	18,6	9,2	17,8
	A2	12,4	19,4	11,0	19,3	9,9	18,5
Temperature increase : Future - Present	A1B	+2,4	+2,9	+2,3	+3,1	+2,3	+3,2
	A2	+3,0	+3,6	+3,0	+3,8	+3,0	+3,9

2.3.2 Detailed simulation of the August 2003 heat wave

The goal of this simulation is to try reproducing the observed August 2003 heat wave effects over the Paris area. Doing so, we get a reference situation that will be used to assess the effects of adaptations measures in part 3. The simulation period corresponds to the peak temperature period from August 8 to August 13 (during which the highest mortality rate was recorded (Hémon, Jougla 2003)). The simulation domain is smaller than for the part 1 and the resolution of the grid covering Paris inner city is much finer: 250m*250m.

The description of the urban fabric also needs to be much more detailed. A specific database of the Parisian urban canopy was developed by CSTB to represent the city in a realistic way. It was elaborated in close collaboration with the Parisian Urban Planning Agency (APUR). These data include the altitude of each grid point, the presence of vegetation, of streets and of water, the height of buildings as well as the types and surfaces of roofs and walls, etc. They have been re-analysed and incorporated into the TEB urban scheme using geographic information software.

Simulations show that the most urbanised quarters in the center of Paris are the seat of intense UHI. A 4 to 7 °C temperature difference is observed at the end of the night between these areas and the low urban density areas around Paris. The influence of the Seine river flowing through the city as well as of the two main green areas on the east (bois de

Vincennes) and the west (bois de Boulogne) of Paris are also visible. Local UHI can also be observed in the inner city (differences of 2 to 4 °C). Peripheral quarters as well as close suburb urban areas situated downwind are also impacted by high temperatures due to the convective energy transfer from the city core.

2.3.3 Adaptation strategies

Previous research helped identifying actions on the built environment that have a potential impact on urban climate and more precisely on the UHI development (Colombert 2008). The most promising interventions are the modification of the surfaces albedo and infra red emissivity (roofs, walls and streets), the greening of urban surfaces with low growing plants (e.g. grass-type vegetation) and the introduction of water in the city (e.g. watering of street surfaces). These interventions are named adaptation measures, i.e. they are said to be effective to reduce the UHI intensity in the future. Doing so, the urban area local meteorological conditions during a heat wave is intended to be more bearable for inhabitants.

Part 3 aims to assess the potential impact of adaptation measures based on these interventions. Our methodology is to simulate the effects of these modifications using the same meteorological context than for part 2 (i.e. during the peak temperature period of the August 2003 heat wave). The comparison between the results of these simulations and the results of the part 2 reference situation provides the assessment we are looking for.

Four scenarios have been investigated as indicated in table 2. Two options are considered for the S2 scenario: green surfaces can be watered or not. The geometrical and topographical parameters (i.e. the size and height of buildings, the width of streets) of the virtually modified Paris city remain unchanged for all these scenarios.

The additional green surfaces have two origins. Firstly we virtually “green” all existing bare-ground surfaces, i.e. 862 hectares. Secondly we also virtually green half of the surfaces of wide enough streets (wider than 15 m), i.e. 305 hectares. The total additional surface increase represents 89% of the present surfaces covered with low-growing vegetation.

Table 2: adaptation scenarios

Name	Reference	Description
Shining Paris	S1	increased albedo and infra-red emissivity of artificial surfaces
Greener Paris without watering	S2	increase of green surfaces
Greener Paris with watering	S2 bis	increase of green surfaces
Watered Paris	S3	water spraying on the streets during the day
Complete	Stot	combination of the three first scenarios

3. Impacts of adaptation measures on UHI

The comparison of part 3 simulations with the part 2 reference situation allows the analysis of the effects of adaptation measures on several meteorological parameters during the development of UHI in the Paris city. We report some of these effects on urban heat balance, outdoor temperature and UHI characteristics.

3.1 Impacts on the urban heat balance

The heat balance expresses the fact that the net radiative flux (difference between incident and reflected/emitted short/long wave radiations) over the urban area is counterbalanced by the sum of the sensible heat flux (energy transferred by convection), the latent heat flux (energy involved in the evapotranspiration of vegetation) and the stored energy (in the thermal mass of the built environment). Under stationary conditions, an equilibrium temperature would be reached. It would be higher in the urban area than in the surrounding rural area. The diurnal cycle creates dynamics so that the terms of the balance are constantly changing. The difference of the dynamic balances between these two areas creates the conditions for the UHI development.

All scenarios (refer to table 2 for description) influence the heat balance of the urban area. In scenario S1, the net radiative flux strongly decreases due to the influence of the increase of surface albedo and of infra red emissivity. The stored energy decreases as well. On the contrary, the net radiative flux increases in woods at the east and west of Paris.

In scenario S2/S2bis, the resulting effect highly depends on the availability of water for the low-growing vegetation. If the vegetation is not watered (S2), it quickly experiences water stress and the contribution of the concerned surface to the heat balance is unchanged compared to the reference situation. If the low-growing vegetation is watered (S2bis), latent heat flux becomes more intense and “consumes” part of the incident solar energy.

Similarly, the energy needed to evaporate the water sprayed on the street surfaces (S3) increases the latent heat flux and decreases the stored energy as well as the sensible heat flux. The complete scenario (Stot) cumulates these effects.

3.2 Impacts on outdoor temperature

3.2.1 Temperature at 2 m above the ground

Impacts on this parameter highly depend on the scenario. The effect we are mainly looking at is the reduction of the highest temperatures. The following results refer to average trends; a more detailed analysis allows more nuanced conclusions. S1 causes a strong decrease of the highest temperatures at 2m above ground. Even more important decrease can be observed with S2bis whilst S2 does not generate significant signal. The effect of S3 is moderate. The combination of all identified adaptation measures (Stot) can locally and temporarily lead to more important temperature decrease: up to 6°C.

An example of a local analysis introduces the nuances we previously mentioned. The selected location is in the south-east of Paris (13th district) where vegetation, buildings and streets surfaces respectively represent 28 %, 40 % and 32 %. In this particular place (simulation grid square surface 250m*250m): 1) S1 and S3 have comparable limited impacts (i.e. a slight temperature decrease during the day with a maximum of 1°C at mid-day, 2) S2 has no impact but S2bis causes a maximum decrease between 2 and 2.5 °C, 3) the decrease can reach 3.5 °C for Stot.

3.2.2 Vertical temperature gradient

Vertical temperature profiles (up to 30 m corresponding to the average height of buildings in Paris) can be plotted for any point of the grid. They reflect the impacts of scenarios according to the following global trends.

All scenarios lead to temperatures along the vertical lower than in the reference situation. For all scenarios, the maximum difference is observed during the day and the night of August 11. Figure 2 presents typical profiles in two contrasted situations: a dense built environment (arr9) and an area (arr7) that offers important green surfaces on wide avenues when S2 is implemented. Days and nights temperature profiles resulting from S1 are rather flat along the vertical. S2 shows no difference with the reference situation (doted lines superpose on figure 2). The impact of S2bis obviously depends on the importance of watered green surface at a given location: the temperature difference between the bottom and the top can reach 3.5 °C during the day and 2.5 °C during the night in green districts while it remains flat in densely built districts. The effect of S3 is more modest (0.5 to 1°C at low altitude) and is limited to lower altitudes. Stot cumulates the effects of all scenarios: vertical temperature differences up to 5°C during the day and 4.5°C during the night can be observed.

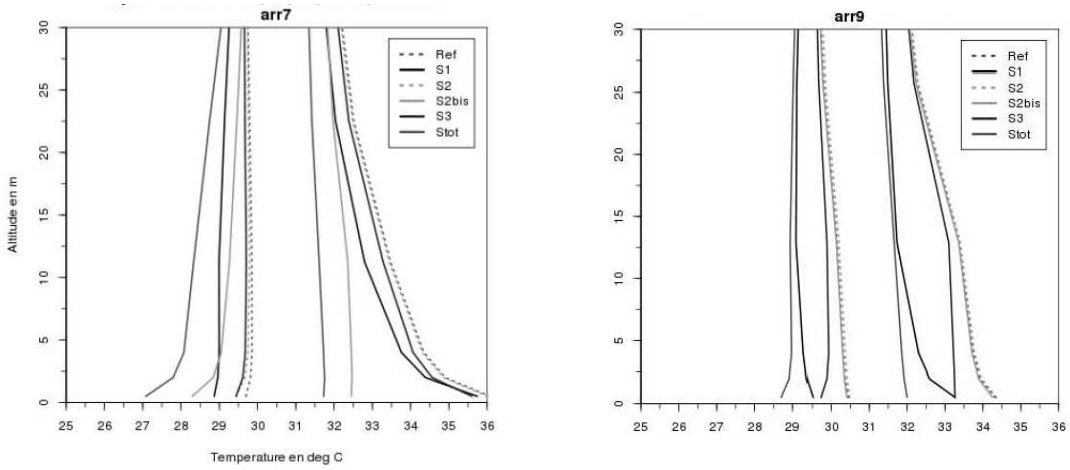

Figure 2: typical vertical temperature profiles in a green area (left) and in a dense district (right). Day/night profiles are represented by left/right groups of curves.

3.3 Impacts on UHI

The temperature curves on figure 3 illustrate the global impacts of the four scenarios. The structure of the UHI remains unchanged with highest temperatures over the dense city centre. A global decrease down to -2,2 °C can be seen over Paris for the complete scenario Stot. The analysis of results over the entire area show that the structure of the UHI is slightly modified as the highest temperatures, located over the centre of Paris in the reference situation are located in the south-west and south-east of the city for Stot. The most intense temperature diminutions are situated over places where vegetation fraction is increased and watered. UHI varies from one day to another in terms of intensity and spatial structure.

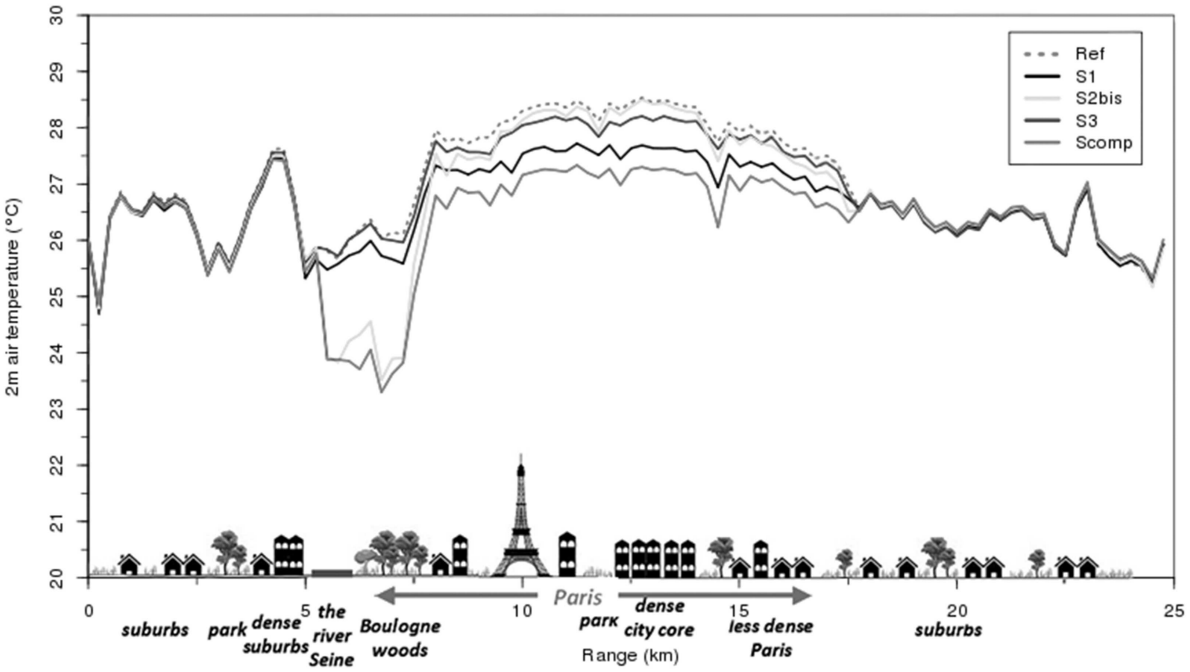

Figure 3: west (left) - east (right) cross section of Paris city showing the influence of scenarios on average temperature profiles

4. Discussion of results

Presented results are part of the outcomes of the project. The influence on other parameters such as relative humidity, wind speed, precipitations (thunderstorm), soil water content has also been addressed. This section introduces a discussion on the presented results.

4.1 Order of magnitude

A main interest of the EPICEA project is to provide credible orders of magnitude of the effects of some adaptation measures on meteorological parameters. This credibility lies in the proved capacity to simulate the August 2003 heat wave pattern (temperatures, relative humidity, wind, precipitations) over Paris and surroundings. These results consolidate previous validations of the TEB scheme (Masson et al. 2002). They also give indication on the pertinence of the description of the built environment that includes different types of buildings according to the date of construction. The computed decrease in temperature

according to considered scenarios has to be further analysed taking into account other issues such as the economic and technical feasibility, the acceptability of proposed measures and side effects (e.g. on health).

4.2 Technical and economic feasibility

In the wake of the “cool-roof” conceptual and technical development, several technical solutions are at hand. We can then seriously consider the S1 option from a technical point of view even if architectural peculiarities of the Parisian roofs would create difficulties to implements these solutions (40% of the roof surfaces are covered with zinc (Colombert 2008)). Products with required properties (high albedo, high infra red emissivity) are not necessarily “white-looking” (Akbari et al. 2006). The present cost of cool watertight roofing membranes for flat roof is about 50% higher than traditional black bituminous or polymer products but this extra cost is very likely to decrease with the development of the market.

Beyond direct investment cost, the aging of reflectance and emissivity properties is a main concern as the expected decrease in temperature in the urban area highly relies on them. Tests show a rapid decrease of these properties due to air pollution and aging of materials (Akbari, Levinson 2008). An ad hoc maintenance consisting in a frequent cleaning could counterbalance this degradation of performance but it has to be organised and budgeted.

The presence of urban surfaces covered with low growing vegetation (e.g. trams railways) brings evidence of the feasibility of scenario S2. The expected contribution of green surfaces to the urban heat balance depends on the availability of water that may be a problem during hot and dry periods. But this is a more general problem to be solved as well for green roofs.

The implementation of S3 is likely to be feasible in Paris due to the existence of a distribution network of non drinkable water that runs along all the streets. It is used for street cleaning. Tests are planned during hot periods to measure the local effect and assess water consumption.

4.3 Acceptability and side effects

Scenario S1 using “white” materials would cause a radical change in the visual perception of the city (Erell, Pearlmutter 2012). The question must be raised of its impact on the attractiveness of the city for millions of visitors a year as well as for the citizens. Additional trees could be necessary to limit glare.

The abundant use of water for scenarios S2bis and S3 may also create unexpected situations impacting the life of citizens and pedestrians. The combination of heat and humidity could favour the development of unusual vectors of disease (e.g. insects).

5. Conclusion

The EPICEA project is a contribution to questions all urban areas experiencing hotter climate will have to face in some decades. We have explored some scenarios the technical

feasibility of which is likely. Nevertheless, cost issues (investment and maintenance) and side effects have of course to be considered to assist decisions by the town authorities.

A town is nevertheless not just a thermodynamic system and decisions cannot be taken only on the results of simulations based on the law of physics, even if we can rely on these results. Many other concerns (e.g. symbolic, architectural and environmental) are at least as important for human groups as the simulation of the thermal behaviour of an urban area under extreme climatic conditions.

These results call for further works that are planned or under way in other projects by the EPICEA partners. The TEB scheme is being improved to integrate green roofs and a more realistic model of buildings. These improvements will allow considering the building scale and comfort issues that could not be approached properly during the EPICEA project.

Health issues deserve a particular attention. The impact of even slight decrease in temperature may have important effects on mortality rate. Prevention and protection of the most vulnerable population can also be organised by other means than the EPICEA scenarios, e.g. by temporarily hosting this population in naturally cool or artificially cooled places. This latter option addressed the important question of energy demand that must not only be analysed during heat wave period but during the whole year including heating and cooling needs. The positive effect of adaptation measures during the heat wave (e.g. use of high albedo and infra red emissivity surface materials) may not be as positive during the heating period.

Acknowledgements

The authors would like to thank the urban planning agency of Paris (APUR) for helping us to elaborate the Parisian urban cover database. The EPICEA project is funded by the city of Paris within the framework of its Climate Plan.

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The central role of the construction sector for Climate change adaptations in the built environment

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Abstract

Over the past years, research has clearly enunciated the necessity of adaptation to climate change in the built environment. Policy is being developed on national and municipal levels to have adaptations implemented. However, for the actual application of the measures, property owners are the actors that have to commission the construction industry to take action. But the construction sector is highly fragmented, causing several barriers for an easy uptake of measures other than the 'business as usual' ones.

Based on rehabilitation intervention processes where technical measures are applied to dwellings of a housing association in the Netherlands, a governance approach for implementing adaptation measures is explored that focuses on collaboration in the construction process. In the proposed approach actors are working closely together, guided by elements of network governance. By not only integrating the complete supply chain, but also making it 'intelligent and aware', climate adaptation is no longer a surplus to the process, but reflected in any decision.

Keywords: Adaptation Measures, Climate Change, Construction Process, Networks.

1. Introduction

There is clear evidence that the global climate is changing (Fussel, 2009; Smith et al., 2009). In order to limit the risks caused by a rising sea level rise or extreme weather events, adaptation to climate change is necessary. At present, governance strategies to a large extent focus on policy making on national (e.g. Biesbroek et al., 2010) and municipal level (e.g. Bulkeley, 2010), not taking into account the policy level of property owners. However, they are the actors that are in the position to commission physical adaptation activities to the construction sector that is responsible for the actual application of physical measures to buildings. Moreover, the construction sector itself is struggling with negative effects of its inherent fragmentation, causing disadvantages such as miscommunication, long lead times and extra costs and it hampers innovation (Davey-Wilson, 2001). The existence of this fragmentation in the construction sector can be clarified by the pivotal position of a building, between a network of stakeholders (owner, user, financer etc.) on the demand side and a network of actors (designer, contractor, industry etc.) on the supply side (Vrijhoef, 2011).

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Moreover, both the demand- and supply side networks have their own fragmentations. For the demand side, this is caused by the different natures of the stakeholders, the owner wants a building that meets the needs of the user, the financer wants a certain return on investment, etc. For the supply side, this is caused by the need for specialisation, necessary for enhancing competitiveness (Dulaimi et al., 2002) in a market-driven environment (Figure 1). Literature has shown that there are developments in the decrease of fragmentation in construction. On the supply side, efforts have been made to bring about better integration, by adopting a partnering approach (Bygballe, 2010) in order to align the differences in goals and values, that originate from the present procurement methods and contracts (Bresnen and Marshall, 2000). However, the current partnering approach is criticized as being primarily a dyadic approach, between principal and construction company, not taking into account other actors in the supply chain (Dainty et al., 2001). Literature on public administration has elaborated on the increasing importance of network governance (Meuleman, 2008), which can be considered a sign of integration by the demand side. The interconnection between actors of the two systems in a multistakeholder partnership (Pinkse and Kolk, 2012) can be a promising starting position regarding the implementation of physical climate adaptations to buildings. However, literature on this matter is scarce.

This paper provides a framework for implementing physical adaptations to social housing, therewith contributing to building knowledge on what adaptation means for business, an area that is still in need of theoretical and empirical elaboration (Nitkin et al., 2009). The central question in this paper is: “How to actively involve the construction sector in implementing physical climate change adaptations in existing social housing?”

In the following chapters we will discuss what measures are to be implemented and what the characteristics are of the process to be followed in order to implement the measures. In the concluding chapter, recommendations for the involvement of the construction sector will be given and topics for further research shall be presented.

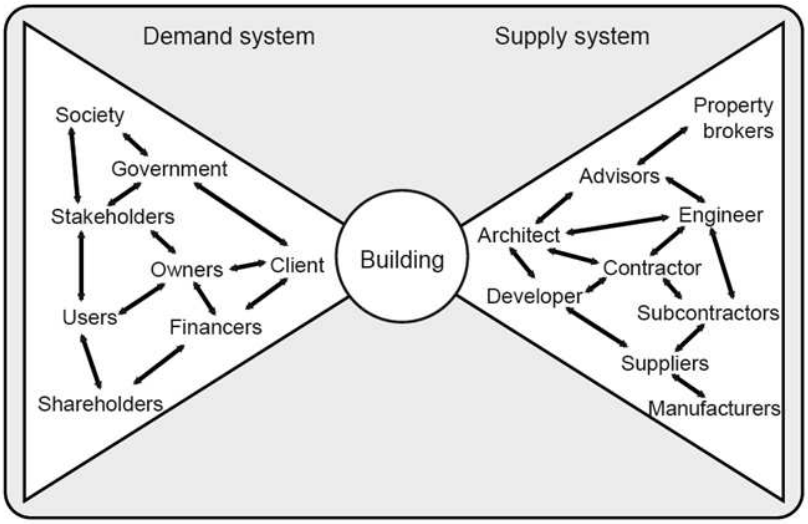

Figure 1: Pivotal position of the building between demand and supply system (Vrijhoef and De Ridder, 2005)

2. Methodology

In order to develop the guidelines on how to shape the construction process involving the construction sector in implementing climate change adaptations, it was important to elaborate on the adaptations themselves, to know what has to be implemented. In addition we elaborate on the rehabilitation intervention process in order to retrieve information on what has to be done to actually implement the measures.

For the adaptations we have taken as a base a list of 155 adaptation measures for the built environment in the Netherlands, drawn up by MWH (2011) under assignment of the Dutch Ministry of Infrastructure and environment, based on literature review and expert judgments (MWH, 2011). The measures on the list focus on the potential of newly built dwellings. However, as the production of new dwellings represents on average 1% of the total stock (www.cbs.nl), taking into account a horizon of 2050, this means that around 40% of the stock will be renewed by then, assuming that all new dwellings substitute old ones. For the Netherlands it is more likely that only half of the newly built dwellings serve as replacement of the stock, while the other half is meant to extend the stock. But even if we assume that all new buildings substitute the existing ones, still 60% of the stock has to be adapted in the existing situation, which also goes for housing associations. Whereas new building provides possibilities to implement climate adaptations at relatively low costs and effort, according to the list by MWH (2011), the existing situation may be different. As this is not elaborated in the original list, we have evaluated the measures for the existing situation.

If we look well at the climate change adaptation measures it turns out that they can be considered as technical modifications to a dwelling, in this case focusing on adaptation to a changing climate. In essence, the measures do not differ significantly from other technical measures that are applied for a special purpose such as energy efficiency or burglary safety, to name a few. For instance, in order to improve energy efficiency, technical measures such as adding an insulating material to the façade are applied, and in order to improve the dwelling's burglary safety existing door locks are substituted for locks that are more difficult to break. In the case of the insulation material, research and development by industry has resulted in a material with good insulating and application characteristics, whereas in the case of the door locks research and development by industry has resulted in locks that are difficult to falsify or are made out of a strong material (alloy) that is difficult to break. In our case, research on climate change adaptation measures has resulted in the measures as brought together in the list by MWH (2011) that make a dwelling more climate resilient.

In this paper we are not focusing on the technical quality of the measures, such as insulation capacity, strength of alloy or the contribution to climate resilience, but we are focusing on the process leading to the implementation of a measure. For this reason we have taken as an example two processes to implement technical measures to dwellings; the first process deals with the implementation of energy saving measures and the second deals with the application of safety measures to the dwelling to obtain the 'Police Label Safe Housing'. The two case descriptions are based on observations by one of the researchers during his four years employment at a housing association in the real estate management department.

3. Physical adaptations

The physical climate change adaptations known to date that can be applied to the Dutch social housing stock are mainly focused on heat, especially the urban heat island, and water nuisance, caused by increased levels of precipitation and river/sea flooding (PBL, 2009). The 155 adaptation measures for the built environment drawn up by MWH (2011) have been elaborated on many characteristics, but for the purpose of this paper we only present the ones that show differences between the new built situation and the existing situation, being application costs and the intensity of maintenance. The measures are collected in a database, which is accompanied by a factsheet for every measure. The factsheets contain information on the characteristics as described above, and have a short description of the measure, the interrelationship with other measures and references to literature.

Before discussing the measures for the existing situation, we will give an overview of the set of measures for the new built situation that are focusing on the level of the building and the building plot (table 1). These measures are considered to be within the responsibility field of the housing associations. Out of 155 measures, 46 focus on the building and plot level. The nature of the measures can generally be considered as having limited extra costs of application, if combined with regular work. Of all measures, 72% falls within this category. 17% is considered to have an equal or lower price, whereas 7% is more expensive than a conventional measure. 4% of the measures cannot be combined with regular measures, so they cannot be assessed on their application costs. Most measures (72%) are expected to have the same maintenance intensity as conventional measures, represented by the '+/-', but 24% has an increased maintenance intensity and 4% requires less maintenance.

Taking the list of MWH (2011) as a base, filtered for the measures on building level and building plot, we have evaluated the feasibility of application of the measures. Here, some significant differences appear. First of all, it becomes clear that measures do not have such low application costs as the new built situation, which is shown by the 33% of the measures with the '-' assessment (newly built 7%). This is mainly caused by the fact that in the existing situation the adaptations have to be designed especially for the situation. Some measures are not even possible to compare, because they cannot be applied to the existing building, for example the orientation of the building cannot be changed. This argument holds for 28% of the measures. Another 30% of the measures has limited extra costs (< 1,000€ per dwelling), while only 9% is cheaper than or equal to the existing situation. The general increase of the application costs is caused by the fact that most measures are additions to the existing situation. In the new built situation a climate adaptation measure can be an alternative product with the same price but with other (i.e. climate adaptive) characteristics. For the measures that were feasible in the existing situation (33 out of 46) we have assessed the application complexity, represented in three scales: applicable by tenant or all-round craftsmen from the housing association; applicable by specialized company within 1 day; or applicable by specialized company in more than 1 day. The figure shows many '-'(52%), meaning that the measures are difficult to apply, but not impossible. From the point of view of the housing association, also the maintenance intensity increases in 45% of the measures, compared to the existing situation.

Table 1: adaptation measures on building and plot level (Adapted from: MWH, 2011)

	New			Existing						
Measure	Application costs	Maintenance intensity		Application costs	Application complexity	Maintenance intensity HA		Inconvenience tenant at impl.	Impact use tenant	Window of opp. (per x yrs)
Improvement soil structure, porous sand	+/-	+/-		+/-	-	+/-		-	+/-	13
Heat and cold storage in the ground	-	+/-		x						
Cooling by river water	-	+/-		x						
Shallow subsurface infiltration	+/-	+/-		+/-	-	+/-		-	-	13
More porous pavements in private plots	+	-		-	-	-		-	+/-	13
Green roofs	+/-	-		-	-	-		+/-	+	25
Green façades	+/-	-		-	+/-	-		+/-	+	1
Temporary nature on wasteland	x	+/-		+/-	+	-		+	+	1
Green spaces	+/-	-		+/-	+/-	-		+	+	1
Mediterranean plantation	+/-	+/-		+/-	+	+/-		-	+	13
New vegetation for allotments	+/-	+/-		+/-	+	+/-		-	+	1
Saline crops	+/-	+/-		+	+	+/-		-	+	1
Water storage crates	+/-	+/-		+/-	+/-	+/-		-	+	13
Blue roofs	+/-	+/-		-	-	-		+/-	+	25
Rainwater tank	+/-	+/-		+	+	+/-		+/-	+/-	1
Backwater flap	+/-	+/-		+/-	+/-	-		+	+	50
Shadowing of buildings	+/-	+/-		-	+/-	-		+/-	+	1
Shadowing by trees	+/-	-		+/-	+/-	-		+/-	+	1
Spray systems on roofs and terraces	+/-	+/-		-	-	-		+/-	+	1
Vegetation at inlets of ventilation shafts	+/-	+/-		+/-	+/-	-		+	+	1
Natural ventilation in buildings	+/-	+		+/-	-	+		+/-	+/-	2
Apply insect screens	+/-	+/-		+/-	+	-		+/-	-	1
Architecture (orientation)	+/-	+/-		x						
High albedo material	+/-	+/-		+/-	-	+/-		+/-	+	6
Insulated, heat reflecting buildings	+/-	+/-		-	-	+/-		+/-	+	1
Building without crawl space	+/-	+/-		+/-	-	+		+/-	+	1
Mediterranean construction style	+/-	+/-		x						
Roof overhang	+/-	+/-		-	-	+/-		+/-	+	1
Sleeping rooms on the north façade	+	+/-		+	+	+/-		-	-	13
No sleeping rooms on the upper floor	+	+/-		+	+	+/-		-	-	13
Extra sun blinds	+/-	-		-	+/-	-		+/-	+	1
Pitched roofs	+	+/-		-	-	+		-	+	25
Water in an atrium	+/-	-		-	-	-		+/-	+/-	1
High rise buildings	+	+/-		x						
Double façade	+/-	+/-		-	-	+		+/-	-	1
Closed building block	+	+/-		x						
Buildings partly in water	-	-		x						
Highwater proof building	+/-	+/-		x						
Dryproof construction	+/-	+/-		-	-	+/-		-	+	1
Wetproof construction	+/-	+/-		-	-	+/-		-	+	1
Bridge buildings	+	-		x						
Bank dwellings	+	-		x						
Pile dwellings	+/-	+/-		x						
Rise ground level	+/-	+		x						
Flexible and demountable building	+/-	-		x						
Own back-up system (water, electricity)	x	+/-		-	-	-		+	+	1

An important factor in the existing situation is the tenant that lives in the dwelling, because it is his living space that is being touched. Only 15% of the measures have hardly or no hindrance for the tenant when being implemented. Small and high hindrance occurs in respectively 48% and 36% of the measures. For example, application of less impervious pavements may be a feasible option from a technical point of view, but implementation can imply that a tenant has to restructure his garden completely. In such a case, the inconvenience for the tenant is considered as high. The inconvenience for the tenant during the use period has been evaluated rather positive, 70% of the measures have hardly any or even a positive impact on the use of the tenant whereas small and high hindrance in use occur both in 15% of the cases.

Even though the measures might not be of a high technical complexity, they merely imply an organizational complexity, as the measures have (temporarily) impact on the living quality of the tenant and the strategic management planning. In the last column an indication is given of the 'window of opportunity', the moment to apply the measure with the least financial impact or inconvenience for the tenant. For example, the measure on applying less impervious pavement in the tenant's gardens requires acceptance by the tenant, so in order to apply these measures the housing association either has to convince the tenant of the necessity of the measure, or has to wait until the tenant moves and apply the measure before the new tenant starts to live in the dwelling. Another example is the application of green roofs, which will only be feasible from an asset management point of view when the technical and/or financial lifespan of the existing roof system is reached.

4. Implementation of measures

In order to have an overview of how a housing association has designed its processes to implement modifications to its dwellings, two of these kinds of processes are described. The first one deals with the implementation of measures necessary to obtain the Police Label Secure Housing (PLSH) for a dwelling, a label that fits within the "Crime Prevention Through Environmental Design" reward scheme in architecture and urban planning, which is comparable with the British Secured by Design scheme (Stummvoll, 2012). The certificate confirms that the dwelling fulfills certain requirements to make a dwelling safer from burglary and fire accidents. The second process deals with the implementation of energy saving measures to dwellings. The measures are being applied as a spin-off from the implementation of the Energy Label. This is an indicator for the energy performance of the dwelling, resulting from the regulations set up by the European Union in the EPBD. Housing associations are obliged to provide an energy label at every transaction moment (selling/renting) of a dwelling (AgentschapNL, 2012). The housing association decided to provide the whole building stock with an energy label, which made it possible to use it as input for the strategic portfolio management.

These processes were selected because in both cases the measures are changes or additions to the existing building which are not strictly necessary from a maintenance point of view neither are they -yet- imposed by legislation. So in governance terms, housing associations are not forced to take action within a hierarchic regime; taking action is deliberate, although from different perspectives. The PLSH for existing buildings can

deliberately be applied by housing associations, but upon applying the label, the measures are mandatory, otherwise the label is not issued. On the contrary, the energy label is mandatory at transaction moments of the dwellings, but does not require any specific measures to the dwellings, as it only rates the energy performance. Although the two processes of applying measures are not mandatory, they deal with applying measures of a specific theme, which makes it possible to serve as an example of applying technical measures, in our case within the theme of adaptation to climate change.

Within the process of applying measures, the housing association followed a two-step approach in the design phase, as described by Pereira Roders (2007). The first phase consisted of an inventory of the existing situation and the second phase entailed planning and decision making on the measures before going on to the execution phase. In both cases the inventories of the existing situation were carried out by specialists from external consultancy companies. They also gave recommendations on the measures to be applied. After the deciding on the measures by the housing association, specifications were drawn up by a consultant or specialist from the housing association. These specifications had to be interpreted and understood by the construction company and 'translated' for execution works. The interventions to the dwellings were carried out by construction companies. During and after the execution phase, the housing association controlled the quality of the work in order to see if it really received what it asked for: an improved dwelling. What we see in the described cases is that there are many moments where information is transferred from one party to the other, implying risks of miscommunication and failure costs.

5. Discussion

5.1 Generic versus local information

Not only because of the risk of miscommunication and failure costs the implementation of climate change adaptations should have a different implementation process than that of the PLSH or energy label. Climate change adaptations namely differ in characteristics from PLSH and energy efficiency measures in the sense that for the latter group the requirements for the dwellings are generic. They are established theoretically, based on standardized values that are equal for all dwellings over the country, for example the thermal resistance of an outer wall of every dwelling should be 5 m2 K/W. On the contrary, climate adaptations are depending on the situation of the local environment (Pinkse and Kolk, 2012), so knowledge of the local situation is required to apply the right measures. This asks for not only integrating built environment professionals, but also policy makers and scientific community (Bosher and Dainty, 2011). The latter actors are to date highly important because of the relatively newness of the topic and knowledge is still being developed. According to Stone (2012) much information on climate change impact in cities is unknown or difficult to retrieve on national level, as it is in some cases only locally known. This presupposes that the coming years there should be a constant influx of information into the construction process in order to make the building stock more vulnerable. Apart from the expected 'top down' information inflow from scientific research carried out on a local, regional or national level, it can also be actively retrieved from the people living in the neighborhood, using a 'grassroots community based approach' (Bosher, 2012). The involvement of the local stakeholders can

create a window of opportunity for applying measures especially if people have already experienced the negative impacts of climate change, for example flooding after heavy rainfall. In many cases action appears to occur only after extreme events have happened (Amundsen et al., 2010). From all perspectives, an integrated process without the traditional barriers between parties and/or phases will enhance free flow of this knowledge between the stakeholders (Bosher and Dainty, 2011).

5.2 Enablers

Housing associations will not apply adaptation measures if they cannot make a good business case or if regulation forces them to take action. In the case of applying energy saving measures, a financial stimulus exists in the process, because saving energy also saves costs. Thanks to the covenant that has been negotiated with the government, housing associations are allowed to increase the rent when the energy label improves (MinVROM, 2008), which provides a direct financial incentive to the housing associations. Moreover, several financial schemes have been in force to incentivize housing associations to take action. For the application of measures prescribed by the PLSH no financial gains can be generated by the housing associations, but still they are willing to apply the measures, thanks to their sense of corporate social responsibility and network pressure by local authorities that want safe neighborhoods in their cities. For some of the climate adaptation measures, a connection can be sought with other actors that can help building the business case. If this is not possible, the most efficient way of implementing the measures has to be sought, preferably by ‘mainstreaming’ them, i.e. combining with other measures (Pinkse and Kolk, 2012). Combined with the sense of social corporate responsibility and the quality improvement of the dwelling, in the sense that the tenants have less hindrance by the impacts of climate change, as much barriers as possible can be overcome.

5.3 The proposed process

When focusing on implementing measures without searching for other actors that can financially help closing the business case, we propose an intervention process that differs from the current situation (Figure 2) where the actors from the design phase are separated from the actors from the execution phase. The main communication instrument in the traditional setting is the document with design specifications, which is drawn up by the design team, confirmed by the housing association and has to be mastered by the execution team. All in all there are many information transfer moments between the actors which leaves a reasonable risk of measures not being applied, because each information transfer moment implies a risk of information loss (Vrijhoef, 2011). The proposed process (Figure 3) is characterized by a more integrated role of the construction sector. Main contractors should not just deliver activities predefined by specifications of housing associations, but in close collaboration with designers, consultants and subcontractors and suppliers they should offer a tailor made answer for a dwelling. The network of supply-side actors operates with full access to knowledge on the one side and requirements of the dwelling on the other side.

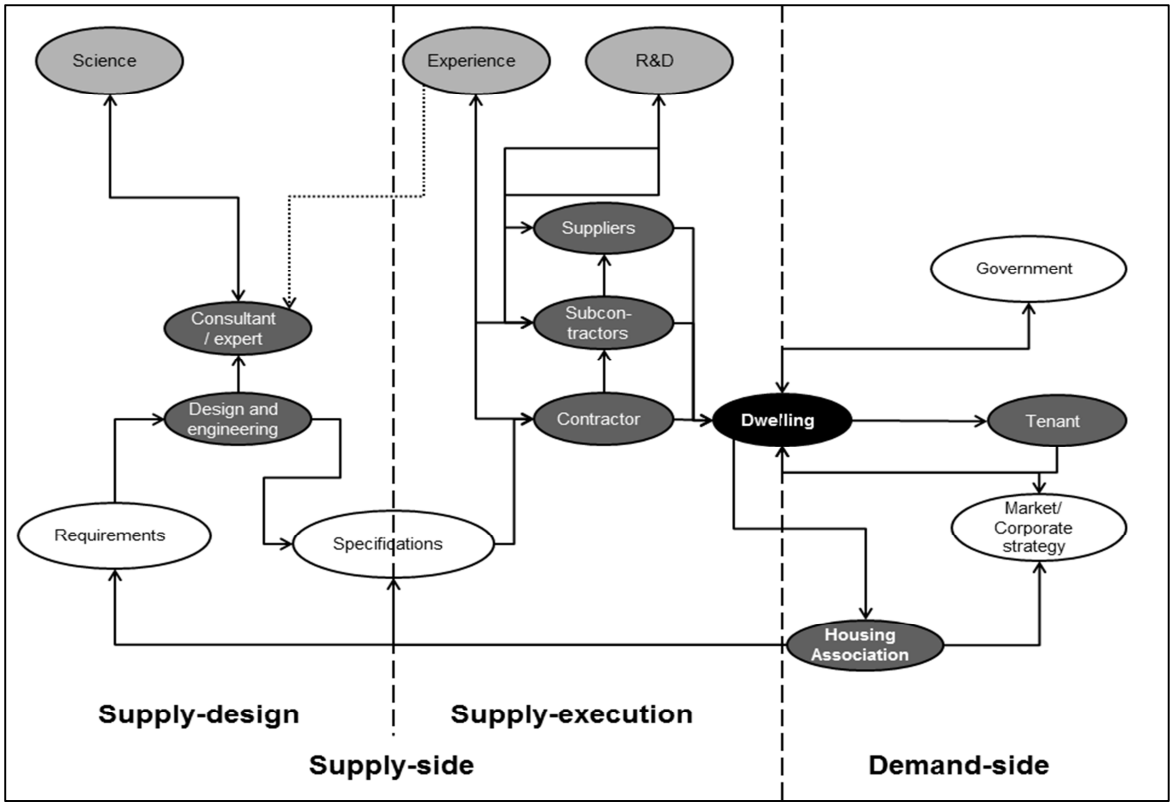

Figure 2: Traditional construction process

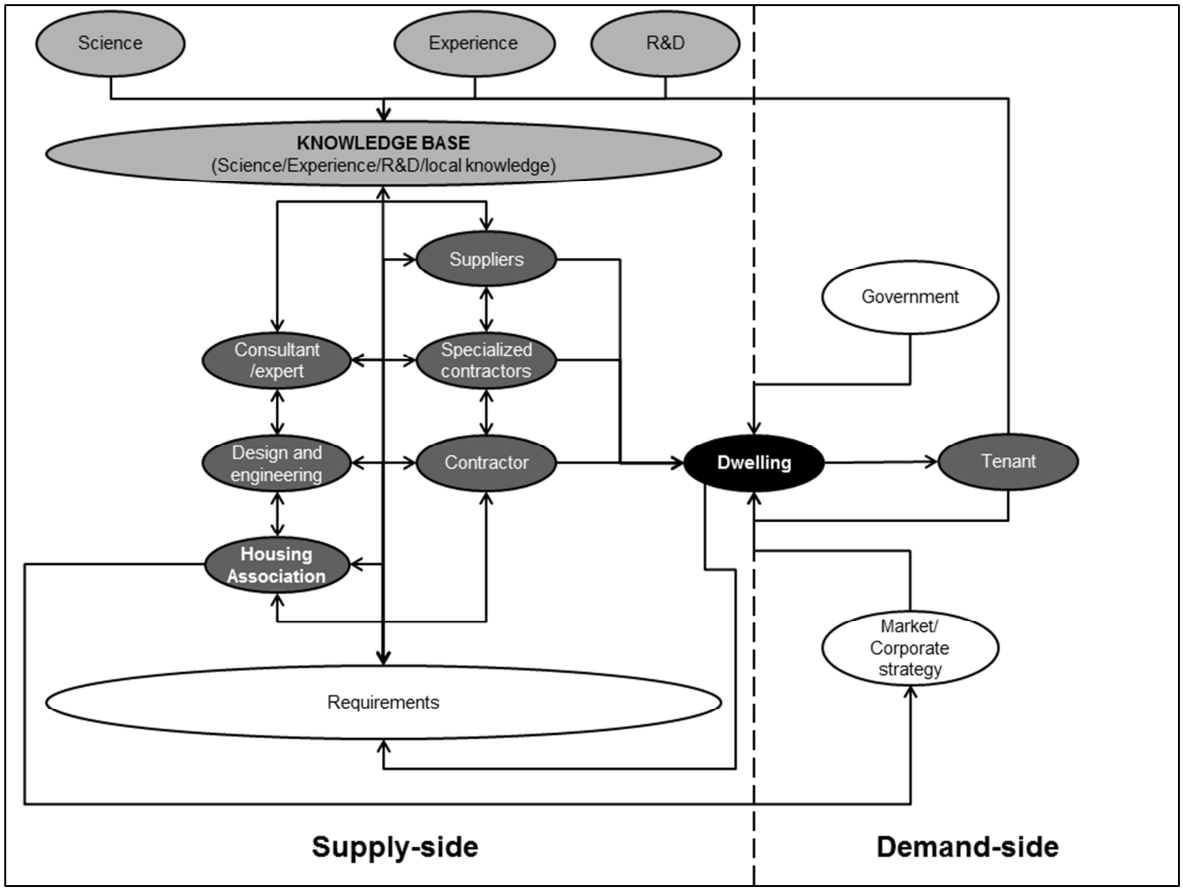

Figure 3: Proposed layout of integrated construction process

In this situation it is the responsibility of the supply-side actors to give a proof of the quality of their bid. In order to be able to offer the best possible solution, the supply-side actors have to know the main requirements the dwelling has to fulfill and to process the knowledge into the rehabilitation intervention. Within the network setting all actors have their own identity which keeps the possibility open to carry out activities individually, without interfering with the goals of the other supply-side members. For example the consultant on the one hand can be working for the housing association providing information on a strategic level, while on the other hand he can serve as a facilitator of knowledge sharing among the supply-side actors, merely for activities on the operational level.

6. Conclusion

The adaptation measures that are available to date are mainly based on newly built dwellings, whereas the renovation sector is becoming more important. In this paper we have assessed the feasibility of measures for the existing building stock. It became clear that the feasibility of measures in the existing stock is lower because of increased investments and maintenance compared to the current situation and implementation causes nuisance for tenants. However, the impact on the tenant during the use period is generally positive. This clearly requests for an efficient implementation process that can take away the implementation complications as much as possible. In order to trace what activities have to be undertaken to implement measures to dwellings we have shortly elaborated on two processes within a housing association that led to the implementation of measures to dwellings. In the case descriptions the increased technical performance is confirmed by a certificate. The use of certificates is possible if the performance is quantifiable and generic for each dwelling, whereas for climate change adaptations there are no normative values possible as the vulnerability of dwellings can differ in every city, even in every neighborhood or street, so no certification system is possible yet.

One could argue that the proposed approach is a very deliberate one, out of the control field of the housing association, especially compared to a traditional construction process and the portfolio approach of the energy label assessments, where the housing association prescribes exactly what has to happen. To a certain extent the housing association is indeed less ‘in control’, but by distilling the requirements of the dwelling that are shaped by: the dwelling itself, local conditions, government and strategies from the housing association, the supply-side actors can together develop a solution for the dwelling, making use of their own experiences and knowledge and those of others. With this process, the application of climate adaptations is framed as a distinguishable quality element within a market setting, which will increase the probability of adoption. However, housing associations have to acknowledge that the climate adaptations are an added value to the dwelling, otherwise they will not reward them. The creation of awareness is clearly a task of the government. Moreover, the construction sector has to be willing to take a proactive role in offering solutions for climate adaptations, developing the project from the beginning together with consultants and the housing association. As the proposed approach is only theory-based, further research is necessary to have its feasibility judged by field experts, and a further elaboration on the relationships between and attitudes of members of the supply chain is needed, for which the existing discourse on partnering and supply chain integration is a valuable starting point.

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Traditional built environment conservation: social and technological aspects

Daniela Bosia[1]

Abstract

In the era of globalization, recognizing themselves as part of the built environment in which they live is an increasingly important social need for people around the world. The identity of places derives not only from the geomorphological features, flora and climate of a place, but also from the characteristics of its traditional buildings. Local materials such as stone, wood, earth, straw, etc., and traditional construction technologies, become essential elements for identifying a place. Today it is important to enhance the identity of places not only by the conservation of traditional buildings but also by applying the rules of sustainable construction to the specific area, in case of new buildings. However, the construction industry often fails to consider these aspects, with destructive effects on the landscape and local identity.

The paper illustrates some of the research carried out in Italy on this subject, focusing on the restoration and refurbishment of existing traditional buildings from the viewpoint of sustainability and local identity. In particular, the paper will explain the guidelines that support the design of maintenance and works of restoration.

These Guidelines have been written starting from direct survey and are addressed to building professional, to owners and to technical employed.

Keywords: building refurbishment, guideline, traditional architecture, building material and sustainability, landscape.

1. Introduction

In the era of globalization, recognizing themselves as part of the built environment in which they live is an increasingly important social need for people around the world.

As defined by the European Landscape Convention of Council of Europe (2000), “Landscape means an area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors”. The landscape is a complex system and, like all systems, it is dynamic: it is in a state of continuous transformation by both nature and man.

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In the past, the relationship between the built environment and the "natural" environment was balanced, based on our empirical but profound knowledge of nature and its workings, natural resources and their characteristics.

Now, all too often, this balance is no longer clear in built landscapes, at times because they have been transformed according to rules that do not respect the natural dynamics, or because they have been abandoned.

The identity of places (called “local identity” or “genius loci”) derives not only from the geomorphological features, flora and climate of a place, but also from the characteristics of its traditional buildings. Especially in small towns and rural regions, local materials such as stone, wood, earth, straw, etc., and traditional construction technologies, become essential elements for identifying a place.

Today it is important to enhance the identity of places not only by the conservation of traditional buildings but also by applying rules of sustainable construction to the specific area, in the case of new buildings. However, the construction industry often fails to consider these aspects, with destructive effects on the landscape and local identity.

2. Traditional building heritage and local identity

Traditional buildings, the ways in which they are grouped in settlements and cities, their links to the place, the construction techniques and materials used to build them are, to all effects, a “cultural heritage” worth protecting.

The physical characteristics that form the identity of human settlements are linked not only to the use of local resources (materials, technologies, altitude, exposure to the sun and wind, etc.), but also to the type of economy prevalent in the area, as well as many other factors.

To re-establish a balanced relationship between architecture and nature it may be worthwhile to study the "rules" (both consolidated and experimental) that made it possible, in the past, to create the landscapes of quality that we now work to preserve and valorize, so that we can apply those principles, updated where necessary, to contemporary landscapes. It may even be necessary to take a different tack than in the past decades, and not simply throw away everything that belongs to the past, but learn from it to build the future.

The UNESCO (2012) Florence Declaration on Landscape expresses fear for threatened and deteriorating landscapes all over the world, due to urban sprawl, industrialization and the intensification of agricultural processes, and stresses how it may no longer be possible to protect the landscapes without being aware of the local knowledge and traditions that generated them, the loss of which destroys a legacy of know-how that could be used to find more adequate responses and innovative solutions. It talks about the importance of safeguarding the landscape for the quality of daily life and maintenance of cultural identity, as well as improving the environment, and stresses the value of knowledge and traditional practices as a background for harmonious programs of technological and innovative development.

UNESCO and IPOGEA recently created a “Traditional Knowledge World Bank” (TKWB, 2012): “these are ancient techniques and practices of specific territories, passed on through the generations and governing soil management, the use and protection of natural areas, rural architecture and the organization of urban centers. They comprise the historical knowledge of humanity, which has led to the construction of architecture and landscapes with universal value, protected by UNESCO as a cultural legacy”.

More and more, we feel the need to understand the principles of sustainability (originated more by need than by our own desires) behind the construction of traditional buildings, so we can evaluate the possibility of applying them once again.

3. Strategies for the valorization of the built landscape

3.1 Actions at the territorial level

Tourism is a resource for areas that have been involved, in recent decades, in processes of abandonment that have profoundly scarred them.

In Northern Italy, particularly in the Piedmont Region, new sustainable forms of tourism, in the last few years, are providing new opportunities to valorize the rural landscape, particularly the hills and mountain landscapes (Fig. 1).

The strategies applied for sustainable development of these mountain and hill areas aim to valorize the landscape as a “product area”: with such a systemic vision, the rural economy, tourism, agriculture, environment conservation, ecology, architecture, nature, culture, food&wine, etc., all become multiple aspects of a single problem. In each of these fields, public and private administrators have launched strategic actions aimed at building a complete “product area” to spend as a tourist product, to improve the quality of life of people and to attract new population.

Environmental concern is the main research field: both built landscape and natural landscape are involved in the lines of action to manage environmental changes.

The process of valorization of the landscape is implemented on various levels, from the regional scale to that of the building, focusing on the environmental aspects that can be considered to run through all the different scales.

On the regional scale, efforts are made, above all, to render the landscape “attractive” as a resource for tourism, offering services and support for sustainable tourism involving both the agricultural and the architectural sector. On this scale, other environmental aspects linked to resources, pollution, waste management, sustainable mobility, etc., are also perceived more and more to be important.

Figure 1: Langhe's Landscape (North Italy)

At this level, natural and human activities are should definitely be managed in a coordinated



way.

To achieve a sustainable model of development it is therefore important to apply an environmental design model shared by those who inhabit, visit and manage the territory. In particular, the environmental quality of a place with a strong vocation for tourism is an added value and a discriminating factor in determining the choice of an ever more demanding type of tourist. For this reason the L.A.G. (Local Actions Group) of Mongioie has undertaken a project of environmental certification. The most extensive combined ISO 14001 environmental certification and EMAS (Eco-Management and Audit Scheme) validation project in Europe was launched with the combined implementation of an Environmental Management System according to the ISO 14001 standard and EMAS validation of over 40 towns which make up the G.A.L. Mongioie territory. It involves many small municipalities scattered over a mountain territory, with fewer than 100 inhabitants.

The territory of L.A.G. Mongioie now benefits from the EMAS certificate, i.e. Eco-Management and Audit Scheme, making its territory the largest European EMAS certificate district. All this was possible through a specific environmental design strategy supported by the citizens, traders, and local authorities living and working in this area, in addition to the tourists themselves, aiming at implementing sustainable development.

The signed "Covenant of Mayors" EU initiative by 40 cities of the "L.A.G. Mongioie environmental district" shows the particular attention to sustainability issues in the territory. As the official web site explains "the Covenant of Mayors is the mainstream European movement involving local and regional authorities, voluntarily committed to increasing energy efficiency and the use of renewable energy sources in their territories. With their commitment, the Covenant signatories aim to meet and exceed the European Union 20% CO2 reduction objective by 2020" (see http://www.eumayors.eu).

3.2 Courses of action for the valorization of the landscape

Certain lines of action focus on the conservation and valorization of traditional rural landscape in its natural and manmade components: a number of studies have been launched to explore aspects of change in the field of traditional architecture and natural aspects of rural landscape. In the research project “Civilization of the Alps area in the Piedmont Region" (research by Politecnico di Torino, funded by the Cassa di Risparmio di Torino Foundation), for example, the dynamics of actual mountain landscape transformations were reconstructed, starting with a study of alpine landscape transformations and with an analysis of several historical buildings. The research also deals in depth with the topic of the alps, important not only for the productive aspect, but also for landscape conservation and the historical, cultural and tourist aspects. Research has also tackled the study of the Alpine landscape and its changes, due in part to the abandonment of mountain settlements and territories and to the changing management of Alpine farming.

3.3 Actions at the level of the building

In the past, the problems of maintenance and renovation of rural architecture were addressed and solved with attention and care by the owners or users of the buildings. In recent years, in the wake of economic process that has, to a varying extent, impacted the entire rural territory, many rural workshops and residential buildings, especially in mountain areas, have been abandoned and have lost their original function.

In the meantime, the material and construction culture that had generated and maintained the constructed rural landscape as transmitted to us has gradually been lost. Today, with newer economic and production prospects, forged by renewed vocations, including rural tourism , there is a tendency to restore rural areas and buildings to new functions without, however, the proper attention due to such delicate cultural landscapes.

All too often, recovery and rehabilitation fails to consider the origins, thereby undermining centuries of rural construction culture, the culture of the “peasant-builder” who, exploiting the limited means available, did everything possible to cater to living and production requirements using local resources (materials, climate, orography of the land, vegetation, etc.).

The “Guides” (Bosia, Franco, Marchiano, Musso 2004; Bosia 2012), produced all over Northern Italy, are a first practical and applicable response to combating this tendency. We refer in particular to the G.A.L (Local Actions Groups) of Mongioie and the Langhe & Roero sites in North Italy.

Each “Guide” has been developed as a methodological and operating tool to support maintenance, conservation and rehabilitation works on rural architecture. They start with a detailed overview of the situation in the L.A.G. region, built through passages of successive depth, from the general (territorial level) to the particular (building and detail level). Both “Guides” can be considered recommended standard instruments and were drawn up on the basis of studies of the construction traditions and characteristics of the landscape in the

reference area, which is largely mountainous and hilly (Fig. 2). These tools support restoration works on the typical architectural and landscape aspects of a rural area to improve the quality of the environment, identifying the eco-compatible, traditional or innovative materials and techniques to be adopted (Fig. 3-4-5). They are “Guides” and not “handbooks”, to avoid the risk represented by traditional tools, already experimented, but with disappointing results, like those of the “conformed solutions” chosen from a sort of catalogue. The Guides are addressed to public operators and to the production and professional sector.

Figure 2: Guideline to rehabilitation works of Langhe and Roero traditional rural architecture: roof technical file

In both cases, the projects were carried out within the Plans for Local Development financed by the EU program “Leader plus”. The Guidelines for restoration of the characterizing elements of the rural architecture of the Mongioie L.A.G. and the Guidelines for restoration of


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COMUNI DI IGLIANO E PAROLDO
ELEMENTI COSTRUTTIVI

COPERTURE IN LATERIZIO

FASI PRELIMINARI ALL'INTERVENTO
Prima di intervenire analizzare la consistenza e lo stato di conservazione del manto, della struttura lignea di sostegno e degli eventuali elementi di completamento della copertura come abbaini, comignoli, cornicioni e muri tagliafuoco, rilevando pendenze, organizzazione generale del sistema, eventuali fenomeni di dissesto e di degrado dei materiali, e verificando la tenuta all'acqua, specie in corrispondenza dell'intersezione con elementi emergenti.

CRITERI GENERALI DI INTERVENTO
Per le coperture esistenti, la variazione della geometria, della organizzazione strutturale, della pendenza delle falde, del materiale e degli elementi di completamento (comignoli, abbaini, cornicioni, muri tagliafuoco) è incompatibile con la tutela del paesaggio. Per il recupero delle coperture in coppi laterizi, è necessario ricostituire il doppio strato di coppi, eventualmente sostituendo quello inferiore con tegole curve di nuova produzione.

INTERVENTI AMMISSIBILI
- Operazioni di manutenzione periodica.
- Sostituzione parziale di elementi deteriorati o mancanti della struttura di sostegno, di abbaini, comignoli e cornicioni con altri analoghi a quelli esistenti per forme, dimensioni, materiali e lavorazione.
- Sostituzione dello strato inferiore del manto di copertura con coppi laterizi di nuova produzione.
- Inserimento di strati impermeabilizzanti e termoisolanti sottofalda, nel rispetto dell'esistente.
- Inserimento di grondaie, pluviali e fazzoletti in rame brunito in corrispondenza dei giunti con gli elementi emergenti (comignoli eccetera).

INTERVENTI NON AMMISSIBILI
- Sostituzione del manto di copertura esistente in coppi laterizi o marsigliesi con elementi e materiali estranei alla tradizione costruttiva locale (lamiera, tegole cementizie, tegole ceramiche greificate eccetera).
- Modifica della geometria complessiva, delle dimensioni, dell'altezza di gronda e colmo, della pendenza delle falde, degli abbaini, dei cornicioni e dei comignoli.
- Sostituzione della struttura lignea di sostegno con una in calcestruzzo cementizio armato o in latero-cemento.
- Posa in opera di nuovi comignoli o sostituzione di comignoli esistenti in muratura con altri prefabbricati in calcestruzzo, laterizio o metallo.

INTERVENTI CRITICI – AMMISSIBILITÀ DA VALUTARE CASO PER CASO
Se necessario, per ragioni igieniche, funzionali o di sicurezza non altrimenti risolvibili, da valutare caso per caso:
- modifica dell'organizzazione strutturale della copertura, senza modificarne dimensioni, pendenze, materiali;
- inserimento di nuovi comignoli, che devono in ogni caso rispettare e riprendere i caratteri dei comignoli appartenenti alle tipologie tipiche dell'ambito territoriale;
- se indispensabile, sostituzione di elementi degradati della struttura di sostegno in legno con altri in legno lamellare o acciaio.


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COPERTURE IN PIETRA

FASI PRELIMINARI ALL'INTERVENTO
In via preliminare è opportuno analizzare la consistenza, il tipo di materiale e lo stato di conservazione del manto, della struttura lignea di sostegno e degli eventuali elementi di completamento della copertura (muri tagliafuoco, abbaini, comignoli, cornicioni, lambrecchini), rilevando pendenze, organizzazione generale del sistema di copertura, presenza di eventuali fenomeni di dissesto e di degrado dei materiali, e verificando la tenuta all'acqua della copertura, specie nelle intersezioni con gli elementi emergenti.

CRITERI GENERALI DI INTERVENTO
Per le coperture esistenti, la variazione della geometria, della organizzazione strutturale, della pendenza delle falde, del materiale e degli elementi di completamento (comignoli, abbaini eccetera) è incompatibile con la tutela del paesaggio. Per coperture in lastre di pietra è opportuno intervenire, se possibile, senza rimuovere il manto o effettuando lo smontaggio e il rimontaggio degli elementi avendo cura di utilizzare, per integrazioni e sostituzioni, elementi di materiale analogo provenienti da cave locali o da recuperi.

INTERVENTI AMMISSIBILI
- Operazioni di manutenzione periodica.
- Sostituzione parziale di elementi della struttura di sostegno con altri analoghi a quelli esistenti per forme, dimensioni, materiali e lavorazione.
- Sostituzioni e integrazioni di elementi delle lastre in pietra del manto di copertura con altri del tutto analoghi a quelli esistenti, provenienti da cave locali o dal recupero di materiale da demolizioni di edifici dismessi nelle vicinanze.
- Inserimento di strati sottofalda per migliorare le prestazioni di tenuta all'acqua e di coibenza termica della copertura, rispettando le strutture esistenti.

INTERVENTI NON AMMISSIBILI
- Sostituzione globale del manto di copertura in pietra esistente con elementi e materiali estranei alla tradizione costruttiva locale (come lamiera, tegole cementizie eccetera) o con elementi in pietra diversi per forma, materiale, finitura, modalità di posa in opera.
- Modifica della geometria complessiva della copertura, delle sue dimensioni (altezza di gronda e di colmo) o dell'inclinazione delle falde.
- Sostituzione della struttura lignea di sostegno con una in calcestruzzo cementizio armato o in latero-cemento.
- Modifica degli sporti della copertura e inserimento di scossaline ai bordi delle falde.

INTERVENTI CRITICI – AMMISSIBILITÀ DA VALUTARE CASO PER CASO
Se necessario, per ragioni igieniche, funzionali o di sicurezza non altrimenti risolvibili, da valutare caso per caso:
- modifica dell'organizzazione strutturale della copertura, senza modificarne dimensioni, pendenze, materiali;
- sostituzione del manto di copertura in lastre di pietra con elementi in lamiera o in tegole laterizie, solo come misura provvisoria a difesa del fabbricato e previa esplicita autorizzazione temporanea;
- inserimento di nuovi comignoli, che devono in ogni caso rispettare e riprendere i caratteri dei comignoli appartenenti alle tipologie tipiche dell'ambito territoriale;
- se indispensabile, inserimento di fazzoletti, grondaie e pluviali in rame brunito;
- se indispensabile, sostituzione di elementi degradati della struttura di sostegno in legno con altri in legno lamellare o acciaio.

the rural architecture of the Langhe & Roero L.A.G. are already operational, have been adopted by the municipalities involved in the project, with pilot operations of applied experimentation already concluded. However, in addition to those outlined above, a further, particularly pressing requirement has now emerged: that of approaching building restoration according to the general principles of respect for the environment for the sustainable development of rural areas.

This need can be interpreted from various viewpoints with regard, for example, to selection of technological materials and solutions, the use of renewable energy sources, etc. Catering to these aspects when recovering traditional buildings – which may be "strong" in some respects and extremely "fragile" in others – inserted in delicate, often unique landscapes, may become extremely complex.



Figure 3-4: Typical rural building of Alta Langa Region (North Italy)

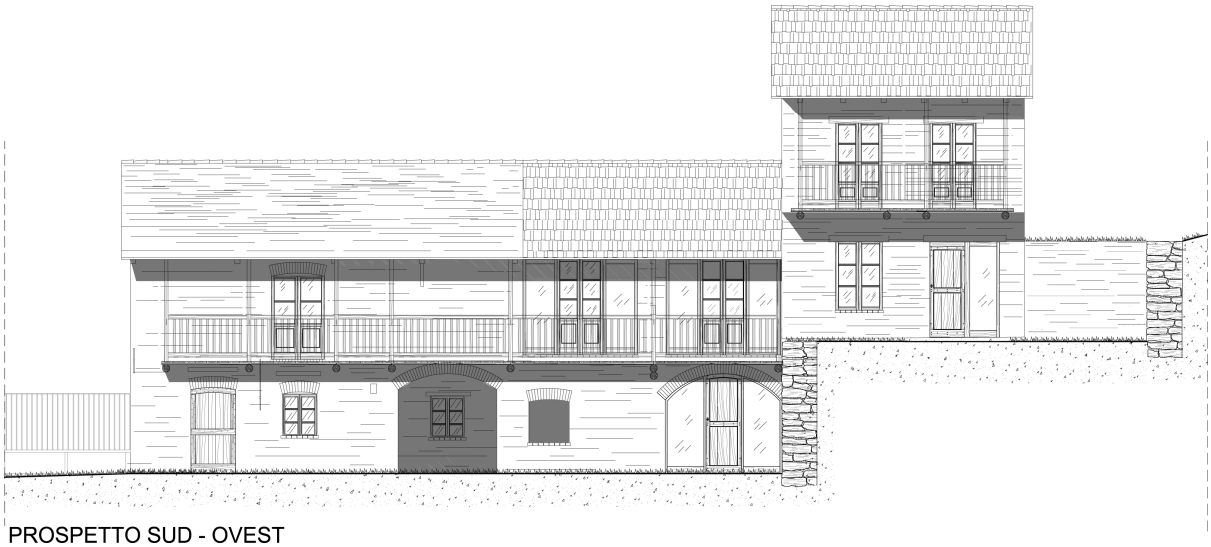

Figure 5: Rehabilitation Design consistent with Guideline and use of traditional materials and building technologies

4. The response of the construction industry

For a number of reasons – such as the unchecked spread of land use in the past decades – the idea of restoring and recovering existing buildings has become more desirable with respect to new construction. The construction industry has not always succeeded in meeting the increasing demand for building restoration with adequate responses. In many cases regarding the valorization of historic buildings and settlements, restored with traditional construction techniques, effective responses have been lacking if not actually harmful.

In the sector of restoration, indeed, while we have seen many efforts in recent years to succeed in “labeling” construction products – constructions materials and elements – as “eco-friendly” or “sustainable”, little or nothing has been done to reintroduce the use of local materials and traditional construction techniques, whose use has been abandoned in the last decades, in favor of standardized techniques applied without variation throughout the world, in line with the principles of globalization.

Perhaps it would be helpful to coin a better definition of the concept of “sustainability” as it applies to construction – it is a concept that is often used improperly and has now been more or less forced to evolve and align itself with the concept of the “smart community”,” smart city” or “smart building” depending on the scale of reference.

Sustainable development is a form of development (which also includes economic development of the city, the community, etc.), which does not endanger the potential of future generations to continue that development, preserving the quality and quantity of its legacy of natural reserves (which are finite, while resources can be considered as inexhaustible and thus infinite). The goal is to maintain an economic development compatible with social equity and ecosystems, so as to operate in a system of environmental equilibrium. This is the first definition; UNESCO, with the Universal Declaration on Cultural Diversity (Stenou 2002) expanded the concept of sustainable development indicating that "cultural diversity is as necessary to humanity as biodiversity is to nature (...) cultural diversity is one of the roots of development seen not only as economic growth but also as a means of conducting a more satisfying existence on the intellectual, emotional, moral and spiritual plane".

Sustainability, therefore, does not have an environmental dimension alone, but also an economic, social and cultural dimension.

With reference to historical and traditional architecture, the use of local resources, materials and construction techniques acquires a central role in the assessment of the sustainability (in the light of the above definition) of any alterations made for its restoration but also, more and more, for any new construction.

The Guidelines for rehabilitation of which we have spoken go precisely in the direction of obliging the construction industry – which in Italy consists largely of Small and Medium Enterprises (SME) – to use local resources and materials, applying them according to traditional construction techniques.

The inertia of the sector is holding back this trend that, however, is slowly gaining ground, with positive fallout that we can summarize as follows:

- economic fallout consisting above all of the reactivation of local micro-economies: in some cases, for example, quarries closed for decades have been reopened;

- environmental fallout, due mainly to the reduction of goods transportation, with obvious economic as well as environmental benefits;

- fallout on the landscape, in particular as regards the preservation of the local identity, reversing the trend toward an idea of “globalized architecture”.

5. From tradition to innovation

If there are some weakly positive signed from the construction industry with regard to the restoration of existing architecture, when it comes to new construction we can report very few signs of the use of traditional materials, even in innovative ways. More and more, selection of construction materials is linked to their eco-friendly aspects, often more presumed than real, or at least not ascertained. Careful study of the LCA (Life Cycle Assessment) should be made, but never is. Using wood for construction in mountain zones rich in this material can be an excellent idea if the lumber is cut and milled at the site. The same is true of stone which, even more, can connotate buildings, affecting the color, structure and strength of the masonry.

One of the critical aspects concerns the relationship between construction tradition and technological innovation. Innovation in the construction sector has always been slow, and even more so if referred to traditional construction technologies. Research is now focusing on this sector insofar as traditional techniques often possess all the elements to be considered sustainable.

When we speak of innovation referring to the field of architectural technology, we’re dealing with “research for mediation between technical and scientific knowledge and the specific values of architecture. That is to say the social, psychological, anthropological, aesthetic and built environment aspects” (Maldonado 1992). According to J. Shumpeter (1912), while invention consists of perfecting a scientific type of knowledge, innovation also includes the circulation and use of innovation, be it a product, a process, service, organization or market.

As well as looking for new markets, with low technological impact innovations, or for new commercial organizations, innovation can also re-use existing and known materials. The idea is not new in itself, as can be seen in a 1931 issue of “La Casa Bella”. Compressed straw panels were accompanied by such words as: “among the materials that help create a new and modern home, some are but a modern and intelligent re-use of old and very common systems, simple, practical ideas that have been taken up by contemporary technology and industry and launched on the market”.

In those days the autarchic economic system was taking root in Italy, and greatly encouraged research in the construction field. These words seem particularly modern if we think of the research scenarios that environmental issues have prospected as solutions. On the one hand they have a high technology content, exploring specific sectors such as nanotechnologies; on the other hand they propose appropriately adapted traditional technologies and materials, such as straw, earth, wood, with an almost direct passage from tradition to innovation.

6. Conclusions

Projects for the restoration of traditional rural buildings carried out without due attention or according to the principles of new constructions may prove to be extremely destructive or negative.

The guidelines that have been drawn up cannot solve all the problems but can certainly steer the projects toward solutions that are suitable for heritage buildings of historic interest and the context in which these are inserted, contributing to configuring an approach that is attentive to landscape and to conservation of the cultural assets involved.

For new construction, however, we have to try to move toward what we can define as “innovative tradition”.

Some studies are effectively examining ways to repropose, in an innovative way, construction technologies pertaining to the local construction tradition and strongly reflecting the local identity such as thatched roofing, once widespread throughout northern Italy. The idea is not so much or not only to rediscover the technique as an artisanal practice, but to study a new technology that, in respect of the characteristics of traditional construction, can be reproduced using “industrial” methods and mass production (also in small series), according to an industrial type of organizational design.

The rediscovery of technologies that use local materials, especially in the mountain and rural areas, can open the way to new types of enterprise and contribute tangibly to preservation of the landscape.

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Proposal of Design Procedure for Seismic Isolation Codes Worldwide

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Abstract

After collecting information on building codes of Japan 2000, China 2010, USA IBC2009, Italy 2008 and Taiwan 2011 and using a benchmark building to compare among those codes, this paper proposes a preliminary design procedure for seismically isolated buildings referred as CW2012 (code of **C**IB **W**114). The CW2012 code mainly follows Japan 2000 code, since the number of seismically isolated buildings is most in Japan and buildings performed well under several great earthquakes where there were large input acceleration amplitudes or large displacements of the isolation system. However, in addition to the Japan 2000 code, several new aspects are introduced to cover other codes. An earthquake load having return period of 2,500 years is introduced to determine the isolation gap (building separations between the isolated structure and surrounding retaining walls or other fixed obstructions) and the test specifications of isolation system. A numerical coefficient related to the super-structure above the isolation system is introduced to maintain the design style using 50 years return period earthquake load of the super-structure such as China 2010 and Italy 2008 codes. Even though all of the codes include provisions for dynamic response analysis, the details required to undertake such an analysis for a seismically-isolated structure are not clearly available in any of the codes. Here, a procedure using time history analysis method to design seismically isolated buildings proposed by JSSI (2010a) is adopted.

Keywords: building code, **seismically isolated building**, **earthquake load**, **equivalent linear analysis, time history analysis**

1. INTRODUCTION

In the 1994 Northridge earthquake in the USA, the 1995 Hyogoken-Nanbu earthquake in Japan, the 1999 Chi-Chi earthquake in Taiwan, the 2008 Wenchuan earthquake in China, the 2009 L'Aquila earthquake in Italy and the 2011 Great East Japan earthquake, seismically

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isolated buildings have been reported perform well (Higashino, M., S. Okamoto, 2006; Saito, etc. 2011). Over the same period, building codes have been revised and updated to include requirements for design of seismically isolated buildings. Feng, *etc.* (2006) had a comparative report on building codes of Japan 2000, China 2001, USA IBC2003, Italy 2005 and Taiwan 2002 which was updated in 2010 (JSSI 2010b). In the USA, seismic isolation provisions have been included in building codes since first appearing in the 1991 Uniform Building Code. The current USA provisions are contained in the International Building Code (IBC 2009) which makes reference to the requirements of ASCE/SEI 7-05. In Japan, the most recent building code provisions took effect in 2000. In China and Taiwan it took effect in 2010 and 2011, respectively. In Italy, the new code took effect in 2008 over EURO 8. Unfortunately, in New Zealand, there is no specific code for seismic isolation, although the technology is well developed and numerous applications exist there.

In this paper, a preliminary design procedure CW2012 is proposed for seismically isolated buildings based on seismic isolation codes mentioned above. The CW2012 code mainly follows Japan 2000 code, since the number of seismically isolated buildings is most in Japan and buildings performed well under several great earthquakes where there were large input acceleration amplitudes or large displacements of the isolation system. However, in addition to the Japan 2000 code, several new aspects are introduced to cover other codes. An earthquake load having return period of 2,500 years is introduced to determine the isolation gap and the test specifications of isolation system. A numerical coefficient related to the super-structure above the isolation system is introduced to maintain the design style using 50 years return period earthquake load of the super-structure such as China 2010 and Italy 2008 codes. Even though all of the codes include provisions for dynamic response analysis, the details required to undertake such an analysis for a seismically-isolated structure are not clearly available in any of the codes. Here, a procedure using time history analysis method to design seismically isolated buildings proposed by JSSI (2010a) is adopted.

First, the concept of earthquake loads is summarized. A design procedure using equivalent linear analysis method or time history analysis method is described then.

2. DESIGN SPECTRUM

2.1 Earthquake load

In general, seismic load is expressed by 5% damping design spectrum as follows for all structures:

$$S_a(T) = Z\ I\ G_S(T)\ S_0(T) \tag{1}$$

Where, *Sa(T)*: the design spectrum on site, *T*: the fundamental period of the structure; *Z*: seismic hazard zone factor, *I* : the occupancy importance factor, $G_S(T)$: site class factor, and $S_0(T)$: the basic design spectrum.

The design spectrum generally consists of three parts, namely, an acceleration increasing portion in the extreme-short period, a uniform acceleration portion in the short-period range,

and a uniform velocity portion in the longer-period range. A two-stage design philosophy is introduced generally in the code for designing an aseismic building. The two stages are usually defined as damage limitation (Level 1) and life safety limitation (Level 2). In the damage limitation stage, the structural safety performance should be preserved in the considered earthquake. In the life safety stage, the building should not collapse to assure the safety of human life.

In this paper, a different two-stage design philosophy is introduced for a seismically isolated building. A large earthquake with 10% probability of exceedance in 50 years (return period is about 475 years), which is used for designing a conventional building too, is defined to design the super-structure and sub-structure. For a RC frame system, the drift angle is proposed to be less than 0.005h (h: story height of a building) and 0.003h in the super-structure and sub-structure, respectively. An extreme large earthquake with 2% probability of exceedance in 50 years (return period is about 2500 years), is defined to obtain the maximum design displacement of the isolation system.

$$S_a(T)_{2500years} = \alpha\, S_a(T)_{475years} \tag{2}$$

Where, α = 1.3-1.5.

Table 1: Return period and story drift corresponding with each building code

	Level	Japan (2000)	China (2010)	USA (2009)	Italy (2008)	Taiwan (2011)	**CW2012**
Return period (Years)	Level 1	50[a]	50	—	50	—	
	Level 2	500[a]	—	UNKOWN	475	475	**475**
	Ex. Eq.[b]	—	1600-2500	2475	975	2500	**2500**
Story drift angle (RC Frame)	Level 1	1/200	1/550	—	1/200	—	
	Level 2	1/50a	1/50	1/50	None	1/50	

a: estimated; b: check the maximum design displacement of the isolation system

Table 2: Performance target of seismically isolated (SI) buildings

Return period (years)		EL1: 475 years	EL2: 2500 years
Super structure	Horizontal strength	Elastic limited[a]	
	Story drift angle	<1/200	
SI layer	Rubber isolator	γ<250% Tensile stress<1N/mm^2 within stable stress and deformation relation	Not Failure
	Sliding bearing	Design limit deformation	Not Failure
	Damper	Design limit deformation	Not Failure
Sub structure	Horizontal strength	Elastic	
	Story drift angle	<1/300	

a: Elastic limited state means the state which 1st hinge appeared in main structural member.

If one of earthquake load mentioned above is not defined in a country code, the relation shown in Eqn. (2) may be used. In accordance with the specific seismicity of each region, the return period of the considered seismic load differs considerably and is summarized in Table 1. Performance target of seismically isolated (SI) buildings corresponding the earthquake loads is shown in Table 2.

2.2 Long period earthquake load

In the Chinese code, the spectrum in the constant velocity portion is additionally increased to ensure the safety of structures having long natural periods, such as high-rise buildings or seismically isolated buildings. In the USA and Italian code, a constant displacement range is defined in the long period such as the earthquake load will be decreased in the long period. In the CW2012 code, we use same constant velocity portion with aseismic buildings for a SI building.

2.3 Damping coefficient

There is usually 20% critical damping in a seismically isolated building under EL1-475 earthquakes. As pointed by Feng (2006), the damping coefficient F_h (by which the spectrum at damping value other than 5% is calculated) defined in the Japanese code shown Eqn. (3) gave good accuracy of the equivalent linear analysis method (ELM), it is used in the CW2012 code.

$$F_h = \frac{1.5}{1+10(h_v+0.8h_d)} \tag{3}$$

Where, h_v : effective viscous damping of a fluid damper, h_d: a hysteretic damper decreased to 80% of the damping ratio which accounts for the effect by an earthquake comparing with stationary vibration. In Figure 1, typical spectral accelerations at 5% and 20% critical damping values are shown.

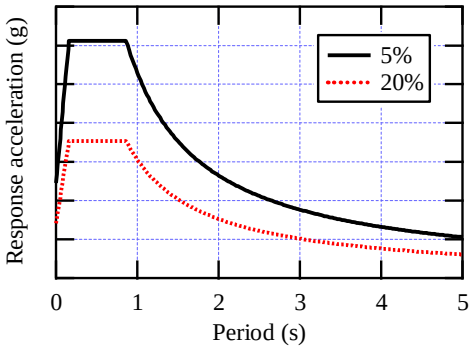

Figure 1: Typical design spectral acceleration at different critical damping values

3. DESIGN PEOCEDURE

3.1 Equivalent linear analysis

To design a SI building, both equivalent linear analysis and time history analysis method can be used. An equivalent linear analysis based on a single-degree-of-freedom (SDOF) system is used under limited conditions shown in Table 3. Almost same limitations proposed in the Japan 2000 code are used for CW2012.

Table 3: Limitations on the applicability of the equivalent linear analysis procedure

Code / Structure	Japan	China	USA	Italy	Taiwan	**CW2012**
Limitation on site seismicity	-	-	S_1 < 0.6g	-	-	
Limitation on soil class	1,2	I,II,III	A,B,C,D	-	1,2	**1,2**
Maximum plan dimension	-	-	-	50m	-	
Maximum height of super-structure	60m	-	19.8m	20m	-	**60m**
Maximum number of stories	-	(H/b<4)	4	5	-	
Location of devices	Base only	-	-	-	-	**Base only**
Maximum mass-stiffness eccentricity	3%	-	regular	3%	regular	**3%**
K_v/K_e (Stiffness ratio between horizontal and vertical)	-	-	-	≥ 800	-	
Tension in isolator	Not allowed	1MPa	-	Not allowed	-	**Not allowed**
Yield strength	> 0.03W	-	-	-	-	**> 0.03W**
Period range of T_e	T_2 > 2.5s	-	$3T_f$ ~3.0s	$3T_f$ ~3.0s	≤ 2.5s	**T_2 > 2.5s**
Maximum value of T_v	-	-	-	< 0.1s	-	

g: gravity acceleration = 9.8m/s^2.
W: total weight above the isolation interface
T_f: natural period of the fixed-base super-structure.
T_2: period of the isolation system considering only the stiffness of rubber bearings.
T_e: equivalent period of the isolation system.
T_V: period of the isolation system in vertical direction.

3.1.1 Procedure of equivalent linear analysis method

In generally, the equivalent linear analysis method (ELM) can be illustrated as follows. The base shear force is obtained from the spectral acceleration and weight as shown in Eqn. (4).

$$\delta = \frac{M\, F_h(h,T_e) S_a(T_e)}{K_e}$$
$$Q_s = \gamma_e\, K_e\, \delta \qquad (4)$$

where,

δ: design displacement of the isolation system
M: total weight of the building
$F_h(h, T_e)$: damping coefficient;
h: damping ratio
$S_a(T_e)$ (g): site response acceleration considering site class
K_e: effective stiffness of the isolation system
γ_e: safety factor related to variation of properties with temperature, ageing or products tolerances discrepancy;
Q_s: shear force in the base of the super-structure;

The shear force, its distribution over the height of the super-structure and sub-structure are summarized in Table 4.

Table 4: The shear force of the super-structure and sub-structure and its distribution over the height

Structure	Symbol	**CW2012**
Isolation system	δ	$\delta = \frac{M\ F_h(h,T_e) S_a(T_e)}{K_e}$
	Q_s	$Q_s = \gamma_e\ K_e\ \delta$
Super-structure	Q_i	$Q_i = \frac{M_i\ H_i}{\sum_{i=1}^{n} M_j\ H_j} \frac{Q_s}{R_I}$
Sub-structure	Q_b	$Q_b = Q_s$

R_I: numerical coefficient related to the super-structure above the isolation system

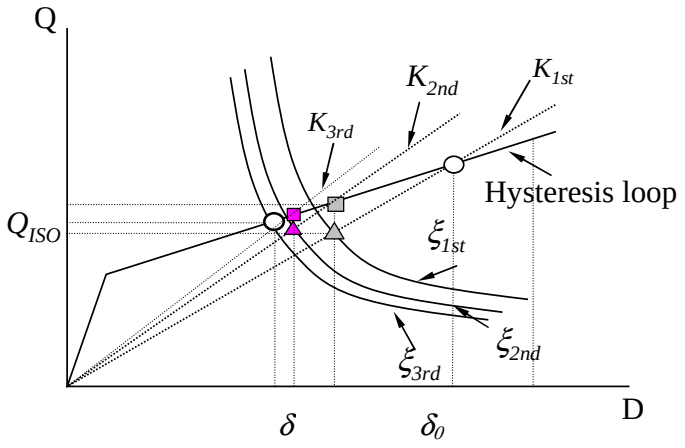

Figure 2: Illustration of the convergence procedure for the equivalent linear analysis method

To use ELM, calculation model must appropriately evaluate one mass for super-structure and characteristics of isolation devices at supposed response range. Modelling of isolation devices must appropriately evaluate stiffness and damping characteristics based on the test

data by manufacturer. The convergence procedure of the equivalent linear analysis method is shown in Figure 2. The procedure is summarized as follows:

- Assume a displacement of the isolation system, δ_0.
- Calculate the effective stiffness, K_e, and damping ratio, ξ_e(h), of the isolation system, assuming a bi-linear model for the isolation system.
- Calculate the equivalent period, T_e, of the isolation system.
- Calculate the corresponding response reduction factor, $F_h(h, T_e)$, and the spectral acceleration, $S_a(T_e)$.
- Calculate a new isolation system displacement, δ, using Eqn. (4).
- Repeat the above steps until δ converges.

3.1.2 Maximum design displacement

The maximum displacement is obtained using same procedure shown in Eqn.(5) under EL2-2500 earthquake load.

$$\delta_{\mathrm{M}} = \frac{\mathrm{M}\,\mathrm{F_h(h,T_e)S_{a,2500}(T_e)}}{\mathrm{K}} \qquad \delta_{\mathrm{rM}} = \gamma_{\mathrm{t}}\gamma_{\mathrm{e}}\delta_{\mathrm{M}} \tag{5}$$

Where,

δ_M: the maximum design displacement under EL2-2500 earthquake load;

δ_{rM}: the maximum design displacement used to determine the isolation cap and test specifications of isolation system;

γ_t: coefficient related to the eccentricity of the isolation system.

3.1.3 Others

Following items should be checked over for isolation system in the design procedure.

- The yield strength of the isolation system should be greater than the wind load.
- No tension is allowed in a rubber isolator at the design displacement.
- The isolation system should not collapse at the maximum design displacement.

3.2 Time history analysis procedure

Even though all of the codes include provisions for dynamic response analysis, the details required to undertake such an analysis for a seismically-isolated structure are not clearly available in any of the codes. In most of the codes two dynamic response analysis methods are defined: response spectrum analysis and time history analysis. For a seismically isolated building, the time history analysis method is the most accurate and is widely used.

In CW2012, a procedure using time history analysis method to design seismically isolated buildings proposed by JSSI (2010a) is adopted.

3.2.1 Input motions

In the time history analysis method, synthetic input motions that have been spectrally-matched with the design response spectrum or real earthquake records appropriately scaled

or modified should be used for the dynamic response analyses. Since results from the dynamic response analyses are strongly dependent on the selected input motions, several input motions are recommended. In the Japanese code, based on more than three (usually six) input motions, the maximum response values are taken as design values. In the Chinese code, based on three input motions, the average response values are taken as design values. In the USA and Italian codes, a minimum of three time history pairs must be used for the analyses. If three time history pairs are used, the design must be based on the maximum response quantities obtained, however, if seven (or more) time history pairs are used the design may be based on the average values of the calculated responses. Since the time history analysis method usually results in smaller response values than those by the equivalent linear analysis method, in the USA and Taiwan codes the results of the time history analyses are limited by the results from the equivalent linear analysis method. For example, in the USA code, the total design displacement of the isolation system shall not be taken as less than 90% of the result due to the equivalent linear analysis method. On the other hand, there is no limitation in the Japanese and Italian codes.

In CW2012, seven (or more) time history pairs are used, thus the design is directly based on the average values of the calculated responses. If vertical spectral acceleration is not defined in the code, ratio between vertical spectrum and horizontal spectrum defined in BRI&BCJ (1992) may be used. The degree of compatibility of the synthetic input motion with the design spectrum is defined by the following four parameters:

- The ratio of the input motion response spectrum $\boldsymbol{S_{psv}(T_i)}$ to the design spectrum $\boldsymbol{DS_{psv}(T_i)}$ should not be less than 0.85.

$$(\varepsilon_i)_{\min} = \left(\frac{S_{psv}(T_i)}{DS_{psv}(T_i)} \right)_{\min} \geq 0.85$$

- The coefficient of variation (ν:COV) of the input motion response spectrum should be less than 0.05. *N* is total point number accounted.

$$\nu = \sqrt{\frac{\sum (\varepsilon_i - 1.0)^2}{N}} \leq 0.05$$

- The total average value of the input motion response spectrum should be larger enough.

$$\left| 1 - \varepsilon_{ave} \right| = \left| 1 - \frac{\sum \varepsilon_i}{N} \right| \leq 0.02$$

- The spectral ratio at long period range (say one to five second for example) should be larger than 1.0.

$$SI_{ratio} = \frac{\int_1^5 S_{psv}(T)dT}{\int_1^5 DS_{psv}(T)dT} \geq 1.0$$

3.2.2 Analysis model

Both super-structure elements and isolation system should be modelled properly in the estimated response range. The isolation system should be modelled based on the test results especially for the characteristics of stiffness and hysteresis.

A simple shear-rocking system having multiple-degree-of-freedom is enough to understand the fundamental characteristics of seismically isolated buildings. The super-structure is modelled as a non-linear shear type system, where the shear elements are usually derived from a static non-linear push-over analysis. However, in case of bending deformation is dominated such as high rise buildings, a bending shear system is preferable. The deformation of the super-structure is smaller than the conventional aseismic building, thus the real damping ratio may be smaller. A stiffness proportional damping matrix is generally used in the response analysis. The damping of the super-structure should be determined based on the first mode of the fixed model. In the case of an intermediate story isolation building, damping coefficients may be determined separately for the super-structure or the sub-structure by similar consideration. The isolation level is modelled as a shear-rocking system, where a bilinear model is used for the shear component. The viscous damping of shear property of a rubber bearing or a lead rubber bearing may be neglected. The elastic rocking component is calculated from the vertical stiffness of the bearings. A horizontal input motion is applied directly at the base.

To obtain the overturning or uplift forces on individual isolators, or the configuration of super-structure or isolation system is not regular, or the torsional vibration is dominated, a three-dimensional model may be used. Since the model becomes more complex, the design should be careful on the modelling of total system. The vertical stiffness of a rubber bearing should be modelled as non-linear to obtain uplift response correctly. One should be careful on the damping matrix also. If stiffness proportional damping matrix is used, the damping in the vertical direction may be overestimated. Three dimensional input motions may be applied all at once. The results may be superposed together after horizontal and vertical analyses separately too.

There developed so many kinds of isolation devices, such as rubber isolators, sliding bearings, steel dampers and oil dampers etc. Analysis models should be determined based on experimental results carefully. The limitation of each model should be taken care also. For instance, hardening is observed in the large shear deformation of a rubber bearing and should be modelled properly in a large deformation response.

Variation of properties with temperature, ageing or products tolerances discrepancy of isolators or dampers should be included in the modelling. If the torsional vibration is dominated, two horizontal direction properties of the isolation system should be modelled properly.

3.2.3 Analysis results

The shear force and story drift angle of the super-structure and sub-structure should be under the capacity of the elements. To keep the function of equipment, the response acceleration is also to be checked. The maximum horizontal displacement of the isolation system should be less than the design allowable displacement. The vertical displacement should be less than the allowable clearance too, especially for the system having large vertical deformation such as friction pendulum bearing system. Torsional vibration may cause larger deformation of outer isolators.

If the deformation of a rubber isolator becomes large, the allowable vertical pressure will become small as shown in Figure 3. If tension occurred in a rubber isolator, the vertical load in all isolators will be re-allocated, which should be checked over by summation by vertical input motion.

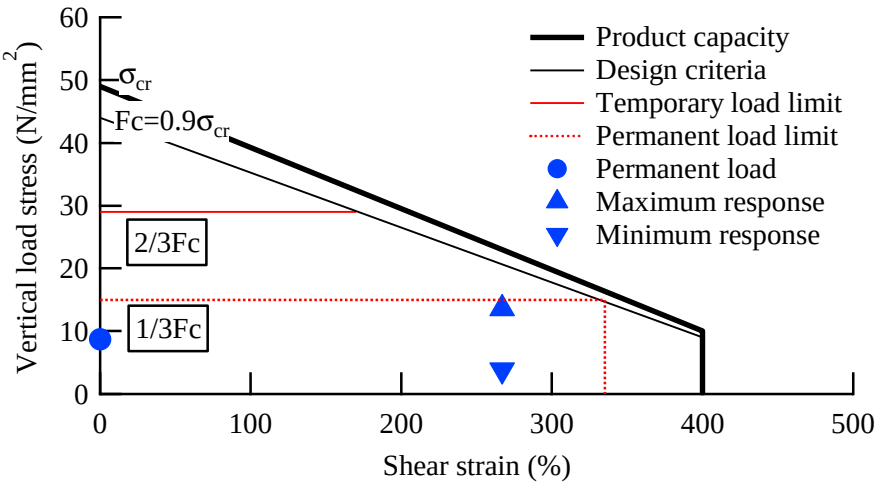

Figure 3: Checking of vertical load with shear strain for a rubber isolator

To understand the analysis results, it is important to confirm how much the input earthquake energy was dissipated by the super-structure and isolation system. The dampers should have enough capacity to dissipate almost all input earthquake energy even in the long duration earthquake such as the 2011 Great East Japan earthquake. The dissipated energy by the super-structure is smaller, the performance of the isolated building is better.

4. CONCLUSIONS

A preliminary design procedure CW2012 was proposed for seismically isolated buildings based on seismic isolation codes worldwide. The CW2012 code mainly follows Japan 2000 code. However, in addition to the Japan 2000 code, several new aspects are introduced to cover other codes. An earthquake load having return period of 2,500 years is introduced to determine the isolation gap and the test specifications of isolation system. A numerical coefficient related to the super-structure above the isolation system is introduced to maintain the design style using 50 years return period earthquake load in some codes. A procedure

using time history analysis method to design seismically isolated buildings proposed by JSSI (2010a) is adopted.

AKCNOWLEDGEMENT

The authors have benefited greatly from discussions within the CIB/W114 (http://www.cibw114.net/) and International Affair Committee, the Japan Society of Seismic Isolation (http://www.jssi.or.jp/).

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Low-cost Housing Delivery to Support Poverty Reduction in the City

Happy Santosa[1], Hasian Siregar[2], Sarah Cahyadini[3]

Abstract

The problem of inadequate housing and settlement still exist in the capital city of East Java, Surabaya. The house dwellers cannot improve their houses because of the poor economic conditions. To follow the Agenda 21 (Habitat, 1996) in Human Settlements, which are:

- Adequate housing for all
- Human settlements in urbanizing world,

research on low-cost housing delivery to support poverty reduction is important.

The research covers the socio-economic aspect; the technology aspect, include the house materials and construction systems; and the environment and cultural aspects. The method use was explorative survey and the use of low-cost housing standard and model in the analysis of housing.

The result shows that low-cost housing with adequate space for economic activities can support the poverty reduction programme.

Keywords: low-cost housing, poverty reduction

1. Introduction

The research was conducted to find the answer of very low-cost housing delivery, to provide adequate housing for the poor people. The problem was: how to develop prototype of a very cheap house, affordable for the poor, at the same time can function as a place for living and for economic activities. With the available space for economic activities, it is hoped that the residents can obtain additional income, which in turn may reduce poverty in the settlement.

The method used was explorative survey and using a house model, to obtain people opinion about the limitation and confirmation of the house model to the resident's needs. The

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research also covered the house design, material, and construction of the house with the minimum price. The adaptation of the house to the natural environment and the socio-cultural conditions of the residents were included in the research.

The discussion was focused on the very low-cost house model, with cost reduction about 50% of the normal house price.

2. Low-cost Housing Programmes

There were some housing development programmes in Indonesia, to provide adequate housing for the poor in the city. In the process of urbanization, many people need settlements and houses in the city and this need should be tackled properly to avoid slum areas in the city. There were also housing programmes for the disaster victims and instant simple house, which could be easily constructed. Some examples of the low-cost housing are presented here.

2.1 House for Disaster Victim in Aceh

The house was called RIA that R means *Rumah* (house), I (first letter of ITS: Institute of Technology Sepuluh Nopember), and A means Aceh. Hence RIA means the house from ITS for the disaster victims in Aceh. The house was designed by the Laboratory of Housing and Human Settlement ITS which could be built by anyone; applicable for multi functions building, such as: house, school, office, health center, market, mosque, etc, by using module. The house also could be built in short period (half day) with minimal material and tools.

The size of the house module was 4 x 5 meter (type 20 square meters) could be developed into 36 m^2, 54 m^2, 72 m^2, and 80 m^2. The materials were planks for walls, cement for the floors, and galvanized iron for the roof. The houses were given freely for the disaster victims, and about 800 houses were built. The house prize was very low, in 2010 was US $ 1,400 (Silas and Setiawan, 2010).

The house design was very simple, to avoid difficulty in the construction and transportation of building materials to the difficult condition of disaster location (Figure 1, 2, 3 shows the house plan, elevation, and the construction process)

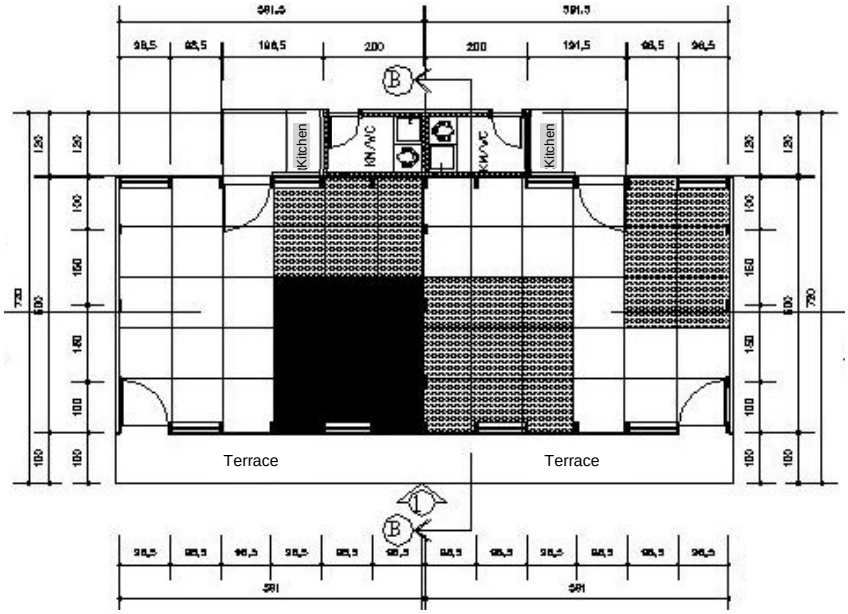

Figure 1:RIA House Plan(Silas and Setyawan, 2010)

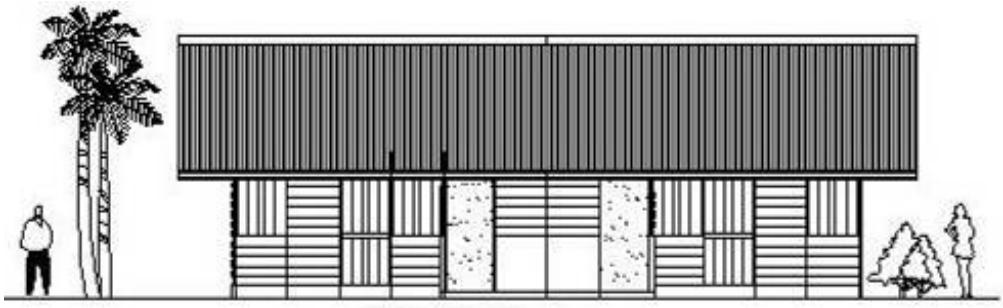

Figure 2: Front Elevation RIA type 36(Silas and Setyawan, 2010)



Figure3: Construction Process of RIA (Silas and Setyawan, 2010)

2.2 Simple Instant House (RISHA)

RISHA means R for *Rumah* (house), IS for Instant and HA for *Sederhana* (simple). RISHA house was built to respond the need of very quick built house, based on the available local materials, including wastes. The structure was simple with pre-fabricated building materials. The RISHA house characteristics are as follows (Menpera, 2011):

- Fast construction house
- Efficient, general materials, multi function and modular
- Low-cost, can be built incrementally
- Good quality: strong, safe and comfortable
- Practice: can be built and reconstructed in other place by the dwellers
- Flexible: free design with the local materials
- Earthquake stand

One unit of RISHA house cost was US $ 3,900. This was twice the price of the RIA house, since the materials were stronger but less heavy. For RISHA house type 36 m^2 the building material'sweight was only 50 kg. Figure 4 shows the construction process of RISHA house, and Figure 5 the variety of RISHA house performance.



Figure 4: The construction process of RISHA house (Menpera, 2011)



Figure 5: Variety of RISHA house performance (Menpera, 2011)

2.3 Pro Poor Housing Programme

The pro poor housing programme was one of the very low-cost housing programmes. This was to provide adequate housing for all, particularly for the lowest income people. The low-cost and very low-cost housing programmes description can be seen in Table 1.

Table 1. Housing Programmes for the Lowest Income

No	Programme	Description
1	Very low-cost house	• Price: US $ 1,000 per unit • Finance: Government, CSR, Private Enterprises • Temporary house, than can be increased to low-cost house • Target: one to two million units
2	Low-cost house	• Price: Maximum US $ 2,500 per unit • Finance: soft bank credit, subsidized by the government • Cheap credit • Target: five to ten million units

(Source: Menpera, 2011)

The very low-cost house was equipped with common facilities, such as communal toilets. The structure was concrete, with bataco walls, asbestos roof, and cement floors. The low-cost house was built with the same materials but with individual toilets.

All the low-cost and very low-cost housing were pro-poor housing programmes. These programmes were to avoid slum and squatter homes. The financing of the pro-poor houses were by the government and the private enterprises as charity. Bearing in mind that the average wages of the poor was about US $ 100.00 per month, the available financial assistances were very important.

The low-cost and very low-cost housing provided by the government however, were not always suitable to the culture of the dwellers. This was understandable since the important aspect considered was the minimum cost of the house. The minimum standard of the house size and construction was matched, in the hope that the dwellers can improve their houses incrementally.

3. Low-cost Housing to Support Poverty Reduction

The low-cost house, including the very low-cost, might be obtained by the poorest house - holds, however the dwellers should be able to maintain and to improve their houses. For this reason some additional income activities should be available. Based on the experience in the city or in the village the low-income houses were generally used for economic activities in line with the domestic activities. The economic activities for examples were selling foods and readymade cakes; household's every day needs and providing services, such as barber, tailor, laundry, photo-copy, etc. Such activities were mostly done at the house terraces, because the very minimum space of the low-cost house.

To support the house dwellers activities in finding some additional income at the house, the low-cost house design should be improved, based on the needs of the dwellers, the environment and the socio-cultural conditions, also the minimum standard of decent housing.

3.1 Low-cost House in the City

Some examples of low-cost house in the city with minimum size of 36 m^2 are discussed here. Usually low-cost house size was varied, from 36 m^2 to 45 m^2. Figure 6 shows the plan of the house with size about 36 m^2.

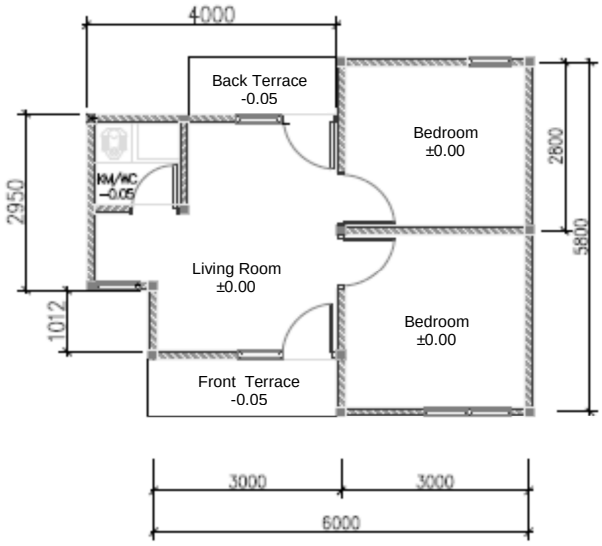

Figure 6: Plan of the House Type 36 (Laboratory of Housing and Human Settlements ITS, Survey 2012)

The use of space in the house was for domestic activities. To obtain more space for the kitchen the dweller extended the back side of the house, while for economic activities space extension was to the front of the house. Due to the unavailable spaces at the sides of the house, space extension could only be done to the back and front of the house.

The house construction was done by the private developer with the conventional technology. Building materials used were available locally. In the swampy area, lime stones were used for the house foundation. The conditions of the low-cost housing in the city were good enough. Figure 7 shows the example of the low-cost housing in the city.



Figure 7: The street picture and the row of low-cost houses in the city (laboratory of Housing and Settlements ITS- survey in July 2012)

In term of the standard for adequate house, the low-cost house was up to standard and was conformed to the culture of the dweller. In term of the environment surrounding the house, was less suitable because some houses were constructed in the remote area of the city. Some empty houses were surrounded by wild shrub and grasses. To support poverty reduction, place for small economic activity in the house was important for consideration.

3.2 Low-cost House at the Fisherman Settlement

The houses of fishermen included in the study were those at the coastal areas of the city. The house size was varied from 36 m^2 to 60 m^2, the example of the fisherman house with 36 m^2 area is shown in Figure 8.

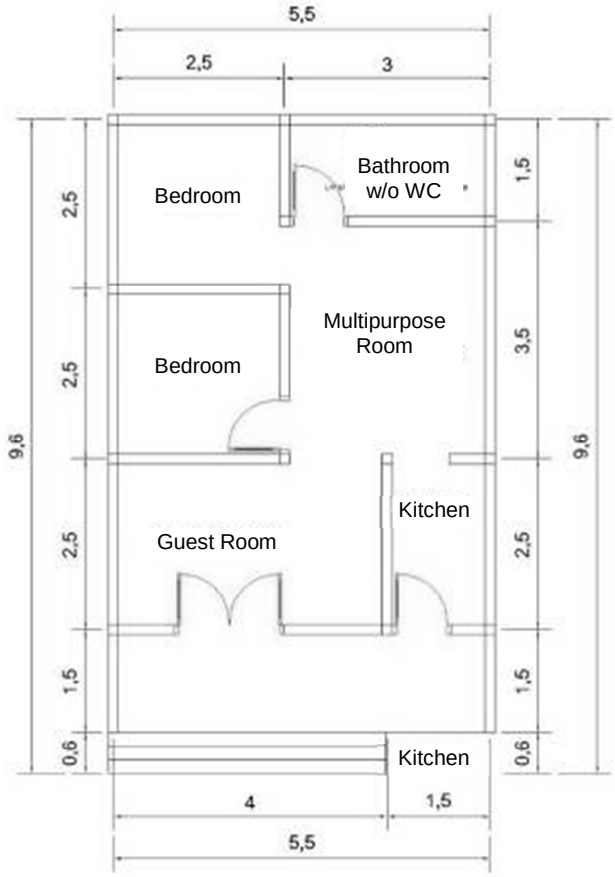

Figure 8: The fisherman house plan, size about 36m² (laboratory of Housing and Settlements ITS- survey in April 2012 by Adinda)

The house was occupied by three persons and three children. Such kind of house actually did not match with the economic activity of the fisherman. Processing of the sea products was outside the house, at the front terrace which was also used for storing the products during rainy period.

The fisherman house was usually built by the dweller with their own money and with the help of carpenters or neighbours. The construction of the house was simple. Building materials were locally available: galvanized iron or asbestos for roof, brick or bataco for walls, and

cement plaster or terrazzo for floors. Extension of the house could only be done to the back and front of the house. Communal sea-product processes were done in the available spaces surrounding the houses, which were used for economic activities. Figure 9 shows the communal space for economic activities.

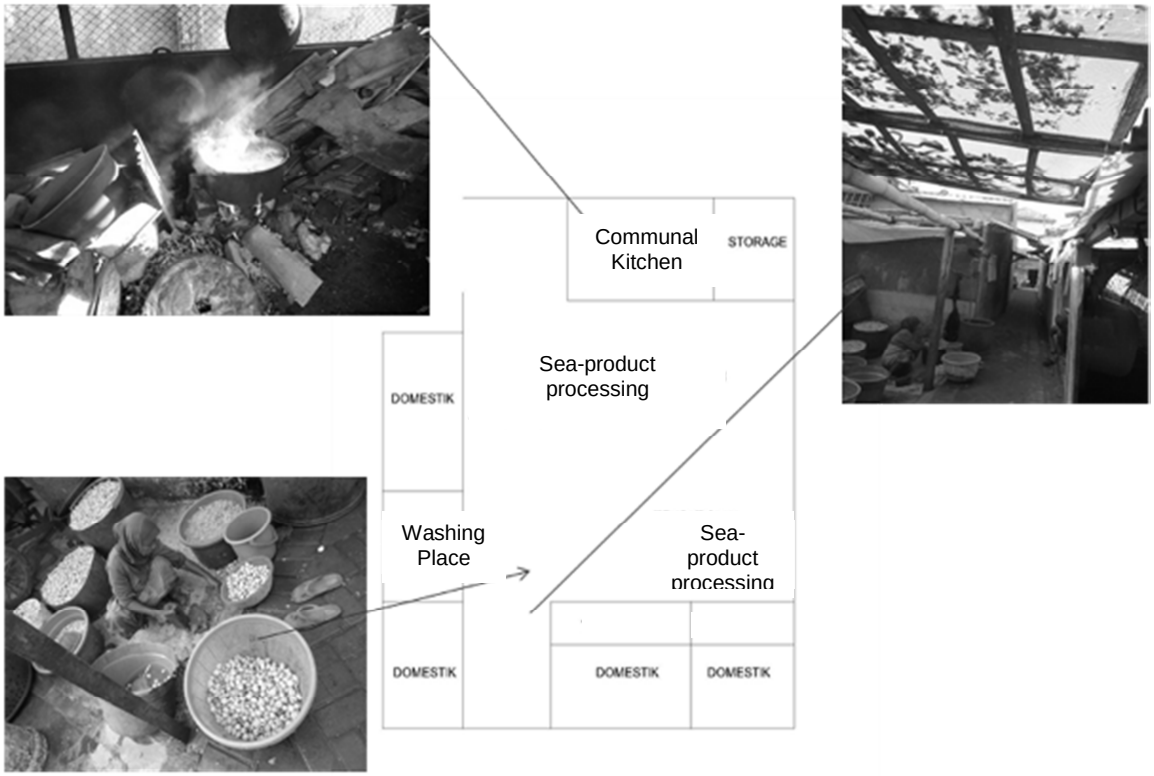

Figure 9: Communal space for economic activities at the fisherman settlement adjacent to the domestic areas (Laboratory of Housing and Settlements ITS- survey in April 2012 by Adinda)

Figure 9 shows that the spaces between houses were used for sea-product processing and for communal kitchen. Washing place for domestic was also used for washing the sea-product. Drying of fishes and other sea-products was at the house lanes, which also functioned as shelters for the passer by.

In term of low-cost house standard, the 36 m^2 house size for the fisherman household was acceptable. The important improvement should be done was the available spaces for drying and processing of the sea-products. In terms of socio-economic and socio-cultural aspects, the fisherman houses were acceptable, but should be improved with more spaces available for economic activities. Some pictures of the fisherman houses can be seen in Figure 10.



Figure 10: Permanent houses at the fisherman settlement (Laboratory of Housing and Settlements ITS- photograph taken by Adinda)

Figure 11 and 12 show the social-economic activities at the fisherman settlements.



Figure 11: Fisherman's wives processing the sea-products (Laboratory of Housing and Settlements ITS- photograph taken by Adinda)



Figure 12: Drying of sea-products along the lanes between row of houses (Source: laboratory of Housing and Settlements ITS- photograph taken by Adinda)

3.3 Low-cost House, Supporting Economic Activities for Poverty Reduction

The prototype of low-cost or very low-cost housing can be developed in the inner city or in the others area. It was proved that the RIA house price was about US $ 1,350, the RISHA house price was about US $ 1,000. These types of very low-cost houses were cheaper than the average formal houses built by developers, which cost about US $ 60,000 (with land of about 60 m^2).

The instalment of the very low-cost house should meet the monthly wage of the dwellers. In the inner city average lowest income of the poor was US $ 100 per month. Hence the maximum instalment would be 20% of the wage, i.e. US $ 20 per month. For the very low-cost house of US $ 1,350, the dweller needs about 70 months or about 6 years to finish the instalment. The maximum time for the instalment was 15 years.

With additional economic activities at the house on average each household could obtain about 10% of the monthly wage. This provided more income for the house instalment. However, to support economic activities at the house, the very low-income house should be provided with more spaces, such as a shelter at the house terraces. Figure 13 shows an example of the very low-cost house with wider terraces.

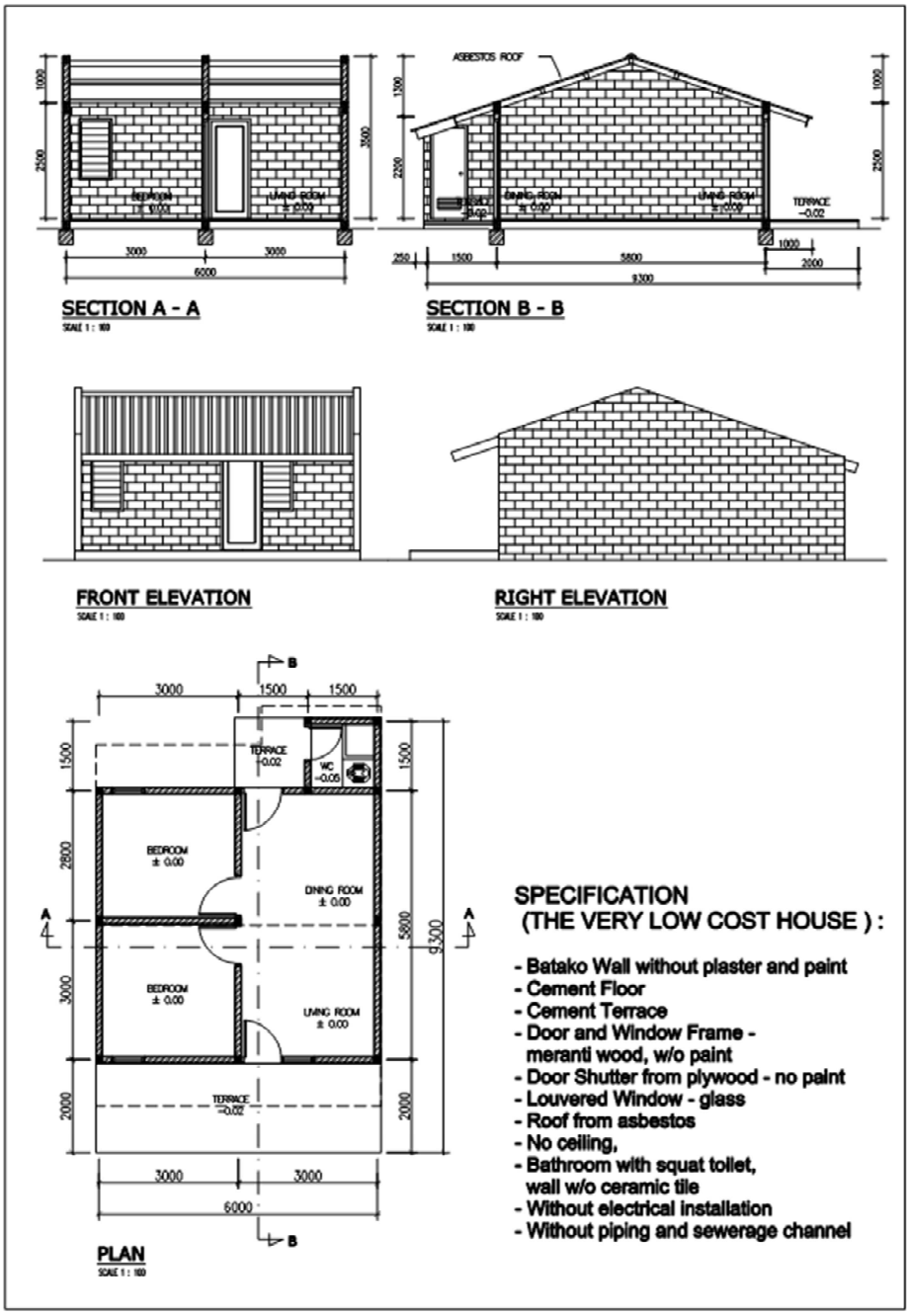

Figure 13: The very low-cost house with wider terraces

At present, the proposed house costs about US $ 1,400. With the same price as the available very low-cost house, the proposed house with wider terraces and shelter is more acceptable. The spaces at the front and back of the house with wide overhang can provide additional space for economic activities.

4. Conclusion

From the research, it was clear that the development of very low-cost housing was aimed at the poverty reduction of the dwellers.

Some suggestion for the house improvement would include the following:

- The house size of 36 m^2 was the minimum standard for four persons. Each person occupied 9 m^2. When the family member exceeded four persons, than the house become over-crowded. It can be mentioned here that the 36 m^2 house is suitable for small family.
- The conformation of the house design with the dweller's needs and socio-economic activities is very important. With the additional spaces at the front and back terraces, the house will be more suitable to cater for domestic and economic activities.
- To obtain the very low-cost house many systems of house financing can be applied, such as government subsidize, installment, CSR assistance.

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The ecomaterials. Science and Innovation to Tackle Housing in Developing Countries.

Fernando Martirena H[1]

Abstract

Housing, health and food are the most urgent problems that developing countries face. Tackling housing deficit in poorer countries prompts for an innovative approach in order to meet the massive demand for land, building materials and technology. The Latin American Network for the Sustainable Habitat, EcoSur (www.ecosur.org) has developed a model for the decentralized production and use of "ecomaterials" based on (a) use of locally available materials, preferably wastes, (b) small scale of production, tapping a local housing market, (c) labor intensive technologies. Universities in Cuba and Europe have engaged in innovation projects, whose aim was to close the loop fundamental-applied-research-technology-implementation in a pioneer's work of cooperation with local governments, NGOs and the civil society in general. A technology for the local production of binders out of agriculture wastes is presented as exampled of the implementation of the ideas. 20 years of successful implementation in developing countries have proven the potential of the new approach to tackle housing problems in a sustainable way. Only in Cuba there are over 50 production units spread throughout the island producing ecomaterials for the construction of approximately 3000 houses per year. The model has been embraced by the Cuban government as a sustainable solution for providing houses to the poorer sectors of society. This model has also been replicated to other countries like Haiti, where disasters have posed a severe burden to the already existing housing needs. This contribution aims at discussing the model and its main contribution to meet social goals.

Keywords: social housing, science & innovation, building materials, disaster mitigation

Introduction

More than two thirds of the world's population lives in the so-called "developing countries", where most of the basic needs are not yet properly fulfilled. The gap between poor and rich nations is most visible in areas like food provision, mobility or housing. Tackling housing problems in poorer nations, where a weak infrastructure and structural economic problems create resistance to progress, prompts for radical innovation; in order to meet the massive demand for land, building materials and technology for the construction of houses, while preserving Mother Nature.

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The building materials industry is amongst the most dynamic areas for modern development. A wide variety of new products has overwhelmed the international market for construction in the XXI Century. However this impressive development has not equally benefited industrialized and developing countries, being the latter often affected. The “global market” in building materials often causes great constrain to local industry which can only opt for becoming a “franchised business” of international trusts to locally distribute the international products.

This phenomena becomes a burden for the lower income sectors of population in developing countries, who cannot afford to have access to products having a foreign exchange share in its price. The other side of the problem deals with the discouragement of local productions, which leads to decrease in job opportunities, above all in rural areas far distant from industrial regions.

Ecology is also a problem of great concern. Modern technologies are the major responsible for the negative ecological impacts created by the increasing amount of wastes generated by industrial and agriculture production. Environmental awareness and damage prevention is currently addressed with some success in industrialized countries, mainly because of the existing infrastructure, the well-organized society and the law enforcement system to preserve the environment.

The goal is to find an appropriate solution for the poorer sectors of population in under-industrialized countries, where the capital cost is high and labor costs are low. This approach, basically denominated as “appropriate technology” or “intermediate technology” [1] has proved to be a sound solution in many cases; however a larger social impact must be sought by improving the efficiency of such technologies without abandoning the original concepts.

This paper aims at presenting the experiences of a joint collaboration between an academic institution and an international Non Governmental Organization in the pursuit of solutions to tackle housing problems in developing countries.

The model for decentralized production of ecomaterials

The International Network for Sustainable Habitat, EcoSur (www.ecosur.org) has triggered an intensive exchange among academics and researchers, mainly based in Cuba, and experienced practitioners who worked in social projects throughout Latin America in the areas of production of building materials and housing issues in general on the search for new paths to the solution of housing problems at community level in developing countries[2].

The model embraced by EcoSur becomes an alternative to production carried out in large industries with automated processes, where the products have to be distributed at long distances and quite often raw materials have to be sourced from distant places. This brings unemployment at the short term, while it increases dependency from foreign technology and raw materials import.

The manufacture of reasonably priced building materials is among the most important issues, since it allows people to have access to affordable housing. The cost of building materials represent a high percentage of total construction costs for housing, that some authors estimate as higher than 40% in developing countries. Among these materials, Portland cement takes a major part that in absolute amounts up to 15% of total cost of housing in these countries[3].

Imported raw materials have a significant share in the local cost of traditional building materials. Had the production of building materials been done locally with raw materials available in the vicinity of the workshops, the resulting product could likely be affordable for a wider range of population that normally does not have access to traditional building materials. The resulting products should be able to compete in quality and price with the traditional ones and would likely have a better environmental profile since local raw materials normally come in the form of recycled industrial or agricultural wastes.

This kind of small-scale production would also stimulate local economy mainly by creating new job opportunities. Besides, the environment is preserved since the potential threats in the form of wastes are profitably used. The amount of embodied energy[4, 5] incorporated in the new product is lower as compared to traditional products since transport costs are cut to the minimum and technological processes are quite simple.

This has brought about the concept underlying this paper: ecomaterials. The “ecomaterials” (eco stands for ecology and economy) have become an alternative to traditional building materials manufacture. They are similar to traditional building materials although their manufacturing conditions are significantly different. The ecomaterials are manufactured at a very small scale, with appropriate technologies, using local resources. They become a source of decentralized development since local unskilled labor is used, while the products are traded in the surrounds of the workshop in order to save transport costs.

The technologies for the manufacture of ecomaterials do include flexible systems for quality assurance based on field and lab trials adapted to local possibilities in underdeveloped countries. This allows attaining a reasonable high standard for the manufactured products, which then become competitive at local scale. The concept “ecomaterials” comprises a wide variety of building materials with different origin and end use. However the best experiences are reported in the manufacture of Microconcrete Roofing Tiles (MCR), lime pozzolana binder CP-40, hollow concrete blocks and non-stabilized adobe bricks.

In conclusion, the resulting product does not significantly vary when compared to the traditional one, moreover, it becomes a competitive alternative in the local market once it has attained local acceptance. The target product is good (good performance, high strength and durability, and soft ecological profile), beautiful (high quality, good looks) and cheap (low cost), which is the golden dream of every entrepreneur/manufacturer.

Implementing the model: technology for the production of low cost binder

In this section ideas on the production of alternatives binders developed by CIDEM in interaction with several academic partners in developed countries will be presented. Although the paper will focus on the research and scientific part of this work, most of the technologies developed were implemented at the grassroots level.

(a) Recycling agriculture wastes for the production of pozzolans for lime-pozzolan binders

Sugar cane has the ability of fixing silica in its organic structure. When burnt, the organic volatiles disappear and the remaining ash is rich in micro-crystalline silica. Depending on the burning and cooling régimes, the ash can occur in an amorphous, reactive, state or in less-reactive crystalline forms. To produce a reactive pozzolan out of sugar cane, it must be fired and the temperature must be kept within 400-800 degrees Celsius, in order to prevent the transition to crystalline phases during heating. [6,7,8,11].

Burning is the most frequent way to recycle these wastes. Different procedures have been developed to burn the organic wastes under controlled conditions. Some of them, like the Fluidized Bed Boiler (FBB) require complicated operational systems, and others, like rudimentary incinerators simply burn under very simple conditions. It appears that burning temperature, residence time and cooling regime are the most influencing factors.

The author has studied different approaches to produce pozzolans through recycling processes that involve burning bio-wastes of the sugar industry:

1. Collecting the ashes produced during firing agricultural wastes in boilers.

2. Producing ashes through firing sugar cane straw under controlled conditions in an specially designed incinerator

3. Producing a reactive ash, which consists of thermally activated clay resulting from firing a solid fuel block (SFB), a briquette made of clay and finely shredded sugar cane straw.

Ashes collected from the boilers of the sugar industry

The easiest procedure is to collect the ashes just as they are produce in the industry, without any further treatment. Two types of ash were examined. The SCBA ash was extracted directly from boilers of the sugar factory “10 de Octubre” in the province of Villa Clara, Cuba. The SCSA ash was sampled from the heaps of open air-burnt straw in the fields surrounding the sugar factory. The ash was collected as a representative sample from the entire heap – e.g. by taking several grab samples at different heap depths and then blending them together.

The main results of this study may be summarized as [9]:

1. SCBA-ash that is produced in boilers of the sugar industry shows a poor pozzolanic activity. The high firing temperatures, incomplete non-uniform combustion and slow cooling that take place in the boilers are likely reasons for the low reactivity. The main factors that affect the reactivity are the resultant degree of crystallinity of the silica present in the ash and the presence of impurities like carbon and unburnt material.

2. SCSA that is produced from burning sugar cane straw in the open air has proved to be a reactive pozzolan that fulfills the principal requirements for pozzolanic materials. Probably, this is due to the lower temperatures occurring in the combustion, mainly providing an amorphous structure for the silica present in the ash.

   Ash treated in rudimentary incinerators

   If one expects a higher reactivity from the pozzolan, the thermal treatment of the biomass during firing must be strictly controlled. With this purpose, a rudimentary incinerator was conceived and built with the aim of firing the bio-wastes at temperature under 700 oC, and the residence time under 2 hours, in order to create optimal conditions to produce a reactive ash. The incinerator was designed to process raw sugar cane straw. The target output of the incinerator is 25 kg of ash per hour. [10]

   The incinerator was built so as to guarantee that the airflow in the combustion chamber travels through meshes in the external walls. After the start of combustion, the incoming air drags heat from the burning mass to the chimney outlet, and cools down the burning chamber. The input of cool air can be regulated in order to attain the target burning temperature and residence time. A faster airflow lowers the temperature inside the burning chamber and lowers the residence time, as the biomass burns faster with an ample supply of oxygen.

   Based upon the strength results, there appears to be no significant benefit in firing sugar-cane wastes in semi-controlled conditions, when compared to firing in open-air heaps. Although the mineralogical study shows that the ashes resulting from incinerator firing have less crystalline phases and more glass phase, this difference is not reflected in strength gain.

   The reason for this could be the relatively long residence time of the ash in the burning chamber of the incinerator, and the slow cooling process afterward, which would not promote the retention of the more-reactive glass phase. This, combined with the low output shown by the incinerators during their use, confirms that from a practical/economic viewpoint transition from open-field firing to rudimentary incinerator firing is not warranted. A more sophisticated, higher output, version of incinerator with better and more uniform temperature control coupled with controlled cooling might prove to be a worthwhile future endeavour.

   Ash from Solid Fuel Blocks made out of clay and waste biomass

   Previous testing has indicated that if firing-temperature is kept below 750 oC, a reactive ash can be obtained by burning bio-wastes, but the practical applications of this solution are limited because at this low temperature heat recovery devices are difficult to implement.

When firing above 750 oC, the ashes resulting from burning bio-wastes become highly crystalline and thus non reactive[11]. At this range of temperature the only chance to produce reactive pozzolans through thermal treatment is by calcining clay. This is a well-known procedure, which involves a relatively large energy consumption, but yields a highly reactive pozzolan. If the energy needed to calcine clay could come from firing bio-wastes, the whole process would be more economically viable, and less dependant on external energy.

To contribute to this, the author has developed the Solid Fueld Block (SFB) [12]. In this block, the bio-waste is mixed with clay before burning and pressed into briquettes; its high calorific value can be used at its maximum potential and the resulting ash – a mixture of the non-reactive ashes from the biomass (approx. 20-30%) and the likely reactive activated clay (approx 70-80%)- can likely be used as a pozzolan. The SFB can be burnt at temperatures around 800-950°C. The higher firing temperature increases the options for use of the resulting energy -- for instance, to fire clay or fly ash-clay bricks. Various techniques for energy utilization from this process are currently under investigation.

The Solid Fuel Block (SFB) is an attractive alternative to recycle waste biomass for the production of reactive pozzolan. Waste biomass, such as agri-wastes, sawdust or waste paper is shredded to fine particles, wet mixed with a suitable clay and pressed into solid fuel blocks. The clay that is used should be high in silica content because the activated clay becomes the main source of pozzolanic material, as the ashes resulting from firing the bio-wastes at temperature above 750 oC are likely non-reactive. The optimum proportion of clay has been found by experiment to be in the range 20-30% by mass. The SFB typically has a dry density of 800 to 1100 kg/m3. The average calorific value is 15 kJ/kg, which makes the SFB acceptable for use a sole source of fuel in an ordinary furnace.

The ash that results from SFB firing needs to be cooled fairly rapidly in order to form a primarily amorphous reactive silica. Slower cooling results in a higher proportion of non-reactive crystalline compounds. Sophisticated techniques for rapid cooling produce optimum pozzolanic activity of the ash but are not practicable for implementation within an agricultural community. It has been found in experimental trials that a simple process of periodically removing the ash from the furnace and spreading it on a metal surface cools the ash rapidly enough to produce a highly reactive pozzolan, which can be used in the manufacture of lime-pozzolan cements or as a supplementary cementing material.

(b) <u>Using calcined clays as supplementary cementitious materials</u>

Metakaolin (Al2Si2O7) (MK) is a highly reactive pozzolan made through the calcination of a clay rich in kaolin. It is produced from high quality crude clays using state of the art technologies to remove impurities and control particle size. The reactivity of MK depends on various factors, such as temperature, heating rate and cooling regime. The optimal temperature window is 700-800 oC, although the dehydroxylation of clay is known to begin above 500 oC [13].

MK is rich in alumina, thus introducing extra alumina in the system when used as SCM in cement. The pozzolanic reaction of MK in blended cements can be then described as:

$AS2 + 5CH + 3H \Rightarrow C4AH13 + 2CSH$

The volume of new hydrated alumina phases is increased as a result of adding MK to the system. If calcium carbonate is supplied through an external source to the system, the alumina phases will further react with it and form the following phases:

Hemicarboaluminate $3CaO \cdot Al2O3 \cdot 0.5Ca(OH)\ 2 \cdot 0.5CaCO3 \cdot 11.5H2O$

Monocarboaluminate $3CaO \cdot Al2O3 \cdot CaCO3 \cdot 11H2O$

Based on this cementitious system, a mass of clinker can be replaced by the same mass of a mix of MK/calcium carbonate having a 2:1 molar ratio, and yet form new hydration products capable of filling out the pore system in the matrix, thus contributing to improve strength. A prognosis based on thermodynamic modeling (Antoni M. et al 2012) shows that up to 60% of clinker can be substituted without decreasing the total volume of reaction products produced during cement hydration, thus the strength should not be compromised. The alumina phases are faster in reacting, thus the strength gain at early ages is not compromised. This cementitious system can move the boundaries of clinker substitution further without compromising performance compared to a normal OPC.

Calcining the clay

Characterization of the Cuban clayey soil from Manicaragua revealed that it was composed of a variety of minerals including quartz, feldspar and 3 types of clays (kaolinite, illite and montmorillonite). The kaolinite content of the soil was 17%. In order to increase its pozzolanic potential, the clayey fraction of the soil was extracted by a sedimentation process and the kaolinite content of the clay obtained was 40%. Those two materials (soil and clay) were thermally activated for their use as cement replacement materials [14].

Characterization of the materials after calcination allowed us to identify an optimum temperature window, which was a compromise between loss of crystallinity and agglomeration of the clayey particles due to sintering phenomena. 800°C was found to be the optimum activation temperature for both the soil and the clayey material.

The study of the interactions with cement was done by substituting 30% of cement by calcined clays in the production of pastes and mortars. It was shown that clay calcined at its optimum activation temperature had a high pozzolanic activity that was indicated by a consumption of the calcium hydroxide produced by the cement during its hydration. This contributed to the final compressive strength of the materials (see figure 1).

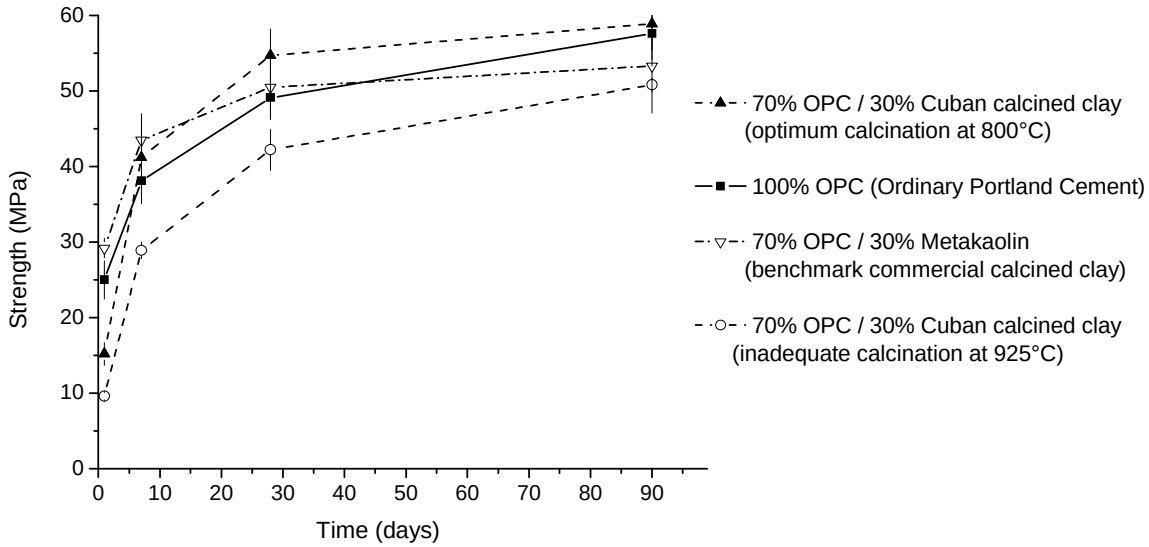

Figure 1: Compressive strength development of Portland-calcined Cuban clays blends compared to standard Portland cement and Portland cement with highly active metakaolin

Ternary blends clinquer-calcined clay-limestone

The aim was to optimize the replacement of cement by calcined clays, including the use of calcium carbonate and gypsum supplementary addition. It has been decided to concentrate on the investigation of the synergies possible in the ternary blends cement – calcined clays – limestone with pure industrial materials, optimize their use in the ternary blends together with limestone and finally study their use in concrete application as well as the durability issues[15].

The new type of cement demands needs optimisation of the sulphate addition at all replacement levels. The replacement of cement by the blend of kaolinitic clay and limestone is associated with increasing reactivity of the aluminates phases, due to the aluminates content of the metakaolin. A correct sulphate level allows a good mechanical strength development by retarding sufficiently the aluminates peak to allow the main peak of the C3S hydration to occur. Gypsum correction for cements made with 15% clinker substitution (B15) and 45% substitution (B45).

Compressive strength of the ternary cement were tested in prisms were cast with a lab made cement using clinker and gypsum from the cement factory Siguaney: (a) SIG-B15, 78% clinker, 10% MK, 5% limestone and 7% gypsum, and (b) SIG-B45, 48% clinker, 30% MK, 15% limestone and 7.5 % gypsum. The mortar prisms were subjected to compressive and bending stress tests. The results (see table 1) prove that the new cements outperform the Ordinary Portland Cement produced in the industry.

Table 1: Compressive strength of mortar prisms made with SIG-B15 and SIG-B45

Index	Parameters	MU	Average CPO in Siguaney	SIG B-15*	SIG B-45*
Mechanical	Bend. Strength 3d	MPa	5.4	10.0	8.2
	7d	MPa	7.1	12.1	11.3
	28d	MPa	9.8	13.1	12.3
	Comp. Strength 3d	MPa	29	36.1	31.9
	7d	MPa	35	51.2	45.0
	28d	MPa	45	61.2	56.1

The whole innovation loop started back in 1992, and the first tonnes of the ternary cement will be produced in Cuba and India in 2013. In the meantime several workshops in Cuba and overseas have produced the lime-pozzolan binder for the local markets. After 20 years, the product has entered a real industrial phase of dissemination, whose impact on economy and environment will be significant.

Appropriate technology? The choice of the scale

Appropriate technology is characterized by: (a) use of locally available raw materials, including the possibility of recycling waste materials, (b) use of machinery adapted to the context, i.e. in rural areas with unskilled labor it should be simple to operate, (c) pursuit of a decrease on the energy consumed in the production process, including transport of raw materials and finished product. In developing countries it could be interpreted as small scale production, mostly done in rural areas [16].

This whole process does not apply for every single technology without exceptions. The author tried in the past to develop a technology for the production of a low cost binder, basically a lime-pozzolan binder, made through intimate mixing and grinding of both raw materials until the desired finesse is reached. The R&D work was done, machinery was developed for the purpose of introducing it at several communities [17], and more than 25 new workshops were created, where pozzolanic cement, together with other materials were produced.

Although still in production, this technology has not been widespread like other similar technologies for several reasons: (a) the production output (1 tpd) did not allow an interesting economic scheme, (b) raw materials processing, above all drying, was extremely complex to implement at a very small scale, and thus the quality of the production was affected, (c) the quality of the resulting product was not consistent through the time, mainly because it proved impossible to scale testing procedures down to the level of field tests, (d)

the product had a poor acceptance among the target population, caused by most of the problems described above.

During the 1970´s interesting reports were launched about the “mini-cement plants” in India[18] . The output was between 100-150 tpd and the plant was conceived for a local and regional market. This idea was abandoned due to the low energy efficiency attained, basically because of the firing technology chosen (vertical shaft kilns).

The new chemistry of cement described above in this paper, where clinker substitution has reached 60% without affecting the properties of cement. The technology has been tailored to the conditions of developing countries, that is, simplified to the maximum and the automation is limited only to specific areas. It would be especially interesting –also for developed countries- in a context where oil prices would skyrocket and long distance transportation could be hindered.

If this project takes off, a new alternative for cheap cement shall be made available on the recently opened building materials market in Cuba –non subsidized- . Further, the possibility of replacing Portland cement in many applications such as the production of hollow concrete blocks and roofing tiles could make these products more affordable for the population, and thus could boost local construction. The relatively large scale of the production could enable a relatively large production, and thus a great impact on the target population in a short period of time.

Replication and/or dissemination of this technology elsewhere are not straightforward. It should be coupled with the build-up of local capacity to test local materials for reactivity, either in local research centres, or by creating scientific core groups at universities in target countries at the universities, which again, would imply a change of paradigms in the connection of science with the grassroots. Further, the developers of the technology should devise a comprehensive methodology as to how to implement the project in the target country; financing schemes to foster the creation of partnerships between the academy, civil society and the private or industrial sector; and the engagement of the governments to establish trade policies to benefit the poor, etc.

Social impact. The Cuba case

From 1959-1988, the system for housing provision in Cuba was based on the centralized production of building materials in large, automated facilities operated by the Ministry of Construction. Prefabricated building materials were produced and supplied by road or rail to areas far from the industrial centers; it was an energy-intensive system based upon the supply of cheap oil from the former USSR.

The collapse of the Soviet Union and East European socialist states had a dramatic effect on the system: energy became scarce, roads deteriorated because of the lack of maintenance, the fleet of trucks became obsolete and the supply of spare parts was threatened. This had a great impact on the construction materials industry, which was no longer able to maintain a steady supply of building materials, particularly to areas distant from the production centers.

The lack of availability of building materials led to a decrease in new housing construction and a rapid deterioration of existing housing stock due to lack of maintenance, as the population did not have the means to renovate or maintain their homes in good repair.

The new situation prompted a fundamental shift from centralized production based on long-distance transportation, to the local production of building materials in order to lower energy and transportation costs. Suitable for both rural and suburban areas, the technologies developed by CIDEM are geared towards small-scale production, with a focus on stimulating the local economy through the creation of new job opportunities. The project's main features include:

- An innovative process of technology development and transfer, which has resulted in a set of appropriate technologies for the manufacture of building materials at municipal level. The whole process has been organized as a south-south endeavor, as machinery and know-how come from Cuba and other countries in Latin America. Ecomaterials workshops are carried out that include personnel training and a post-sale advisory service.

- A large-scale decentralized program for production of building materials at municipal level, which contributes to providing affordable and accessible building materials in a sustainable manner, particularly in areas where hurricanes have caused serious damage and a quick post-disaster response is required. This model has been embraced by the Cuban government as the model for housing development, and since June 2009 it has become the official approach of the Cuban government for housing at municipal scale.

- Creation and further improvement of a new decentralized management model for housing renovation, which gives local authorities new opportunities to act independently as well as increase their capacity for resolving urban renewal issues. The model includes the new legal framework for small and medium enterprises working on private (non-state) or collective (cooperative) property, and the launch of pilot projects that stimulate this new production sector in the Cuban society.

CIDEM's work has resulted into a contribution to the gradual migration from a centralized production model based on state-owned, subsidized enterprises to a decentralized production model based on non-state, market oriented production figures operating at municipal scale: 48 municipalities equipped with facilities to locally produce approximately 65% of the materials needed for their own housing programs; a national program for the Local Production of Materials launched by the Ministry of Construction, with funds allocated to progressively expand the model to the rest of the municipalities in Cuba.

Cuba is moving slowly towards an economy where market shall play an important role. The party congress in 2011 has approved a series of measures that will introduce real changes in the municipal economy. However, this is not being implemented as an economic shock, the measures will be solidly planned and implemented within the framework of the constitution and defined in laws (not in decrees). CIDEM has been called to provide advisory service at a very high level at the Cuban government and at Parliament level, to implement a

new housing program based on the use of local resources, and a clear emphasis on the non-state productive sector[19].

Concluding remarks

- The collaboration between cutting edge science institutions in industrialized countries and partner in developing countries is feasible and desirable, and can bring about interesting results for both the industrialized and the developing countries.

- The incorporation of fundamental research, coupled to applied research, lowers the possibilities of improvisation, and thus the potential errors or flaws in the technology implementation, which are so common in our environment.

- The collaboration itself becomes a mechanism to build capacity at the partner institution in the developing country, which then –due to the prestige acquired- is called by local clients in the industry to introduce their results.

- Innovation oriented to sustainable production practices could attract industrial stakeholders and thus create potential financing schemes. For instance, a sound partnership with the cement industry in Cuba has helped favouring a sustainable introduction of results, with own funding allocated for the technological transfer.

- The "domino effect" of good scientific partnerships North-South for developing countries can be created: more capacity built, better options for R&D work, more credibility at governmental level, more funding comes.

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Why Spatial Planning often Fails to Control the Spreading Locations of Large Scale Commercial Facilities with Regional wide Catchment.

Tatsuo Akashi[1] ~~[DO NOT INSERT YOUR AUTHOR DETAILS IN THIS PAPER]~~

Abstract

The purpose of this paper is to clarify the mechanism of 'Planning Failure' on land use control in case of sprawl~~ed~~ developments of large scale commercial facilities, which is often seen in many countries.

Firstly, the paper introduces two cases that are observed in local regions in Japan. The f~~F~~irst case is a huge retail accumulation developed between t~~win~~wo central cities in the region. The development site is just~~only~~ in the middle of rice field, but the paper demonstrates that there is the most optimum location for retail accumulation ~~in~~ targeting ~~of~~ automobile users who are the majority of the residents. The s~~S~~econd case is two large retail accumulations ~~which~~ developed in northern and southern fringes of urban area sandwiching the downtown. This case seems geographically opposite to the first case, but the paper also demonstrates that the location~~s~~ of these two developments is~~are~~ also optimum for customers who use automobile.

Secondly, the paper introduces the third case that happened just~~soon~~ after a city government introduced the regulation that prohibits large store development in ~~the~~ suburban area, many large shopping malls were established one by one in neighbouring municipalities. Given~~By considering~~ the case, the author points out that a municipal government with small territory is not an appropriate body to control~~on~~ land use ~~of~~of ~~commercial~~ facilities with broad~~large~~ catchment area ~~such as a large retail establishment,~~ because neighbourhood municipalities are in competitive position with each other. Theoretically speaking, the scale of catchment area of the ~~objective~~ development and the scale of territory of a responsible~~in charged~~ planning authority should be consistent, even in the localism era.

Lastly, the author points out a~~what the~~ serious problem of sprawl~~ed~~ developments of large scale commercial facilities~~,~~ because it is often misunderstood. In highly motorized society, market is naturally led only by automobile users ~~and habitat space changes to an automobile friendly form~~. However, even though automobile users are ~~the~~ majority, people

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who do not use automobile ~~is~~are not minority. Thus, the most crucial problem ~~that~~ caused by retail sprawl is exclusion of~~to~~ automobile~~-~~ poor people. To avoid retail sprawl is one of the most significant issues for spatial planning in matured motorization era.

Keywords: Large scale retail store, ~~Spatial planning,~~ Urban sprawl, Social inclusion, Catchment area

1. Backgrounds and Purpose

Evolution of retail industry in recent decades ~~has been~~ largely influenced ~~to~~ the form of urban land use and spatial structures in many cities in the world, especially regarding~~on~~ ~~the~~ location of commercial accumulation districts which are~~is~~ ~~the~~ places where large number of residents visit~~come and get together in the city~~. The traditional land use pattern was a city~~that~~ has downtown as a~~the~~ prominent commercial centre with large department stores. It is already became an old tale, even in ~~the~~ regional core~~central~~ cities. Instead of that, huge shopping mall developments in suburban areas, and even in outside of urban areas, are often seen.

In addition to location, size of retail establishments ha~~i~~s increased tremendously. A single new retail development in the suburbs with almost the same scale of floor area as retails in the whole traditional downtown is not unusual today. Typical size of a suburban shopping mall (more than 10 thousand square meters) exceeds the normal~~usual~~ size of supermarket (some thousands square meters), and far exceeds the size of a roadside shop (some hundreds square meters). Typical suburban~~-~~-type~~d~~ commercial accumulation in these days is consisted of a huge indoor shopping mall and some surrounding large stores ~~around~~. ~~As a matter of course,~~ They have~~there are~~ huge amount of parking space for automobile comers with some thousands of parking lots in the districts.

Understandably, these retail developments with more than 10 thousand square meters forth ~~to~~ change~~d~~ their location ~~of the primary commercial centre of the city~~ from the traditional downtown to ~~the~~ suburbs, or even sometimes to ~~the~~ outside of a~~the~~ city. As a matter of course, the influence is not small~~.~~, The m~~M~~ost crucial problem ~~that~~ caused by retail sprawl is~~would be~~ alienation of~~exclusion to the~~ people who do not use automobile. Even though automobile users are ~~the~~ majority, ~~the~~ people who do not use automobile ~~is~~are not minority.

The purpose of this paper is to clarify the necessity of a regional perspective of~~viewed~~ land use control in order to prevent the phenomenon of sprawl~~ed~~ developments of large scale commercial facilities in matured motorization era. In order to clarify the mechanism of~~why~~ huge retail accumulations established in outskirt of a~~the~~ city, this paper introduces three simple but true cases ~~which~~ observed in Japan. Further, ~~by consideration of~~given the cases, the author points out that a municipal government with small territory is not an appropriate body on land use of facilities with large catchment area such as large retail establishments~~,~~ because neighbourhood municipalities are in competitive position with each other.

2. Case 1: A New Retail Accumulation between T~~win~~wo Cities

2.1 Outline of the Case Cities

The first case is a new large retail accumulation developed in the midst of rice field area between t~~win~~wo cities. Around the district where the new large retail stores were developed, there was nothing but rice field and an arterial road that connects two cities. However, soon

after the large stores ~~were~~ opened, ~~seles~~sales power of two downtowns in the t~~win~~wo cities was rapidly shrank and decreased.

The names of the t~~win~~wo cities are Tsuruoka City and Sakata City. Both cities are in Yamagata prefecture, located in northern part of the main island of Japan. They~~Both cities~~ have similar size of population. ~~that is~~ Tsuruoka City ha~~i~~s approximately 130,000 people, where Sakata City ha~~i~~s 110,000. The locations of t~~win~~wo cities are both in Shonai Plane with~~where is~~ approximately 53,000 hectares of flat fields combined~~surrounded~~ by the sea and mountains. The two cities are functioning independently. ~~, which means a separated world,.~~ Distance between the ~~two~~ downtowns of the t~~win~~wo cities is approximately 20 km. ~~Both cities are in Yamagata prefecture, located in northern part of the main island of Japan.~~

2.2 What happened?

Figure 1 and Table 1 show the~~are~~ comparison between before and after the new large retail stores were ~~–between the two cities established within a district~~. Figure in the left side describes the retail situation in the region in 1997 which is "Before". The largest retail accumulations in the region were seen in two downtowns of the t~~win~~wo cities; downtown Tsuruoka with 38,648 m^2 of total retail floor and downtown Sakata with 39,497 m^2 (both in 1997). Seeing the aspect of total annual retail sales in 1997, downtown Tsuruoka's sales were~~as~~ 24,814 million yen whereas downtown Sakata's were~~as~~ 24,781 million yen. In the "Before" period, the t~~win~~wo downtowns were definitely in the position of the retail centres of the region.

Figure in the right shows~~describes~~ the situation in 2007 a~~which is "A~~fter~~"~~ the large retail accumulation was developed. The new commercial development~~district~~ was~~is~~ located in the territory of Mikawa Town just in the middle of the t~~win~~wo downtowns, ~~where~~ approximately 10 km away from the both downtowns. ~~Actually, the district is located within the territory of~~ Mikawa Town~~, which~~ is a different municipality from the both t~~win~~wo cities.

~~Within the new developed retail district,~~ The total retail floor area of the newly developed retail district~~for retail sales has~~ reached to 51,299 m^2 and the annual retail sales ~~has also~~ reached ~~to~~ 15,340 million yen (both in 2007). As comparing it with the t~~win~~wo downtowns by data of ~~"~~after~~"~~ it was developed, both of t~~win~~wo downtowns have~~s~~ shrunk and decreased, ~~which is to the value of~~ 27,712 m^2 of floor and 13,204 million yen of sales in downtown Tsuruoka, and 25,967 m^2 and 11,979 million yen in downtown Sakata (both in 2007). According to these data, the newly developed retail district ~~has~~ definitely affected ~~to~~ the old t~~win~~wo downtowns, and moreover, it got the position of the largest retail centre in the region in terms of both floor area accumulation and amount of sales. On the contrary, the positions of the two~~both~~ downtowns as regional retail centres ~~are~~ largely fell and declined.

2.3 Considerations for~~on~~ Case 1

This case ~~is~~ look~~ed~~ very simple, but presents a real picture of~~ly observed fact in a~~ local region~~s~~ of Japan. From a geographical point of view, the traditional downtowns are located in the centre~~s~~ of each urbanized area~~s~~, which is~~. These locations are~~ supposed to be

~~approximately~~ optimum location for customer catchment because they are ~~the~~ centres of urban areas where most of the people lives ~~in.~~. Besides~~Moreover~~, the train terminals as the gate of the city are located nearby and~~so that they~~ are close to the public transportation network hubs including~~such as~~ bus services ~~are concentrated in the area~~.

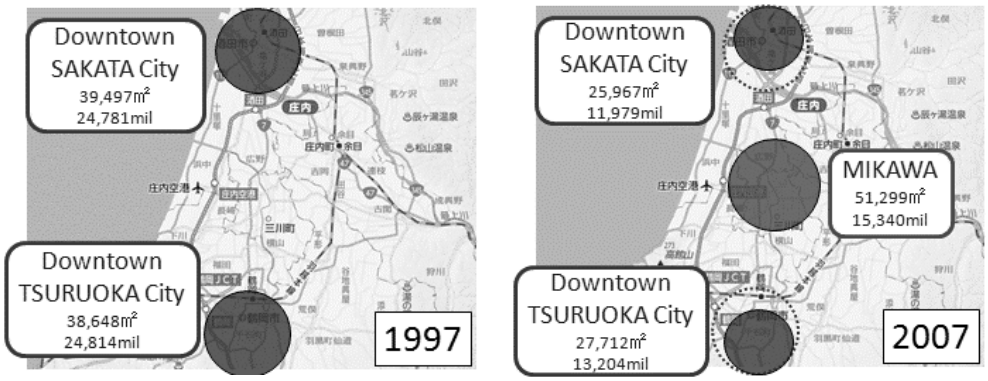

Figure 1: Change of Retail Accumulation ~~in Twin Cities Region~~ (1997, 2007)

Table 1: Change of Floor and Sales of Retail Accumulation ~~in Twin Cities Region~~ (1997 to 2007)

		1997	2002	2007
Floor	Downtown Tsuruoka City	38,648m^2	40,469m^2	27,712m^2
	Downtown Sakata City	39,497	28,502	25,967
	Large Stores in Mikawa Town	-	23,817	51,299
	Mikawa / Both Downtown	0%	35%	96%
Sales	Downtown Tsuruoka City	24,814mil	19,159mil	13,204mil
	Downtown Sakata City	24,781	14,738	11,979
	Large Stores in Mikawa Town	-	6,166	15,340
	Mikawa / Both Downtown	0%	18%	61%

On the contrary, the newly developed retail district is located far from residential accumulations, which are both urban areas of the t~~win~~wo cities. ~~In other words, it is the most distant location in simple mean of distance from where people lives in.~~ It has~~There~~ is no convenient transport access ~~means~~ but automobile. However, regarding~~focusing on~~ the accessibility for automobile, 10 km from urban areas without traffic congestion means less than 15 minutes drive ~~without congestion~~. In addition, large number of free parking spaces~~s~~ provided by the new commercial facilities attracts~~is convenient for~~ automobile users.

It sounds different from common sense, but the above facts indicate that places~~ ~~outside ~~of the~~ urban area are more convenient and more accessible for automobile users rather than places inside ~~of the~~ urban area~~,~~ so long as along there are ~~the~~ arterial roads. Therefore, it can be said that in case of automobile us~~ers~~ing people are~~were~~ ~~the~~ majority of residents in the region, the positional reverse between inside and outside of the urban area will be occurred inevitably. Thus, in a matured motorized society, the optimum location of~~n~~ regional retail accumulation shifts~~must be changed~~ from a~~the~~ central district of urban area to ~~the~~ outside ~~places~~ of urban area, especially between urban areas~~the cities~~. This t~~win~~wo cities' case eloquently demonstrates the truth of the ~~theoretical~~ geographical upset caused by motorization.

3. Case 2: Two New Retail Accumulations that sandwich ~~a~~~~the~~ Traditional Town Centre

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3.1 Outline of the Case City

The second case is two new large retail accumulations located in northern ~~side~~ and southern side~~s~~ of urban fringe area. Each accumulation is about 5 km away~~distant~~ from the central station of the city, which is the centre of ~~included in~~ the traditional downtown ~~area~~ of the city. Both new retail accumulations consist of some large~~-~~-scale commercial facilities~~stores~~ including a suburban ~~typed~~ large~~-~~scale shopping mall with more than 10,000 m^2 of retail floor (Table 2). ~~From geographical point of view,~~ T~~t~~he two new retail accumulations sandwich the urban area of Yamagata City, ~~so that also sandwich~~ the downtown where there is ~~include~~ traditional retail accumulation. The distance from the central station to the two new retail districts are approximately 5km each.

~~The name of the city is Yamagata City.~~ Yamagata City is a capital city of~~also located in~~ Yamagata prefecture, thw same prefecture as the case 1 but in a different region ~~from above twin cities~~. The place is called Yamagata Basin w~~ith~~~~hich~~ approximately 40,000 hectares of plane field~~s~~ surrounded by mountains ~~Cities~~. Yamagata City is bigger than the t~~win~~wo cities of the case 1 in terms of~~with~~ population which is~~of~~ approximately 250,000 and s~~. S~~ize of urbanized area which ~~is also bigger; urban area of Yamagata~~ is approximately 3,000 hectare (as Densely Inhabitant District (DID) ~~which~~ defined by the National Statistic Survey of Japan) whereas Tsuruoka and Sakata have ~~is~~ 1,340 hectares and ~~Sakata is~~ 1,620 hectares of land respectively.

3.2 What happened?

The two new retail accumulations were developed rapidly in a short time. Table 2 shows the floor~~established year~~ of major large retail stores and opening year in ~~each~~ northern and southern accumulation districts. ~~Northern district is in 1997 and southern district is in 2000 when m~~Most of the retail stores were established in 1997 in the northern district and in 2000 in the southern district. Now Yamagata City has three districts that have more than 10,000 m^2 of retail floor; the downtown, the northern district and the southern district. ~~There are only the two districts where large suburban shopping malls with more than 10,000 m^2 retail floor in Yamagata City except in downtown area.~~

Figure 2 and Table 3 are comparison between before and after the new retail accumulations were established. Figure in the left side describes the former size of retail accumulation in the downtown ~~Yamagata~~ in 1994 b~~which is "B~~efore~~"~~ the new retail accumulations were~~had~~ established. It had~~was~~ 92,957 m^2 of total retail floor with ~~in the downtown district and~~ 85,267 million yen of annual retail sales. Those~~Occupied~~ shares were ~~each~~ 30.0% and 24.6% of the whole city respectively.

Figure in the right side shows~~describes~~ the changed situation in 2007 ~~which is "A~~after~~"~~ the two new retail accumulations were~~had been~~ established in northern and southern ~~of~~ urban fringe areas. Total amount of annual retail sales of the two newly developed districts exceeds~~is~~ a bit ~~exceeded~~ that of the traditional downtown. Total amount of retail floor in the downtown ~~was~~ severely decreased. ~~I so that i~~t fell to lower amount than total of the two new districts.

Table 2: Major Large Stores in North & South Retail Accumulation District

Northern District (Mamigasaki)			**Southern District (Wakamiya)**		
Large Stores	Ret. Floor	Year	Large Stores	Ret. Floor	Year
Mega Shopping Mall	21,822	1997	Mega Shopping Mall	28,782	2000
Furniture Store	6,674	1997	Furniture Store	5,635	2000
DIY Store	5,363	1996	Electronics Store	4,959	2000
Sports Goods	3,142	2005	Sports Goods	2,452	2002
Others	4,280	-	Drug Store	3,060	2000
District Total	41,281		**District Total**	44,888	

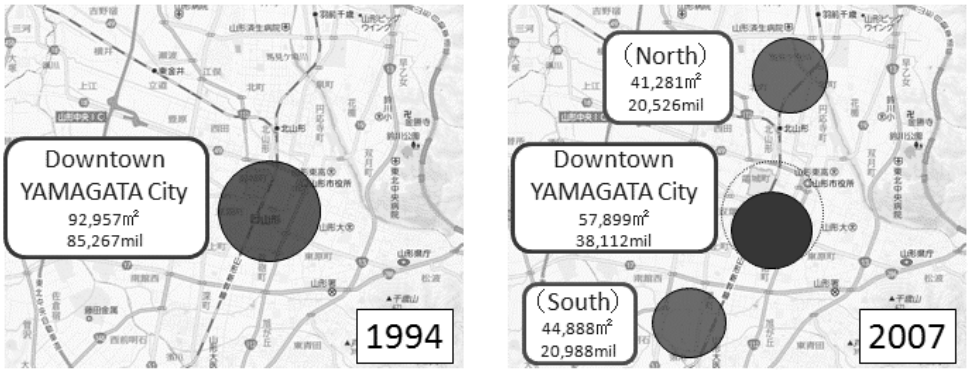

Figure 2: Change of Retail Accumulation in Yamagata City (1994, 2007)

Table 3: Change of Retail Accumulation in Yamagata City (1994, 2007)

Retail Accumulation		1994		2007	
		quantity	share	quantity	Share
Floor	Downtown	92,957m^2	30.0%	57,899m^2	14.4%
	North Dist.	-	-	41.281	10.3
	South Dist.	-	-	44,888	11.2
Sales	Downtown	85,267mil	24.6%	38,112mil	11.9%
	North Dist.	-	-	20,526	6.4
	South Dist.	-	-	20,988	6.5

3.3 Considerations for~~on~~ Case 2

According to these data, the new retail developments in the urban fringe areas ~~has~~ definitely affected ~~to~~ the old central downtown. M~~I~~n ~~m~~ore precisely, each n~~N~~orthern and s~~S~~outhern ~~of~~ new retail accumulation~~s~~, ~~which~~ located in ~~each~~ fringe of the urban area, does not exceed amount of the downtown~~, which located in the centre of the urban area~~. But the total of the two new accumulations remarkably exceeds the downtown.

This case tells us that only two huge~~-~~-scal~~ed~~ suburban retail developments with large amount of parking lots are able to dominate the whole city as the position of commercial centre~~s~~, instead of the traditional downtown. They are locate~~ds~~ the opposite side~~s~~ of urban fringe, which is advantageous location because not only the half of residents in the urban area but also ~~the half of~~ residents living~~in~~ outside the urban area can~~is~~ easily access~~ible to~~ the place~~s~~ by automobile.

Therefore, it also sounds different from common sense, but the above fact~~s~~ indicate~~s~~ that the urban fringe is possible to be more accessible location for automobile users rather than the centre of the urban area~~,~~ so long as it is located along the arterial ring road and so forth.

4. Compare above two cases

Comparing above two cases, they look~~s~~ like opposite. That is, the first case is a new retail accumulation established between two old cities, whereas the second case is two new retail accumulations sandwiching~~ed~~ the urban area. Therefore, we can easily notice that the two cases are in opposite geographical phase~~s~~. In other words, the first case means the new one in the middle destroys the old two in both sides, whereas the second case means the new two in both fringes destroy~~s~~ the old one in between. Then, what is the essential difference between the two cases?

Figure 3 and Figure 4 abstracts the difference of the two cases. Seeing the figures in comparison with~~of~~ the two cases, we can notice two~~that the~~ major differences ~~are able to focus in two points~~; one is positional relation between the locations of new retail accumulations and the DIDs (Densely Inhabitant District defined by the National Statistic Survey in Japan which approximately correspond~~s~~ to the urban built~~-~~-up areas), and the other is the distance between the old and the new.

Considering the distance regardingin view of converting to the necessary access time for the automobile users residents to the new retail accumulations, it can be found that each average access time of the two cases are almost exactly the same, not much difference between the two cases. In tThe first twinwo- cityies case is that the distance from the centres of twinwo urban areas to the new retail districts isare both approximately 10 km, and the both access routes are high speed arterial roads in the rice fields area between the cities. So, that it can be estimated that the average access time would be around 15 minutes. On the other hand, the second sandwiched case is that the distance from the centre of the urban area to the two new retail districts are both approximately 5 km, and both the alongside of the access routes are densely urbanized building sites. So, that it can be estimated that the average access time would be also around 15 minutes.

In conclusionsummarise the above consideration, it can be said that the two cases are seemingly in opposite phases from a geographical point of view, but from the retail developer's point of view, we can find that the two cases are very similar. The sites of new retail accumulations are both located at places of about 15 minutes drive oin average from residential accumulationed areas, nearby the arterial roads, large inexpensive sites available to prepare large amount of parking spaces. Therefore, it can be recognized that these are the optimum locations for retail developments in matured motorization era.

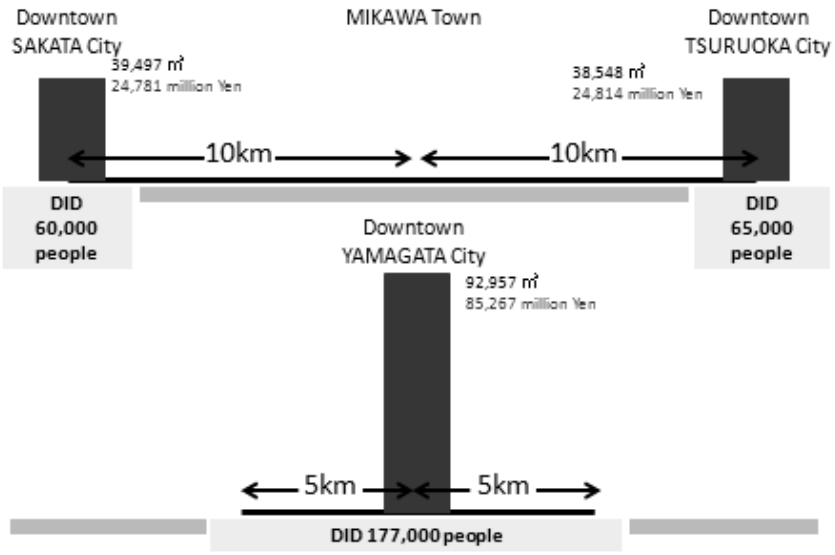

Figure 3: Situation of Retail Accumulation Districts (Before)

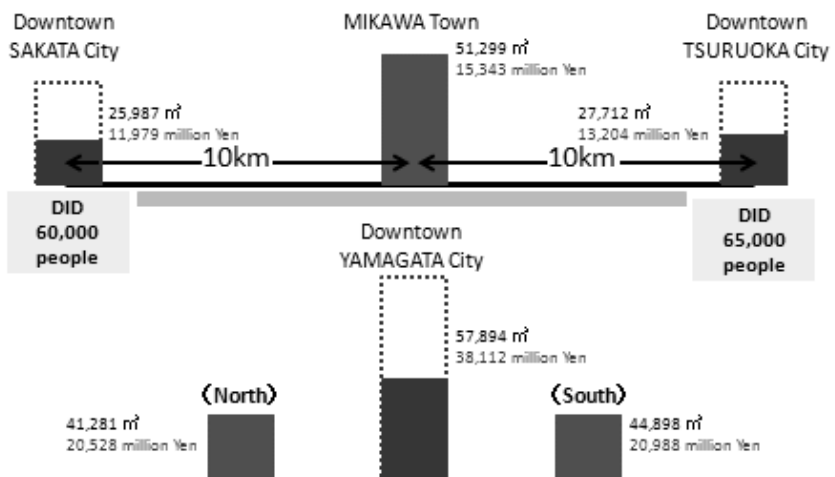

Figure 4: Situation of Retail Accumulation Districts (After)

5. Case 3; Large Retail Developments in Small Municipalities

5.1 What happened?

The third case is a story of Toyota City and the surrounding municipalities. Toyota City is well known as athe home town of TOYOTA Automobile Company, with population of 409,000. It is located in the eastern end of large flat field of Nobi Plane. S~~,~~ so, ~~that~~ eastern neighbour municipalities have mixed landscape that consists of farmlands, residential settlements and factory sites, whereas western sides are non-~~-~~urbanized mountain areas.

According to the municipal policy, land use regulation in Toyota City is relatively strict than the surrounding municipalities. Traditionally, large-scale ~~sized~~ retail store developments~~s~~ have been restricted in suburban areas of Toyota City. In addition to that, when a new land development project was carried out to~~for~~ establish~~ing~~ new research facilities in suburban area within Toyota City, the municipal government of Toyota City introduced a new land use regulation to prohibit large retail development with more than 3,000 m^2 retail floor by a local ordinance and applied it to the new developments~~ed area~~ in the suburbs. It was the year of 1997.

Figure 5 describes the scene that large scale shopping malls with more than 10,000 m^2 of retail floor were established one by one in neighbour municipalities of Toyota City. It happened~~was~~ only within three years after 1997 when the municipal government of Toyota City introduced the ordinance to prohibit large retail development in the suburbs.

Actually, the ordinance of Toyota City is only valid within the territory of Toyota City. S~~,~~ so, ~~that~~ it was impossible to prohibit these large-~~-~~scale shopping mall developments that are located outside ~~of~~ Toyota City unless the neighbour municipalities ~~would~~ introduce the same sort of ordinance as Toyota City. Consequently, so many huge-~~-~~scale~~d~~ shopping malls were established one after another in neighbour municipalities. As the result ~~of that~~, retail sales share of Toyota City in the region ~~was~~ decreased (Table 4).

Table 3: Change of Retail Sales Share in Toyota & Neighbour Municipalities

Municipality	Retail Floor (m^2)			Sales Share	
	1997	2002	difference	1997	2002
TOYOTA	369,797	338,409	▼31,482	27.9%	26.2%
SETO	105,824	126,303	20,469	7.9%	7.3%
NAGAKUDE	37,074	59,458	22,384	3.5%	3.9%
KARIYA	148,080	154,752	6,672	11.8%	11.2%
MIYOSHI	32,146	60,929	28,783	2.2%	4.0%
CHIRYU	89,141	92,821	3,680	5.2%	5.3%
ANJO	179,929	193,587	13,658	12.5%	13.7%
OKAZAKI	417,211	460,500	43,289	29.0%	28.5%

TOTAL	1,379,206	1,486,759	107,553	1,448(mil)	1,370(mil)

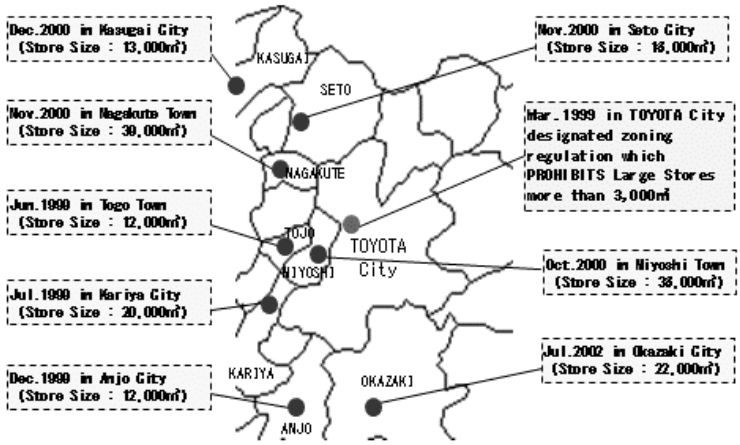

Figure 5: Large Store Establishment in Toyota & Neighbour Municipalities

5.2 Considerations for~~on~~ Case 3

Why did they~~were these~~ happen~~ed~~? Why such huge malls can be developed~~locate~~ even in small municipalities? Two reasons are easily thought; one is that the customer catchment areas of these large malls are so wide and broad that they can even reach ~~to~~ the suburban residents of Toyota City beyond the boundaries~~y~~ of their municipalities. The other~~Another~~ reason is that all the municipalities except Toyota City ~~are~~ welcome ~~the~~ large mall establishments within their territories~~y~~ because ~~the~~ large malls would contribute to the local economy of the municipalities, especially tax income increase.

Considering further ~~on~~ the two reasons above, it can be understood that a municipal government with small territory is not an adequate body in charge of development control on such facilities with wider catchment area than their municipal boundary as large scale commercial facilities.

As we can see, neighbouring municipalities are in competitive relationship with each other in terms of selecting location of facilities with large catchment area. Therefore, it is often seen that a small municipality invites large~~-~~-scale retail establishment ~~in~~to their territory for their

economic interests, or at least in order to avoid falling in disadvantageous position in the neighbourhood region by the case that large store would be located in outside of their territory. The above twinwino cities case (Case 1) also corresponds to this kind of pattern because the site of the new large retail development was located in a small town called Mikawa, notot in in either of territory of twinwino cities territory.

Thus, as a conclusion of this thought, it is not adequate that a municipal government with a limited territory takes responsibilitycharge of for the specifical planning on the potential location of large scale commercial development with large catchment area, at least planning without checking and consent of its upper regional jurisdictional government. It must be said that the size of catchment area of the objective development and the size of territory of a responsiblein charged planning authority should be spatially consistent, even in the localism era.

6. Conclusion

Major findings from above three cases are as followings:

According to progress of motorization, optimum location for retail accumulation had been changed from the centre of urban area to fringe area and even outside of urban area so long as it is well accessible toby arterial roads. This phenomenon corresponds to a local city region where majority of people use their own automobile for shopping.

By observing the actual cases, the location in the outskirt out of urban area, location in the middle of twinwo cities as well as the locations that sandwiching the urban area wereare demonstrated as examples of optimum location for retail accumulation rather than the central downtown in a motorized local city region. Both locations are approximately 15 minutes by automobile from the centre of urban area. These simple patterns are occurred naturally in the market with progressed large retail facilities. Therefore, theyit can be said as theoretical optimum patterns of location for large retail accumulation in condition of highly motorized wealthy local citiesy, though it seems different from former .common sense of spatial planning.

RegardingConcerning development control on location, Case 3 as well as Case 1 proved that a municipal government with small territory is not an appropriate body foron land use planning with large catchment area such as large retail establishment, because neighbourhood municipalities are in competitivenflicted relationship with each other. Theoretically speaking, the scale of catchment area of the objective development and the scale of territory of a responsiblein charged planning authority should be consistent, even in the localism era.

Lastly, I would like to consider what the fundamental problem on retail sprawl is.

In a highly motorized society, most of the families have their own automobiles. Therefore, market is naturally led by automobile users who are the majority of people. U and urban habitat space itself is changed to automobile friendly forms. Automobile has characteristics

to equalizing everywhere so long as there are arterial roads, but also requires large amount of parking spaces as a result of that.~~,~~ L~~l~~ocation of every facility including retail stores is driven~~ove~~ to spread out.

However, even though the majority is people who use automobile, people who do not use automobile is not the minority. There are so many automobile~~-~~-poor people who are not able to use their own cars for some reasons such as economy, age, physical disability or something lack of suitability. Thus, it is supposed that the most crucial problem ~~that~~ caused by retail sprawl is alienation of~~exclusion to~~ automobile~~-~~-poor people.

An u~~U~~rban form should not be automobile dependent, not only for greenhouse gas reduction but also more for social ~~inclusi~~inclusiveness~~on~~. Large scale commercial accumulation is a~~the~~ place for all the residents.Therefore,~~ so that~~ it~~there~~ should be accessible by all the means of transport, not only automobile. To avoid retail sprawl is one of the most significant issues for spatial planning in matured motorization era.

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Developing a Research Framework for Studying Performance Evaluation of Engineering Facilities in Commercial Buildings in Hong Kong

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Abstract

The property value of commercial buildings in Hong Kong is in the top tier around the world. Underpinning the proper functioning of these buildings are various engineering facilities, which entail substantial resources for their operation, maintenance and management. In order to assess the effectiveness of such resources input, the performance of the facilities needs to be evaluated but a holistic scheme for evaluating the performance of engineering facilities in existing commercial buildings is yet to be established. This article reports on the initial phase of work of a research study that addresses this issue. Through a comprehensive literature review, a broad range of performance indicators were identified and the indicators have been systematically categorized under five aspects, namely physical; financial; task and equipment related; environmental; and health, safety and legal. On this basis, a research framework comprising four stages of work has been established. In addition to describing the tasks to be undertaken under this framework such as focus group discussion, questionnaire survey and case study, the future works needed are also identified.

Keywords: commercial buildings, engineering facilities, literature review, performance evaluation, research framework.

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1. Introduction

Commercial buildings in Hong Kong are well-known for their high sale and rental values but their values could be eroded by inadequate performance of their engineering facilities, such as air-conditioning, electrical and other installations. On the other hand, substantial amounts of resources need to be input for proper operation, maintenance and management of the facilities and, therefore, the output, viz. the performance of the facilities, needs to be evaluated such that whether the resources are utilized effectively can be measured.

Although there were studies that pinpointed at particular aspects of performance of engineering facilities in existing commercial buildings, e.g. their energy or environmental control performance, few have addressed holistically their performance, which covers a wide variety of operation and maintenance issues. With the objective of establishing a holistic scheme for evaluating the performance of engineering facilities in commercial buildings, a research study is being undertaken and this article reports on the outcomes of the initial phase of the study.

The findings of a literature review are summarized in the next section, which covers the typical range of engineering facilities in commercial buildings; the stakeholders of such buildings; the impetus for having a system that can enable evaluation of the facilities' performance; and the major evaluation tools relevant to the objective of the present study. Also reported in Section 2 are the large number of performance indicators identified from the literature and the categories into which they were classified. Section 3 describes the essential stages of work to be carried out in the study, including the approach for developing a scheme for evaluation of the performance of the facilities. In the concluding section, the key findings of the initial stage of the study and the planned stages of further work are reported.

2. Literature review

2.1 Engineering facilities and stakeholders

The engineering services (facilities) that are essential to buildings include those that provide: energy supply (gas, electricity and renewable sources); fire detection and protection; cooling, heating and ventilation; water supply and drainage; lighting; vertical transportation; refrigeration; communication; security and alarm; etc. (Chartered Institution of Building Services Engineers, 2012). They are means for delivering the services needed by users of buildings, which help maintain a safe, healthy, convenient and comfortable indoor environment suitable for the activities of the building users. Without them, buildings are but inhabitable cells that can hardly fulfil the purposes that they are intended to serve. In addition to the capital input for making available the facilities in the first place, further inputs of resources are needed in the delivery process of the services that the facilities provide, which include human resources, energy and spare parts and materials for their operation and maintenance (O&M) and for management of the O&M processes. The performance of the facilities may be gauged by the quantities of physical outputs that they turn out, such as the amount of ventilation air or cooling delivered or the number of persons transported, against

the amount of resources input into the process; the precision and stability of the indoor environmental conditions that they are able to maintain; or the reliability of the facilities in providing the needed services. Nevertheless, the eventual performance of the services delivery process may also be judged by how well the needs of the end users are satisfied (Figure 1). The performance of engineering facilities in buildings, therefore, needs to be assessed from different perspectives. As engineering facilities may change with building function in response to new owner requirements or organisational revolutions (Then et al., 2004) and their performance may be affected by the effectiveness of the on-going management and a variety of endogenous and exogenous factors (e.g. wear and tear, end user demands), assessment of their performance should be a continual process.

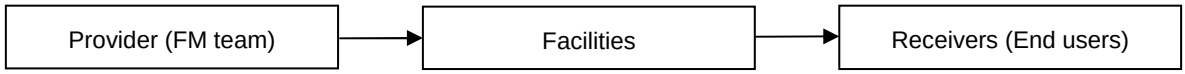

Figure 1: Service delivery process of facilities

2.2 Need for a performance evaluation system

Managing the engineering facilities in buildings is a key application of facilities management (FM), which has emerged as a professional discipline that deals with facilities that support the core business of an organization. FM covers a wide spectrum of property and user related functions that may be brought together for the benefit of an organization, by optimizing the efficiency, cost and quality of the support services (Amaratunga et al., 2000).

FM also emphasizes putting in place a performance evaluation scheme to identify and measure the effectiveness of the FM functions. Performance measurement, which enables facility managers to monitor the output quality of the works they manage and to compare and identify any needs for improvement (Kincaid, 1994), is a key management activity that informs effective decision making (Webster and Hung, 1994), including decisions on allocation of resources (Thor, 1991). A multi-dimensional and balanced performance measurement system can provide impetus that drives a company forward (Najmi et al., 2005).

2.3 Performance evaluation tools

Fit-for-purpose measurement tools are a prerequisite to performance evaluations, and many such tools have been devised and widely used in various sectors. For example, the “Balanced Scorecard” (BSC) was developed for assessing financial and non-financial aspects of companies in the business sector (Kaplan and Norton, 1992), which measures performance in four perspectives, namely financial, customer, internal business process, and innovation and learning.

The SERVQUAL model (Parasuraman et al, 1985) is for measuring and managing quality of services, which can be an efficient tool for an organization to shape up their efforts in bridging the gap between perceived and expected services (Ingram and Daskalakis, 1999). This model, however, cannot be applied in a straightforward manner to measurement of the performance of engineering facilities in commercial buildings because the “customers” are

laypersons to engineering and they would not normally realise how the facilities are operated and maintained. Nevertheless, their perceived levels of satisfaction about the availability of services, degree of thermal comfort, quality of lighting output and water supply, etc., is indeed a reflection of the ultimate performance of the facilities. It follows from this argument that reference should be made to the dimensions covered by the SERVQUAL model in developing a scheme for performance evaluation of engineering facilities in buildings.

Key performance indicators (KPIs) are meant to provide objective quantifications of the critical aspects of performance of a process. Appropriate KPIs are essential to measurement of the performance of maintenance processes, which will allow performance to be compared internally and, where applicable, against external benchmarks, through which to identify strengths and weakness and to control progress and changes over time (British Standards Institution, 2007). In the construction sector, some KPIs were established for reflecting the performance of construction projects (Chan and Chan, 2004). In the study of Ho et al. (2000), which attempted to develop a set of performance metrics for facilities management, corporations in the Asia Pacific region were asked to rate the importance of 97 metrics on a five-point scale and indicate if the metric was being used in their FM practice. They found that there was limited understanding and practice of FM benchmarking in the region and the awareness of the impact of FM on overall business was low.

For engineering facilities in existing commercial buildings, some initiatives have been taken to develop KPIs for evaluation of their performance. In the work of Lai and Yik (2006), it was found that the hurdles to the development of KPIs include the knowledge, financial, motivation and information barriers of the FM practitioners. Nevertheless, a hierarchy incorporating some common KPIs has been suggested for measuring the performance of different levels of O&M works (Table 1). With reference to this hierarchy, further work is needed to develop KPIs for applications on existing commercial buildings.

Table 1: A hierarchy of KPIs for engineering facilities *(adapted from Lai and Yik (2006))*

Hierarchical level	**Key Performance Indicator**		
	Input	Process	Output
Strategic	$\frac{O\&M\ cost}{Building\ area}$	-	$\frac{Building\ income}{Building\ area}$
Tactical	$\frac{O\&M\ cost}{Capacity\ of\ installation}$	*% compliance with required response time*	*% users dissatisfied*
Operational	$\frac{No.of\ manhours}{Capacity\ of\ installation}$	*No. of equipment faults per month*	*No. of completed work orders per staff*

2.4 Performance indicators and performance categories

From the literature, 71 indicators have been identified as potentially suitable for performance evaluation of engineering facilities (as listed in the Appendix). For facilitating effective management and reporting of performance, these indicators should be systemically classified into different categories with reference to the aspects of performance (British Standards Institution, 2007; Lavy et al., 2010; Muchiri et al., 2011; Parida and

Chattopadhyay, 2007; Shohet, 2006) or the stages of the process (e.g. Muchiri et al., 2011) to which they apply. A summary of the past classification efforts is shown in Table 2.

Table 2: Past efforts in classifying performance indicators

Research	Field/ application	Methods	Number of indicators	Categories classified
Gilleard and Wong (2004)	FM	Identified by a director of facility management services at a property development company	Not specified	(1) Financial performance, (2) productivity, (3) project performance, (4) equipment availability, (5) compliance, (6) complaint and accident frequency, (7) customer satisfaction
Shohet (2006)	Healthcare facilities management	KPIs were developed based on statistical and quantitative analysis	11	(1) Asset development, (2) organization and management, (3) performance management, (4) maintenance efficiency
British Standards Institution (2007)	Industrial and supporting facilities (buildings, infrastructure, transport, etc.)	Not specified	71	(1) Economic, (2) technical and (3) organizational
Parida and Chattopadhyay (2007)	Process and utility industries	Literature survey and interviews	28	(1) Equipment related indicators, (2) maintenance task related indicators, (3) cost related indicators, (4) impact on customer satisfaction, (5) learning and growth, (6) health, safety, security and the environment (HSSE) and (7) employee satisfaction
Lavy et al. (2010)	FM	Literature review and a brief survey with eleven FM professionals who are involved in FM services and consultancy	35	(1) Financial, (2) functional, (3) physical, (4) survey-based
Muchiri et al. (2011)	Manufacturing industry	Literature review	31	(1) Leading (work identification, work planning, work scheduling and work execution), (2) lagging (measures of equipment performance and measures of cost performance)

The 71 performance indicators can be grouped into five categories - (1) physical (impact on customers' satisfaction), (2) financial, (3) task and equipment related, (4) environmental, and (5) health, safety and legal. Physical indicators, e.g. thermal comfort, visual comfort, aural comfort, etc., include those representing the physical quality of services delivered by the engineering facilities. While reflecting the feelings or perceptions of end-users, the quality of the services impacts on the customers' satisfaction. Financial indicators (e.g. percentage of contractor cost, O&M cost per building area) are those indicators related to costs and

expenditures associated with O&M works for the facilities. Task and equipment related indicators (e.g. work request response rate, mean time to repair) are those indicators that can reflect how well the equipment are operated and maintained, and whether O&M tasks are effectively managed and implemented. Environmental indicators (e.g. energy use index (EUI), energy consumption per person) measure the impact of the facilities' operations on the environment. Health, safety and legal indicators (e.g. number of accidents per year, number of legal cases per year) reflect how well the FM team has done in safeguarding the health and safety of the building occupants as well as its performance in avoiding legal costs arising from any malpractices of facilities operation and maintenance.

3. Development of a performance evaluation scheme

Grounded on the above, a study has commenced in order to develop a scheme for evaluation of the performance of engineering facilities in existing commercial buildings. The study comprises four stages of work (Figure 2).

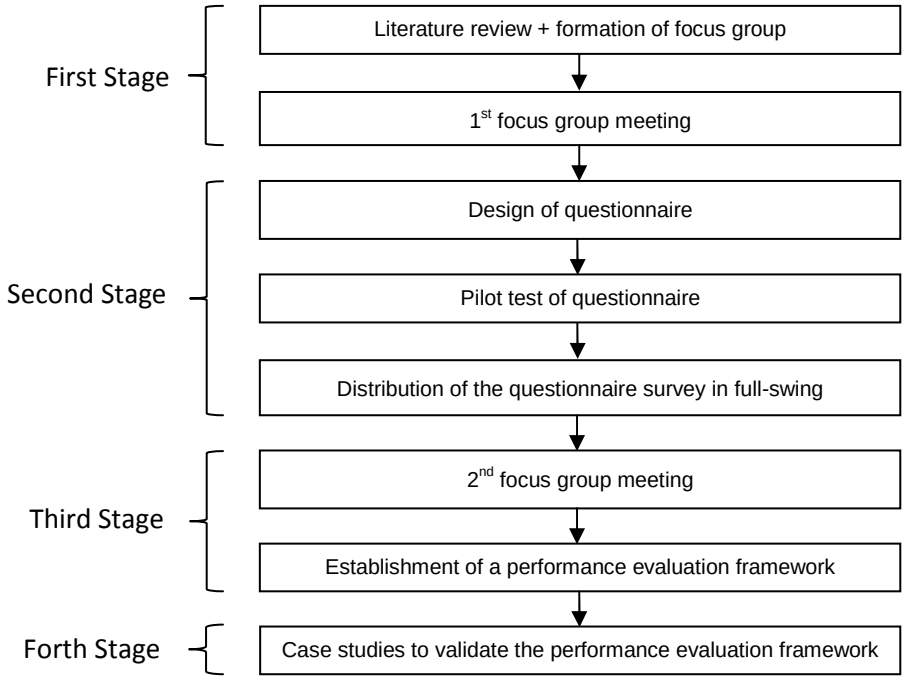

Figure 2: Flow chart of the 4-stage study

In the first stage, as has been reported in the preceding section, performance indicators that are usable in the context of the present study were identified from the open literature. Then, experienced FM practitioners working on typical commercial buildings in Hong Kong will be invited to provide their opinions on the usability of the indicators. For this purpose, a focus group discussion will be arranged, through which direct interaction between the researcher and participants will provide rich data. While this method will allow certain flexibility in discussion in terms of format, types of questions and desired outcome, the findings may not

represent the views of the whole population. To minimize this limitation, careful selection of the group members who are experienced and representative in the field is necessary, and good facilitation skills are required to enhance the efficiency in obtaining the findings (Fern, 2001; Hesse-Biber and Leavy, 2004).

During the focus group meeting, the participants will be facilitated to discuss and identify the typical and major engineering facilities in their buildings and the criticalities of such facilities. Besides asking them to comment on the suitability of applying the listed performance indicators on existing commercial buildings, the participants will be guided to brainstorm and suggest any other essential indicators which are beyond those on the list. Furthermore, the identified indicators will be subdivided into four kinds: (a) important and feasible to find; (b) important but hard to find; (c) less important but feasible to find; and (d) less important and hard to find. Shortlisting of indicators will be made on a balance between their importance and the feasibility of finding out such indicators.

Based on the shortlisted indicators, a questionnaire will be designed in the second stage to investigate the levels of usefulness of the performance indicators. To ensure that the questionnaire will be effective in collecting useful responses, it will be pilot-tested before a full-scale survey is carried out. The questionnaire will be adjusted to address any problem discovered in the pilot test. Upon finalization of the questionnaire, it will be distributed in full swing to FM practitioners. Through a questionnaire survey, a large amount of data can be obtained from a large number of practitioners in the field (Thomas, 2003). By requesting the respondents to indicate their opinions in a written questionnaire, there is no guarantee of how many responses will be received and whether they can be received in a timely manner. Therefore, telephone invitations and explanations will be made to the target respondents to help raise the response rate, followed by allowing sufficient time for them to return the questionnaires.

In the third stage, the responses collected from the second stage will be analysed to screen out the less useful indicators. The useful indicators will be organized into a hierarchical structure and a second focus group meeting will be arranged. Based on the hierarchical structure (Figure 3), the focus group members will be asked to make a series of pairwise comparisons between the performance indicators using a 9-point scale. Each comparison, expressed as equal, moderate, strong, very strong or extreme, is assigned a number (i.e. how many times more): 1, 3, 5, 7, 9. The numbers 2, 4, 6, 8 are used for compromise between two adjacent judgements, and reciprocals are used to represent inverse comparisons. Each paired comparison made by the respondents requires the estimation of how many times more one indicator has over the other indicator. The ratings obtained in such comparisons will be computed by Saaty's (1980) analytic hierarchy process (AHP) to generate importance weights for the indicators. With such weights determined, an assessment scheme will be established, which can be used to evaluate the performance of engineering facilities in commercial buildings when the performance levels of the engineering facilities are made available.

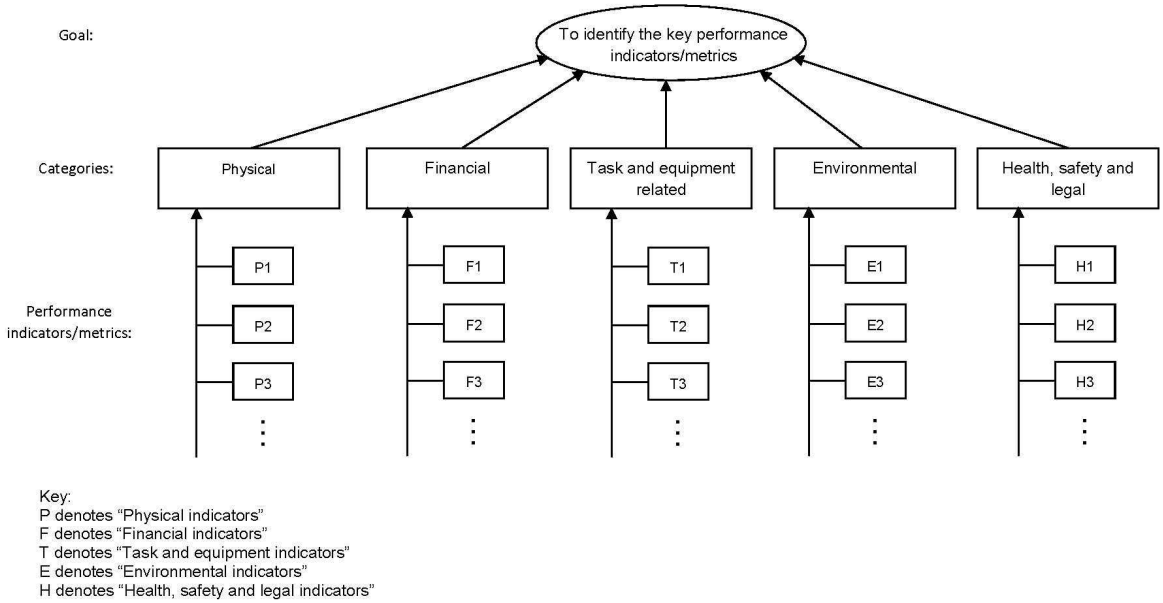

Figure 3: Analytical hierarchy of the performance indicators

In the final stage, a group of commercial buildings of different grades and scales will be the targets of investigation. For each of these buildings, an in-depth case study will be carried out. Empirical data which are essential for computing the KPIs identified in the preceding stage will be retrieved from relevant records of the buildings. To enable collection of reliable data, interviews will be held with the responsible FM personnel. In particular, face-to-face interviews will be used, as they can allow more opportunity to: i) assess the respondent's understanding and interpretation of the questions; and ii) clarify any confusion that arises about the meaning of the questions or the response. Furthermore, interviewing the practitioners face-to-face will help establish a relationship of trust between the interviewer and the interviewee, enhancing the opportunity to solicit answers to questions which the interviewees are reluctant to answer (Greenfield, 2002; Thomas, 2003).

Performance levels of the facilities, which may be figured out based on the buildings' records or determined according to the perceptions of the interviewees, will be taken to validate the applicability of the performance evaluation scheme. Where necessary, fine tuning will be made to improve the scheme further and when this is done, the scheme will be ready for application for holistic performance evaluation of engineering facilities in existing commercial buildings.

4. Concluding remarks

Over the years, a number of performance evaluation methods have been developed but one that is tailored for monitoring and assessing specifically the performance of engineering facilities in commercial buildings is yet to be seen. A review of the relevant literature has identified a long list of performance indicators, which can be categorised by the hierarchical level of a FM organisation as well as the stages of a FM delivery process. Classification of the indicators by their nature and characteristics revealed that they fall into different groups,

namely physical, financial, task and equipment related, environmental, and health, safety and legal.

Based on the five groups of indicators, a research framework comprising four stages of work has been established for developing an evaluation scheme for assessing the performance of engineering facilities. The initial findings obtained from the first stage of work have been reported in the above. Results of the subsequent stages will be published in future.

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Appendix: List of performance indicators/metrics

(Sources: British Standards Institution, 2007; Building Services Research and Information Association, 2011; Campbell, 1995; Chan et al., 2001; Electrical & Mechanical Services Department, 2007; Electrical & Mechanical Services Department and Environmental Protection Department, 2010; Hinks and McNay, 1999; Ho et al., 2000; Hong Kong Quality Assurance Agency, 2012; Lai and Yik, 2006; Lavy et al., 2010; Leung et al., 2005; Lukzkendorf and Lorenz, 2006; Muchiri et al, 2011; Parida and Chattopadhyay, 2007; Tsang et al., 1999; Vesela and Michael, 2001).

Physical (impact on customer satisfaction)

(1) Thermal comfort (e.g. temperature, mean radiant temperature, humidity and air speed)
(2) Visual comfort (e.g. illuminance and glare)
(3) Acoustic comfort (e.g. reverberation)
(4) Indoor air quality (e.g. total volatile organic compound, CO_2 level, concentration of radon)
(5) Percentage users dissatisfied
(6) Number of users' complaints per year

Financial

(7) Percentage cost of personnel
(8) Percentage cost of subcontractors
(9) Percentage of contractor cost
(10) Actual costs within budgeted costs
(11) Direct maintenance cost
(12) Breakdown severity
(13) Equipment replacement value (ERV)
(14) Maintenance stock turnover
(15) Percentage of maintenance material cost
(16) Percentage of corrective maintenance cost
(17) Percentage of preventive maintenance cost
(18) Percentage of condition based maintenance cost
(19) O&M cost per building area
(20) O&M cost per capacity of installation
(21) Cost of equipment added or replaced
(22) Energy expenditure per building area
(23) Energy expenditure per person
(24) Total safety and security expenditure
(25) Security expenditure per building area
(26) Security expenditure per person
(27) Building income per building area
(28) Total rentable value of the building

Task and equipment related

(29) Work request response rate
(30) Scheduling intensity
(31) Manpower utilization rate
(32) Manpower efficiency
(33) Manpower utilization index
(34) Preventive maintenance ratio (PMR)
(35) Percentage of reactive (corrective) work
(36) Percentage of proactive (preventive) work
(37) Percentage of condition based maintenance work
(38) Percentage of improvement work
(39) Number of manhours per capacity of installation
(40) Number completed work orders per staff
(41) Area maintained per maintenance staff
(42) Quality of scheduling
(43) Schedule realization rate
(44) Schedule compliance
(45) Work order turnover
(46) Backlog size
(47) Urgent repair request index (URI)
(48) Corrective maintenance time
(49) Preventive maintenance time
(50) Response time for maintenance
(51) Percentage compliance with required response time
(52) Number of maintenance induced interruptions
(53) Failure/breakdown frequency (number of equipment faults per month or per year)
(54) Mean time between failures (MTBF)
(55) Mean time to repair (MTTR)
(56) Availability
(57) Efficiency of facilities
(58) Gross floor area under safety and security patrol

Environmental

(59) Energy use index (EUI)
(60) Energy consumption per person
(61) Greenhouse gas emission per building area
(62) Conduction of energy audit
(63) Conduction of carbon audit
(64) Conduction of environmental assessment (e.g. LEED, BREEAM, BEAM Plus, HKQAA SBI)

Health, safety and legal

(65) Number of accidents per year
(66) Number of legal cases per year
(67) Number of compensation cases per year
(68) Amount of compensation paid per year
(69) Number of health and safety complaints per year
(70) Number of lost work hours per year (i.e. convalescent leave given by doctor)
(71) Number of incidents of specific diseases in building per year (e.g. legionnaire's disease)

Evaluating Early Stakeholder Engagement (ESE) as a Process for Innovation

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Abstract

Neglecting to engage key stakeholders early on is one of the common points of failure in projects. Problems such reworks, disputes, cost overruns, poor communication, and failure of the supply chain are just some of the common problems that arise from stakeholder conflict during the construction phase. This is due to the fact that different project stakeholders have differing goals and priorities, and it is therefore unlikely that all stakeholder expectations could be met. The early involvement of stakeholders could identify any potential problems early-on and continue providing input throughout the construction phase. Therefore, there is a need to engage the stakeholder in the project as early as possible to determine the need and capture stakeholder inputs in such projects. Innovative procurement tends to increase opportunity for innovation in construction productivity through the integration of the design and construction functions. Higher levels of innovation arise when a more innovative procurement method is chosen. Alliance procurement is one of the innovative procurement methods, introducing organisational innovation through early stakeholder engagement in the project. No major studies have so far been completed that examine in depth how early stakeholder engagement influences the innovation process. This paper therefore aims to evaluate the impact of early stakeholder engagement and how it influences the innovation process in construction projects. The potential of innovation through various procurement methods will be discussed. Then, the relationship to early stakeholder engagement is examined. The findings suggest that promoting early stakeholder engagement, regardless of the procurement system, is vital to avoid rework and unnecessary cost, enhance quality, overcome disputes throughout the construction process and overcome the problem of low productivity. Furthermore, long term procurement relationships, especially in collaborative procurement, need early stakeholder engagement as an effective way of developing trust among stakeholders, thus facilitating innovation.

Keywords: Early stakeholder engagement, Innovation, stakeholders, stakeholder engagement, procurement methods

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1. Introduction

Stakeholders in construction are affected in both positive and negative ways due to the different stages and nature of construction projects from initiation to handover of completed construction (Olander, 2007). Problems such as reworks, disputes, cost overruns, poor communication, and failure of the supply chain are just some of the common problems that arise from stakeholder conflict during the construction phase. Conflicting interests arise because project participants have differing goals and priorities (Barlow, 2000). Such conflicts are often linked with one another and resulting in a knock on effect on the project management process (Olander, 2007). Thus, Mathur et al. (2008) suggest that the construction industry should engage with stakeholders to determine what they need and El-Gohary et al. (2006) state that capturing stakeholder inputs in such projects is crucial. Research by Lee and Chan (2008) portray the evidence in the recent Guangzhou – Shenzen – Hong Kong Express Rail Link project, where stakeholders failed to reach a consensus during the participation process in the early stages of the project (e.g. planning stage). They further suggested that this could increase the chance of failure, or even lead to confrontation between decision-makers and local citizens, as the project progresses.

Alliance procurement is a form of relational contracting which introduces innovation in stakeholder management through early stakeholder engagement in the project. This results in jointly made decisions, increased commitment to the no-dispute rule and, furthermore, mutual liability waivers among the key participants. Introducing early stakeholder engagement in the construction phase eliminates low productivity, unnecessary risk and rework on the project. Tammer (2009) supported, the presence of key clients and stakeholders during project brief meetings, as the problem-owner can make the project more tangible and accessible by illustrating problems and objectives, and answering questions from parties involved. Sharma (2008) added that engaging the stakeholder early on can help offset any potential misunderstanding. Yang et al. (2009a) stated that different stakeholders have different levels and types of investments and interests in the project in which they are involved. An evaluation based on case studies by Olander and Landin (2005) shows that stakeholder demands and influence should be considered as a necessary and important step in the planning, implementation and completion of any construction project. Many of the industry's performance problems occur from inadequate inter-organisational co-operation (Barlow, 2000) which, in turn, adversely affects productivity, creates an adversarial environment and results in the limited take-up of technological and business process innovations.

Innovation is co-created in a multi-party environment and shaped by the project requirement (Ozorhon, 2012). Innovation not only can be implemented to the process and product but also to the organisation. OECD (2005) describes innovation as being either technical or non-technical. Technical innovation can be either product or process innovation, whereas organisational innovation includes changes to organisational structure, introduction of advanced management techniques and implementation of new corporate strategic orientation. Considering the multi-party environment in construction, innovation analysis should be done at the project level and should take into account the role of project stakeholders and their interrelationships (Ozorhon, 2012) thus, helping to increase

innovation in construction projects. Engagement of stakeholders at an early stage is likely to foster innovation throughout the supply chain and procurement process.

This paper aims to evaluate early stakeholder engagement as a process for innovation in construction projects, through a review of available literature. The paper describes the potential for innovation in construction procurement, followed by a discussion of the impact of early stakeholder engagement within the various procurement systems. No major studies have thus far been undertaken that examine in depth how early stakeholder engagement influences the innovation process.

2. Innovation in construction procurement

Innovation can be categorised into product innovation, process innovation, marketing innovation and organisational innovation (Damanpour et al., 2009). A well-known definition by Slaughter (1998) defines innovation as, "the actual use of a non-trivial change that results in an improvement in a process, product or system that is novel to the institution developing the change". Steiner (2008) explained innovation as a means of coping with change and future development, and not an end in itself. Innovation in construction increases when moving from traditional procurement methods to more collaborative procurement methods. This is due to the fact that the nature of the system becomes more complicated and key member and stakeholder involvement impacts more at an organisational level. OECD (2005) distinguishes between technological and non-technological innovation, the latter of which includes organisational and marketing innovation. Figure 1 plots the potential for innovation against the various types of construction procurement process. The input includes technological and non-technological innovation impact.

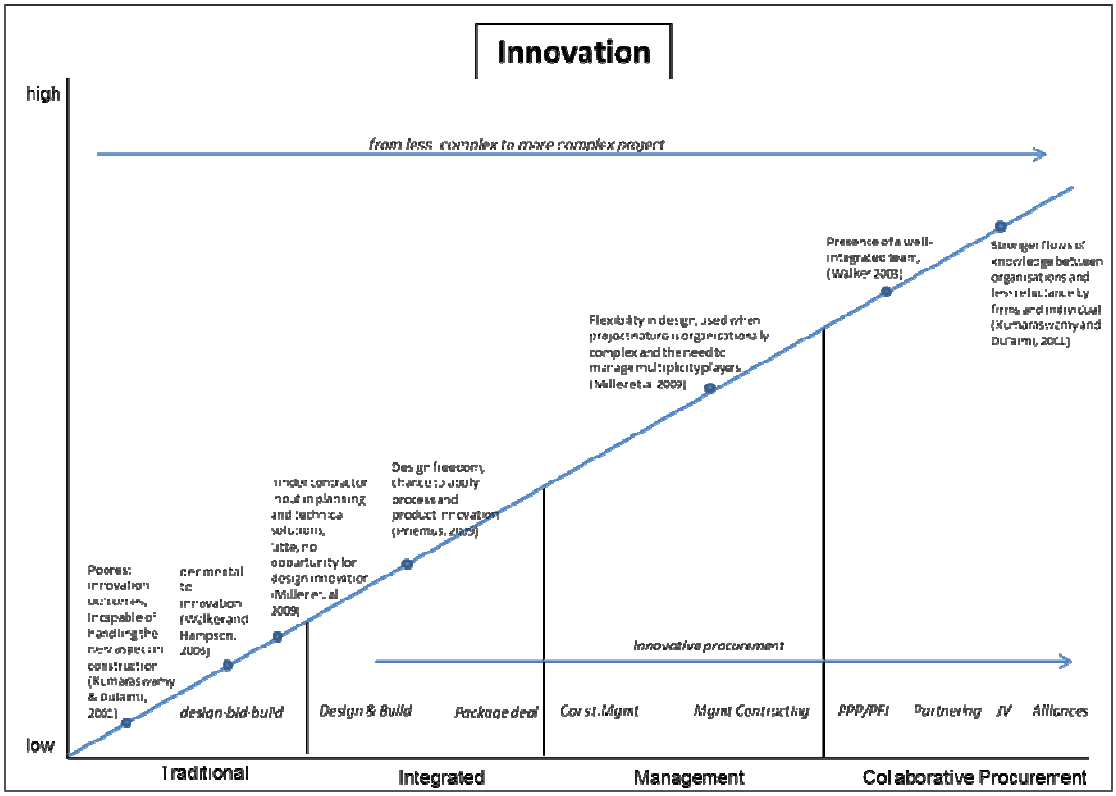

Figure 1: Potential for Innovation process through various procurement method

Traditional procurement (design-bid-build) methods impede the contractors input into innovation planning, technical solutions and buildability of the projects, resulting in little or no opportunity for design innovation (Miller et al., 2009). The traditional procurement approach was found unsuitable to the current need, as projects are becoming more complex which demand greater emphasis on management techniques and engineering skills (Ng and Yusuf, 2006). Kumaraswamy and Dulaimi (2001) describe traditional procurement as the most conservative and detrimental to innovation, resulting in the poorest innovation outcomes (Walker and Hampson, 2003).

On the other hand, the main contractor in Design and Build contracts (sometimes referred as design and construct) frequently works closely with a design team, subcontractors and suppliers. Priemus (2009) claimed design and construct can give the contractor plenty of design freedom and that the contractor often gets a chance to apply process and product innovations.

Moving further along the innovative procurement spectrum, Miller et al., (2009) highlighted that management contracting and construction management are suited to large, fast moving projects where early completion is desirable. Such contracts allow room for innovation, as the management contractor is appointed at an early stage and the client has a considerable degree of flexibility on design matters.

Walker et al. (2003) view, from an innovation perspective, the most importance aspect of a procurement system to be the presence of a well-integrated team which they consider as vital in driving innovation. Communication, learning, and innovation are also improved across the supply chain through management by a single entity (Walker et al., 2003). Furthermore, collaborative procurement reduces costs, reduces project times, improves quality, and improves client satisfaction. These benefits also apply to the alliance procurement model, perhaps with greater surety given the existence of commercial drivers to ensure co-operative behaviour under alliances (Bresnen and Marshall, 2000). Ozorhon (2012) claimed that much of innovation is co-developed with other project participants, such as clients, contractors, sub-contractors, suppliers, consultants, and designers, all of which have a different role in the innovation process. A review of the literature shows that the more innovative the procurement system the more stakeholders will engage with the process. Collaborative procurement engages various types of external and internal stakeholders throughout the project phase.

2.1 Impact of stakeholder to the procurement system

Rwelamila (2010) ascertained that there is in fact sufficient time to identify internal and external stakeholder in traditional procurement methods by running the identification process in parallel with the process of preparing project documentation. The project manager, with skill and knowledge, will have a chance to manage the process of identifying project stakeholders. Even so, if stakeholder's goals include contractor collaboration in the design process and client involvement, the traditional procurement method is weak in dealing with these issues. To deal with this, Rwelamila (2010) suggested adjusting the traditional procurement method to a hybrid system or to select a different procurement system (other

than separated and cooperative procurement system) thereby enabling the negative impact on stakeholder management to be accommodated.

In contrast, in the Design and Build procurement system identifying stakeholders is easy because the two central tasks of the project are implemented through a single point of responsibility. The process of assessing the environment around the project in terms of the impact of the project within its locality and beyond is easy to undertake since the two key stakeholders the designer and contractor are working as a team. Design and build in its typical form does not have an appropriate mechanism to deal with stakeholders, other than the construction team, if they have an interest in the management of the project, facilitation of high quality levels and other related issues (Rwelamila, 2010). This type of procurement is likely to be favourable, if project stakeholders expect positive impacts such as appropriate risk sharing, client involvement, time management and close control expenditure for their project.

In package deal contracts the majority of contractors employ their own in-house designers and can thus be categorised as pure design builders and, as such, are expected to perform well in terms of the cost and time criteria. If these two requirements are central to project stakeholder requirements, then smooth stakeholder management could be achieved (Rwelamila, 2010). However, some products of this system lack aesthetic appeal, but this can be avoided as the potential stakeholders are able to see actual examples of the contractor's product before reaching a decision.

Management contracting is based on the appointment of a professional project manager as an equal member of the design team with construction expertise, but the actual construction is carried out by package contractors employed, co-ordinated and administered by the management contractor. This type of organisation promotes teamwork and efficient use of resources through improved planning, but it is important to limit the overlap, in terms of supervision and monitoring, between the management contractor and the designer (Bower, 2003).

Alliance contracting theory is based on the notion of collaboration. In the Alliance model, there is a joint rather than a shared commitment between partners (Walker and Hampson, 2003). Alliance contracts fall under the general umbrella of collaborative contracting and can be described as multi-party contracts which are developed and executed by key project participants.

3. Early stakeholder engagement as an innovation process

PMI (2008) defined project stakeholders as individuals and organisations that are actively involved in a project or whose interests may be affected as a result of project execution or completion. It is important to gauge stakeholder opinion and concerns to better facilitate the development of a project that will meet the needs of those stakeholders. Olander (2007) categorised stakeholders as either internal, those who are actively involved in project execution, or external, those who are affected by the project. The process involved in stakeholder management includes identifying, negotiating and achieving objectives, such as

social, environmental or economic, through active stakeholder participation in the project phase (Pajunen, 2006).

Ozorhon (2012) stated that long term procurement relationships, collaborative working and early engagement in projects are effective ways of developing trust among parties and thereby facilitating innovation. Robichaud and Anantatmula (2011) highlighted the need for several modifications in traditional project management practice to deliver innovative and sustainable construction solutions. They suggest integration should be achieved through early involvement of all stakeholders to ensure that project objectives are understood and met in every phase of the project life cycle. In principle, the construction procurement system determines the overall framework of responsibilities and authorities for participants within the construction process, and is a key factor contributing to project success and, hence, stakeholder satisfaction (Rwelamila, 2010). Engaging stakeholders at an early stage of the project can offer a constructive discussion and sense of ownership that may lead to positive interest, increasing credibility, more transparency and the early identification of constraints (Tammer, 2009). Successful innovation often requires effective cooperation, coordination and working relationships between the different parties in construction projects (Ozorhon, 2012).

3.1 Stakeholder engagement in construction

Stakeholder engagement was recently identified by Rodriguez-Melo and Mansouri (2011) as the defining factor increasing managers' awareness, helping legislation to be effectively implemented and making sustainability highly appealing to clients. Greenwood (2007) defined stakeholder engagement as practices that the organisation undertakes to involve stakeholders in a positive manner in organisational activities. Atkin and Skitmore (2008) observed that enhanced stakeholder involvement can help with managing their needs, decreasing unanticipated risk and reducing unconstructive actions or reactions that have a possible impact on the project success.

The stakeholder involvement programme should not be overlooked. It is one which determines stakeholder concerns and integrates them into the design of a project to achieve collaborative integrated project development (El-Gohary et al., 2006). For instance, in Public Private Partnership (PPP) project planning, positive involvement with stakeholders can be a decisive factor that can 'make or break' a project. It is important to determine different stakeholder concerns, opinion and interest to better facilitate the development of a project and resolving conflicts in reaching a consensus at the early stage of the project (Li et al., 2012). Understanding of the concepts that underlie stakeholder involvement is an essential step towards creating a strong involvement programme, for example in infrastructure projects, will help project proponents and stakeholders to communicate effectively (El-Gohary et al, 2006).

3.2 The importance of early stakeholder engagement to the project

Construction projects involve production of unique projects on site by a variety of teams brought together temporarily. Blayse and Manley (2004) claimed that difficulties in

monitoring the different activities carried out by different parties in each stage of the construction project impedes the innovation process. Alliance procurement introduces innovation in organisational activity through early stakeholder engagement to the project. Jointly made decisions increase commitment to the no-dispute rule and furthermore, to mutual liability waivers among the key participants. Expectations can be managed, hidden agendas can be brought to the surface and project priorities can be established (Yang et al., 2009b). Many problems can be overcome, such as a lack of effective early stakeholder dialogue, misunderstanding of project objectives, conflicts, cost issues etc., if stakeholders are actively included at the early stage of front end planning and integrated into the project team (Tammer, 2009).

Brian and Martin (2008) and other scholars studying the construction sector have realized that stakeholder involvement has undeniable impacts on project outcomes. Lahdenpera (2012) elaborates on the idea of continuous workshopping throughout the project process derived from project partnering where it was initially needed to create and maintain trustful relationships between relatively independent organisations. Early involvement of the key parties and intensified early planning make the parties members of the same team, eliminating the need to put emphasis on *ad hoc* activities. For instance, tools like a partnering charter and decision ladder are important elements of the early project partnering approach, improving cooperation and minimising the possibility of misunderstanding. In contrast, project alliance practice evolved from the need to improve the implementation of demanding and risky investment projects. In project alliances, most organisations also engage a coach to help them through the team development process (Morwood et al., 2008).

Early involvement of key stakeholders is intensified by exploiting the means offered by advanced information and communication tools (ICT). Amongst client, project team, and contractors the building information model (BIM) is an example ICT solution that multiple parties can utilize. Heravitorbati et al., (2011) stated that to meet the differing demands of the various stakeholders, project managers have to involve these stakeholders in order to increase effectiveness and efficiency of decisions in the construction project lifecycle (Saghatforoush et al., 2010).

3.3 Impact of early stakeholder engagement on time, cost and quality.

Quality management is an important aspect in construction and building projects. In order to increase the quality of the ultimate project and to reduce rework, revision and waste, and failure costs in the entire project life cycle, the importance of quality has to be understood by the key project team members (Heravotorbati, et al., 2011). The project team, therefore, have to develop high-quality relationships with key stakeholders, in particular the main customers for the project, in order to understand the perception of quality systematically (Tam & Le, 2007). Effective relationships among key stakeholders (Wang and Huang, 2006) and stakeholder involvement in quality decisions of the project (Heravotorbati et al., 2011) are helpful in improving the final quality of a construction project.

Lahdenpera (2012) added that early involvement cannot be based on price and various qualitative selection criteria. This has resulted in an approach-oriented participant selection. The identification of the cost related risks, underlying drivers and impediments for effective management must be assessed in the context of three key stakeholders, namely clients, contractors and consultants. It has been emphasised that if a project's stakeholders are not satisfied with the quality of the project management or the final project, the project team will be required adjust scope, time and cost to meet stakeholder requirements and expectations on quality issues (Heravitorbati et al., 2011).

4. Discussion

It is believed that early stakeholder engagement could contribute to the process of innovation in construction. Based on a review of the literature there is evidence that long term procurement relationships, especially in collaborative procurement, need early stakeholder engagement as an effective way of developing trust among stakeholders, thus facilitating innovation. As the innovation process take place, promoting early stakeholder engagement through various procurement systems is vital to avoid rework and unnecessary cost, enhance quality, overcome dispute throughout the construction process and overcome the problem of low productivity. The stakeholders' commitment, interest and power should be fully assessed so that project managers can tackle the key problems in the stakeholder management process. It is believed that effective engagement at an early stage could bring together viewpoints and identify potential concerns and interests from the point of inception. Early stakeholder engagement aims to minimize risks and expose opportunities available by ensuring the issues within the project can be identified earlier. Productivity Partnership (2012) reported that being involved in the early stages allows the stakeholder to understand the initial scope and future of the programme to ensure that the technical foundations for the project are appropriate in the longer, as well as shorter term. Project managers, with regards to any procurement system, should take into consideration the stakeholder existence at an early stage of the project. If the proposed procurement model is not innovative enough for dealing with the stakeholders, for example the traditional procurement system, steps to dealing with the issue include moving from a traditional procurement system to a hybrid system.

Relational contracting has been offered as a solution to the challenge of demanding and risky projects by promoting integration and joint risk management (Pishdad and Beliveau, 2010). The more innovative the procurement method, the more stakeholders are collaborative, committed and co-ordinated. The quality of the end product is guaranteed to be superior as the early stakeholder engagement, through its jointly made decisions, increases commitment to the no-dispute rule and mutual liability waiver among the key participants. Any expectations can be managed, hidden agenda can be brought to the surface and project priorities can be established. Clients and project managers should involve key stakeholders in the quality decisions of a project to get the desired level of quality and meet the expectation of key stakeholders as well as the end-user (Heravitorbati et al., 2011). Stakeholders' participation satisfaction shows that stakeholder engagement is key in making a project successful (Shenhar et al., 2001). Dealing with early stakeholder

engagement will embrace innovation in organisational activity as a non-technical innovation process. This idea could be implemented in any of the other procurement systems.

5. Conclusion

This paper gauges early stakeholder engagement in a project as a process for innovation. The insight of the paper highlighted the need for early stakeholder involvement from the inception phase to avoid redundancy of work, reduce unnecessary cost and to increase the productivity of the project to meet the expected in time, within cost and high quality goals. Stakeholder involvement in different procurement systems should be understood, so that stakeholders know their roles and responsibilities well in the project.

6. Future Research

This preliminary study is part of the conceptual framework of a doctoral research project to further explore the significance of innovation at the process, product and organisational level with respect to different procurement methods. For the next step of the research, a quantitative and qualitative approach will be conducted through questionnaire and interview, respectively. The questionnaire will be designed to support the proposed innovation framework and categorise the indicator (project, process, product or organisation) and procurement system.

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A process-oriented approach to supporting Off-site Manufacture in construction projects

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Abstract

It is well-known that the use of off-site manufacture (OSM) techniques can assist in timely completion of a construction project though the utilisation of such techniques may have other disadvantages. Currently, OSM uptake within the Australian construction industry is limited. To successfully incorporate OSM practices within a construction project, it is crucial to understand the impact of OSM adoption on the processes used during a construction project. This paper presents how a systematic process-oriented approach may be able to support OSM utilisation within a construction project. Process modelling, analysis and automation techniques which are well-known within the Business Process Management (BPM) discipline have been applied to develop a collection of construction process models that represent the end-to-end generic construction value chain. The construction value chain enables researchers to identify key activities, resources, data, and stakeholders involved in construction processes in each defined construction phase. The collection of construction process models is then used as a basis for identification of potential OSM intervention points in collaboration with domain experts from the Australian construction industry. This ensures that the resulting changes reflect the needs of various stakeholders within the construction industry and have relevance in practice. Based on the input from the domain experts, these process models are further refined and operational requirements are taken into account to develop a prototype process automation (workflow) system that can support and coordinate OSM-related process activities. The resulting workflow system also has the potential to integrate with other IT solutions used within the construction industry (e.g., BIM, Acconex). As such, the paper illustrates the role that process-oriented thinking can play in assisting OSM adoption within the industry.

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Keywords: Offsite manufacture, construction projects, business process management, process automation, workflow systems.

1. Introduction

Effective and efficient management of construction processes is crucial in driving successful execution of a construction project. One way to increase the productivity within the construction sector is to include a greater percentage of off-site manufacture into each project. However, to successfully incorporate off-site manufacture (OSM) practices within a construction project, it is crucial to understand the impact of OSM adoption procurement on the construction management processes. In other words, a different assessment has to be made as to which activities need be changed or adjusted for an OSM procurement delivery method. These changes include OSM products information availability, appropriate timeframes for OSM-related decisions, and how and when these changes should be incorporated in the construction management process (Rezgui & Cooper, 1998).

Business process management (BPM) provides organisations with the ability to save money and time by systematically documenting, managing, automating and optimising their business processes (Weske, 2007). This is achieved by promoting a process-centric view of an organisation through end-to-end management of business processes. Progressively, the construction industry has started looking at its processes in order to gain standardisation as well as process efficiencies (Kagioglou, Cooper, & Aouad, 1999; Motzko, 2008). Sophisticated procedures exist in most areas in order to comply with legislative requirements including (but not restricted to) procurement processes, building processes and healthy, safety and environment management processes. These construction management processes have improved as the opportunity arises, especially as new technologies are accepted. Substantiated by research in real-time management of construction processes, Motzko (2008) argues for the implementation and stabilisation of strict processes within the construction industry in order to increase process optimisation and undertake the process of continual improvement of processes. Generally speaking, a clear place to start assessing the optimisation of process within the construction industry would be to look at current processes and the use of them. In addition, with the introduction of lean management concepts in the construction industry, BPM is clearly an important contributing factor.

This paper presents how a systematic process-oriented approach may be able to support OSM utilisation within a construction project. Process modelling, analysis and automation techniques which are well-known within the BPM discipline have been applied to develop a collection of construction process models that represent the end-to-end generic construction value chain (Kanjanabootra, Wynn, Ouyang, Kenley, & Harfield, 2012; Kenley, Kanjanabootra, Ouyang, & Wynn, 2012). The collection of construction process models is then used as a basis for identification of potential OSM intervention points in collaboration with domain experts from the Australian construction industry. Based on the input from the domain experts, these process models are further refined and operational requirements are taken into account to develop a prototype process automation (workflow) system that can support and coordinate OSM-related construction management process activities.

2. Research Approach

The research approach adopted in this study is in line with the Design Science methodology in information systems research (Hevner, March, Park, & Ram, 2004). Also, it is similar in nature to the previous research that was conducted involving application of process-oriented approach to film productions (Ouyang, La Rosa, ter Hofstede, Dumas, & Shortland, 2008) and to the scheduling in surgical care processes (Ouyang et al., 2011). Successful adoptions of the Design Science methodology in previous research have further assured us to apply the same methodology in this study.

There are seven guidelines for the Design Science methodology as reported in (Hevner, et al., 2004). According to Guideline 1 (Design as an Artefact), the project started with the development of construction process models and the design of a purposeful IT artefact – a prototype workflow system that can support and coordinate OSM-related process activities within a construction project. Moving to Guideline 2 (Problem Relevance), this artefact is innovative and purposeful to the domain of construction management based on the fact that process management in the building industry is considered important but not sufficiently addressed. Guideline 3 is concerned with Design Evaluation. Through interviews with stakeholders, on-site observations, and literature review, access to domain expertise was available for the design and development of our artefact as well as validation of the design to a certain extent. Our research aims to contribute to the field of construction management with regard to Guideline 4 (Research Contributions), and due to the adoption of a well-established theory (i.e. process-oriented lifecycle approach) we consider our research outcome as addressing Guideline 5 (Research Rigor). The research process though is not finished and the resulting artefact requires continuous questioning, revision, and extension. This indicates that the design of our artefact is a Search Process as in Guideline 6. Finally, following Guideline 7 (Communication of Research), our research process aims to expose the research to both the IT community, among others through publications, and to the building industry, which includes the Sustainable Built Environment National Research Centre (SBEnrc) in Australia.

3. Analysing/Discovering Construction Processes

When an organisation takes on a BPM initiative, it goes through the different phases of the BPM lifecycle (see Figure 1). There are typically a number of distinct and iterative phases; namely, design, implementation, enactment and diagnosis (Weske, 2007). During the design phase, the process requirements are gathered from the stakeholders and an initial set of business process models are designed based on the requirements. In the implementation phase, the processes are further refined and operational requirements are taken into account to enable implementation as a software system (i.e. executable workflows with data and resource perspective). During the process enactment phase, these workflows are then executed to provide automated support for the business processes using workflow systems or process-aware information systems. During the diagnosis phase, the executed processes are carefully examined and the performance of these processes is monitored so that process improvement activities can be carried out, which in turn, leads back to the design phase (often known as process redesign).

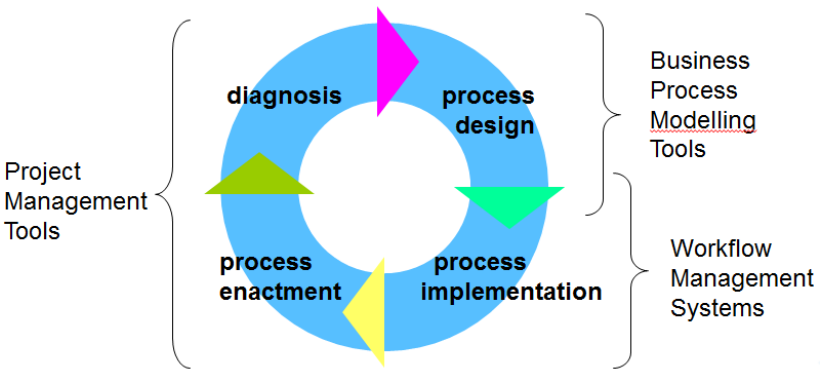


Figure 1 Business Process Management lifecycle (adopted from (Dumas, van der Aalst, & ter Hofstede, 2005))

Construction process modelling has been studied before. Al-Bazi et al (2010) developed a process model of concrete production crew allocation to manage pre-cast concrete production process (Al-Bazi, Dawood, & Dean, 2010). A number of IT related applications were developed to support construction process in a specific stage of the construction such as the design or the production (Baldwin, Poon, Shen, Austin, & Wong, 2009; Benedict & David, 2012; Bouchlaghem, Shang, Whyte, & Ganah, 2005; Forsman et al., 2012). BIM technology has been proposed to be used in off-site manufacturing (Brodetskaia, Sacks, & Shapira, 2011; Frawley, 2011; Sacks, Radosavljevic, & Barak, 2010). However, BIM technology by itself is not a one-stop service that can enable OSM in a construction project. The construction process modelling mentioned in the literature cannot be applied directly for OSM adoption. Many applications focused on only a specific stage of the construction process and they typically do not cover all relevant stakeholders involved in the construction process. In (Kanjanabootra, et al., 2012; Kenley, et al., 2012), we presented our work on how construction process models with OSM-related activities are created using domain knowledge from different stakeholders.

We developed a generic six-phase construction value chain model described in Business Process Modelling Notation (BPMN) notation as part of the process design phase. The six phases where OSM intervention points could be incorporated are: Arrange Project Team, Develop Detail Design, Prepare Tenders, Tendering Award Contract, Build, Hand Over and Operation. Detailed BPMN models describing the individual phases can be found in (Kenley, et al., 2012). These simple phase distinctions were made with the understanding that any generic model is only a representation of a very complex set of processes taking into account a variety of stakeholder perspectives. The development of this value chain model is grounded in a research team with professional industry experience combined with a review of the literature and analysis of industry reports and policies. At each point appropriate for OSM consideration of capability and capacity is indicated by reference to an OSM Checklist. The entire construction process BPMN model serves as a baseline model for the development of a prototype workflow application, which is the focus of this paper.

4. Construction Process Workflow

4.1 The YAWL language

While the BPMN notation is an appropriate modeling technique to represent high level processes, the notation is not ideally suited to model executable workflows (Wohed, van der Aalst, Dumas, ter Hofstede, & Russell, 2006). The Yet Another Workflow Language (YAWL) notation can be used to model formal and executable business processes (van der Aalst & ter Hofstede, 2005). The YAWL language is supported by the open-source workflow environment developed using the service-oriented architecture (van der Aalst & ter Hofstede, 2005). Because of its formal foundation and its support for design, enactment, implementation of complex executable processes, the YAWL language has been chosen as the modelling language for executable workflows and the YAWL environment as the development framework within our research project.

A YAWL process model consists of tasks and conditions (see Figure 2). Each process model starts with a unique input condition and a unique output condition, which signal the start and the end of the process, respectively. There are atomic tasks and composite tasks. Atomic tasks correspond to atomic actions, i.e. actions that are either performed by a user or by a software application. Each composite task refers to a sub-process that contains its expansion. In addition to tasks and conditions, there are routing constructs (those split and

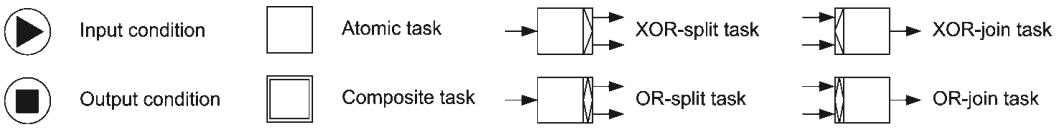


Figure 2 A subset of the YAWL modelling notation

join tasks) used for modelling the divergence and convergence of the flows between tasks. The AND-split and -join tasks capture parallel execution of tasks. The XOR-split and -join tasks capture an exclusive choice among a number of alternative task executions, while the OR-split and -join tasks capture inclusive choices.

4.2 YAWL Workflow for the Construction Process

An overview of the phases in a typical construction project is captured by top level YAWL model (making use of composite tasks to represent phases) as shown in Figure 3. In this paper, we focus on demonstrating how the various activities within the “Arrange Project Team” phase can be supported by a workflow system.

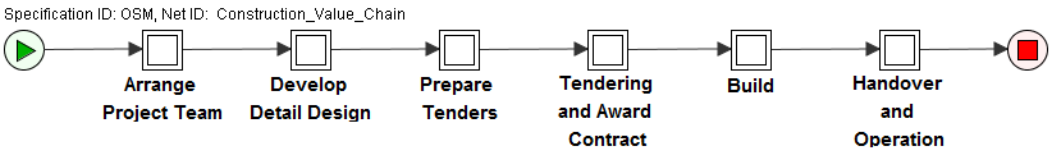


Figure 3 Construction Value Chain YAWL Model

A workflow model captures three different perspectives: the control flow perspective, the data perspective and the resource perspective. The **control flow perspective** of a workflow

is concerned with the order in which tasks within a process is executed. Most of the tasks within the “Arrange Project Team” workflow follow a sequential order (see **Error! Reference source not found.**). There are also decision points in the model, for instance, an XOR-split following the task “Review Business Plan” represents a decision to go forward a path (one of approve, revise or reject) based on the outcome of the review task. This decision by the user is captured using a data variable that is selected from a dropdown list (see **Error! Reference**

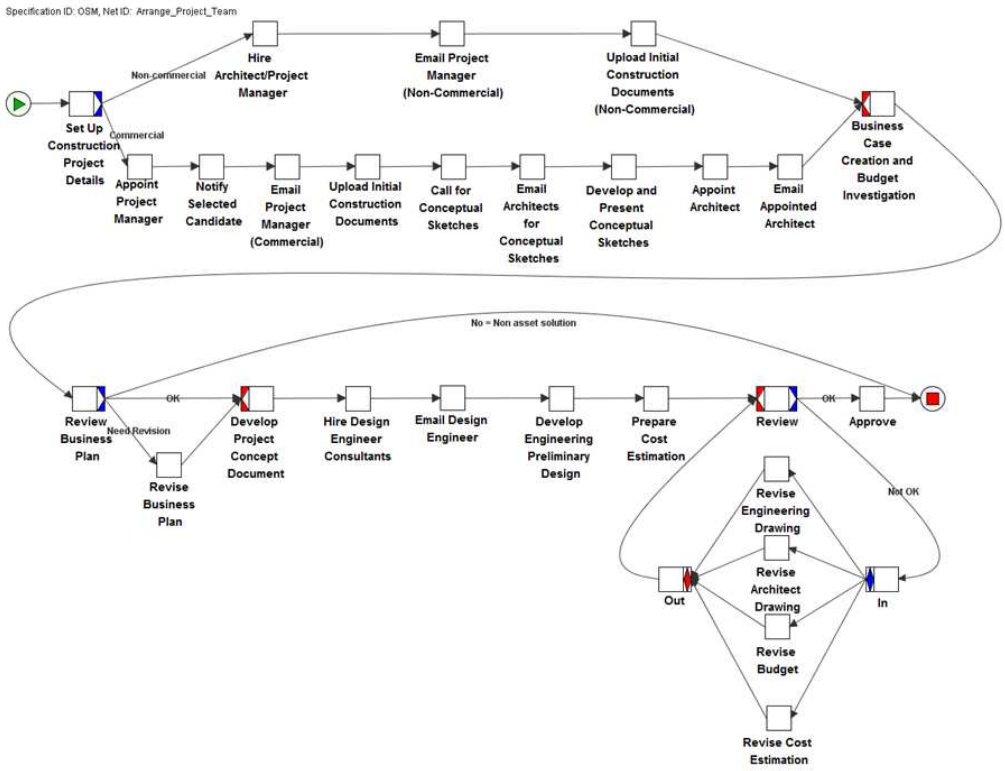
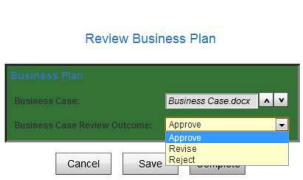


Figure 4 Appoint Project Team YAWL Models



source not found.).

This is representative of **the data perspective** which captures information being passed between various tasks. The YAWL workflow environment supports a sophisticated data handling mechanism making use of XML data types.

The **resource perspective** of a workflow is concerned with capturing the “actor” who is responsible for carrying out tasks. This actor/resource can be a human, a machine, an IT system or the workflow environment itself. In the “Arrange Project Team” process, there are a number of different actors involved. Most are human resources who have roles of Architect, Client, Engineer, Project Manager and Quality Surveyor (i.e., role-based resource allocation mechanism is used), some are modelled using web services (e.g., email, file upload). The YAWL environment allows many sophisticated resource allocation strategies.

Figure 5 XOR Decision making example

In the “Arrange Project Team” workflow, the “Four-eyes principle” is used to specify that the person who reviews the business plan cannot be the same person who created the business case and the budget. The “Chain Execution strategy” is used to specify that the person who completes the “Appoint Project Manager” task is assigned to carry out the next task of notifying the selected candidate.

A number of tasks within the “Arrange Project Team” workflow have been identified as having **OSM implications**. The OSM-related tasks include: Business Case Creation and Budget Investigation, Develop Project Concept Document, Develop Engineering Preliminary Design, Prepare Cost Estimation, Review, Revise Engineering Drawing, Revise Architect Drawing, Revise Budget, Revise Cost Estimation and Approve. For these OSM-related tasks, notifications/alerts are available to download a checklist provided for OSM. This

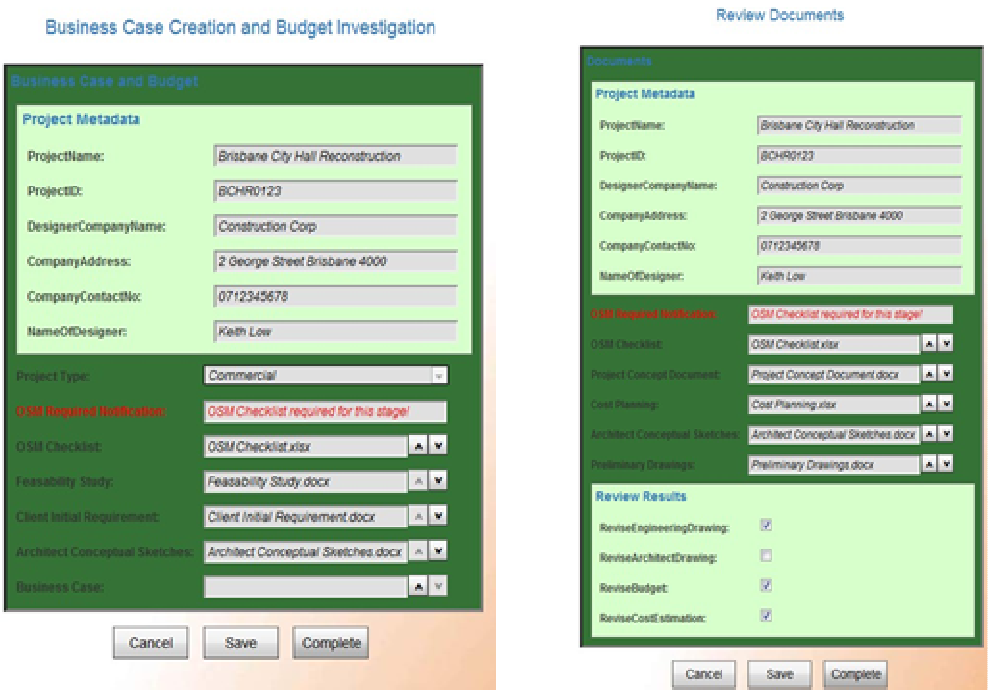


Figure 6 Tasks that have been identified as having OSM Implications

checklist can then be re-uploaded after making modifications as shown in Figure 6.

4.3 Process Enactment with the YAWL environment

In this section, we illustrate how the resulting workflow for the “Arrange Project Team” workflow is enacted and supported within the YAWL environment.

4.3.1 Resource Service

Firstly, the workflow is uploaded to the YAWL environment and a case for the new project can be started within the resource service. After a new case is started by the client, web forms are available to fill in the project details (as seen in **Error! Reference source not found.**). The YAWL environment provides automatically generated web forms that can be customised (as seen in **Error! Reference source not found.**). Further customisation is possible (e.g., by adding the logo of the organisation etc.) using the feature of custom forms.



Figure 7 YAWL's work item queue

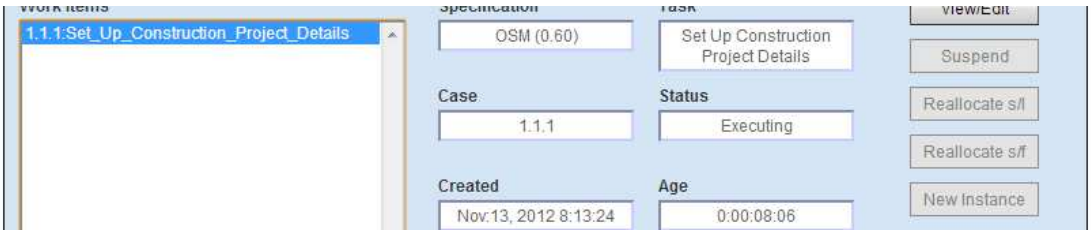




Figure 8 Upload initial construction documents page

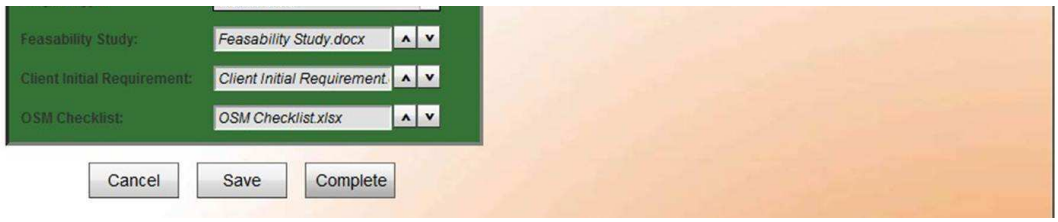




Figure 9 Appoint project manager custom form

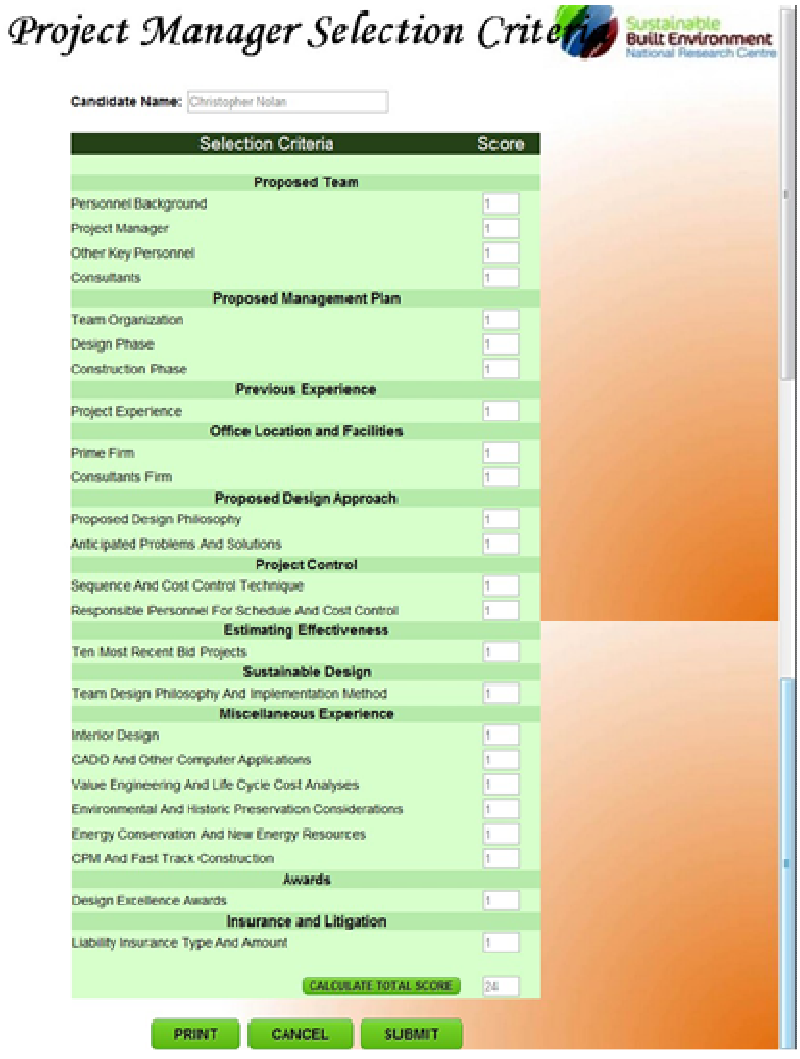


Figure 10 Project manager selection criteria custom form

Three custom forms were developed for the “Arrange Project Team” workflow using the

colour scheme of SBEnrc. Figure 9 shows the form for the “Appoint Project Manager” task where the scores for the shortlisted applicants can be calculated (Figure 10) and recorded using the “Edit Score” function. The candidate with the highest score is then selected for appointment. These custom forms were used to capture the user interactions with the YAWL environment.

4.3.2 Mail, Document Upload, and Monitoring Services

In addition to user tasks, the YAWL environment enables third-party web services to be automatically invoked through automatable YAWL tasks by setting up the links within the YAWL workflow editor. Another custom webform is created to capture the necessary details to notify the selected Project Manager applicant of the appointment (see Figure 11). When the form is submitted, the **mail custom service** is automatically invoked to send out the email.

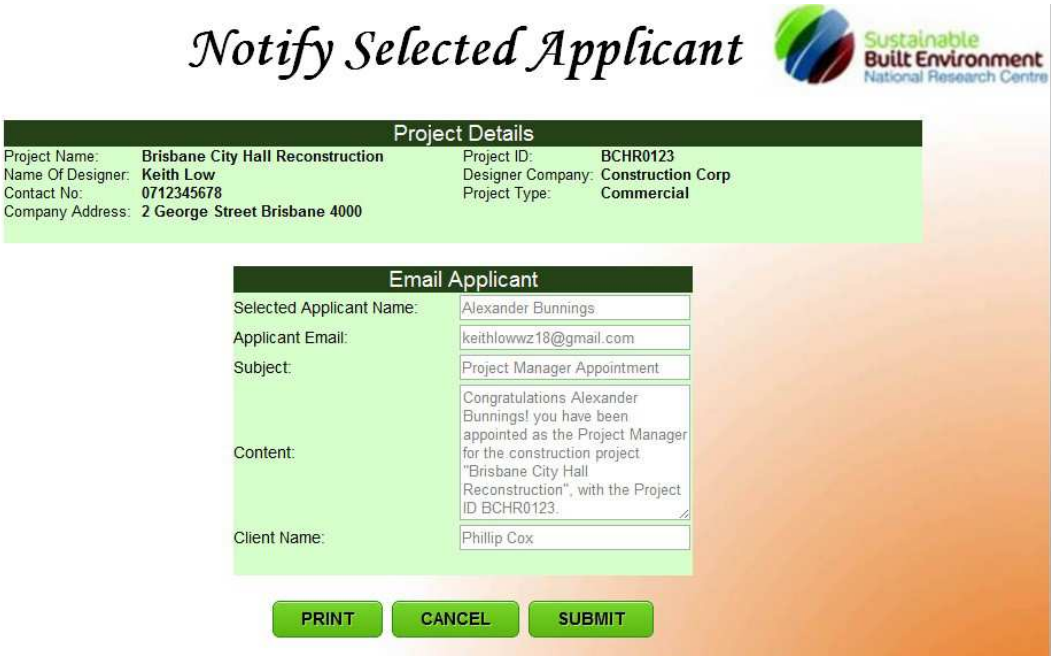
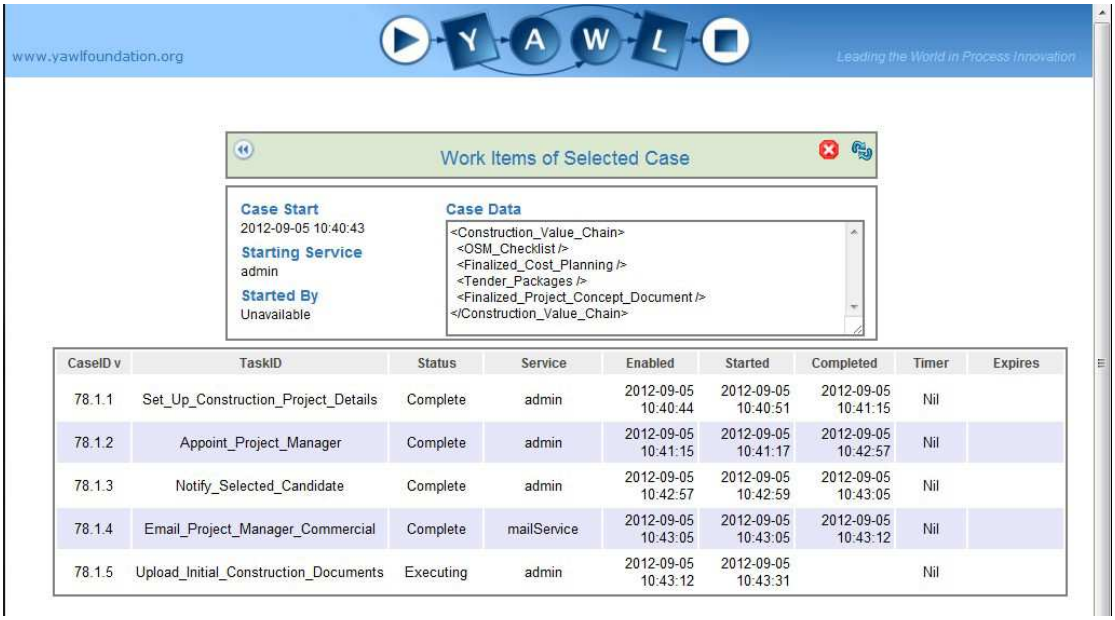


Figure 11 Notify (by email) selected applicant custom form

Another custom functionality that was used within the workflow is the **document upload service** which supports the storage and passing of documents between tasks. The service enables uploading, transfer and downloading of documents such as OSM Checklist, Architect Conceptual Sketches, Business Case, and many more (see **Error! Reference source not found.** and Figure 8).

All the cases running within the YAWL environment can be closely monitored by an administrator using the **workflow monitoring service**. Figure 12 shows the sample screen for monitoring activities carried out within the construction workflow projects.

There are also many other capabilities of the YAWL environment that can be useful for construction workflows. They include the use of timer tasks to indicate deadlines and



reminders, the use of digital signature service to fast track approval in a safe and secure

Figure 12 Monitoring services page

manner, the use of SMS services for employees to complete tasks on a mobile device, etc.

5. Conclusion and Future Work

This paper presents how a systematic process-oriented approach may be able to support OSM utilisation within a construction project. Several interviews with domain experts from the Australian construction industry enable researchers to develop a collection of construction process models and a detailed OSM checklist which are then used as a basis for development of a prototype process automation system in the YAWL environment to illustrate how OSM-related process activities can be supported and coordinated. As such, the paper illustrates the role that process-oriented thinking in the form of process modelling, analysis and automation could potentially play in assisting OSM adoption within the industry.

Due to the project's interdisciplinary scope, further evaluation can be approached from two different angles. On the one hand, as researchers in the field of BPM (more broadly the domain of information systems), we plan to apply the observational method where our artefact is evaluated through demonstrations to the stakeholders. On the other hand, in the domain of construction management, our findings are expected to bring process innovation to the building industry. To this end, alternative evaluation strategies such as Design Experiments (Brown, 1992) or Design-based Research (Barab & Squire, 2004) can be applied to evaluate the significance of the innovation for the building industry.

Acknowledgement: This work is funded by the SBEnrc and it is carried out by researchers from Swinburne University of Technology and Queensland University of Technology. This is one of the outcomes for Project 2.2, Offsite Fabrication and Links to Product and Process Innovation, under the Research Program 2, Developing Innovation and Safety Cultures. Further information of the project can be found on http://www.sbenrc.com.au/.

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Towards a New Advanced Industry for an Energy Efficient Built Environment

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Abstract

The key objective of the Energy Efficient Buildings Association (E2BA), representing a large set of stakeholders of the construction sector and associated technology sectors, is to promote the creation of an active industry for the production, supply/distribution of advanced systems, solutions and added value services with a view to satisfy the needs on energy efficiency for the built environment.

The Association is engaged since 2009 in a Public-Private Partnership on Energy-efficient Buildings (PPP EeB) with the European Commission (EC) to develop and deploy a full Research, Development and Innovation (RDI) program at EU level. As a matter of fact, buildings provide a large untapped cost effective potential for energy savings, but in order to speed up the deployment of key technologies at least cost, it is crucial to increase innovation in the fields of energy efficient construction processes, products and services.

The paper includes a brief presentation of the main results of the tenths of collaborative trans-national RDI projects launched in the framework of this PPP. Some of these results are already available and disseminated by the projects; some of them are still under development. It is also dedicated to the presentation of the new Roadmap recently prepared by the Association in cooperation with the EC, containing the major RDI challenges faced by the sector by 2020 to meet the EU decarbonization goals.

Keywords: energy efficiency, buildings, districts, smart cities

1. Introduction

Worth at least 1.3 trillion Euros of yearly turnover in 2010, the European building sector and its extended value chain (material and equipment manufacturers, construction and service companies) is on the critical path to decarbonize the European economy by 2050. It must enable reducing its CO2 emissions by 90% and its energy consumption by as much as 50%. This is a unique opportunity for sustainable business growth provided that products (new or refurbished buildings) and related services are affordable and of durable quality, in line with several past or future European Directives. Yet, together with the 2050 deadlines, such Directives are putting more constraints onto a sector which is directly impacted by the on-

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going financial and economic crisis (less purchasing power, but also potentially increasing building costs due to more stringent requirements to meet building energy performances). The time frame left to develop innovative technology and business models in line with the 2050 ambitions is narrowing down to less than 10 years.

2. The running Public Private Partnership on Energy-efficient Buildings (PPP EeB)

The running PPP EeB was launched as part of the economic recovery plan in 2008. The PPP EeB uses existing mechanisms of the Framework Programme of the European Commission (EC) whilst providing a mid-term approach to R&D activities. It brings together various Directorates Generals (DGs): DG Research and Innovation - Nano, Materials & Processes (NMP) and Environment (ENV) priorities -, DG Energy, and DG Communications Networks, Content and Technology, in close dialogue with industry. In this framework, a roadmap was built on the following pillars, namely: 1) systemic approach; 2) exploitation of the potential at district level; 3) geo-clusters, conceived as virtual trans-national areas/markets where strong similarities are found, for instance, in terms of climate, culture and behaviour, construction typologies, economy and energy/resources price policies, Gross Domestic Product, but also types of technological solutions (because of local demand-supply aspects) or building materials applied etc.

These pillars are definitely brought forward in a new Research and Innovation Roadmap (to be published in 2013) which indeed is strongly based on the long term programme defined by the PPP EeB (2010) around a “wave action”. In this “wave action” plan, continuous, on-going research feeds successive waves of projects as shown in Figure 1. The knowledge gained in the first “wave” feeds in the second at the design stage, realising a continuous implementation process.

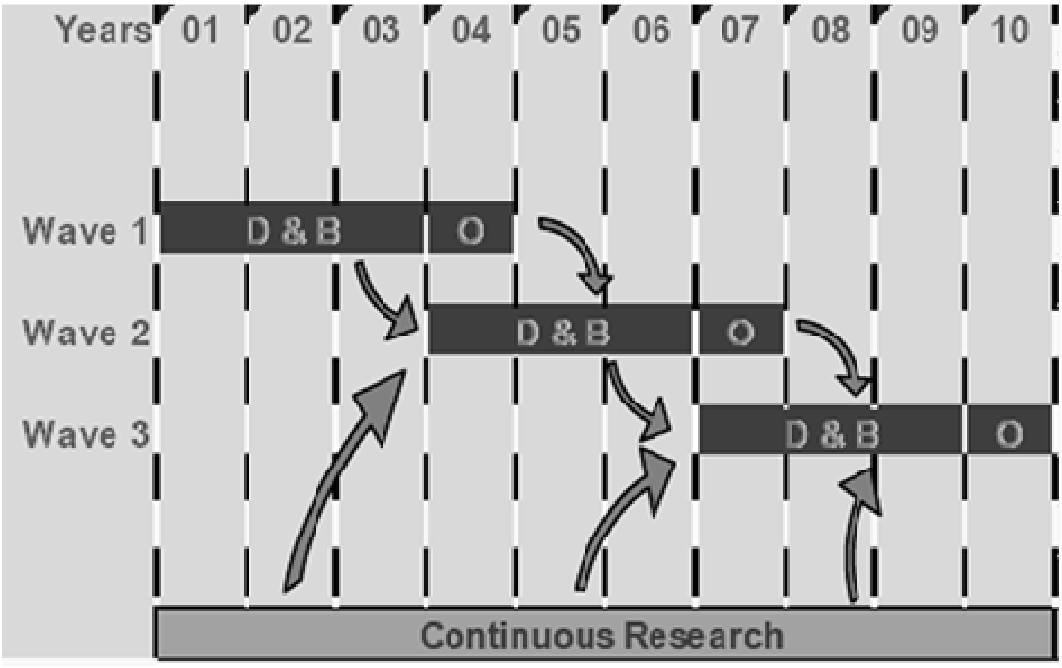

Figure 1: Wave action along the roadmap (D&B: Design&Building; O: Operation)

As a result of this “wave action”, industry expects to reach impact following a stepped approach, namely:

- Step 1: reducing the energy use of buildings and its negative impacts on environment through integration of existing technologies (main focus of the current PPP EeB);

- Step 2: buildings cover their own energy needs;

- Step 3: transformation of buildings into energy providers, preferably at district level.

The long term programme set by industry tackles also the development of those enabling knowledge and technologies which are instrumental to achieve these targets, launching the required more fundamental and applied research actions. This long term approach has mobilised heavily industry with over 50% participation in calls and Small and Medium size Enterprises (SME) involvement beyond 30%, figures which are well above business as usual in collaborative research projects under the EC framework programme.

Reviews by E2BA (2011, 2012) of the different running projects have highlighted some of the innovations under development, such as:

- Nanotechnology coatings
- Integrated air quality sensors
- Tools to improve indoor environment
- Operational guidance for performing Life Cycle Assessment (LCA) studies
- Sustainable, innovative and energy-efficient concrete
- High performance bio-composites for buildings
- Component and systems for buildings, such as multi-functional façade panels
- Components and systems for districts, such as energy storage solutions
- Standardized building and user friendly models
- Energy control hardware
- Building Energy Management Systems (BEMS)
- Heating Ventilation and Air Conditioning (HVAC) control systems
- Energy performance simulation
- Virtual building models
- Integration of multifunctional energy modules
- Business models.

3. Overall vision till 2030 and strategic objectives

3.1 Vision 2030

Based on the achievements so far, the E2BA ambition is to drive the creation of an innovative high-tech energy efficiency industry extending the scope of the running PPP EeB beyond 2013. Connecting construction industry to other built environment system suppliers will be the decisive step for Europe to reach its economic, social and environmental goals, contributing to the objectives of the Innovation Union. By creating and fostering this

paradigm shift, EU companies will become competitive on a global level in the design, construction and operation of the built environment while sustaining local economies across EU-27 through job creation and skills enhancement, driven by the vast majority of SMEs active in the value chain.

In line with ambitious 2050 targets, it is expected that already in 2030 the entire value chain will produce advanced systems, solutions and high value services for intelligent and sustainable buildings and districts. The long term strategic objectives defined by E2BA (2012) include:

- Most buildings and districts become energy neutral, and have zero CO_2 emission. A significant number of buildings would then be energy positive, thus becoming real power plants, integrating renewable energy sources, clean distributed generation technologies and smart grids at district level.

- Industry will employ highly skilled individuals capable of efficiently, safely and quickly carrying through construction processes. This means an extended value chain and collaborative “assembly” line delivering adaptive and multifunctional energy and resource efficient buildings and districts solutions.

- Unemployment will be kept low as skilled local jobs will be created through an effective and dynamic matching of demand and supply. Public Private Partnerships will indeed cover the entire innovation chain, fostering performance based contracting and innovation friendly procurement practices. This will be achieved with sustainable financial incentives schemes on the demand side. On the supply side, systemic technical solutions optimised at European scale will be integrated locally.

- Urban planning and smart cities implementation leverage on these novel solutions at building and district scale, creating the basis for intelligent connections between buildings and districts and all urban resources.

- Such globally competitive energy efficiency industry will be able to deliver new business opportunities, jobs and solutions. In terms of environmental impacts, greenhouse gas emissions will be reduced to 80-95% below 1990 levels, as required by the Energy Roadmap 2050 (COM(2011) 885/2). In addition, the use of renewable energy and efficiency technologies is extended as required by the Strategic Energy Technology Plan, the Energy Efficiency Plan and the recast of the Energy Performance of Buildings Directive (EPBD).

Indeed in Europe, each Member State with its own building stock is faced with a combination of four implementation options to comply with the challenges ahead, inevitably mixing rehabilitations and construction of new buildings:

- Option 1: increase significantly the rate of high performance, deep rehabilitation of commercial and residential buildings, while lowering the costs of rehabilitation.

- Option 2: increase the overall depth of rehabilitation by favoring district rehabilitation in priority.

- Option 3: valorise energy production and use within new districts to make these districts “energy positive”.

- Option 4: scrap all poorly insulated buildings and replace them by high performance buildings (energy neutral and, when possible, energy positive).

Member States have a reduced set of optimization parameters to address properly these options:

- the spatial scale chosen for energy demand optimization (single building versus district); the district dimension provides new energy optimization possibilities, for instance through the connection to existing grids (electricity, heat and cooling networks), via the design and operation of a set of buildings as components of an integrated energy system, which can in turn contribute to improved peak load management.

- the rate of new constructions versus the rate of refurbishment which in turn is conditioned by:

    - the depth of refurbishment versus the new building energy performance level (set by law)

    - the split between technology-based (energy demand) and behaviour-based (energy use) solutions, whatever the project under scrutiny.

Implementing pathways at the right pace to make innovation breakthroughs possible requires the building sector to go through a profound mutation before 2030 which shape a vision as described below:

Vision 2030

By 2030, increased and faster collective research and innovation has allowed the European building sector to mutate into a mature, innovative and energy efficient enabling industry:

- delivering new or refurbished, user centric and affordable buildings/districts in line with EU2020 and national strategic objectives and commitments towards 2050;
- working according to quality standards that encompass the whole life cycle of any building, thus guaranteeing durable building performances;
- valuing not only energy performances but also aesthetics, acoustics, accessibility or comfort as purchase criteria for end users;
- committing to long term performance guaranteed contracts on the energy bills.

In doing so, industry aims at introducing as most technology and market flexibility as possible for the benefits of policy makers and investors when facing the decarbonisation of the building sector. Any mix of the above four scenarios can then be addressed by the building industry in the next 40 years, industrial maturity being reached by 2030.

3.2 The critical role of refurbishment

Tackling refurbishment of existing building is a top priority; it is expected that, by 2050, about half of the existing building stock in 2012 will be still operational. BPIE (2011) emphasized the critical role of refurbishment, when considering various pathways to achieve the 2050 building sector decarbonisation goals. The proposed pathways differ from one another by:

- the speed at which buildings are refurbished (the refurbishment rate),
- the level of energy or greenhouse gas emission savings that are achieved when refurbishing a building (the refurbishment depth).

The BPIE study developed five scenarios that may or may not achieve the 2050 target for the building sector: only two work well –the Deep Scenario and the Two-Stage Scenario. When comparing these two scenarios with the current situation, it can be seen that:

- both rate and depth of refurbishment must at least double and even triple, compared to the currently observed situation,
- the depth of refurbishment must start increasing before 2020 to avoid the need for a two-stage refurbishment process, which in turn would yield a higher share of zero energy buildings by 2050.

Nevertheless, the BPIE study has not addressed the impact of a third critical parameter: the **district dimensions** which could possibly relax either one of the above trajectory parameters and **innovation**, since allowing for cross building energy cooperation and/or smart energy generation and use within districts. At any rate, deep refurbishment will be required, meaning:

- breakthrough technological and economic performance improvements for the building envelope (reduce the demand);
- proper downscaling/management of energy equipment (adjust to a lower demand without losing energy use efficiency);
- durable performance improvements (avoiding user's misuses and/or building disorders).

Another relevant aspect not considered is this report is the associated investment to these scenarios. Research and innovation are clearly needed to reduce the huge additional investment required to reach the renovation targets in terms of energy efficiency, which are measured over 60 billion € additional investment per year. Finally, a last aspect which the

paper does not include but may hinder innovative and energy efficient refurbishment is represented by the large number of micro and small enterprises involved in the refurbishment operations: it is well known the uptake of innovative technologies by SMEs is rather slow due to limited economical and knowledge resources.

4. Research and Innovation Strategy

4.1 Methodology

The preparation of the EeB Roadmap has been driven by industry in the framework of the Ad-hoc Industrial Advisory Group set-up within the running PPP EeB. The private sector is represented by the European "Energy Efficient Buildings Association" (E2BA), as industrial interlocutor of the European Commission in the PPP EeB.

The scope of the Roadmap was indeed to update the research and innovation priorities to align the industry long term plans with the content of the next EC RDI Framework Programme "Horizon 2020" proposal, where a clear research line on "Technologies for Energy efficient Buildings" has been proposed by the EC. In this framework an extensive review of running research and demonstration projects and major initiatives at EU scale such as the SET Plan (including the recent Roadmap on materials enabling low carbon energy technologies), the Smart Cities European Innovation Partnership, the Intelligent Energy and Eco-innovation programmes under the CIP framework, the InnoEnergy Knowledge and Innovation Community (KIC) running under the European Institute for Innovation and Technology (EIT), the Lead Market initiative and recent Communication on "Sustainable Construction" by DG Enterprise as well as the Energy efficient roadmap and consultation on "Financial support for energy efficiency in buildings" by DG Energy, to name a few. Inputs and contributions from key stakeholders have been mobilised within the framework of the ICT4E2B Forum (www.ict4e2b.eu) and Building-Up (www.buildingup-e2b.eu) projects gathering experts from construction, energy as well as ICT domains, and relevant European Technology Platforms (i.e. European Steel Technology Platform (ESTEP), Forest-Based Sector Technology Platform (FTP), European Technology Platform for Sustainable Chemistry (SusChem), European Technology Platform for Advanced Engineering Materials and Technologies (EUMAT), European Technology Platform for the future of Textiles and Clothing). They have been complemented by inputs and feedbacks received within an open consultation launched in early July 2012 and closed on October 1st 2012.

The innovation rationale proposed by industry is to extend the ambition of the running PPP EeB beyond 2013 in line with the 2030 vision to develop and to validate a set of innovative integrated to novel tools, technology and process components covering the whole value chain. They will then be integrated to meet future market conditions, thus:

- transforming barriers and regulatory constraints into innovation opportunities,

- fostering the creation of innovative supply chains, that become more user centric to cope with the difficulty of implementing refurbishment strategies,

- reorganizing and stimulating innovative procurement of buildings and ordering of technology/services with the integration of new smart grids technologies for single buildings as well as for whole districts (new buildings and existing stock).

Today's fragmented nature of the construction chain still gives little freedom for innovations that are indispensable to shape a more sustainable built environment. Yet, collaborative project management in the construction sector has become a prerequisite to develop a building stock that is technically and economically optimized: this goes against centuries of working habits. Moreover, the focus must be on creating value (not only in terms of economics, but also in terms of comfort, health, environment, etc.) for all the users involved. This requires new skills together with a major behavioural shift within the entire construction sector. Coalitions must be given birth, dedicated to collaboration between players from different disciplines to contribute to the realization of buildings with energy-ambitious goals.

The whole value chain (see Figure 2) will be involved in this continuous optimization process which follows three major steps:

- Step 1: From design to commissioning of new or refurbished buildings, the optimization consists in picking amongst a portfolio of material and energy equipment solutions, the ones which meet both a cost of ownership target and minimal potential GHG emissions over the foreseen life cycle.

- Step 2: During this life cycle, robust user-centric energy management systems ensure that the initial GHG emissions targets are continuously met thanks to adaptive energy management tools able to correct for or modify behaviours of users. Only natural ageing of technology can impact the initial energy performance at commissioning.

- Step 3: The next refurbishment involves another optimisation approach where the investment for refurbishment can be recovered through further savings on the cost of ownership.

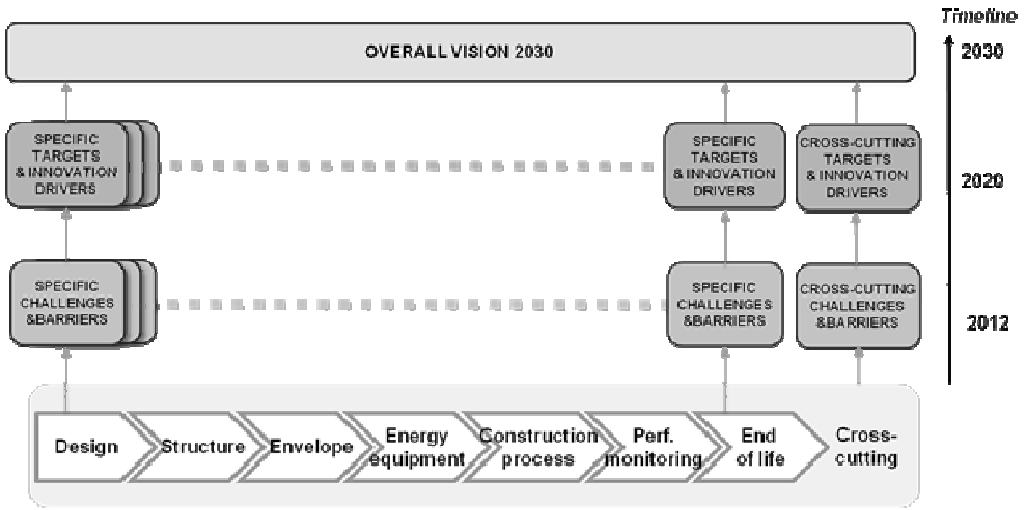

Figure 2: Representation of the segmentation of the value chain and road mapping process

This optimisation approach requires that all the stakeholders perform according to quality rules where interfaces and responsibilities between any of them are transparently exchanged. The innovation process will be open to various technologies, materials or processes focussing on valuable improvements. Interaction with other research areas especially the integration of supply systems for renewable energy including storage systems will be mandatory. Indeed novel Information and Communication Technologies (ICT) as well as materials technologies will be key enablers throughout the whole value chain, from the design phase to the end of life. An overview of the enabling role of ICT is provided in Figure 3.

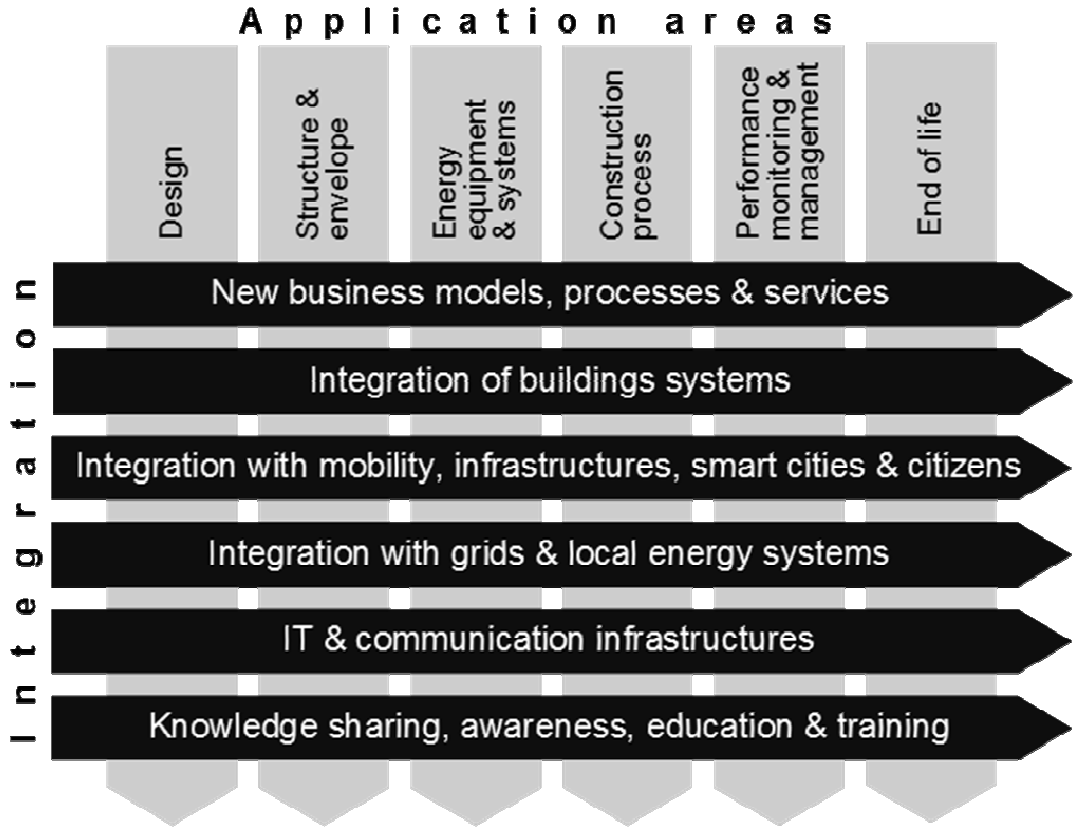

Figure 3: The pervasive role of ICT along the value chain

4.2 Main elements of the strategy

It is at the **design stage** that more than 80% of the building performance is set both in terms of energy savings (generation when embedded in a zero energy district) and cost of ownership over the life cycle before refurbishment. Yet, the relative gap between the design value for energy performance and the commissioning measured result is still too large (and will probably widen when the more stringent building code standards for 2020 are in place). A new regional and urban planning of smart grids and cities promotes decisions at the design phase for better solutions. Thus, planning with a holistic approach for energy-efficient and sustainable buildings (new and refurbished) will be mandatory. Hereby, ICT technologies from true interoperability to decision support systems can be used.

Load bearing structural parts of a building can be mechanically and thermally optimized with sophisticated tools: the focus must now be put on the embedded CO_2 which comes from the materials (concrete, various brickwork, steel, wood …). This CO_2 will become the most prominent part of GHG emissions as the share of energy neutral building grows. Alternative construction processes e.g. with significantly lower embodied energy will help to bind CO_2. Hereby, renewable energies and sustainable cultivation plays a key role.

The **building envelope** becomes the most critical part when it comes to energy efficient buildings:

- For new buildings, materials and energy equipment integration already allows reaching very low energy demand (e.g. based on a high heat resistance, high air tightness or integrated ventilation systems with connection to heat recovery systems). Yet, the investment costs have to be further reduced while taking care of several other design constraints (acoustics, fire, seismic, air quality, adaptation requirements for ageing population...). In the long run, active envelope could make buildings energy positive by, for instance, smartly managing solar fluxes onto the building.

- For refurbishment, the diversity of architectures and climates in Europe requires a whole value chain innovation process where design, technology choice and construction are even more intertwined than for new buildings – special efforts are likely to be necessary for cultural heritage buildings. The integration of the district dimension can allocate refurbishment performance settings to reach very ambitious zero energy districts. Overall, refurbishment depths must go beyond 70% while valuing non energy related benefits to make the business models more attractive.

- Prefabrication of envelope parts, multi-functionality and compact solutions presumably will significantly reduce costs and produce new markets.

The **energy equipment** must adapt to the new smart grids and to lower unit energy demands from more energy efficient buildings, which requires sizing down to-day portfolio while keeping energy efficiency at the highest level possible as well as unit investment cost down. Beyond existing technologies, breakthrough solutions can be expected from heating/cooling systems combined with renewable energy sources, storage (heat and electricity) and building or district integrated solutions in combination with smart grid technologies. Interoperable systems which integrate all different energy fluxes like electric energy sources and sinks, heat sources and sinks (including storage) and innovative control systems are required. The costs for different energy sources will vary depending on supply and demand. Smart solutions will offer best prices for investors and end-users.

Construction processes are now part of the critical path to reach the final energy performance: any defect can lead to disorders and even pathologies which hamper the durability of the building performance. Several complementary routes can be envisaged, with the envelope and the technical equipment at the heart of the integration process:

- Prefabrication of standard units which facilitate field integration.

- New field integration process with more detailed internal performance control following elementary construction steps. New sensors can help check intermediate performance steps before commissioning (ex: blower-door test in combination with thermal imaging for air tightness) which, in turn, require collective work in the field.

- Continuous improvement processes become part of a quality process which increases energy and comfort performances for new and refurbished buildings. RFID technology will improve productivity at the building site as well as the training of workers e.g. on the impacts of a wrong installation on the buildings' performance.

- Starting at the design phase new standardized BIM exchange formats allow a continuous information flow towards a computer aided construction process.

Performance monitoring (both at commissioning and during the building life) is mandatory: it enables smart grid integration, allows users to oversee and control their own consumption and allows detecting inappropriate operating conditions. Moreover, conditional maintenance approaches can bring added value in guaranteed performance contracts. New IT solutions and embedded sensors will come from other fields of use (transportation for instance) as pervasive technologies that will be user centric.

Performance management allows merging the best available technologies and processes to optimize both costs and performances of new or refurbished buildings. The ability to interact with smart grids will be mandatory. This implies not only connection capacities for energy supply including smart storage functionality, but also adaptable solutions for the buildings or districts themselves. The prediction of peak loads (e.g. by weather forecast) or support for low prices to load batteries for e-mobility will be implemented. Any changes of the boundary conditions in terms of changing energy production, energy demands, load cases, etc. will be handled. New learning control systems or control systems based on human behaviour may be introduced. Mitigation strategies for climate change can be part of this strategy. All these technologies are based on ICT.

End of life: building demolition is an environmental issue which will grow under the pressure of deeper refurbishment. It can be addressed, both at design (reusable components) and demolition levels (reusable materials). The building industry is already involved in significant waste recovery (with a focus on concrete, metal and plastics). Innovation is expected in view of contributing both to the lowering of embedded CO_2 and resource efficiency.

Some of the ICT have an even broader context for future new or refurbished buildings and districts:

- **Sensor networks** are key components not only as standalone devices, but also embedded in smart Energy Consuming and Producing Products [EupP] The vision of these devices includes growing embedded intelligence, for instance product and repair information.

- **User awareness**, occupancy modelling and decision support now become more complex in a scenario with variable prices for energy and changing supply and demand. Highly integrated solutions are planned at the design phase and influence even the buildings' end of life.

- **True interoperability** will reduce redundant information and information affected with errors. Beginning at the design phase all components of the value chain can be enhanced by secure and long-term working data models and interfaces.

- **New data support systems** provide reporting, data aggregation and statistical elaboration guidance and facilities (see www.concerto.eu). Regulation and standardisation e.g. for EPDs (Environmental Product Declarations) can benefit from it.

5. Conclusion

This new Research and Innovation Roadmap gives dedicated R&D trajectories for each element of the value chain of the building sector: progressive market availability of technologies and processes will come from large scale demonstrations. They will show irrefutably that the best technical and cost performances can be reached on time for the market demand, thanks to integration processes taking care of the global optimization at building or even district level, and data sharing to help minimizing the interface risks inherent to any such complex system optimization process.

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Using Pareto Principle plus statistic methodology in establishing a cost estimating model

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Abstract

Previous experience and research indicated that the Pareto Principle (80/20 Principle) has been widely used in many industries to achieve more with less. The study described in this paper concurs that this principle can be applied to improve the estimating accuracy and efficiency, especially in design development stage of projects. In fact, establishing an effective cost estimating model to improve accuracy and efficiency in design development stage has been a subject, which has attracted many research attentions over several decades. For over almost 40 years, research studies indicate that using the 80/20 Principle is one of the approaches. However, most of these studies were built by assumption, theoretical analysis or questionnaire survey. The objective of this research is to explore a logical and systematic method to establish a cost estimating model based on the Pareto Principle. This paper includes extensive literatures review on cost estimating accuracy and efficiency in the construction industry that points out the current gap of knowledge area and understanding of the topical. These reviews assist in developing the direction for the research and explore the potential methodology of using the Pareto Principle in the new cost estimating model. The findings of this paper suggest that combining the Pareto Principle with statistical analysis could be used as the technique to improve the accuracy and efficiency of current estimating methods in design development stage.

Keywords: Pareto Principle, Cost Estimating Model, Cost Estimating Testing

1. Background

The study described in this paper is intended to explore a logical and systematic method to establish a cost estimating model using the Pareto Principle (80/20 Principle), which was proposed, by many academics (Yu, Lai and Lee, 2006), to be used in the early cost estimating stages of projects to improve the cost estimating accuracy and efficiency.

Previous experience and research indicated that the 80/20 Principle has been widely used in many industries to achieve more with less (Korch, 1998). The research described in this paper considers that the Pareto Principle can also be applied to the Quantity Surveying field

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to establish cost estimating models through a logical and systematic method. This study has faith in the established cost estimating model in assisting the quantity surveyor to improve the understanding and skills of conducting the cost estimating in the early budgeting and cost planning stages of projects, such as the concept and sketch design stages. Most importantly, it is also believed that the proposed cost model will enhance the efficiency and accuracy of the cost estimate. The possible future study is listed in the conclusion. The objective of the research described in this paper is to prove that the Pareto Principle could be used to set up a logical and systematic method in establishing and testing an elemental cost estimating model in the early pre-tender stages.

2. Literature Review

In the mid 1960s, Stone (1966) suggested the building industry is one of the most important activities in any economy. It can account for 8% to 10% of national employment. The importance of the construction industry in a national economy has been established by scholarly work in the field of economics. Smith (1998) concluded that the construction industry consistently contributes 7% to 10% to the GNP (Gross National Product). Ashworth (2004) agreed with this, and he suggested that the construction industry is an important industry worldwide, even in poor countries. He described how governments regard the construction industry as an economic regulator, an important tool in government's management of the economy. In Australia, according to ABS (2012), during 2010-2011, construction is the 3rd GDP contributor with 7.7% share after Finance and Insurance Services with 9.7% and Manufacturing in 8.1%. At August 2012, there was nearly one million people employed, representing 8.5% of the total workforce (ABS, 2012a). Therefore, it is essential to continuously investigate and regulate the building economy.

2.1 Building Economics

Before going into the specific field of the cost estimate accuracy, it is worth introducing the more general areas, such as "building economy", "cost planning of buildings", "building economy" and "estimating and cost control". In the 1950s and 1960s, a booming population caused a dramatic increase in demand for construction work in the world; especially an increased demand for housing. Building projects became larger and more complex. Therefore, there was a need to officially establish "building economics" as a research subject. Many researchers have studied building economics since then. Ashworth (2004) listed the building economics texts from 1950s to 2000s, which includes more than thirteen studies. Nisbet (1961) concluded that cost plays its part throughout every stage of the whole design and building process. Cartlidge (1973) agreed with this assertion and advised that throughout the design development, cost had a continuous influence on a building project. Cost planning plays a very important role in decision-marking in the building industry. For a small building owner, building investment might be once in a lifetime decision. For a larger building owner, cost planning would affect his future investment policy. Ferry, Brandon and Ferry (1999) suggested that the developer or investor is likely to be affected the most by cost planning. They analysed the impact of cost from the developer's viewpoint and identified cost planning has a role in profit development, social or public sector user development, private user development and mixed development.

2.2 Cost Estimating Accuracy in the Building Economics

Due to the important role highlighted above that cost planning plays in the construction industry, many research studies suggested that cost estimating accuracy has always been one of the important topics in the building economic and the cost planning. Ferry Brandon and Ferry (1999) described how the government recognised that unrealistic cost rules can lead to bad design. Therefore, the government would put enormous efforts to allow money saved in one direction, which could be spent in another. Most importantly, tantamount efforts were also put in to work out complex cost criteria to achieve accuracy. In 1973, Trimble and Jupp developed cost models using regression techniques for various facets of building work. In 1981, Bennett stated that the key activity in the quantity surveying profession's cost planning service is cost estimating. The main task is to improve the estimating accuracy. Morrison (1984) examined the accuracy of cost estimates prepared by quantity surveyors in the design stage of construction projects. He suggested that the most likely area for improvement lies in developing methods of using large cost databases. Skitmore (1985) strongly agreed the importance of the availability and adequacy of the essential cost information in the accuracy of cost estimation.

2.3 Using Pareto Principle in the Construction Industry

Therefore, it is viable to adopt a logical and systematic method based on the Pareto Principle and establishes a cost estimating model to improve the cost estimating accuracy and efficiency. This 80/20 Principle was identified by an Italian economist – Vilfredo Pareto in 1906. He found that a minority of the people held most income and wealth. He also discovered that a consistent mathematical relationship exists between the proportion of people and the amount of income or wealth that this group has (Koch, 1998). Today, this Principle has become a golden rule in the management field to help millions of managers separate the "vital few" from the "useful many" in their activities (Reh, 2002). The reason that the 80/20 Principle is so valuable is, because this principle asserts the pattern of imbalance exists everywhere, in everything. The imbalance relationship may be 65/35, 75/25, 80/20, 95/5 or any set of numbers in between.

From 1980s, the 80/20 Principle was widely adopted in the construction industry. Ashworth and Skitmore (1982) and Thompson (1981) suggested that 20% of the items of a bill or quantity contained 80% of the value. Shereef (1981) developed an alliterative estimating, which predicted an accuracy of +/- 5% without pricing more than 30% of items in the bill of quantity. Bennett (1981), POH and Harner (1995) and Morrison (1984) agreed that the majority of the cost lies in a small number of 'cost significant' items. Shaket et. al. (1986) established a cost significant model, which can be used both to estimate and control construction projects. This model contains only 10% to 20% of the items in a conventional bill of quantities.

2.4 Improving Cost Estimating Accuracy by the Pareto Principle

Further to the various research studies described above, there also have been many studies investigating the possibility of using the Pareto Principle to improve the cost estimating

accuracy. Curran (1989) studied to link the Pareto Principle with cost estimating accuracy and efficiency together. He found that in almost all project estimates the uncertainty is concentrated in a select number of critical items. Curran further suggested that relatively small items are often critical while very large ones may not be critical at all. Further to his study above, Curran (1989) developed the Range Cost Estimating, which can significantly reduce the risk of overestimating or underestimating associated with cost estimation. Range estimating is a risk analysis technology that combines Monte Carlo sampling, a focus on the few critical items, and heuristics (rules of thumb) to rank critical risks and opportunities. This approach is often used to establish the range of the total project estimate (Humphreys, 2008). Furthermore, Humphreys (2008) use Curran's research and Monte Carlo analysis techniques to determine probabilities and contingency in a reliable manner.

Later on, Raftery (1994) suggested that 80% of the project cost might be accounted for by measuring the largest 20% of the units of finished work. However, he indicated that this ratio is just a rule of thumb. Whether 80% of the project cost is covered by 20% of the items measured in the bill of quantities depends on which method of measurement was used. Horner and Zakieh (1996) agreed and indicated that it is possible to aggregate cost significant items into cost significant work packages, which represent a consistent and high (close to 80%) proportion of the total value of any project in the same category. Therefore, the total value of a project can be determined by pricing the relevant cost-significant work packages (Asif and Horner, 1989). In 1998, Koch simply stated that the Pareto Optimum Criterion suggests 80% of the overall project cost determined by 20% of the cost items. Therefore, instead of estimating the quantities of all cost items, only the top 20% most significant cost items' quantities were estimated and their related unit prices were sought. With the Pareto Optimum Criterion, almost 80% of estimation cost and time can be saved; not only does it reduce the cost but also expedites the estimation process.

Yu, Lai and Lee (2006) used the 80/20 Principle to create a web-based intelligent cost estimate (WICE) system, which fulfils the need for real-time response to construction cost estimating and to increase the estimate accuracy. The author recognised there are two construction cost elements - quantity of the cost item and unit price of the cost item. They used the 80/20 Principle to accommodate the changes of unit price and indicated that 80% of the overall project cost is determined by 20% of the cost items. Therefore, WICE only estimates the top 20% most important cost items and their related unit prices. This does not only reduce the cost, but also expedites the process of estimation,

As shown, over some 40 years, the 80/20 Principle has been used to develop the cost estimate models in order to improve the cost accuracy and efficiency in the construction industry. Academics suggested that the cost estimating accuracy topic has attracted more and more attention from the construction industry participants and academics. However, comparisons with other research topics of the construction industry, the number of study carried out to test, examine and review the reliability and effectiveness of the cost estimating model is still limited. Therefore, in one aspect, the study described in this paper proposed to use the 80/20 Principle to set up a logical and systematic method in establishing an elemental cost estimating model to improve the accuracy and efficiency of cost estimating. In

another aspect, this study also tests and validates the reliability and effectiveness of the established cost estimating model including the theory.

3. Methodology

The literature review above revealed the history and development of cost estimating modelling and the cost estimating accuracy. The Pareto Principle has been identified as one of the most constructive theories, which could be used to establish cost estimate models. The application should include two phases. Phase 1 is about the establishment of the cost estimating model based on the Pareto Principle. This includes applying 80/20 Principle and using statistical methodology to analyse cost data and test the statistical analysis results. This follows by Phase 2 which is interpreting and validating the statistical analysis methodology in order to test and validate the theory and cost estimating model established in precedent phase.

3.1 Phase 1: Proposed Analytical Method

This study mainly uses the statistical methodology as the analytical method. Statistics is widely used by individuals and organizations to analyse and understand data in order to make judgments and decisions throughout the natural and social sciences, medicine, business, economics and other areas (Corty, 2007). The main perspective of this study involving the analysis the correlation study examining the extent to which differences in one variable were related to differences in another variable (Leedy and Ormrod, 2005). Therefore, the statistical technique of regression analysis would be a suitable method of deriving a cost model (Buchanan, 1972). The analysis was carried out using multiple regression to examine the data and the SPSS (Statistical Package for the Social Sciences) was used in this study to assist in the statistical analysis, because it is one of the most used computer programs for statistical analysis in the social science (Argyrous, 2011). Two types of regression analysis were applied in this study.

- Stage 1 (Multiple Regression Analysis) – the establishment of the cost estimating model

- Stage 2 (Bivariate Regression Analysis, also named as Linear Regression Analysis) – the testing of the cost estimating model

3.1.1 Stage 1: Multiple Regression

In Stage 1, the multiple regression is used to establish the cost estimating model. Multiple regression is an extension of the linear regression analysis, in which several independent variables (IVs) are combined to predict a value on a dependent variable (DV) for each subject. The equation 3.1 below represents the best prediction of a DV from several continuous IVs:

$$Y' = A + BX_1 + BX_2 + BX_3 + BX_4 + \ldots + B_kX_k \qquad \text{(Eq. 3.1)}$$

Where Y' is the predicted value on the DV, A is the Y intercept (the value of Y when all the X values are zero), the Xs represent the various IVs (of which there are k), and the Bs are the coefficients assigned to each of the IVs during regression (Pallant, 2007). Pallant (2007) concluded that each independent variable is evaluated in terms of its predictive power, over and above that offered by all the other independent variables. The multiple regression analysis could also indicate how much unique variance in the dependent variable each of the independent variables explained. The elemental costs studied in this research were defined as the independent variables. The total cost analysed in this study was defined as the dependent variable. The standard multiple regression of SPSS categorised by Pallant (2007) was used to carry out the establishment of the cost estimating model in Stage 1. The primary goal of the regression analysis in this study is to investigate the relationship between the total cost and the elemental costs. Through the analysis, this study could identify what are the essential elemental costs to predict the total cost. The multiple regression analysis is also used to find the best prediction equation. There are 3 questions asked in the correlation study which are listed as below:

- How well do the independent variables (elemental costs) predict the dependent variable (the total cost)?

- How much variance in the total cost can be explained by those elemental costs?

- Which elemental costs have the strongest correlation relationships with the total cost? Which elemental costs have the weakest correlation relationships?

3.1.2 Stage 2: Bivariate Regression (known as Linear Regression)

Stage 2 is to test the reliability and effectiveness of the cost estimating model established in Stage 1 including the supporting theory. There are two variables included in Stage 2:

- Total cost of the project – calculated using the equation composed by the major cost contribution elements investigated using Equation 3.1

- The winning tender price – the successful contractor tendering price at the tender stage of each project

Bivariate regression has the ability to predict scores on one variable from scores on another variable. This is also called the simple regression, which is to discover the correlation relationship between two continuous interval variables. Therefore, Bivariate Regression was adopted in this stage.

Overall, in both multiple regression and bivariate regression analysis, this research carried out the process in using the Pareto Principle as a logical and systematic method to establish and test the cost estimating model based on the elemental costs excluding the preliminaries, overheads and profits. One of the purposes to analyse the elemental costs excluding preliminaries, overheads and profits is to eliminate the differentiation between each data. This can ensure the validation of the statistical analysis.

3.2 Phase 2: Interpretation of output from the statistical analysis

Following the above description regarding Phase 1 of this study, the interpretation of output from the statistical analysis can be defined into two parts:

- Part 1 – the establishment of the cost estimating model, this research used the Multiple Regression Analysis.

- Part 2 – the testing of the cost estimating model, this research used the Bivariate Regression Analysis (linear regression analysis).

3.2.1 Establishment of the cost estimating model

This part is to combine the multiple regression analysis and the Pareto Principle to establish a cost estimating model, which uses the major cost elements to predict the total construction cost of projects, especially in the early stages of the projects. In this part, five steps are taken to illustrate the details of the findings.

- Step 1: Analysing multi co-linearity

Multi co-linearity is designed to assist the researcher to analyse whether there is at least some relationship between the elemental costs and the total cost. This step also checked that the correlation between each elemental cost was not too high. If there are strong relationships between elements, these relationships will distort the final results of the multiple regression analysis regarding the relationships between the element costs and the total construction cost. The study referred the Pearson's correlation coefficient between two independent variables shown on the Correlations table to assess whether there were any concerns in terms of multi co-linearity. A correlation of 0.7 or more is the warning sign (Tabachnick and Fidell, 2007). In this study, if two of the elemental costs were highly correlated, one of these costs would be omitted.

- Step 2: Checking outliers, normality, linearity, homoscedasticity and independence of residuals

The second step is to check the outliers, normality, linearity, homoscedasticity and independence of residuals. These critical values could be tested by a number of methods — Normal Probability Plot of the Regression Standardised Residual and Scatterplot.

- Normal Probability Plot – a reasonably straight diagonal line from bottom left to top right suggests no major deviations from normality, which means there is no presence of outliers.

- Scatterplot – If the Scatterplot of the standardised residuals does not achieve a roughly rectangular distribution (with most of the scores concentrated in the centre), this suggests that deviations and violations exist. Tabachnick and Fidell (2007) define outliers as cases that have a standardised residual of more than 3.3 or less than -3.3.

Tabachnick and Fidell's (2007) concluded that with large samples, it is not uncommon to find a number of outlying residuals. If only a few residuals are found, it may not be necessary to take any action. In a normally distributed sample, only 1 per cent of cases would be expected to fall outside this range.

- Step 3: Evaluating the model—Identifying how much of the variance in the dependent variable can be explained by the model including all independent variables.

This step looks in the Model Summary box and check the value given under the heading R Square. The R Square can indicate how much of the variance in the dependent variable (total cost) is explained by the model, which includes all the independent variables (elemental costs). For a small sample, the Adjusted R Square value provides a better estimate of the true population value than the normal R Square value (Tabachnick and Fidell's, 2007).

- Step 4: Evaluating each of the independent variables

This step is to answer the third question listed above, which of the variables included in the model contribute to the prediction of the dependent variable? This information is labelled as "Coefficients". The Beta value under Standardised Coefficients can be used to compare the different variables. 'Standardised' means that these values for each of the different variables have been converted to the same values so that the comparison is feasible. The larger the Beta coefficient value is, the stronger the unique contribution the particular elemental cost makes towards explaining the total cost, and vice verse. The value of "Sig" indicates whether a variable is making a statistically significant unique contribution to the equation. If the Sig. value is less than 0.05, the variable is making a significant unique contribution to the prediction of the dependent variable. If the Sig value is greater than 0.05, then that variable is not making a significant unique contribution to the prediction of the dependent variable Tabachnick and Fidell (2007).

- Step 5: Determining the cost estimating equation

This step is to use the results from Step 1 to Step 4 to establish the cost estimating model. This study used the cost per square metre as the measurement unit. Cost per square metre is the cost predictor most used by quantity surveyors, as it provides a measure of cost that is essentially independent of building size (Emsley, Lowe, Duff, Harding and Hickson, 2002). This was also applied to price/m2 and price/ft2, which could be calculated as (cost/m2 = total construction cost divided by gross floor area (GFA). GFA equals to FECA (Fully Enclosed Area) plus UCA (Unenclosed Area). In this study, further to Equation 3.1 listed in Section 3.1.1, when all the X value are zero, the value of Y is zero as well. Therefore, the above equation is rewritten as the below Equation 3.2:

$$Y' = BX_1 + BX_2 + BX_3 + BX_4 + \ldots + B_kX_k \quad \text{(Eq. 3.2)}$$

3.2.2 Testing the cost estimating model

As described in the introduction paragraph of Section 3.1, the second stage is to test the cost estimating model using Bivariate Regression. The relationship analysed is the total construction cost predicted using major elemental costs excluding preliminaries, overheads and profits and the winning tender prices. According to the statistical theory of Bivariate Regression (Corty, 2007), three assumptions have been made.

1) Two variables were considered.

   Independent Variable X – The predicted construction cost, calculated by the equation with the major elemental costs ($/m2)

   Dependent Variable Y – The winning tender price ($/m2).

2) Hypothesis.

   The null hypothesis, H_0 is $\rho_{xy} = 0$

   States that there is no linear relationship between the predicted construction cost and the winning tender price.

   Thus, the alternative hypothesis, H_1 is $\rho_{xy} \neq 0$

   States that there is a linear relationship between the predicted construction cost and the winning tender price, and the observed correlation in the sample will reflect this.

3) The hypothesis is non-directional, therefore, a two tailed test is applied.

The statistical test used in this study was the Pearson product moment correlation coefficient, since the relationship between two interval level variables were examined (Corty, 2007). Three steps were set up for the statistical study of the testing.

- Step 1: Pearson product moment correlation coefficient 'r'

The Pearson product moment correlation coefficient r is used to verify the hypothesis. The r is value obtained from the linear regression analysis is described as follows:

1) According to the basic statistical rule, firstly, set up the Type I error as $\alpha = 0.05$ means that there is 5% chance making a Type I error. A Type I error is that we reject the null hypothesis when it is true. The intention of the test is to find there is a linear relationship between the two variables. Secondly, find the critical values of r— r_{cv} (Critical Values of r for Pearson Product Moment Correlation Coefficients When $\rho = 0$ (Corty, 2007), which is the cut-off point fr rejecting the null hypothesis.), based on the sample size.

2) Use the r^2 obtained by using SPSS software to calculate the absolute value of the observed value of r. If $r > r_{cv}$, then the null hypothesis is rejected. This indicates that there is a linear relationship existing between the predicted construction cost and the winning tender price.

- Step 2: Examining the strength and the meaningfulness of the correlation

As labelled above, this step is to examine whether the linear relationship between the predicted construction cost and the winning tender price is strong. In other words, examining the strength is to validate whether the predicted construction cost based on the major elemental costs is capable of forecasting the winning tender price. From the statistical principle, if the hypothesis is statistically different from zero, the next focus is to prove the statistical significance. Statistical significance means that the observed difference between samples is large enough to reflect a difference between populations, and the possibility of obtaining such a difference by chance is low. Practical significance means having a meaningful effect, and having relevance in practice (Corty, 2007). Three tests are applied to quantify the predictive capacity of a correlation coefficient, which could prove whether statistical significance represents practical significance.

1) Test I – Testing the strength of correlation, by creating a confidence interval of r at the 95% level (the most commonly calculated interval). The narrower the confidence intervals for a Pearson r, the smaller range within which the "real" correlation value, the population parameter, falls.

2) Test II – Testing the strength of association, by calculating a coefficient of determination with r^2. Cohen (1988) offered the 'effect size' theory about correlation in the social and behavioural sciences. He suggested that a variable that predicts ≈ 1% of variance has a small effect; one that predicts ≈ 10% of the variance has a medium effect; and one that predicts ≈ 25% has a large effect.

3) Test III – Testing the statistical power with r. The statistical power is the probability of correctly rejecting the null hypothesis. Power is defined as 1 – β. β is a Type II error, which is incorrectly failing to reject the null hypothesis. The accepted convention is to set β at 0.20, and make power at 80%. This test is used to compare the calculated power from samples with conventional power in order to determine whether the power is significant enough and to find the minimum case number of samples.

In conclusion, the methodology can be displayed as the following flowchart Figure 1.

4. Conclusion

This paper has set out the literatures and methodology framework to set up a logical and systematic method in the establishment of the cost estimating model by using the Pareto Principle in order to improve the cost estimating accuracy and efficiency. This study described in this paper has also demonstrated the method of testing the reliability and

effectiveness of the cost estimating model with the provisional theory. In the last four decades, the improvement of the cost estimating accuracy and efficiency has been a recurring subject in building economics. However, literature reviews suggested that the number of research studies directly investigating the methodology of testing and validating the reliability and effectiveness of the cost estimating model including the provisional theory is limited. Therefore, the need of carrying out this study is identified.

The methodology described in this study represents the outset of a series of investigation regarding using the Pareto Principle to discover a logical and systematic method in establishing and testing a cost estimating model in order to improve the cost estimating accuracy and efficiency. Further research could be:

- Conduct further analysis using the low-rise residential projects to test the theory described in this study
- Conduct further analysis using other types of projects, such as the high-rise residential projects and the office buildings.
- Conduct further analysis applying the same method on the trade format

These possible future works are to further prove the reliability of the methodology described in this paper. This also enables the finding of the logical and systematic method described in this study can be widely used in the building industry throughout different types of projects. However, there are some possible underlined issues, which the researchers would have to face. First of all, it is difficult to obtain a sufficient sample due to the poor data keeping habit and the sensitivity issue of the cost data in the construction industry. Second is the limitations regarding the assumptions of multiple regression used in the scientific and commercial fields – Theoretical Issues and Practical Issues (Green, 1990), which would could be further investigated and discussed in the future studies.

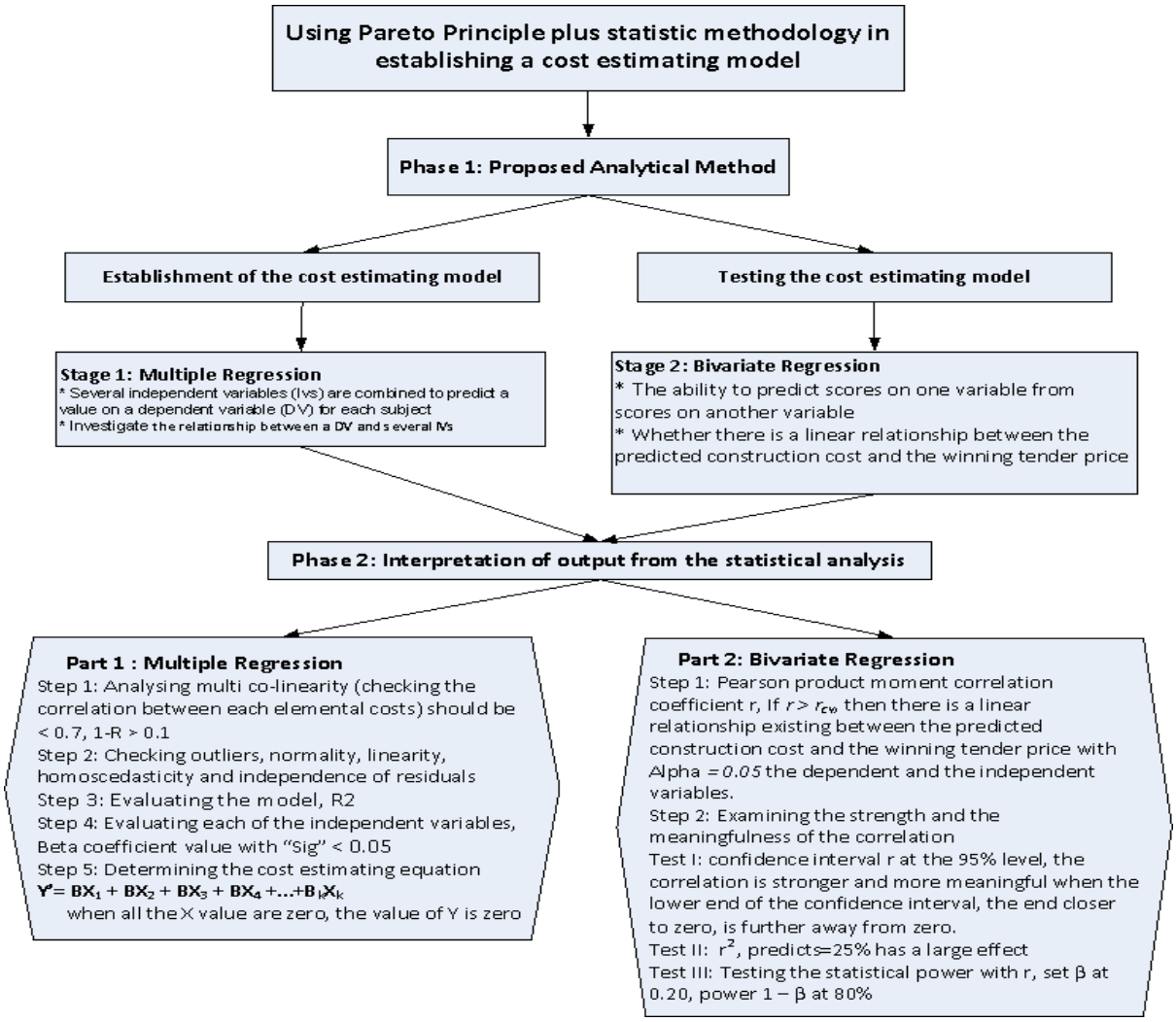

Figure 1: Methodology Flowchart

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CIB 2013 World Congress

Navigating the social dimension of sustainability decision making of mega-projects

Anna Phelan[1], Les Dawes[2]

Abstract

Until recently, sustainable development was perceived as essentially an environmental issue, relating to the integration of environmental concerns into economic decision-making. As a result, environmental considerations have been the primary focus of sustainability decision making during the economic development process for major projects, and the assessment and preservation of social and cultural systems has been arguably too limited. The practice of social impact and sustainability assessment is an established and accepted part of project planning, however, these practices are not aimed at delivering sustainability outcomes for social systems, rather they are designed to minimise 'unsustainability' and contribute to project approval. Currently, there exists no widely recognised standard approach for assessing social sustainability and accounting for positive externalities of existing social systems in project decision making. As a result, very different approaches are applied around the world, and even by the same organisations from one project to another. This situation is an impediment not only to generating a shared understanding of the social implications as related to major projects, but more importantly, to identifying common approaches to help improve social sustainability outcomes of proposed activities.

This paper discusses the social dimension of sustainability decision making of mega-projects, and argues that to improve accountability and transparency of project outcomes it is important to understand the characteristics that make some communities more vulnerable than others to mega-project development. This paper highlights issues with current operational level approaches to social sustainability assessment at the project level, and asserts that the starting point for project planning and sustainability decision making of mega-projects needs to include the preservation, maintenance, and enhancement of existing social and cultural systems. It draws attention to the need for a scoping mechanism to systematically assess community vulnerability (or sensitivity) to major infrastructure development during the feasibility and planning stages of a project.

Keywords: mega-projects, social systems, sustainability decision making, community vulnerability

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1. Introduction

Until recently sustainable development has been primarily perceived as an environmental issue, and the social dimension of sustainability has commonly been recognised as the weakest 'pillar' of the sustainability platform (Lehtonen, 2004). In fact, it was not until the late 1990s that social issues were taken into account within the sustainability agenda (Colantonio, 2007). As a result, the management of natural capital and its measurement during the economic development process has been a key aspect of the standard approach to sustainable development, and the assessment of social and cultural capital has been arguably too limited (Missimer, Robèrt, Broman & Sverdrup, 2010). This is especially significant for large infrastructure projects which have a global track record of social benefit shortfalls, cost overruns, and underestimation of risks (Flyvbjerg, 2009). Major industrial and infrastructure projects that cost more than US$1 billion are typically called mega-projects. Globally, investment in mega-projects from the public sector alone has exceeded $5 trillion in the last five years (Flyvbjerg, 2009). With so many projects in the pipeline - and many taking place in emerging economies – the effectiveness of sustainability and impact assessment process is particularly important.

Many industries and private companies worldwide have acknowledged the need for, and the benefits of including sustainability as a key consideration in the design, delivery and operation of major projects, however, the main focus in this endeavor remains unclear. A study of social and environmental disclosure in the mining industry, for example, revealed that as there are no generally accepted auditing or accounting standards for reporting or reviewing sustainability performance information (Jenkins & Yakovleva, 2006). Auditors typically select commonly used indicators such as the level and severity of safety and environmental incidents, energy and water use, and carbon dioxide emissions. *Anything that falls outside of the scope of the auditor is not verified, particularly social indicators, which are harder to quantify* (Jenkins & Yakovleva, 2006).

Although the practice of social impact and sustainability assessments are established and accepted parts of the decision-making process, very different approaches for assessing the impacts on social systems are applied around the world, and even by the same organisations from one project to another. This situation is an impediment not only to generating a shared understanding of the dimensions of social sustainability as related to major industrial and infrastructure projects, but more importantly, to identifying common approaches to help improve social sustainability outcomes of proposed activities. For many projects, at the operational or tactical level, the focus of sustainability assessment remains predominantly seen as performance against a simple checklist**.** Often, it seems that sustainability issues are pursued more coincidentally than with a clear strategy. Depending upon a company's core business, these positive sustainability efforts can be several orders of magnitude smaller than the (potentially negative) impacts of the core business (Missimer et al., 2010).

Governments are now acknowledging this gap and new requirements are emerging such as Infrastructure Australia's strategic assessments of proposed infrastructure (Australia, 2009). A number of approaches are being trialled to address the necessary strategic assessment that incorporates sustainability principles; however, there is no targeted approach for assessing community vulnerability (or sensitivity) to mega-project development. With no sound legislative drivers or explicit requirements for social sustainability impact assessment practice at Commonwealth or State levels, the impetus for sustainability assessment remains largely in the hands of industry proponents, driven by their commitment to their respective Corporate Social Responsibility (CSR) policies.

What are the variables or characteristics that make some communities more vulnerable than others to mega-project development? Not all communities react in the same way to large scale industrial or infrastructure development. Communities, just like individuals, respond to stress in a variety of ways. The adaptive capacity of the community is not merely an additive result of individual responses but rather an interplay of unique capacities the community embodies prior to the onset of the project (Sherrieb, Norris & Galea, 2010). Given increased public scrutiny to major projects, as well as industry's commitment to socially responsible business practice and sustainable decision making, this paper discusses the importance of understanding the characteristics that make some communities more vulnerable than others to mega-project development, and the need for an effective, systematic method for assessing community vulnerability during the feasibility and planning stages of a project.

2. Mega-projects and the Sustainability Decision Making Process

Mega-projects are large infrastructure investment projects, typically defined as costing more than US$1 billion. These projects tend to attract high level of public attention or political interest because of substantial direct and indirect impacts on the environment, community, and budgets (Altshuler & Luberoff, 2003).

Mega-projects include, but are not limited to bridges, tunnels, highways, airports, seaports, railways, power plants, dams, wastewater projects, oil and gas extraction projects, mining projects, information technology systems, aerospace projects, weapons systems, large-scale manufacturing and waterfront redevelopments. The risks associated with mega-projects are substantial and cost overruns of over 50% are common (Flyvbjerg, Bruzelius & Rothengatter, 2003). Similarly, many mega-projects experience substantial economic and social benefit shortfalls. Differences between estimated and actual outcomes for regional development effects, as well as environmental and social impacts are pronounced (Flyvbjerg, Garbuio & Lovallo, 2009). Despite the risks, and poor performance record in terms of costs and benefits, more and bigger mega-projects are being planned and built worldwide. Over half of infrastructure investments are now taking place in emerging economies, and Morgan Stanley predicts that over this decade emerging economies will spend $22 trillion in today's prices on infrastructure (Flyvbjerg, 2009). In addition to issues related to risk and financial uncertainty (Flyvbjerg, 2007), mega-projects are also often associated with adverse and irreversible impacts affecting the local environment and dependent populations living in the project area (Harris, 2003).

World's Best Practice and the sustainability platforms of most CSR policies require the consideration of how any given project proposal or plan would impact on the environment and society. For mega-projects, cost-benefit analyses and environmental and social impact assessments (EIA and SIA) are typically at the core of documentation and decision making process (Flyvbjerg, 2009). These standardised approaches are not designed to account or value the positive externalities that flow from the 'goods and services' provided by the social and cultural systems of the community, (such as, family cohesion, community resilience, social networks, stewardship for the land, and cultural identity). Over the years, business, corporate and research sectors have developed numerous sustainability assessment tools and techniques that can be framed within the CSR and sustainability design initiatives (Singh, Murty, Gupta & Dikshit, 2009). These tools typically incorporate social, economic and environmental concerns into a single metric and are based on the integrated assessment approach with the aim to minimise 'unsustainability', or to achieve triple-bottom-line objectives (Colantonio, 2011). Finding a meaningful way to aggregate social, environmental, economic and institutional metrics into a composite index that can be compared at both spatial and temporal levels has proven difficult (Keirstead & Leach, 2008; Pope, Annandale & Morrison-Saunders, 2004).

Critics of the integrated assessment approach highlight the fact that societies, economies and ecosystems are complex adaptive systems that cannot be fully captured through a single lens, and call for the adoption of diverse methods and metrics rather than a single sustainability index (Gasparatos, El-Haram & Horner, 2007). In addition, proponents of 'assessment for sustainability' point out that project proposal should not be assessed for their contribution to sustainability, but to determine whether or not they are, in themselves sustainable (George, 2001).

3. Sustaining Social Systems

To improve accountability and transparency of project outcomes, and reduce risk, the sustainability of social systems needs to be incorporated into decision making process of mega-projects. The challenge is not to fall back on the typical strategies historically used to address the social dimension of sustainability in project decision making. More often than not, the performance measures of the social dimension of sustainability are primarily based on job creation and safety records as related to the project, as well as monetary contributions and compensation made to the community. Although noble in their own right, these strategies are not designed to deliver long term social sustainability outcomes for the community affected by the project.

The starting point of assessment for sustainability during the decision making process of a mega-project should answer the question – "What is to be sustained as part of this project?" The original concept of sustainable development, the Brundtland definition - *"Meeting the needs of the present without compromising the ability of future generations to meet their own needs"* (Brundtland, 1987) urges us not to degrade the ecological and social systems upon which we all depend. Furthermore, sustainable development discussed in literature focuses on the relationship of what is to be sustained (namely ecological and social systems) and what is to be developed, (namely the economy and society) (Hawken, Niznik & Institute,

1992) (Anielski, 2002). Preserving ecological systems is now a key normative goal of environmental decision making; however, preserving social systems and the intangible goods and services they provide to society is not yet common practice (Thompson Jr, 2008).

It is largely understood that if the sources of life support on earth are not sustained, the life of many species including humans will be threatened. Sustaining sources of life support includes preservation of the environment, biodiversity, ecosystems, natural resources, and ecosystem services (Bolund & Hunhammar, 1999; Boumans et al., 2002; Costanza et al., 1998; Daly & Farley, 2010). Ecosystem services refer to *benefits or goods and services that humans recognize as obtained from ecosystems that support, directly or indirectly, their survival and quality of life* (Costanza et al., 1998).

Over the years, in an effort to preserve ecological systems, numerous approaches for valuing ecosystem services have evolved. For example, the ecosystem services approach (EsA) has been developed as a strategic and tactical framework for taking account the services provided by ecosystems within decision making (Fish, 2011). The EsA development began as a theoretical framework in the early 1990s as a way to address the conservation of valued ecosystem services and has steadily evolved into policy and practical applications (Haines-Young & Potschin, 2010). Variations of this concept have emerged, such as, Valuing Ecosystem Services (VES) scheme and Payment for Ecosystem Services (PES). The basis of these frameworks is the natural environment's contribution to human well-being. In another words, avoiding the basic destruction of ecological systems is currently an acceptable starting point when planning major projects, the same fundamental premise, however, is not always applied for social systems.

Social systems are highly developed human constructs, and in addition to having roots in evolutionary social biology, these systems include, but are not limited to; networks, groups, relationships, and cultural ties and are derived from communities, families, cultural groups, and geographic factors. While ecological systems are mostly a result of evolutionary processes, social systems invariably contain different layers of complexity. Community identity is related to culture, groups, networks and sense of place. Personal identity is often secured through family structure and the ability to maintain a culture within the larger society (Margalit & Halbertal, 2004). Communities are complex web of relationships between a set of individuals who share norms, values, history, and identity, and to the extent these are threatened, the community is threatened (Folke et al., 2002). In addition, traditional and long standing social and cultural systems often evolve to become ecologically restorative in their techniques and interactions with the natural environment, (Mann, 2005) (Diamond, 2006).

When it comes to the sustainability of social systems what are some of the key factors to consider? The concept of social sustainability is broad and multifaceted, and has been examined by numerous disciplines and across various contexts. It includes, but is not limited to socio-cultural, socio-institutional, socio-economic, and socio-environmental dimensions of sustainability (Colantonio & Lane, 2008). Based on the extensive literature review of definitions of social sustainability, it is suggested that sustainability of the community can be preserved and maintained with the presence of the following components:

- Capacity to improve quality of life – (sustained and self-directed access to opportunities to meet basic human needs
- Concern for wellbeing of future generations
- Care of social equity and social justice issues
- Recognition of the relationship between natural and social capital
- Support and preservation of cultural dynamics

It is understood that these components are dynamic social change processes and are directly dependent on the social systems and culture within which a project is imbedded. Furthermore, the ecological economics perspective of 'strong sustainability' highlights that quality of life is dependent on all capitals (stocks of assets - natural, built, human, and social) and their systemic interaction - (Costanza et al., 2007) and that each capital is of inherent value and investment in one will not compensate or substitute for lack of investment or loss in another (Costanza et al., 1998).

Based on the above perspective, and the multifaceted concept of social sustainability, it can be concluded that social systems should be sustained as part of responsible business practice. And the starting point for project-planning and sustainability decision making of mega-projects, in addition to environmental considerations, needs to include the preservation of existing social and cultural systems.

4. Incorporating the Adaptive Capacity of the Community into Decision Making

Not all communities react in the same way to large scale industrial or infrastructure development. The resilience and sensitivity to changes and impacts associated with the development of a mega-project is unique to each community. This is due to the variance in social, cultural and ecological factors from community to community. Just like individuals, communities have the tendency to respond to stress in a variety of ways (Sherrieb et al., 2010). The adaptive capacity of the community is not merely an additive result of individual responses but rather interplay of unique capacities the community embodies prior to the onset of the project. The ways in which various social change processes are perceived or valued depends on the social context of the community. Some sectors or groups in society are able to adapt quickly and seek out opportunities that arise from the new situation, others are less able to adapt, and will therefore, bear most of the negative consequences of change (Vanclay, 2002).

Gellert and Lynch (2004) describe mega-projects as spatially situated and inherently displacing and analytically divide them into four types: (i) infrastructure (ports, railroads, highways, water treatment facilities), (ii) extraction (minerals, oil and gas), (iii) production (dams, power plants, pipelines and petrochemical plants) and (iv) consumption (real estate developments, malls, tourist installations). These project types can often occur in combination. Mega-projects require coordinated flows of international and state finance capital, involving public and private partnerships, the use of sophisticated technologies and heavy equipment. (Gellert & Lynch, 2004).

Mega-projects transform landscapes rapidly, intentionally and profoundly, and involve not only the displacement of dirt, substrate and other geological or hydrological patterns, but the displacement of people, communities and workers (Gellert and Lynch, 2003). Displacement refers to the ways in which human and bio-geophysical elements in the landscape interact and change as mega-projects are introduced. Due to the global pace of development over the last four decades many communities, particularly in developing countries and rural areas, have been separated from their productive assets and homesteads on account of large-scale infrastructure projects launched by public and/or private sector parties (Downing, 2002; Lehrer & Laidley, 2008; Sharma, 2003). Despite programmes and policies addressing rehabilitation, resettlement and compensation, the social costs of displacement are high, particularly for communities that are more sensitive to industrial development. The stresses incurred as the result of loss, or threat of loss to productive assets and community ties are significant and long lasting. Communities that are ill-prepared for the disruption of a mega-project socially and culturally can suffer great impacts that might cause less harm elsewhere (Loney, 1995).

People living in communities affected by mega-projects face the uncertainty, as well as the reality of being separated from their productive assets (particularly land) and homes, and in many cases, their traditional sources of livelihood and social networks (Sharma, 2003). Whether in rural or urban areas, the process of land acquisition for large-scale infrastructure and industrial projects directly affects the displacement of people from their productive assets. Communities relying on traditional sources of sustenance are particularly affected. As Loney (1995) points out; *"The consequence of mega-project impacts which damage the resource base and affect harvesting activities extends far beyond the continuing availability of a plentiful source of nutritious food".* Some of the consequences include: disruption to socialisation patterns and the family unit, damage to self-esteem, decreased sense of security, and weakening of the native economy.

Previous research, especially in post-technological disaster settings, has demonstrated that resource loss and/or threat of loss – particularly over time – combine to create individual stress and collective trauma that affect the capacity of the community to generate and sustain social capital during the very time when trust and positive relationships are critical (Ritchie, 2012). Also, social capital, as described by Norris et al. (2008), has been found to exhibit a set of adaptive capacities that can support the process of community resilience to maintain and sustain community health. However, capturing the relationship between economic and socio-cultural structure of the community and its ability to withstand a mega-project event, and incorporating that into the decision making process has not been proposed until now.

This paper suggests that systematically assessing community vulnerability (or sensitivity) to large-scale infrastructure development is a necessary first step of the sustainability decision making process for mega-projects, and asks; what are the variables or characteristics that make some communities more vulnerable than others to mega-project development? . Further research is required to ascertain which socio-cultural and socio-economic characteristics contribute to the adaptive capacity of the community to withstand a mega-

project event, and the best way to incorporate these as part of a scoping mechanism that is objective, scalable and transferable.

5. Conclusion

Major infrastructure projects play a significant role in influencing Australian and global environmental, social, and economic outcomes. Evidence in the literature supports that research is required into the methodological approaches for improved social sustainability outcomes of mega-projects.

Displacement and landscape transformation are inherent in mega-project development (Gellert and Lynch, 2003). Communities affected by mega-projects are faced with challenges associated with changes in access to resources and perceived loss or threat to resources. These include, but are not limited to: loss of traditional livelihoods, erosion of community networks that were built up over generations, effect on the family unit, and marginalisation of some sectors of the population. Previous research has shown that diminished social capital can exacerbate individual stress and collective trauma. Understanding the characteristics that make some communities more vulnerable than others to mega-project development can improve the effectiveness of social impact and sustainability assessment studies leading to better impact predictions, thereby reducing potential collective trauma. In addition, for large infrastructure projects, when it comes to decision making, better accountability that is reflective of all systems, is not only important for better project outcomes, but can also help improve forecasting techniques and identify risks (Flyvbjerg, 2009).

This paper highlighted that the starting point for project planning and sustainability decision making of mega-projects needs to include the preservation, maintenance, and enhancement of existing social systems, and proposed that systematic assessment of community vulnerability (or sensitivity) to major infrastructure development during the feasibility and planning stages of a project can improve accountability and transparency in project decision making, thereby improving the social sustainability outcomes of the project.

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A framework for evaluating and improving design guidance & control

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The visual appearance of cities is no longer being left to chance as an increasing number of cities assess design attributes of new development proposals as part of regulatory processes. The emphasis placed on design control can largely be attributed to public dissatisfaction with the effects past unregulated change has had on streetscape appearances. Or can it? If people are dissatisfied, what are the streetscape attributes that design control should target in order that places can become more attractive to those who live, work and play there? The paper looks at aesthetic perception and evaluation.

The paper presents a brief summary of design review in the context of regulatory planning in the USA, Britain and New Zealand. It then presents the key concepts of environmental aesthetics, particularly those factors influencing perception of urban settings. A disconnection between research in this field and regulatory planning processes is highlighted, noting that this may be a factor in the failure of regulation to deliver likeable places. As design professions often base opinions on theories that are not empirically validated, their professional dogmas should be put to one side in order to make design control more effective. The paper argues that those responsible for design control must understand the preferences of the people and sets out a framework to inform further research in the field.

Keywords: environmental aesthetics, streetscape, design guidance, townscape.

1. Introduction

The appearance of cites is often found to confound the critics. "Why", asks Layla Dawson, "does the Auckland CBD, situated in a stunning natural environment, have the appearance of a jumble of high-rise blocks" (Dawson 2010). A little further afield in Sydney, John Punter (2004) is critical of the poor quality built environment that still continues to be created in the post-WWII years. Sydney is a city that has succumbed to "spectacularly ordinary commercial development" during that period and he continues to comment that this ordinariness has only been excused by a discerning public because of its spectacular setting (p. 406). It seems that contemporary practices shaping towns and cities lead to poor outcomes with the impact of this made worse because of the inescapability of the built environment (Carmona and Tiesdell 2007). Even so, opinions that are critical of the visual characteristics of the built environment are not difficult to come by and a fundamental question to ask is whether it really matters..……is the visual quality of the built environment something to be concerned about?

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Addressing this question we can first consider that aesthetic perceptions of the built environment have been linked to mental and physical wellbeing. Poor urban environments can induce higher levels of emotional and psychological stress in people and have been shown to diminish faith and self-esteem (George and Campbell 2000; Pallasmaa 2001). On the other hand, aesthetically pleasing places can help generate, celebrate and sustain life through making a person feel more complete and satisfied (Porteous 1996; Dovey 2001). Arguing for greater coherency of built form, Smith connects aesthetic pleasure to natural selection processes. Studies have shown that sensory pleasure, including positive visual experience of one's environment, can raise levels of immunoglobulin, a key antibody that bolsters the human immune system thereby increasing chances of survival (Smith 2003 p. 95).

A second matter that establishes the relevance of the appearance of the built environment is financial. The visual qualities of the built environment can have tangible influence over property values, thereby directly affecting the financial well-being of those who own property or conduct a business in the area. It seems that visually attractive places are more sought after by the public, helping to increase demand and therefore economic values. Increasingly, the built environment is being used as a tool in the battle between cities for business investment, tourism and high-calibre workers (Carmona, Magalhaes et al. 2002; Cuthbert 2006). In recognition of this and because the market cannot be relied on to consistently deliver appropriate change to cities it becomes necessary for government intervention on behalf of those who must live with the consequences but do not otherwise have a say in the nature of those changes (Delafons 1994; Ellin 2006). Scheer (1994) explains that cities are motivated to review design outcomes in order to improve the quality of life for their citizens, promote vitality, protect property values and generally improve their appearance. George & Campbell (2000 p163) advise that "aesthetic controls are based on the belief that there is a collective good in their application greater than the sum of their cost to each individual".

2. Regulatory planning

Toward the end of the 19th century in Britain, town planning emerged as an intellectual response to the squalor and poverty that had developed during the Victorian period. Coinciding with visions of the new, ordered settlements proposed by Ebenezer Howard and others at the time, planning envisaged a bright future through progressive repair of existing settlements (Cherry 1974). Nevertheless it was the design of new extensions to existing towns that was addressed by the first Housing and Town Planning Act, written in 1909. Regulation was mainly directed at the design of new roads and to protect the amenity provided by open spaces. Changes to existing urbanised areas were not considered to be of consequence, as redevelopment of the scale and intensity necessary to affect existing character was not anticipated (Punter 1986). This assumption proved to be wrong and cities began to suffer from changes that were insensitive to local character. By 1925 local authorities were encouraged to write bylaws to help ensure preservation of buildings and neighbourhood character. There was certainly unease on both sides of design regulation, with local authorities concerned about the liability they might assume in censoring design and the architectural profession annoyed that planners, untrained in design, were given

scope to meddle with their designs. The RIBA successfully lobbied government to limit the scope of the regulatory process to preventing design outrages and those buildings that would be offensive to their surroundings (Punter and Carmona 1997). To assist councils in judging major developments and civic design projects the Royal Fine Art Commission was set up in 1924.

Whereas the British system of regulating design outcomes has evolved to allow local authorities considerable discretion, the American system has developed to provide individual landowners with certainty about what they can and cannot do on their land (Delafons 1994). This contrast reflects the different attitudes in these places toward the land and toward public space. Throughout recorded history American land has been surveyed, subdivided, sold and developed; it considered a commodity, to be owned and exploited by individual owners. Attempts to limit the ways in which land can be used have been met with resistance, not only by affected individuals but also by the courts (Scott 1969). Rights of the individual are one of the cornerstones of the American culture. This is an attitude that has not prevailed in Great Britain, at least to the extent that would cause widespread resistance to planning regulation.

It was not until early in the 20th century that the planning profession began to emerge, initially on the back of the *City Beautiful* movement. Establishing civic pride and place identity through careful planning of civic buildings and the spaces around them were a focus for planning during this period. Also at this time planning began to concern itself with the effects unregulated development was having on the quality of residential areas and the streets of cities (Scott 1969). Addressing the first, cities began to write bylaws limiting the areas in which certain harmful activities could take place. No longer was it acceptable to build factories and other industrial facilities in areas that were designated for residential use. This method of separating between activity areas has become the foundation for all city planning throughout the United States (Boyer 1983; Delafons 1994). Zoning was also used to prescribe development form by establishing maximum heights, requiring form to be stepped or limiting floor areas. Rules like these were attached to zoning regulations to help ensure adequate light and air could be enjoyed at street level. Although a blunt instrument, zoning effectively imposes an aesthetic outcome on American cities.

In terms of regulating design outcomes, zoning provides certainty to all participants. It was therefore seen to be an ideal method for regulating building form in light of the litigious nature of American society. Early legal challenges to zoning were easily dismissed and the method has regularly been upheld by the courts as a valid form of police authority (Boyer 1983; Fishman 2000). Then in the 1970s and in response to increasingly insensitive redevelopment in areas of rich visual character and insensitive changes [including demolition] of heritage buildings, local authorities began to implement discretionary design review alongside zoning in some areas . This much more problematic form of control has also been subjected to legal challenges and upheld in circumstances where design review is part of a comprehensive plan of action to improve the visual qualities of the city. The uptake of design review was very rapid and by 1990 Scheer (Scheer and Preiser 1994) found that 83% of all local authorities in the US had established such procedures in one form or another. Some cities established advisory panels comprising of lay and professional people. Early on, review was undertaken without clear assessment criteria, leading to claims of

subjectivity. As a consequence, most cities have now developed guidance that the land owners as well as the review panel can make use of. Despite this there remains a high level of anxiety and stress around the whole process of aesthetic regulation in the United States, revolving primarily around the issue of personal freedom.

Development of towns and cities in New Zealand followed plans drawn up well in advance of settlement that was led by various sponsoring agencies and government departments. Town planning was at the same time becoming established as a discipline and the plans of New Zealand cities were clearly influenced by British planning discourse revolving around health and wellbeing. In addition to enabling the land to be commodified for sale more easily, gridded street layouts provided easier access to open spaces within and around the settlements (Memon 1991; Hamer 1995). While the plans for settlements did not generally nominate land use activities or three-dimensional form, they did provide certainty around the layout of public spaces such as streets and parks. The certainty provided by plans for each settlement, coupled with societal attitudes that valued freedom of the individual and exploitation of the environment (Memon 1991), meant that regulatory town planning was slow to establish on these shores.

Nevertheless, by 1926 the government had passed the Town Planning Act, which required all towns and cities to develop plans by which land use in their jurisdictions could be regulated. The plans were based on Euclidean zoning, adopting methods used in the United States. Miller (2002) attributes the growing enthusiasm for town planning during this period to the many civic beautifying associations that had established around the country. Many extended their activities beyond tree planting to lobby local authorities for enhanced planning control and to arrange design competitions for key projects. However, despite having good legislation to work with, town planning was not delivering visually attractive or functionally sound cities according to some critics. Martin (1949) considered that this was in large part due to the general public's lack of discernment regarding matters of design. He also argued that there was a shortage of town planners with the necessary skills to design and regulate for a coherent built environment.

The New Zealand planning regulation context changed dramatically with adoption of the Resource Management Act in 1991. That RMA, which weaves town planning legislation in with laws governing use of water and other natural resources, provides comprehensive high level guidance on management of the country's resources (Jackson and Dixon 2007; Higgins 2010; Miller 2011). The RMA has its roots in a period of economic liberalisation and was written to support a performance-based planning approach, contrasting with the inflexible and prescriptive planning paradigm it replaced (Baker, Sipe et al. 2006). There is a substantial literature on planning, and to a lesser extent urban design, in the aftermath of the RMA. Hunt (2008) and Higgins (2010) express the widely held view that planning around urban development has not been well served by the RMA largely because of its focus on the biophysical realm, its emphasis on measuring effects rather than the nature and scale of development and that it is overly reliant on market forces to determine appropriate development. Despite the potential for performance-based planning to emerge local authorities have in large part fallen back to fixed rules as the basis against which proposals are judged (Baker, Sipe et al. 2006). This has led to design issues being marginalised in the

vast majority of planning decisions because, where building form and location are controlled by clear standards, local authorities do not believe it is their role to comment on aesthetic matters (Hunt 2008).

3. Environmental aesthetics

It has been noted that the environment does affect people's physical and mental wellbeing and that they make choices on the basis of aesthetic value. However, there is also an idea rooted deeply in our society and promoted extensively by those who are critical of design review that aesthetic judgement is entirely subjective and so it is difficult to agree on notions of beauty (Scheer 1994; Taylor 1994). If this is true then the very idea that aesthetic outcomes could be effectively controlled for the benefit of a wide segment of the population is fraught. Fortunately the field of ***environmental aesthetics*** can help us to understand widely held notions of beauty. Cuthbert (2006) suggests that an aesthetically pleasing experience is one that provides pleasurable sensory experiences, a pleasing perceptual structure and pleasurable symbolic associations. Aesthetic experience can therefore be conceptualised over three levels; sensory perception, cognition and meaning. Following social science and psychology methodologies, a number of studies have been carried out since the 1960s examining people's perceptions and judgments of their environments as well as to confirm the validity of theories explaining the processes of perception (Nasar 1988, Stamps 2000). Using mapping techniques developed by Lynch (1960) in his classical study of people's mental images of cities and survey techniques, Nasar consulted residents and visitors in two American cities. He set out to identify general characteristics of 'likeable' places. Key factors that influence likability are naturalness, openness, upkeep, historical significance and order. Critics observe that this research simply confirms what most people would assume (Chapman 1999) but others also see this as its strength. Empirical research findings such as Nasar's provide confidence to regulators when preparing design guidelines.

Porteous (1996) offers a useful and comprehensive outline of environmental aesthetics, which he structures into four separate paradigms. *Humanists* approach their study of landscapes in a historically traditional manner, contemplating and seeking universal truths intuitively. *Activists* are extremely passionate about the environment but lack adequate rigour in their arguments, therefore lacking in credibility. In Porteous' view of environmental aesthetics the *Activist* group is aligned most closely with the public. *Experimentalists* are scientists and they seek evidence for the way people perceive and experience their environments, often linking perception with behaviour in their approaches. *Experimentalists* are however only interested in the answers to questions and not necessarily in how these answers might be used in a more practical sense. Porteous argues that *Planners* approach environmental aesthetics with the rigour of the *Experimentalists* but seek to give this information greater relevance by using it to manage, design and make policy toward enhancing and improving the perceived quality of urban and natural landscapes. Porteous (1996) is troubled by the failure of the three parties around whom environmental aesthetics revolves, the general public (*Activists*), researchers (*Humanists* and *Experimentalists*) and *Planners*, to coordinate their efforts in order to influence development driven change toward aesthetically pleasing outcomes. The key to solving this problem is to increase public

participation in aesthetic planning, a goal that will largely be fostered through environmental education (Porteous 1996 p240).

4. Design Review

A number of methods of regulating and controlling aesthetic outcomes of urban development have been developed and operate successfully in different parts of the world. Punter (2007) notes that design review practices are either regulatory or discretionary. Regulatory (also referred to as administrative) systems are an add-on to zoning controls, where design outcomes are controlled by rules and objective measures. Examples of this are maximum height limits, prescriptions for location of buildings in relation to boundaries and floor area ratios. These systems provide high levels of certainty to all parties and regulation is able to be conducted through largely administrative functions, reducing local authority resourcing needs. However, they are also criticised for being coarse in nature with a tendency toward monotonous environments, where all projects are built to the prescribed limits (Delafons 1994; Madanipour 1996).

Discretionary systems are more 'pragmatic' as they allow regulation to refer to the immediate setting and other variable factors that cannot be accounted for in most rules based regimes. The more successful discretionary systems, in terms of meeting the needs of different stakeholders, are informed by design guidelines or briefs that provide both a target for designers and a reference for those assessing the proposal (Nasar and Grannis 1999). While discretionary systems often do allow local conditions to be taken into account they are often criticised by the development industry and by designers for their arbitrariness (Scheer 1994).

Over the past 30 years there has been a tendency for regulatory design control to become more discretionary to create scope for development design quality to be scrutinised more closely. Likewise, design guidance informing discretionary systems has become more prescriptive in response to calls for more certainty around the process for applicants. In short, design control systems appear to be converging as they are modified to include both discretionary and regulatory characteristics (Punter 2007).

Table 1: The cases for and against design review

Case for	Case against
Raises the standard of development by ensuring more thought goes into its design	Impedes the quality of building design
Prevents 'outrages'	Merely cosmetic
Encourages designer to stand up to client	Encourages imitation
Can provide a bridge between lay and professional tastes –depending on methods	Bureaucratic baggage
Seeks to improve quality of life	Lacks fair predictability
	Violates property rights
	Violates freedom of speech

The underlying aim of design review is that regulation will lead to a better built environment for all. However, it is not a field without controversy. Scholars, design practitioners and

regulators have identified the key areas of controversy to be that it creates inefficiencies in the development process, is redundant in a free market economy, that it stifles freedom of expression and that really excellent design outcomes are a casualty of a process that favours continuity (Habe 1989; Scheer and Preiser 1994). Table 1 sets out the various promises of design review against the challenges the process must overcome if it is to achieve all that is promised.

An extensive US study, reported to an international symposium on design review, found planners and members of the public to be reasonably satisfied with design review, calling only for improvements to the process through refinement of guidelines and greater autonomy to decision makers. Architects, on the other hand, were largely dissatisfied (Scheer 1994). In 1990, about the same time as Scheer was doing her analysis, Schuster (1997) surveyed members of the Boston Architectural Society. One of his key findings was the "markedly positive" view architects have of design review. Schuster confronted the discrepancies between the two surveys and found that Scheer had widely circulated a memo through the American Institute of Architects, inviting responses. Hers does not appear to have been an impartial survey and Schuster comments that individual architects who have particularly negative views were more likely to make the effort to respond. Although the jury is still out on the opinion architects have of design review, it seems an increasing number of local authorities include consideration of design as part of development control (Scheer 1994).

To improve the processes and the outcomes (products) of aesthetic review as it is currently administered in local government development regulation, a number of challenges outlined in the literature must be confronted. Design review is time consuming and expensive, it is easy to manipulate through persuasion and it is administered by overworked and inexperienced staff. Scheer (1994) identifies these as issues that plague the process but which are easy to solve. By that, she insinuates that they can be resolved with the addition of financial or human resources, through education and with by ensuring the process is adequately audited for political involvement. She proceeds to identify problems that are more difficult to diffuse, as they generally represent matters that exist as tensions between competing social, political or legal forces. The first of these is *power* and the question of who makes the key decisions. Scheer points to the law and notes that it is only those who are expert in the field that are authorised to make key decisions or to judge. She argues that design review is the only field in which lay (or those not specifically trained in design) people are left to rule over professionals directly in their areas of expertise.

Freedom to express oneself through the built environment is another matter that troubles design review. Concerns about freedom in the design review process are triggered by societal values aligned with property ownership in many places, particularly in the 'new world' countries. Nevertheless, the courts have consistently upheld the ability of local government to control this right, provided it comes through a comprehensive process aimed at improving the quality of the built environment (Lai 1994).

Punter (2007) incorporates these criteria into a comprehensive framework for design review and development management (Table 2). The twelve principles are grouped under four headings; community vision, design planning and zoning, substantive design principles and

due process. The principles under the first heading aim to capture the views of the community as a step in generating a comprehensive view to guide development and control. The community vision becomes the reference for all decisions. Secondly, three principles inform development of a suitable process that includes incentives as well as requirements necessary to regulate for high quality design outcomes. The next three principles address the nature of the relationship between the comprehensive plan and the development industry charged with implementing it. Punter argues that the relationship should be pluralistic and not overbearing in order to allow creative solutions to emerge. Under the final heading four principles address issues of fairness in administering the design control regime.

Table 2: Principles for Progressive Design Review

Source: Punter 2007

Community vision

1. Committing to a comprehensive and coordinated vision of environmental beauty and design
2. Developing and monitoring an urban design plan with community and development industry support and periodic review

Design Planning and Zoning

3. Harnessing the broadest range of actors and instruments (tax subsidies, land acquisition) to promote better design
4. Mitigating the exclusionary effects of control strategies and urban design regulation
5. Integrating zoning into planning and addressing the limitations of zoning

Broad, Substantive Design Principles

6. Maintaining a commitment to urban design that goes well beyond elevations and aesthetics to embrace amenity, accessibility, community, vitality and sustainability
7. Basing guidelines on generic design principles and contextual analysis and articulating desired and mandatory outcomes.
8. Not attempting to control all aspects of community design but accommodating organic spontaneity, vitality, innovation, pluralism: not over-prescriptive.

Due Process

9. Identifying clear *a priori* roles for urban design intervention
10. Establishing proper administrative procedures with written opinions to manage administrative discretion, and with appropriate appeal mechanisms.
11. Implementing an efficient, constructive and effective permitting process
12. Providing appropriate design skills and expertise to support the review process.

5. Analytical framework

Research that monitors the effectiveness of design review responds to recommendations made by Porteous (1996), Punter & Carmona (1997) and others. By understanding people's perceptions of a place that has been transformed through a number of discrete projects it is possible to determine the success of the design review *filter.* Figure 1 describes a relationship between the factors that might influence the characteristics of the setting that is to be evaluated. Gjerde (2011) provides an outline of the factors that influence aesthetic perception and experience of the city, the bottom half of the diagram. Above this, the design review process can be envisaged as a filter, where regulation influences the shape and form of the built form through the design principles on which it is based, the capabilities of those making decisions, the legal and planning contexts as well as the physical context that will receive the development proposal. All twelve of Punter's (2007) principles of design review can be seen to be provided for in the framework. A key influence on the design review process is the community's vision for its future. The built environment is fixed in the centre of the framework, it results through the efforts of individual property owners to (re)develop their sites and those charged with regulating to help ensure the outcomes are not skewed

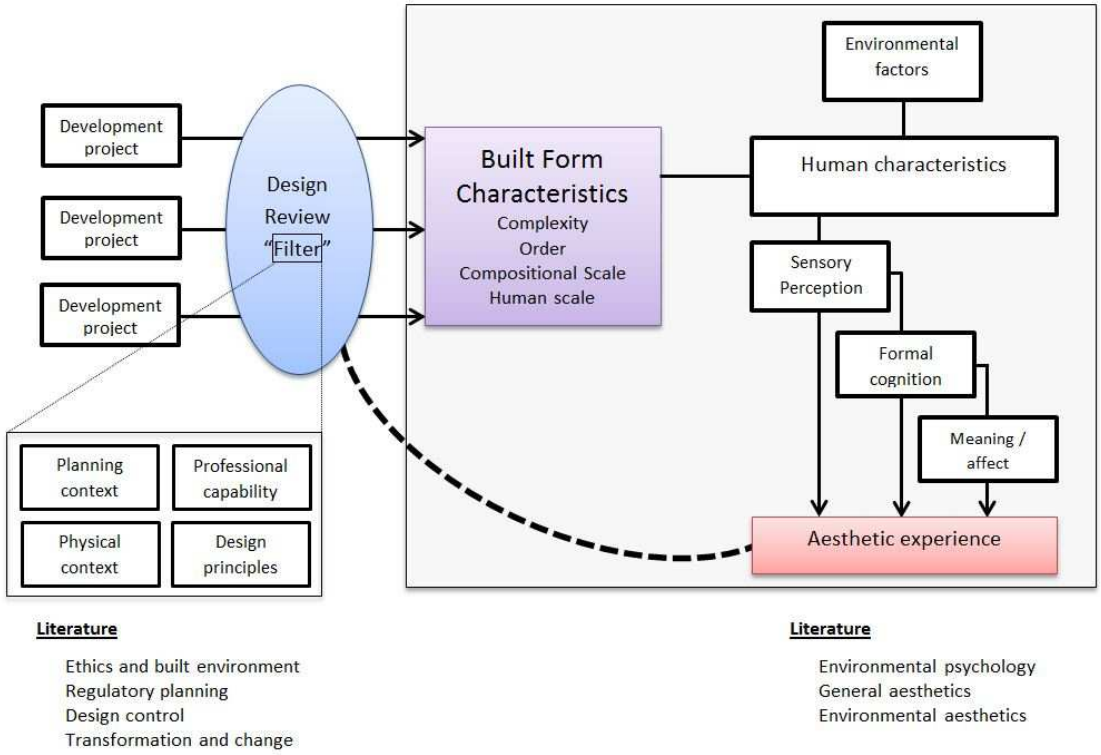

Figure 1: Diagram of the conceptual framework for the research.

through private interests. The same environment provides a catalyst for aesthetic evaluation following a process made known through environmental aesthetics.

6. Conclusion

There are good reasons to make efforts to improve the aesthetic quality of the built environment. Visual qualities of the environment have a bearing on people's physical and mental as well as their financial well-being. Increasingly, local government politicians and managers recognise the importance of the built environment in attracting visitors and high-calibre workers to their settlements. Despite these imperatives there is considerable evidence to suggest that new development does not lead to environments of such a standard as the public wants and deserves. Design review, as part of a comprehensive planning regulation regime, has been widely used to confront market forces in an effort to improve the visual quality of the built environment.

The paper has developed a framework for evaluating the effectiveness of design review tools and processes. To generate the framework the paper has traversed literature in the fields of environmental aesthetics, design review and the history of regulation, aiming to understand motivations and other background in the United States, Britain and New Zealand. Further research, making use of the framework to understand the effectiveness of different design review processes in different contexts, is called for to improve the basis on which design outcomes are regulated.

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Aligning Safety Policy Development, Learning and Implementation: from Boardroom to Site

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Abstract

This paper has two aims: (1) to investigate if any misalignment exists from the company's boardroom decision making to onsite implementation in relation to construction safety and (2) to understand how on-site workers learn and develop their safety attitude, skills and knowledge. To achieve these aims, questionnaires were developed and distributed and interviews were conducted with key project leaders. Analyses found several misalignments and human factor barriers during the process of safety policy implementation and improvement. This paper suggests that the misalignments can be minimised by realising the nature of safety learning in practice which leads to changes in the safety learning approach for on-site workers, and the barriers can be removed by improving project leaders' skills, such as self-awareness, visioning, apparent sincerity, and understanding people.

Keywords: construction safety, safety implementation misalignment, safety learning, skills of project leaders

1. Introduction

Although senior management commitment is indispensable for successful construction safety program implementation, safety should not only be the responsibility of senior managers. Without the participation of onsite personnel and workers, construction safety implementation will never be effective. Whilst the senior management may be committed to safety, the onsite workers' interpretation and implementation of safety may not be the same or aligned with the senior management expectations. Research has shown that there is a real issue of misalignment in implementing safety policy from the governments' policy development, to company's boardroom decision, and to onsite implementation. Habibi and Fereidan (2009) assessed the attitudes of three levels of refinery personnel in Iran, including top management, supervisory staff and frontline workers, towards safety culture in the organisation, and they found significance differences between the management level and both the supervisory staff and frontline workers. In the Thai construction industry, Pungvongsanuraks and Chinda (2010) found a misalignment of safety culture perceptions between management and workers, where top management believes that safety empowerment and training are important whilst workers consider this as a waste of time because they want to focus their effort at maintaining their productiveness. Likewise, Fung et

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al. (2005) found divergences of behaviour, attitude and perception towards safety culture among top management, supervisory staff and frontline workers in the Hong Kong construction industry. Similarly, Chen et al. (2012) found a gap in construction safety climate awareness between management and workers in Taiwan.

This paper aims to investigate whether this misalignment exists in the Australian construction industry using quantitative and qualitative methods. It will also discuss barriers that may hinder safety policy implementation. By considering the learning process of workers for developing their safety knowledge and skills, this paper will provide recommendations to minimise safety implementation misalignment in construction organisations.

2. Research Methods

2.1 Quantitative method

Questionnaire survey was the quantitative method used in this research. This method was suitable to collect a large number of data for comparing results between groups. A self-assessed questionnaire was used to assess the level of safety climate in construction projects. The questionnaire items were developed based on a review of the existing safety climate studies (Zohar, 1980; Brown and Holmes, 1986; Dedobbeleer and Béland, 1991; Williamson et al., 1997; Cox and Cheyne, 2000; Glendon and Litherland, 2001; Mohamed, 2002; Lin et al., 2008; Zohar and Luria, 2005; and Zhou et al., 2009) to find commonalities and ensure the content validity of the questionnaire. Twenty-two items were identified based on this existing literature.

To fulfil the research aims, project management personnel, such as project managers, site managers, project engineers and supervisors, working at large construction organisations in Australia were selected as the target population. These organisations typically consider safety as one of their priorities and have an established safety management system. Members of the Australian Constructors Association (ACA), an association representing the Australia's leading construction organisations, were invited to participate in the survey. As a result of this, 356 project management personnel participated in the questionnaire survey. However, 83 responses had missing data, and were discarded. In total, 273 responses were valid and analysed further.

In questionnaire development, only those items that provide the best representation of the construct should be retained. Item analysis was performed to evaluate the 22 items identified initially and to retain only those with the highest item-to-total correlations, i.e., item-to-total correlations of 0.40 or greater (Nunnally and Bernstein, 1994). Item no. 19 (it is only a matter of time before I am involved in an accident) had a correlation of 0.158 and was eliminated. The remaining items were further evaluated to identify those that could not load to any factors or generated loadings that did not exceed 0.4 (Lin et al., 2008). Factor analysis with a principal components method and varimax rotation was carried out for this purpose (Nunnally and Bernstein, 1994). The pattern of factor loadings showed that item no. 4 (necessary equipment/ tools to perform the job safely are readily available) did not load to any factors, and so it was eliminated.

In order to determine the factor structure of the 20-item safety climate questionnaire, factor analysis with principal axis method and varimax rotation was performed. The Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy is 0.915 and Bartlett's test of sphericity is significant ($p<0.05$) indicating that factor analysis is suitable for analysing the data. Based on the eigenvalues (greater than one) and the scree plot, four dimensions of safety climate were extracted, namely, management commitment, safety training, employee's involvement, and safety rules. The items that form each dimension are listed in Section 3.

2.2 Qualitative method

Semi-structured interview was the qualitative method adopted to provide insights from construction practitioners and to enrich the quantitative research results. Potential interview participants were selected from the questionnaire survey respondents who indicated their willingness to participate in the interview. Furthermore, the interview participants were purposely chosen to represent various roles in construction projects. A total of eight interviews were conducted and the profile of the interview participants is presented in Table 1. This variety of job positions is advantageous for the research because it enables the proposed relationships to be verified by industry practitioners from different management functions. Furthermore, the interview participants had an average of 21.8 years of experience in the construction industry, thus ensuring that they had sufficient experience of safety issues across different contexts. Two key questions were asked during the interviews. The first question was about common issues or barriers that hinder safety performance improvement in the Australian construction industry. The second question sought the opinions of the interview participants concerning the misalignment in construction safety implementation and/or perceptions between management and on-site workers.

Table 1: Interview participants

Code	Position	Age	Education	Experience (yr)
CAM-01	Commercial administration manager	50-54	Bachelor	37
PM-02	Project manager	45-49	Bachelor	24
HSEM-03	Branch EHS manager	45-49	Diploma	28
PE-04	Project engineer	25-29	Bachelor	5.5
CM-05	Construction manager	35-39	Bachelor	19
CE-06	Commissioning engineer	>55	Diploma	36
SM-07	Site manager	40-44	High school	15
HSEM-08	National HSE manager	40-44	Diploma	10
Average year of work experience =				**21.8**

3. Results and Discussions

3.1 Safety Climate Perceptions: Managers vs. Supervisors

The quantitative data were classified into two groups. The first group is managers comprising construction managers, project managers, site managers, safety managers, and

other managerial positions. The second group is supervisors comprising project engineers, site engineers, site supervisors, safety officers, and other engineering or supervisory positions. The t-test with independent samples was used to compare the means of the two groups and the results are presented in Table 2.

Table 2: Safety climate comparison between managers and supervisors

No	Items	Group 1 (N=178)	Group 2 (N=95)
	Dimension 1: Management commitment	**4.21**	**3.95**
SC1	Top management considers safety as equally important as production and profits.	4.31	4.07
SC2	Top management acts decisively when a safety concern or problem is raised or occurred.	4.35	4.18
SC3	Top management evaluates (give rewards/discipline) employees' safety performance.	3.76	3.65
SC5	Site safety personnel have sufficient power and authority.	4.15	4.02
SC6	Top management requires each manager/department to improve/maintain safety performance.	4.31	4.00
SC7	My supervisor or line manager follows safety procedures in every situation, e.g., during deadline, behind schedule, planning stage.	4.11	3.86
SC8	My supervisor or line manager is committed and shows interest towards safety.	4.31	4.12
SC9	My supervisor or line manager considers my safety performance.	4.20	3.81
SC10	My construction project site is a safe place to work.	4.28	3.95
SC11	Supportive working relationships exist in the project when it comes to safety.	4.20	3.87
SC15	The company encourages and acts upon feedback from employees on safety issues.	4.19	3.94
SC16	The company frequently holds safety campaigns or safety awareness programs.	4.20	3.94
SC22	Safety rules and procedures are enforced in the project.	4.34	4.00
	Dimension 2: Safety training	**4.10**	**3.85**
SC12	I have received enough training to perform my job safely.	4.04	3.82
SC13	My safety training provides sufficient knowledge to identify potential safety risks and hazards.	4.15	3.87
	Dimension 3: Employee's involvement	**4.51**	**4.20**
SC17	Safety is one of my priorities when I do my job.	4.58	4.33
SC18	I am involved to improve safety performance in the project.	4.44	4.07
	Dimension 4: Safety rules	**4.10**	**3.86**
SC14	Company's safety policy, information, and issues are available to everyone involved.	4.35	4.07
SC20	The safety rules and procedures in the project/ company are practical, realistic, and appropriate.	3.98	3.73
SC21	It is easy to access safety rules, procedures, and information when required.	3.97	3.77
	Safety Climate Average	**4.21**	**3.95**

The underline numbers signify significant differences between the two means at 0.05. Similarly as found in previous studies, the results also confirm that there are different safety perceptions between the management and supervisory levels in the Australian construction industry. Generally speaking, managers perceived higher level of safety climate than the supervisors. This condition is disconcerting as it indicates that the managers are detached from the real safety condition on-site. This misalignment needs to be minimised if safety performance to be further improved.

3.2 Sources of misalignment

Thematic analysis of the interview transcripts supports the quantitative results. All interview participants agreed that there is a misalignment in safety implementation in their organisation. The managers have certain expectations in the implementation of safety policies and system, but the implementation at the site level does not meet these expectations. It seems that the enforcement of both national and organisational safety policies is not adequate to correct this.

There are various sources causing this misalignment:

- The first source is the experience and knowledge of individuals. Interviewee PM-02 said that the management understands the law and what needs to be done to meet the requirements; however, the workers may not understand this, thus creating a misalignment. Interviewee CAM-01 explained further that the management is placed in a situation that allows them to have greater understanding of potential safety risks because of their experience and training. Supervisory level, on the other hand, may not possess the same experience and associated knowledge when it comes to identifying and managing safety risks.
- The second source is the differing perceptions on the importance of safety. The managers may consider safety as an important aspect in their projects. As such, they try to identify as many safety risks as possible in the project and fill in many paper works and forms. The supervisors, however, may perceive safety as an extra work. Since the managers have identified many risks, the supervisors feel compelled to do hours of tool box talks and prepare safe work method statements. From the workers' perspective, they simply want to do their day-to-day tasks, but they are required to listen to lengthy tool box talks and fill in numerous safety permits which they consider as a hindrance to their productivity.
- The third source is ineffective safety management system caused by poor skill training and development programs. For example, the management wants to progress quickly, but their human resource does not have the capacity to do it. Interviewee HSEM-08 stated that it is impossible to improve safety without a specific system in place and capable people who can follow and manage the system. There is a timeframe involved in an investment, in the people, and in the system to get the outcome that the management is after. Interviewee CE-06 also stated that when the management writes procedures that cannot be achieved by people, then the whole thing is destined to failure. Furthermore, the management tends to defend their system by saying that they have applied training process to equip their people.

However, they may have not assessed the effectiveness of such training. An attempt to accelerate the learning process by 'forcing' people to sit in a room for several days and expecting them to implement what they have learnt is pointless. It should also be considered that some people may learn well in a classroom-structured environment, but the others may feel that this approach is irrelevant and a waste of time as pointed out by several interviewees including CAM-01, PE-04, CM-05, and CE-06.

3.3 Barriers in safety program implementation

When the interview participants were asked about barriers in implementing safety policies and programs, four barriers were put forward: complacency, multi-sociocultural characteristic, lack of safety commitment, and resistance to change. First, in relation to complacency, management must acknowledge the fact that workers will cut corners, take shortcuts, get distracted, and make mistakes no matter how perfect the safety management system is. Therefore, it is important to scrutinise the system to help minimise those mistakes in critical times. The key steps, from the safety perspective, should be determined. If workers tend to make mistakes at a particular step, then the risks should be properly identified and the right controls be put in place. This is not about writing more statement or contents in the work instructions or project plan; it is about understanding the workforce. For example, 'if the workers are doing shortcuts because they want to be home at 5.30pm to watch a sport match, then the managers need to acknowledge this fact and adjust their plan to eliminate safety risks of rushing with work in late afternoon' (HSEM-08).

The second barrier is the multi-cultural characteristic of the Australian construction industry and the diverse backgrounds of construction workforce. An interview participant (CAM-01) gave a simple, but intriguing example on how a simple question 'do you understand?' can cause miscommunication, which may lead to a bigger problem. In responding to this question, when individuals from a certain culture say 'yes', it means 'yes, they understand'. On the other hand, for individuals from another culture, they may say 'yes' because of politeness, whilst in reality they actually do not understand or only understand partially. Furthermore, cultural background also influences how people develop certain values or concepts in regards to safety. Interviewee CM-05 highlighted that Australians are risk-taking people who have a belief that encourages them to trust themselves and take risks. This belief may make them over confident and do unnecessary risk-taking behaviours.

The third barrier is poor safety commitment from senior management and client. Many construction practitioners still focus on traditional project objectives like time and cost instead of safety. Even senior managers are also susceptible to this traditional mindset in their leadership and operation. They may say that they are committed to safety, but during tough times they 'overlook' safety and strive to gain as much profit as possible from the project. Clients are also responsible in creating a work environment that sets safety aside. In many cases, cost is the main factor that determines which company would win tenders, a condition that is particularly prevalent in government projects. Without the support and commitment from the clients, it is difficult for construction organisations to uphold safety whilst attaining time and cost objectives (PM-02, HSEM-03, SM-07).

The fourth barrier, which is also related to human characteristic, is the resistance to change. People, who have been in the industry for many years, believe that they 'know' how to work and do not like to change. They tend to resist new things that they do not understand. Although some may realise that there is a better and safer way to work, but since they have done it in a certain way for a long time, it is hard for them to change.

3.4 Removing the barriers and rectifying the misalignment

This research has identified several strategies for removing the barriers and rectifying the misalignment, including top management commitment, safety learning and safety skill development, and each of these strategies is discussed in details in the following sections.

3.4.1 Top management commitment

In order to rectify this misalignment, there is a basic factor that should be focused upon, that is, management commitment. Safety policy and program/system implementation must flow in a top down manner because top management is the one who has the authority to establish safety budget and enforce safety implementation throughout the organisation. Senior managers should be committed and accountable to safety by doing the talking, i.e., they should consider 'safety first'. By demonstrating such commitment, they become the initiator for fostering a strong safety culture in the organisation (PM-02, HSEM-03, CM-05, HSEM-08).

3.4.2 Safety learning

The interview participants explained how their organisations provide safety training and learning for implementing standard safety measures to maintain and improve safety performance. Initially, they train everyone to a minimum standard, for example, by using the Safety White Card Course, which has been mandated in Australia, requiring individuals to complete the course before they can undertake any construction activities. Passing this course, therefore, can be considered as a common denominator and an indication of basic safety competence in the Australian construction industry. Achieving this minimum requirement is far from sufficient for construction organisations who aspire to uphold safety as one of their priorities and project objectives. Consequently, they 'upgrade' their personnel's safety knowledge by authorising regular safety training, safety induction to explain work hazards, and a daily tool box talk at the start of the day.

However, there is an issue concerning the ineffectiveness of the current safety training programs. A study has shown that a classroom-like training setting only has short-term impacts on safety performance and that workers tend to forget what they have learnt and as a result safety performance returns to where it was before (Laukkanen, 1999). Learning is clearly necessary for construction practitioners, especially workers, to perform their work safely. This learning is fundamental for maintaining and improving safety performance in the construction industry. However, although organisational learning and knowledge management have been widely implemented, current practices seem to have overlooked the problems and complexities of knowledge making and learning process (Styhre, 2006).

In many cases, learning was seen as an acquisition of knowledge which can be accomplished through classroom instruction and training. This view of learning considers that knowledge can be easily transferred from one medium to the minds of learners (Gherardi and Nicolini, 2000, 2002). From this perspective, learning is mainly focused on its outcomes and very much taken as a "given". This view sees learning as being achieved by simply plucking an item from the tree of knowledge (Tsoukas and Mylonopoulos, 2004). Many educational and training methods adopt a philosophy that views learning as a product or on-the-shelf solution that can be simply added to the mind or readily stored and transmitted via some kind of electronic technology (Hager, 2004). Consequently, much organisational learning literature and many studies are concerned with the potential to codify, package, and disseminate knowledge throughout organisations and workplaces. Although this approach may seem to be practical and straightforward, it is important to realise that learning does not comprise a technological device aimed at capturing, processing, storing, and disseminating data and information, but is situated in local practices where people collaborate and cooperate to solve daily issues (Styhre, 2006). From this perspective, safety should be considered as the final outcome of a collective construction process. A safe workplace, therefore, is the result of constant engineering of diverse elements, e.g., skills, materials, interpersonal interactions, which are integral to the work practices of various project stakeholders. In other words, learning about safety involves taking part in the social world, i.e., learning takes place among and through others. Knowledge is integrated and distributed in everyday activities, and so learning cannot take place if participation in those activities is not possible (Gherardi and Nicolini, 2002).

Although the importance and necessity of existing safety training programs is undeniable, learning should not only be seen as a product, but also a process where the learner is part of the environment (Hager, 2004). Rather than solely depending on 'arm's length' methods, there is a need to use approaches to safety learning that are more collaborative, and which prioritise dialogue and practical problem solving (Bluff, 2011). Aligning with this view, some interview participants (CAM-01, PE-04, CM-05, SM-07, and HSEM-08) voiced the need to have a kind of on-the-job training and informal training/learning for safety. On-the-job training is flexible and relevant to what people do in the organisation. It is a type of training in which an experienced employee adopts or mentors a new employee to teach him or her how to perform job duties (Samson and Daft, 2009). Informal training, on the other hand, occurs through interactions and feedback among employees as a result of a learning need in the context of working. Much of what people know about their jobs they learn informally from asking questions and getting advice from other employees and their supervisors, rather than from formal training programs. Informal training may involve group problem solving, job shadowing, coaching, or mentoring (Mathis and Jackson, 2011). As shown previously, a great deal of safety learning occurs informally, thus construction organisations should be able to harvest the advantages of informal learning by developing a work environment that promotes such learning. Having argued the importance of informal training, construction organisations should also make sure that the correct learning contents are used and exchanged during the learning process. Unsafe habits, shortcuts, and ways to bypass regulations, for example, are not learning experience that organisations want to nurture. Therefore, the correct culture of safety has to be developed first and become the basis of both on-the-job and informal trainings.

3.4.3 Developing project leaders' safety skills

It is fair to say that the safety implementation barriers identified are related to human factors. As such, there is a need for project leaders to improve their skills to manage these factors. Research has found that self-awareness, visioning, and apparent sincerity are the foundational skills. They are precursors of scoping and integration, and self-management, which are the first-tier mediator skills. Thereafter, the second-tier mediator skills are social awareness, social astuteness, and relationship management (Zou and Sunindijo, 2012). Five of these skills are discussed below.

Self-awareness is the first foundational skill because when people are aware of their values, strengths, and weaknesses, it will affect the way they manage themselves (self-management) which will also be reflected on their actions. These actions, subsequently, will impact on the quality of relationships they build with others, which eventually determine their leadership effectiveness (HSEM-03 and CM-05). Previous studies also found that self-awareness is the core and starting point of self-management, relationship management, and effective leadership (Goleman, 2001).

Visioning, as the second foundational skill, is closely related to goal setting, both personal and organisational goals. In the context of this present research, safety should be part of the overall vision in which zero harm set as one of the key project objectives (PM-02). A maxim which says 'what you see is what you get' cannot be any truer in relation to this concept of visioning (HSEM-03, CM-05, and HSEM-08). Another important consideration about visioning is that the goals must be achievable and clearly expressed (CE-06). This is the basis to motivate and inspire people by providing meaning and challenge to their work (Samson and Daft, 2009). Visioning helps project leaders establish scope and integrate safety into specific goals and expectations, which align with the capability of the human resource and the organisation in general. When a goal is beyond the capacity of the organisation, the goal would simply be nice words on a paper without any realisation in practice (CE-06).

Apparent sincerity, the third foundational skill, is needed to create positive first impressions, which is important in every socialisation process. First impressions are crucial in any relationship because they are lasting and influence the way people see subsequent data about the perceived object or person. Therefore, project leaders need to appear sincere and create a first impression which conveys that they are genuinely interested in the effective management of safety risks and improvement of safety performance. In addition, apparent sincerity is needed to communicate safety vision effectively because project leaders have to cultivate trust first before influencing people to accept the vision. As a consequence of this, other project stakeholders will recognise the importance of safety and project leaders will have a positive start on influencing the others to consider safety as equally important as other project objectives.

Social awareness and social astuteness are also important skills for understanding people and remove barriers that hinder safety program implementation and improvement as explained by interviewees CAM-01, PM-02, and SM-07. The multi-stakeholder characteristic

of construction projects and the diverse backgrounds of construction workforce make these skills crucial for project management personnel to communicate effectively, build trust, and embed safety values in others. Completing a project is about getting work done through others. Without the ability to understand people, it is difficult to relate to others and get work done through them. The temporary nature of construction projects and the involvement of multiple stakeholders also limit the luxury of gradually building long-term relationships with the team. As a result, project leaders have to be able to quickly and accurately read and understand the others involved in the project execution to develop trust and productive relationships for achieving project success.

4. Conclusion

Figure 1 summarises the issues and factors that have been discussed in this paper. There is misalignment in safety implementation between top/senior management, supervisory, and worker levels caused by differences in knowledge, experience, perceptions on the importance of safety, and poor safety training programs. Rectifying this misalignment requires project leaders and senior managers, as well as frontline workers to modify their safety learning approach. Safety learning and knowledge development should depend not only on classroom-structured approach, but also on a realisation that safety learning occurs in practice through interactions with artefacts and people at work. Safety learning requires active participation of the learner in the real project execution context.

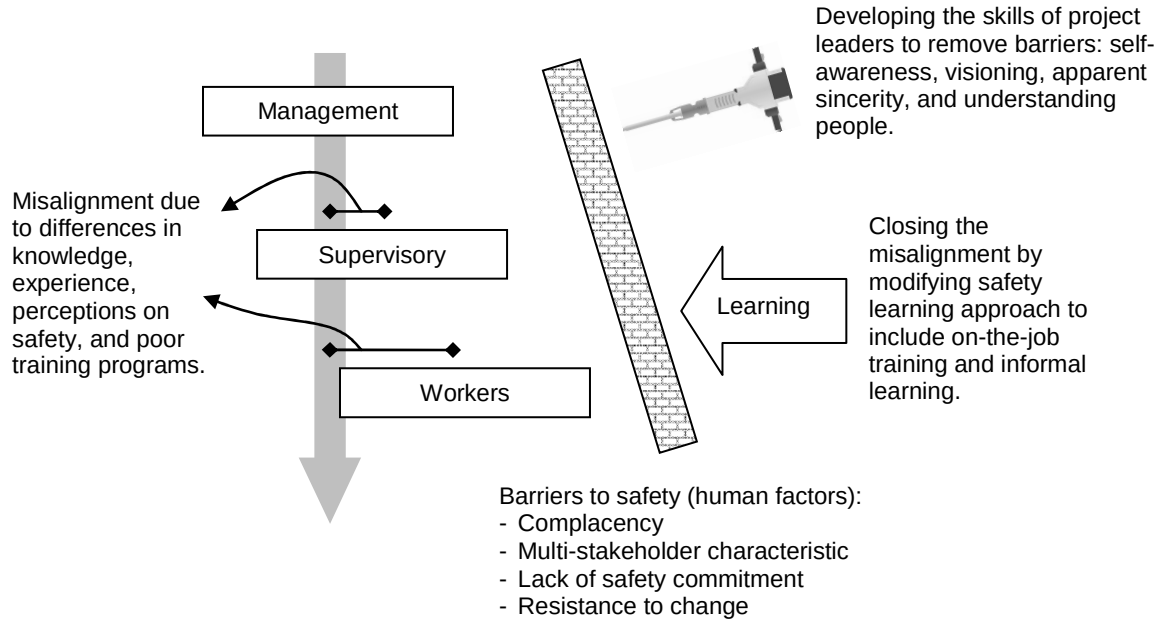

Figure 1: Rectifying the misalignment and removing the barriers in safety implementation

Such approach, however, will not be successful without removing the existing human factors barriers that hinder safety implementation. Removing these barriers requires project leaders

to develop their skills which include aspects of self-awareness, visioning, apparent sincerity, and social astuteness and social awareness to understand people.

Future research should aim at developing assessment instrument and learning strategies for project leaders to develop their skills for safety. At the worker level, construction organisations need to find ways to promote the effectiveness of their on-the-job safety training and informal safety learning process, that will improve workers mental model, attitude and technical skills in recognising safety risk and mitigate the risks by developing and implementing safe work methods and behaviour.

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Carrot and stick – how to reduce the amount of defects in Danish construction

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Abstract

Defects are considered a lack of product quality and represent an economic loss. Since 1986, systems or initiatives applying a carrot-or-stick approach have been implemented in the Danish construction sector to improve the quality of buildings. The initiatives range from mandatory solutions to more or less voluntary benchmarking or insurance-based systems aimed at specific sub-sectors.

Based on a literature review including web-pages the different systems and initiatives are presented. The different approaches and some of the fundamentals or institutional settings in which these systems operate are discussed.

Insurance-based mandatory systems for social housing and urban renewal introduced around 1990 showed remarkable reduction in the volume of defects, but when more or less voluntary systems were introduced for single-family houses a similar success was not seen. This is explained by too little information about the cost-benefit and the easy access to avoid taking out an insurance policy. Mandatory systems seem to be preferable, depending on the target group and the institutional settings.

Since 2009, authorities no longer examine the project documentation when issuing building permissions for smaller buildings. Together with the more performance-based Building Regulations this is criticized for favouring large contractors. The amount of requirements that companies must fulfil should be put against the risk of excluding small contractors, without knowing whether smaller contractors construct houses with lower quality.

Keywords: Defects, construction sector, carrot-or-stick approach, cost-benefit, performance-based requirements

1. Introduction

For several years the lack of quality and the volume of defects in the construction sector have been issues for debate in Denmark. Since 1971 when the law concerning governmental building projects was adopted, building projects for the Danish Government

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have to be carried out in the economically most advantageous way with consideration to their planned use and future operation (Ministry of Housing, 1971).

For a short period in the 1960s and 1970s when many large industrialised housing projects were constructed, completely horisontal roofs became popular in Denmark. Unfortunately, the roofing materials were not durable for completely flat roofs, and many roofs leaked. This resulted in expensive renovation projects which in 1986 in turn initiated an announcement and guidance on quality assurance in construction that counts for governmental and publicly subsidised building projects (National Building Agency, 1986a, 1986b).

The announcement was based on the expectation that preventing damage and defects is less expensive than doing repairs, for the society as a whole as well as for the construction sector. The period of liability was harmonised to 5 years for consulting engineers, contractors and suppliers, instead of 5, 20 and 1 year, which had resulted in differing incentives to ensure the quality. With the quality assurance reform, the Building Defects Fund (for social housing) (BDF) and the Building Damage Fund for Urban Renewal (BvB) were introduced in 1986 and 1990.

In spite of the reform in 1986, the Danish construction sector was repeatedly criticised in the press and in government reports during the 1990s for its apparent lack of efficiency and quality of work. Therefore, the Benchmark Centre for the Danish Construction Sector (BEC) was established in 2002 to run a benchmarking scheme with key performance indicators with the aim of improving quality and efficiency within the construction sector for the building process and the completed building (Danish Trade Promotion Authority, 2000).

In 2002, costs related to defects were estimated at about 10 % of the annual turnover in the Danish construction sector (Danish Enterprise and Housing Authority, 2004), which the Minister of Economy and Enterprise wanted to reduce by 50 % by the year 2008. A Danish index of defects based on six different sources including BDF, BvB and BEC was developed to measure whether this could be achieved (Nielsen and de Place Hansen, 2007), including data going back to 2001. The index showed a marked reduction in defects in 2001-2005, but the economic boom in the construction sector in 2004-2008 slowed down the reduction after 2005. It still remains to be seen, whether the financial crisis and the derived lower and less hectic activity in the construction sector have reduced the volume of defects.

Parallel with the initiatives launched since 1971 related to quality and defects, the Danish Building Regulations (DBR) has since 1961 gradually become less specific and more performance-based (Ministry of Housing, 1961). DBR sets minimum requirements for the performance of buildings, i.e. accessibility, structures, fire safety, indoor climate, energy performance and building services (Danish Enterprise and Construction Authority, 2010).

Performance-based requirements promote innovation of new design and new ways of constructing buildings, makes the aim of a specific requirement visible and clarifies the client’s responsibility. However, the majority of building projects are relatively simple, e.g. construction or renovation of single-family houses, and often involves a non-professional client and small contractors but no architect or consulting engineer. It is discussed, whether

a development towards performance-based requirements is preferable for such buildings as non-professional clients need guidance to handle these. Often they prefer specific requirements that explain in detail what to do. Therefore, in 1985-2008 construction and renovation of single-family houses were regulated by specific Building Regulations (National Building Agency, 1985; Ministry of Housing, 1998) as many of the provisions in the general DBR were not relevant for these types of buildings.

2. Systems implemented in the Danish construction sector

Governmental building or social housing projects were often the first to be included by the systems implemented in the Danish construction sector to improve the quality of buildings applying the carrot-or-stick approach. These types of projects were the simplest to regulate and it was expected that it could motivate the construction sector in general to take similar initiatives on their own. Systems implemented in Denmark to improve the quality of buildings and discussed in this paper are summarised in Table 1. They also include more or less voluntary benchmarking systems and insurance-based systems for private housing projects.

Table 1: Characteristics of systems intended to improve the quality of buildings

System	Building Defects Fund (BDF)	Building Damage Fund for Urban Renewal (BvB)	Benchmark Centre for the Danish Construction Sector (BEC)	Insurance at sale of private housing projects (HIS)	Insurance of new private housing projects (BIS)
Year of introduction	1986	1990	2002	1995	2008
Coverage	Social housing	Publicly subsidised renovation	All types of building projects	Private housing	Private housing
Target group	Government and the construction sector	Government and the construction sector	Contractors and consulting engineers	Consumers	Consumers
Building inspection	After 1 and 5 year	After 1 and 5 year	At hand-over	At sale	After 1 and 5 year
Coverage period	20 years	20 years	Running	5 – 10 years	10 years
Financing	Payment of the construction cost	Payment of the renewal cost	Service charge (differentiated)	Insurance premium	Insurance premium
Access to data	Public	Restricted*	Restricted **	Seller and buyer	Client and buyer
Mandatory or voluntary	Mandatory	Mandatory	Mandatory when bidding for governmental projects	Voluntary	Mandatory except when buyer acts as client

*: Will be public in the future.

**: Public if the company gives permission.

2.1 Building Defects Fund (BDF)

The Building Defects Fund (BDF) was introduced in 1986 as a mandatory insurance-based system for social housing projects. The responsibilities are: 1) To carry out building inspections one and five years after the completion of the building, 2) To give financial

support for the repair of building damage, and 3) To communicate findings and experience to the construction sector with the purpose of preventing future building damage.

The Fund covers 95 % of the costs of the repair of significant building damage claims for the first 20 years after construction. Deficiencies are not covered. The Fund's expenses are covered by the payments of 1 % of the total construction cost from every housing scheme, paid by the client, a social housing association. The building inspections focus on those parts of the building where by experience defects and damage occur that have the largest consequences or the majority of the defects arise. They are solely made by companies who have experience of social housing projects, while the evaluation of the inspections is made by the Fund's own experts to ensure a uniform assessment.

Since the introduction of BDF in 1986, the volume of defects in social housing projects was greatly reduced; from defects in 36 % of the projects built from 1987 to 1992 to 4 % in the projects built from 2001 to 2011 (Building Defects Fund, 2012). Since July 2011, the Fund covers not only new social housing projects, but also major renovation of such buildings, if the renovation leads to improvement or modernisation of the buildings.

2.2 Building Damage Fund for Urban Renewal (BvB)

The Building Damage Fund for Urban Renewal (BvB) was established in 1990 as a mandatory insurance-based system parallel to BDF to prevent damage and other problems in the building process in publicly subsidised urban renewal projects. The Fund has four responsibilities stipulated by the law: 1) To support the repair of building damage, 2) To inspect the renovated buildings one and five years after the completion of the renovation, 3) To communicate the findings and knowledge concerning the prevention of future building damage to the construction sector, and 4) To participate in other activities that can improve and promote quality and efficiency in construction.

The Fund's expenses are covered by the payments of 1.5 % of the total renewal costs, paid by the municipality for buildings that have received a subsidy for renovation. In return, the Fund provides the building owners the right to compensation for up to 95 % of the costs of the repair of substantial building damage until 20 years after the renovation. Like BDF, BvB operates with a separation of inspection and evaluation.

Since the first inspections made by BvB in 1995, significant building damage and defects have decreased from about 8 % of the projects inspected in 1995 to less than 3 % of the projects inspected from 2006 to 2011 (Building Damage Fund for Urban Renewal, 2012).

2.3 Benchmark Centre for the Danish Construction Sector (BEC)

Established in 2002 as a private business foundation, the Benchmark Centre for the Danish Construction Sector (BEC) relies strongly on a government announcement stating that all contractors with more than 10 employees since Jan 1, 2005 must submit key performance indicators (KPI's) based on at least three previous building projects to qualify for government building projects with a contract sum of more than DKK 5 million (EUR 0.7 million) (Danish

Enterprise and Housing Authority, 2003). Contractors also have to deliver KPI's for the specific building project at hand-over and at the inspection one year after hand-over, including quality, expressed by the number of deficiencies at hand-over per DKK 1 million. The contractor himself chooses whether the KPI's should be public or not. Since September 2008, contractors also must submit KPI's to qualify for social housing projects (Ministry of Social Affairs, 2007). These are administered by the Building Defects Fund.

The number of deficiencies at hand-over per DKK 1 million in government building projects rose substantial from 2004 to 2007 but have since decreased to well below the level from 2004 (Danish Enterprise and Construction Authority, 2011). For social housing projects, it is too early to conclude on the effect of KPI's on the quality.

2.4 Insurance-based systems for private housing projects

Two insurance-based systems exist for private housing projects in Denmark, at sale or at construction. Both systems focus on giving the consumer protection rather than communicating findings as this is difficult to do in a simple way, especially for houses at their sale as they are of different age and renovation or extension have taken place at different times. Therefore, the success of these systems is measured in the number of insurance policies, year by year, rather than the volume of defects as used by BDF and BvB.

2.4.1 Insurance at sale (House Inspection System, HIS)

Since 1995, the seller of a house could be insured against claims from the buyer by requesting an offer for insurance, based on an inspection documented in a Home Condition Report made by a building expert (Ministry of Justice, 1995). The seller pays for the Home Condition Report and if the buyer accepts the offer, the insurance premium is split between seller and buyer. By using HIS, the seller is freed from a 20-year responsibility for damage and defects no matter whether buyer chooses to accept the insurance offer or not. For 5 or 10 years the insurance covers defects and deficiencies that are not mentioned in the Home Condition Report, which typically costs between DKK 7000 and DKK 14000. The building inspection is visual with the option of using simple hand-held instruments, if relevant, but with no destructive measures allowed.

The insurance is voluntary but about 10 years after the introduction of HIS, an insurance policy is taken out in about 90 % of all cases involving single-family houses (Realdania, 2006). However, in multi-storey housing estates (flats) insurance is taken out in less than 10 % of the cases as this involves both an inspection of the building or estate as a whole and an inspection of the specific flat, which would be very costly.

2.4.2 Insurance of new houses (Building Insurance System, BIS)

In 2008 an insurance-based system for new private housing projects was introduced (Ministry of Economy and Enterprise, 2007), based on the remarkable effect of BDF and the fact that there had been cases where it was impossible to get a client to pay for substantial defects and damage arised during the construction of a house. The insurance should cover

such defects and damage. The client should pay the insurance premium, which in average is about 1.3 % of the construction cost (Danish Energy Agency, 2012), compared with 1.5 % as assumed when the bill was put forward in the Danish Parliament based on the level of the payment for BDF (1 %) and BvB (1.5 %). However, opposed to BDF and BvB, BIS solely cover defects and damage that stems from the construction, not those that arise afterwards.

If the buyer of the house declares that he is the client building the house for his own use, he is not forced to take out an insurance policy. This rule is mainly to avoid too expensive houses and maybe reducing the number of houses built. In 2009, 2010, 2011 and the first six months of 2012, insurance policies were taken out in 26 %, 48 %, 58 % and 69 % of the cases (Danish Energy Agency, 2012). Insured houses were found to have severe defects in 8 % of all cases but it was twice as high in houses without insurance (BYG-TEK, 2011). An increasing number of consumers to seem have realised that damage and defects can be very costly and that it will be harder to sell a house without insurance. Given that insurance policies were expected to be taken out in 85 % of all cases there is still room for improvement.

3. Performance-based building regulations

Parallel with the different systems implemented in the Danish construction sector to improve quality and reduce the amount of defects the DBR has become gradually more performance-based. And since Jan 1, 2009 authorities no longer examine the documentation of constructional elements when issuing building permissions for single-family houses (detached or joined). Both changes have been criticized for favouring large contractors; performance-based requirements increase the need for guidance, i.e. the amount of documents that the companies in the construction sector are expected to know increases. And the lapse of examination leaves out the possibility of consulting the authorities when applying for a building permit.

3.1 Guidance dealing with moisture in the construction phase

As an example of performance-based requirements, DBR has since 2008 stipulated that building structures and materials should not, on moving in, have a moisture content that is liable to increase the risk of mould growth (Danish Enterprise and Construction Authority, 2008). This requirement minimises the risk of moving into overly damp buildings and the risk of mould growth, in both new buildings and renovation projects and is related to the rising number of cases with mould growth in buildings in Denmark.

The authorities have the possibility of requiring measurements or other types of documentation provided by a moisture specialist to verify compliance with the requirements. However, not until 2011 was a guideline introduced to help the client comply with the requirements and the intentions in DBR concerning dealing with moisture at each stage of the building process (Møller, 2010). This includes the categorisation of a specific building in a humidity risk class, as the risk of moisture damage is related both to the expected exposure to moisture during the construction phase and the building's susceptibility to moisture.

3.2 Examination of documentation of building projects

Since 2009, building owners decide what kind of project documentation is important when constructing single-family houses. The documentation is not examined by the authorities unless a problem arises. It was done to move resources in the municipalities to the larger and presumably more complicated building projects. It was criticised for resulting in smaller buildings that were worse documented than before; at least that was the expected result. It was implemented shortly after the introduction of the requirements concerning moisture in the construction phase and before the appurtenant guidance was prepared.

Concurrent, the municipalities no longer had the possibility of requiring documentation of moisture content at hand-over. This explains why documentation of moisture content was non-existing for single-family housing projects (de Place Hansen and Aagaard, 2013), although it was mentioned as part of the appropriate documentation that the client should deliver to the municipality when he notified the completion of the building project (de Place Hansen, 2010).

4. Discussion

Based on the presentation of the systems and initiatives implemented in the Danish construction sector and DBR to reduce the volume of damage and defects, the following issues are discussed:

- Are mandatory or voluntary systems preferable?
- Have systems aimed at protecting the consumer been a success, and if not why?
- Have the systems and initiatives favoured large contractors and companies manufacturing standard houses?
- Are performance-based requirements preferable to document standard of buildings?

4.1 Mandatory or voluntary systems

As opposed to the availability of data from BDF, BvB and BEC, no kind of communication of data from BIS – not even generic – takes place, presumably because minimisation of costs was given high priority. This makes it impossible to evaluate the effect of BIS as opposed to the other systems. However, compared with the number of single-family houses built since 2008, very few inspections are made after one year. A majority of single-family houses are made by companies manufacturing standard houses and only a few of a specific type are inspected, even if they are built at different places around the country (Møller, 2012).

So why not make BIS mandatory like BDF and BvB as they have been successful in reducing the volume of damage and defects? As the housing projects covered by BDF and BvB are publicly subsidised, a mandatory system is reasonable in order to ensure that public resources are spent most economically. But it can be argued that a consumer constructing his own house should have the option of choosing whether to take out an insurance policy or not like he has the option of choosing whether he wants to insure his household goods.

BEC deviates from the other systems by focusing on the track-record of the contractor. This can explain why it is used not only by the primary target group as several contractors have voluntarily submitted KPI's to BEC without bidding for either government or social housing projects. Instead, they use the KPI's as a way to profile the company in the construction sector in general. A similar effect is seen when some manufacturers of standard houses add information about how to handle moisture during construction and documentation of the moisture conditions at hand-over even though they are not required to do so.

Therefore, both mandatory and voluntary systems could be relevant, depending on the settings and the target group. The question is rather whether the system is working or not in terms of reducing the volume of defects or ensuring that the owner is covered if building damage and defects detected at inspection can be ascribed to the construction phase.

4.2 Problems with systems aimed at protecting the consumer

Two types of problems with BIS have been detected since the introduction in 2008. First of all, the possibility of avoiding insurance was misused by some contractors, as they made the buyer declare that he was the client, building for his own use, although the real client was the contractor. The main argument was that the buyer would save money but of course it could also make the offer from the contractor more attractive, increasing his chances of being chosen to build the house. This "solution" was widely used mainly in the first years after the introduction of BIS, explaining the low number of insured houses.

In 2010, it was emphasised in DBR that a municipality has the responsibility to ask the client to document that he did take out an insurance policy (Danish Enterprise and Construction Authority, 2010). If not, the housing project cannot be registered as completed by the authorities, apart from those cases where the client built the house for his own use. The increasing number of insured houses year by year and the authorities' reluctance to force price-raising steps on private housing projects is probably the reason for not making the system mandatory in all cases, as concluded in (Danish Energy Agency, 2012).

Secondly, the client may wait to take out an insurance policy until just before completing the project. This is a problem if the client, e.g. a contractor, goes bankrupt; one of the main reasons for introducing the system in 2008. In the future it will be registered in the Building and Housing Register that the house is not insured and why (Danish Energy Agency, 2012) in order to ensure that the owner is not put in a bad position when he wants to sell his house.

Neither the system aimed at houses at sale (HIS) was regarded as bullet-proof by the consumers. For several years 45 % of all claims were rejected by the insurance companies (Realdania, 2006). The consumers believed that the insurance covered all damage and defects not mentioned in the Home Condition Report; however it does not cover damage and defects that are common for a house of a specific type and age. For instance, that a house from the 1930s often has a damp cellar. Therefore a revision of the system in 2012 focused on giving the consumer more information on potential damage and more information about what is covered (Ministry of Housing, Urban and Rural Affairs, 2012). For houses that are built after the introduction of BIS in 2008, it is also planned to add information in the

Home Condition Report about whether an insurance policy referring to BIS was taken out, and if not then why (Danish Energy Agency, 2012).

The problems with the implementation of BIS and HIS show that a bullet-proof system in the sense of protecting the consumer against unwanted costs related to damage and defects including information about the cost-benefit is vital for a voluntary system to be a success.

4.3 Systems and Building Regulations favouring large contractors

Besides of the debate about the protection of the consumers it is discussed whether BIS has favoured large contractors and companies manufacturing standard houses (Nørgård, 2012; Danish Energy Agency, 2012; Erhvervsbladet, 2008). Large, consolidated contractors that can document that they have a well-functioning quality assurance system and experience of the most common building systems will be offered a lower insurance premium than a small, less consolidated contractor with less documented quality assurance. The average BIS insurance premium (1.3 %) is at the same level as for the mandatory systems BDF and BvB, but in some cases the size of the insurance premium made it difficult for smaller contractors to compete. A task force was established in 2012 to investigate whether the setup of the insurance-based system gives the large contractors an advantage at the expense of the small contractors and whether the examples of very high insurance premiums are exceptional or typical (Nørgård, 2012; Danish Energy Agency, 2012).

The development towards more performance-based building regulations and the increasing demands for documentation are also criticised for favouring larger contractors. An investigation concerning the documentation of building projects (de Place Hansen and Aagaard, 2012) showed that the amount of houses that involved a company manufacturing standard houses increased significantly from 2008 to 2010. Why this is the case is not documented, but a reasonable explanation could be the economic development, resulting in a 67 % reduction in the number of constructed single-family houses from 2008 to 2010, which indicates that consumers tend to choose “safe solutions” when the economy is tight.

The higher amount of projects involving companies manufacturing standard houses also resulted in a significantly higher amount and average quality of the documentation in 2010 compared with 2008 as the amount and the average quality of the documentation in general was higher for standard house projects. This shows that strict control like in 2008 not necessarily gives the best-documented houses. It was not investigated whether the termination of examination has had any consequence for the quality of the house itself as only the documentation was studied.

Both HIS and the more performance-based building regulations indicate that large contractors and companies manufacturing standard houses are favoured. Of course this could be an underlying purpose but it presupposes that houses constructed by smaller contractors contain the most defects. However, the knowledge of the quality of private houses, opposed to social housing or governmental projects is very scarce, as there is no collection of data in BIS and HIS opposed to BDF, BvB and BEC.

4.4 Documentation of standard using performance-based requirements

With (more) performance-based building regulations there will be less focus on compliance with measurable requirements, e.g. a specific minimum ceiling height or a specific minimum sound insulation. However, with performance-based requirements it is difficult to document that a specific house is constructed with a higher standard than stipulated by the DBR, which is relevant for instance when the house is put up for sale. Such levels of standards exist in Denmark but only for some of the properties included in the Building Regulations, e.g. for sound insulation, structures and energy performance.

Therefore, performance-based requirements should be followed by recommendations for the levels of standard, where each step represents a marked increase in standard. Such recommendations were introduced in 2008 for some of the subjects included in DBR as the specific Building Regulations for single-family houses ceased to exist (Dela Stang, 2008).

5. Conclusion

The main findings of this study were:

- Mandatory systems seem to be preferable, depending on the target group and the institutional settings. Mandatory systems based on KPI's may be attractive to use for other companies than the target group depending on the cost benefit

- Thorough information directed at the target group is crucial for a voluntary insurance-based system to succeed

- The setup of systems and the amount of requirements that companies must fulfil should be put against the risk of excluding small contractors, without knowing whether smaller contractors construct houses with lower quality

- The increasing use of performance-based requirements in the building regulations highlights the need for recommendations for levels of standard and for communication about the experience with building materials and systems.

Whether carrot-or-stick approach is applied or not, systems that aims at reducing the volume of defects and increase the quality will be necessary in the future with the continuous development of the Building Regulations stipulating higher – and may be novel – requirements to the performance of buildings.

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Façade Assessment Procedure for the Evaluation of Durability of Existing Buildings

Bruno Daniotti[1], Silvia Erba[2], Elisabetta Rosina[3]

Abstract

The aim of the research is the development and application of a method for the assessment of durability and environmental impacts in the context of sustainable construction with regard to existing buildings. The method is based on the evaluation of the residual service life which, carried out through non-destructive surveys and laboratory tests, assesses the damage of the buildings envelope and its energy efficiency, correlating the level of degradation to residual performances. This analysis will be followed by maintenance planning and life cycle assessment concerning sustainability. In the case of historical buildings the analysis, together with specific surveys and documentation, allow to design a preventive preservation plan in order to avoid further damage and risk factors.

The method has a direct experimental application within the project "Città Studi: Sustainable Campus", which has the aim to transform the university quarter in Milan into an exemplar campus with respect to life quality and environmental sustainability. In particular the paper will report about the recovery-requalification of existing buildings of Politecnico di Milano at Leonardo Campus, which are nowadays under investigation/study through visual inspections, imaging diagnostic, and especially, IR Thermography. The case study deals with both the issue of repairing and increasing energy efficiency, considering durability and management of buildings, and the cultural issue of preserving masterpieces of the contemporary architecture, since many of the buildings under investigation have the famous architect Giò Ponti as author.

Keywords: sustainability, diagnostic, durability, IR Thermography, planned conservation

1. Introduction

The integration of environmental balances, within the processes of assessment and definition of the design choices, is essential towards the goals of a *sustainable* intervention; the *life cycle* approach is fundamental in order to determine the performances criteria which are necessary for an environmental critical analysis of the whole building. The search of a

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methodological formulation is unavoidable from a consideration of *durability* aspects, based on service life data of components, which represents the starting point for the development of an *analytical method*, to be applied on a representative sample of buildings.

As part of a project dedicated to the identification and enhancement of the application of service life information in the context of sustainable constructions, this paper focuses on the first part of the research, i.e. the determination of the present damage state necessary for the evaluation of *residual service life* of components belonging to the external envelope of existing buildings, including the listed ones. Within the standards framework, the ISO 15686 – Buildings and constructed assets. Service life planning – defines *service life* as the period of time after installation during which a building or its parts meets or exceeds the performances requirements upper or equal to the accepted limits [1] [2].

For existing buildings and components must be taken into account the *residual service life,* defined as the service life remaining after a certain moment of consideration. To assess residual service life of an inspected building or component is important to know its history, i.e. data on the original performance values, information on the installation, maintenance, trend of deterioration, etc., which can involve several difficulties to be obtained. During the process of assessment of the residual service life of the existing building/component, must be planned that during the remaining service life the performance levels will be maintained equal or higher to accepted limits, taking into account *sustainability* aspects and *maintenance plans* [3].

In the case of monuments, life-cycle assessment offers a holistic method for comparing the costs of renovation against maintenance and in the case of historic buildings the economic advantages of conserving existing finishing, support also the planned conservation strategy [4].

As case studies, the research takes into account some buildings inside Campus Leonardo of Politecnico di Milano, where nowadays it’s in progress a project of revitalization and transformation of the university quarter Città Studi into an exemplar campus with respect to life quality and environmental sustainability. As a matter of fact since 2010 an articulate and widespread research has been developing at Politecnico of Milano and State University of Milan, titled “Sustainable Campus Leonardo”. Focus of the research is to involve the scientists employed at Politecnico and at State University of Milan on the study, analysis, survey, assessment, management, repair, enhancement of the university’s campus in the eastern area of Milano.

The buildings under study are characterized by the presence of cladding systems with ceramic tiles, popular practice in Italy since the 50-60s, due to their good wear resistance, high temperatures stability, hardness, tenacity and inertia. Besides the durability of the ceramic materials, their low cost, stainless and apparently low sensitivity to the effects of pollution and finally the low requirement for maintenance are some of the reasons of their diffused application in the middle-southern region of Europe, as an effective alternative to brick faced masonry, timber cladding and stucco [5]. Nowadays, after 50 years of usage, the façades present degradations problems on materials and systems, such as detachments,

missing tiles and discoloration, due to the action of atmospheric agents, to the loss of adherence between the support and the tile or among the layers of the support, to the absence of a correct maintenance [6].

Among these research lines, the authors developed a methodology to assess the state of conservation of the facades, especially ceramic finishing [7]. In the paper it's shown the improvement in the field of diagnostic and preliminary tests, in particular non-destructive surveys through IR Thermography, based on the solution of the mathematical model of heat transfer in the ceramic medium. The preliminary tests had their validation by softly hammering both the detached area and the "safe" one: the different sounds of hammering revealed the detachment of the finishing.

The experimental application has been performed on historical buildings among which some were designed by one of the most famous architect of 50-80's, Gio' Ponti, who realized these buildings with contemporary techniques and materials. For this reason the assessment of façades in Campus Leonardo is an important issue both for economical aspects related to the costs of maintenance and usage of the most advanced techniques, and for the project of repair that deals with contemporary buildings having high historical-artistic value.

From this side, the critical point is to preserve the authenticity of a building. It is unanimously accepted in the current debate on restoration of historical building that the repair should be clearly identified, although it should not affect the aesthetical unit of the work of art, and that a "mimetic" solution, with the substitution of materials and elements with new ones "a l'identique" is a banned practice since the third decade of the 20° century. Therefore it rises up the need to limit as much as possible the substitution, preventing the damage by reducing the risk factors (environment, building techniques, use, lack of maintenance, etc.) and by means of a plan of conservation. This is inevitably linked with a life cycle assessment of the building which keeps into account the durability aspects aimed at the evaluation of proper maintenance plans.

2. Description of buildings and diagnostic

2.1 Buildings description

In the research were taken into account three different types of tiles belonging to three buildings inside Campus Leonardo.

Building 12 - whose tiles are in grès, flamed at high temperature, produced by the Italian Society of Grès, now acquired by Italcementi spa. These tiles are no longer under production. The paste of the material is compact and the superficial layer has the typical glazed structure obtained through a partial melting while burning, whose thickness varies between 50 µm for plane/linear tiles and 150 µm for corner tiles *(fig. 1.a)*.

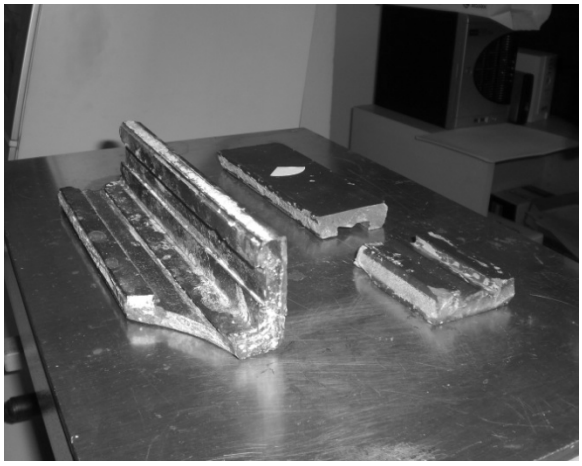
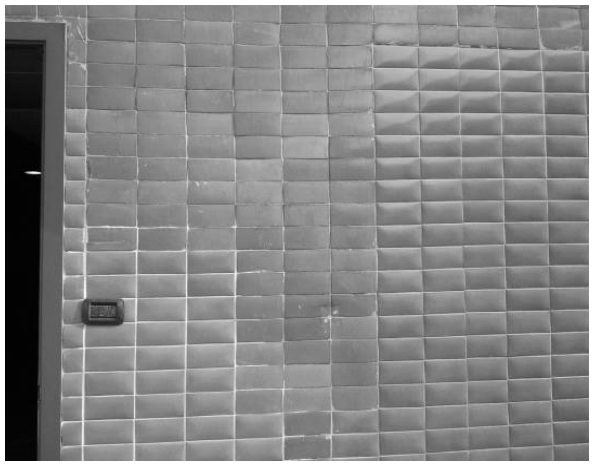



Figure 1: a. Building 12 – tiles details, b. Building 14 – original and new tiles

Building 14 “La Nave” – presents grey clinker tiles placed on a finishing of mortar (2,5 cm thick). On the façades it’s possible to recognize two different types of tiles: Giò Ponti original tiles and new ones, after maintenance interventions. The new series of tiles have flat and smooth surface while the original has rounded polyhedral surface *(fig. 1.b)*.

Building 15, has grey clinker tiles with a vitrified layer on the surface. The tiles are characterized by a small projection 1 cm thick, placed with different inclination in order to create effects of light and shade *(fig. 2)*.

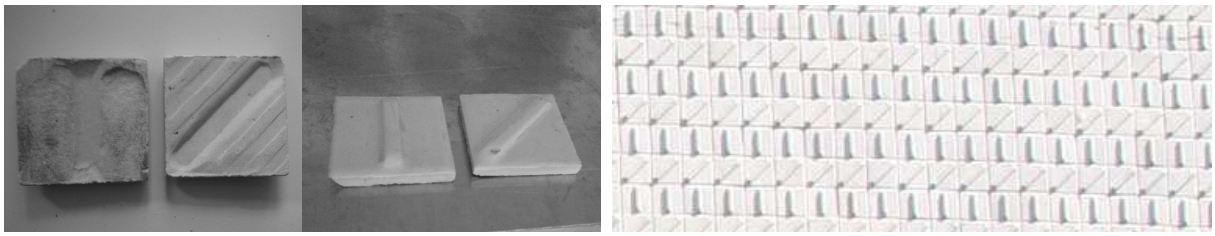


Figure 2: Building 15 – tiles details

2.2 Inspection, diagnostic and laboratory test

The first step to assess the residual service life was to analyze the present state of damage of the external cladding system of the façades. This was performed testing the buildings through visual inspections, non-destructive surveys (IR thermography and hammering) and laboratory tests (emissivity and heat conduction tests).

The thermographic survey and the consequent thermal analysis has been developed through alternative methodologies based on the identification of reference temperatures; these let the optimization of the phase of defects mapping and allow to underline their geometric localization on the façades. The use of this innovative technology allowed to obtain more accurate results avoiding manual and punctual analysis of single areas [7].

2.2.1 The investigation Procedure of the thermographic survey

The following procedure has been used in the phase of analysis of thermograms to evaluate the presence of possible detachment problems in adhered cladding systems, consisting of clinker tiles placed on a substrate by means of mortar.

The thermographic survey was achieved under passive technique: this means the measurements were done at ambient conditions without artificial sources of heat.

The investigation procedure, aimed at detecting delamination problems, was performed in transient conditions since this type of defect is in these conditions more reliable. During the heating phase, the heat is transmitted by conduction to the inner layers of the material according to its heat capacity. If within it, the voids are formed, the layers of air interposed between the heated surface and the substrate prevent the linear propagation of the heat, causing a differential heating of the surface: the defect appears as a warmer area when the net heat flux is entering the building [8].

The proceeding consisting of three steps provides plausible results with a probability of check-up that can reach 80%. This probability value is influenced by different reasons: it does not reach 100% because at the state of the art there are still unknown aspects due to uncertainties regarding the methods of heat transfer and boundary conditions. Moreover the discoloration and the different reflectance of the surface can influence the results and therefore decrease the security of check-up of the pathology.

Thermal images were acquired after heating by solar irradiation for 2 hours. This time window has been determined to obtain the better contrast between delaminated areas and adhered ones. The factors that play a prominent role in the heat diffusion in the cladding system are its thickness and thermal characteristics, the supposed depth of the defect, the environmental conditions (temperature of the air, wind speed, humidity), and the season (consequently the inclination of solar rays).

The first phase of the analysis (performed by IRT Analyzer) is based on the identification of the temperature gradient which characterizes the presence of detachment defects. This was obtained by manually selecting small homogeneous areas representing safe and detached areas and comparing their temperatures. In the second phase, the previous results have been compared with the outcomes of the analysis of the thermograms performed by ArcGIS, in which the low and high isotherm has been set up by means of the values previously identified and characterising respectively the “safe” and detached areas. Through this analysis were systematically individualized the areas which can be more probable seat of detachment defects. In the third phase the previous results have been inspected through hammering. In addition, laboratory tests have been performed for the evaluation of heat transmission and emissivity.

2.2.2 The application on study cases of the thermographic survey for the



3.a



determination of possible detachments

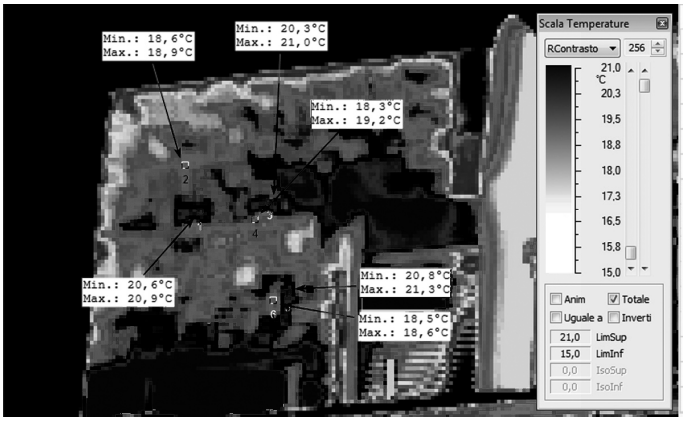
Figure 3: a. Building 12, South façade; b. Building 14 "La Nave" North façade

These two case studies have been presented in order to show the application of the methodology and to study the effects of the different orientation and therefore solar exposition of the façades in the thermographic analysis. In the picture on the left it's possible to notice areas interested by missing tiles and it's visible the presence of mortar on detached tiles above the window. The picture on the right represents a portion of the North facade of building "La Nave" where the tiles look intact by visual examination. From the pict 3.b s possible to see moisture stains caused by percolation below the window sills.

During the thermographic analysis, it's important to take into consideration the different colour and reflectance of the tiles or the presence of stains in order to avoid misidentification. In the first part of the analysis has been determined the emissivity value through laboratory tests on angular and linear tiles. In the case of Building 12 the value has been set equal to 0.95; for "La Nave" the value is 0.9 [9] [10].

Phase 1 - Identification of the characteristic gradient of temperature through IRT Analyzer

The following pictures show the analysis of the thermogram, in which the characteristic gradient of probable detachment has been identified through the selection of small adjacent areas having different temperatures. In particular for the Building 12 a gradient around 2°C has been evaluated as characteristic of the pathology while in the case of "La Nave" it is equal to 1°C. This difference is due to the orientation of the façade under study which in the case of North side receive less solar irradiation.

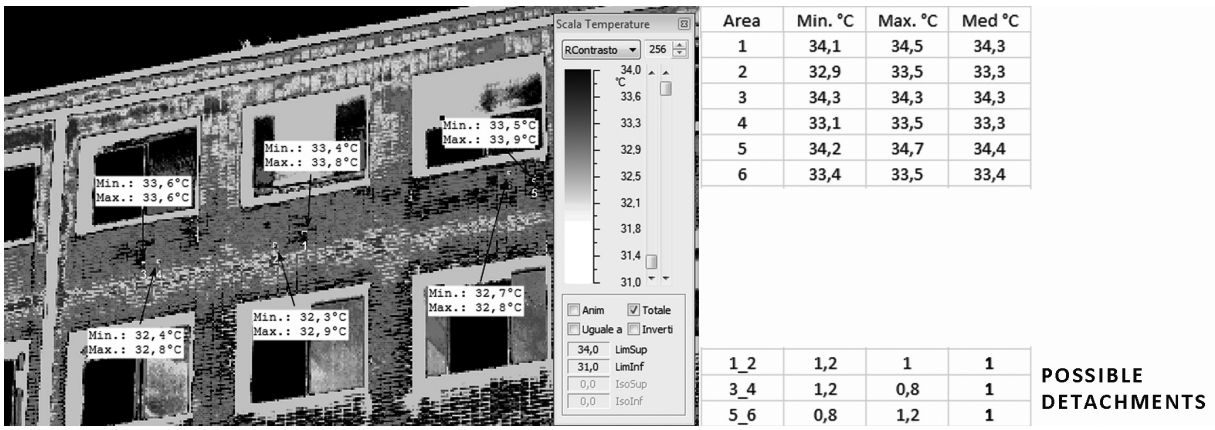


Area	Min. °C	Max. °C	Med °C
1	20,6	20,9	20,7
2	18,6	18,9	18,7
3	20,3	21	20,7
4	18,3	19,2	18,7
5	20,8	21,3	21
6	18,5	18,6	18,5

1_2	2	2	2
3_4	2	1,8	2
5_6	2,3	2,7	2,5

POSSIBLE DETACHMENTS

Figure 4: Building 12, South façade, 5th floor – characteristic thermal gradient identification



Area	Min. °C	Max. °C	Med °C
1	34,1	34,5	34,3
2	32,9	33,5	33,3
3	34,3	34,3	34,3
4	33,1	33,5	33,3
5	34,2	34,7	34,4
6	33,4	33,5	33,4

1_2	1,2	1	1
3_4	1,2	0,8	1
5_6	0,8	1,2	1

POSSIBLE DETACHMENTS

Figure 5: Building 14 North façade, 6th floor – characteristic thermal gradient identification

Phase 2 - Insertion of the isotherms and analysis by ArcGIS

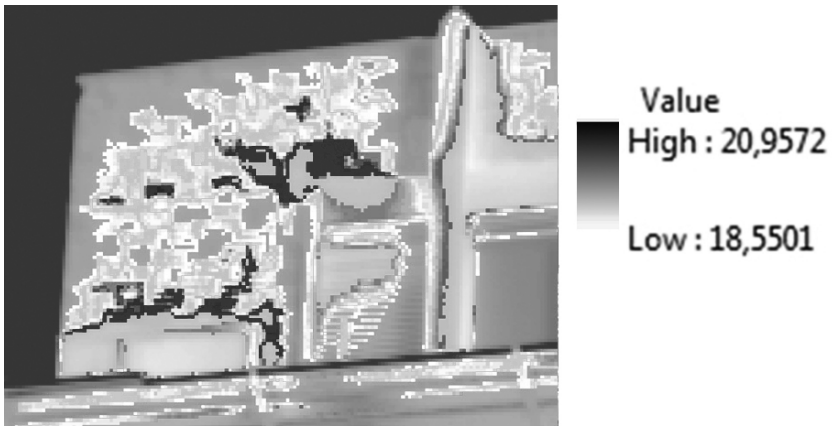


Figure 6: Building 12, South façade, 5th floor – areas with possible detachments (in black) and adherent ones (in white)

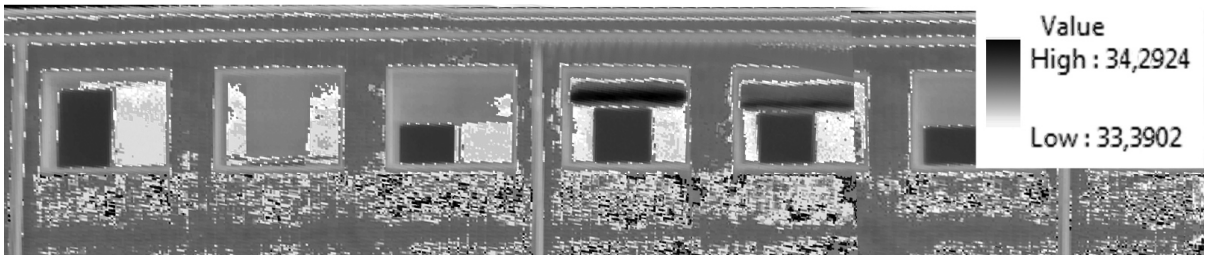


Figure 7: Building 14 North façade, 6th floor – areas with possible detachments (in black) and adherent ones (in white)

The temperature difference between the surface with possible detachment (in black) and the adherent ones (in white) is respectively 2°C for Building 12 and 1°C for “La Nave”. The areas characterized by higher temperatures but affected by gaps or by the presence of different materials are to be identified through a rigorous comparison with the picture of the visible

and omitted. In the case of Building 14 can be observed that once evaluated the characteristic thermal gradient it's possible through ArcGIS to analyze the whole mosaic of the façade. In the third phase the areas have been subjected to hammering and, after having checked the correspondence of the thermografic information, a probability of detachment has been assigned.

As example, the following figure shows the outcomes of the process through the map of the possible tiles detachments as regard the East façade of Building 12, for which has been evaluated a characteristic gradient around 3°C, due to high solar irradiation. The areas in which the thermal anomalies are representative of detachments are represented with boxes: the areas with higher probability of detachment (80%) are highlighted in black, in white the ones with medium probability (50%). The areas with white border indicate probable



detachments of single tiles diffuse along a certain surface.

Figure 8: Example of application: Building 12 East façade, possible detachments of cladding tiles

These results will be used in the next phase of the research with the aim to construct fault trees and consequently to evaluate the residual service life of the components.

3. Results analysis

3.1 Anomalies and their probable causes classification

As a result of the surveys phase a series of pathological failures have been listed and classified according to the gravity associated (possible danger and therefore repair intervention):

1. detachment and missing tiles

2. cracking of the cladding system

3. discoloration and chromatic alteration

The most important damage tallied is represented by detachments, since they represent a source of danger for people (in particular for the case of a public building as it is university) and they imply the necessity of a timely intervention in order to guarantee safety [11]. The detachment is expressed in terms of lack of adhesion and the corresponding degradation level has been divided in low, medium and high according to the entity, the probability and the superficial extension (localized or diffuse) of the pathology. A large extension is linked to the possibility of fractures which can imply the collapse of the element: this is associated to a high degradation level. These three level of damage are associated to the probabilities of check-up previously explained and have been fixed in order to quickly and intuitively localize the areas more affected by the pathology and therefore to plan possible interventions aimed at flanking and reinforcing the fragile element.

The main causes have been listed according to the classification proposed by Silvestre & de Brito (2011) [12] *(fig. 9)* in design errors, execution errors, accidental actions, environmental actions, lack of maintenance, changes from initially predicted conditions.

DESIGN ERRORS
Incompatible, omitted or unsuitable choice of materials
Texture inconsistent with the background characteristics
Prescription of single bedding instead of double
Incorrect design of the ACT joints
Non-existence of peripheral, quartering or construction joints
ACT areas inaccessible to cleaning
Deficient care in detailing singularities of the ACT
Non-existence or defect in peripheral elements
Excessive background deformations
Rising damp

EXECUTION ERRORS
Use of non-prescribed and/or incompatible materials
Application in extreme environmental conditions
Disregard of the settling time between the stages of execution
Application in dirty, powdery or non-regular backgrounds
Disregard of the adhesive pot-life
Inadequate thickness of the tile bed
Incomplete contact between tile and tile bed
Tiles laid over structural joints
Single bedding instead of double
Use of tile bed or grout with high shrinkage
Filling of unclean joints
Joints of insufficient width or depth/missing joints
Incomplete filling of the joints
Disregard of the ACT's texture
Inlaid metal accessories unprotected at the joints

ACCIDENTAL ACTIONS
Impacts against the ACT
Vandalism/graffiti
Stress concentration in the background
Deformation of the background

ENVIRONMENTAL ACTIONS
Wind
Solar radiation
Reduced solar exposure
Thermal shock
Leaching of ACT materials that contain cement
Damp within ACT
Biological action
Air pollution
Crypto-efflorescence
Natural ageing

LACK OF MAINTENANCE
Lack of cleaning of the ACT and surrounding areas
Incorrect cleaning of the ACT

Figure 9: Classification of the causes of failure of cladding systems façades according to Silvestre & de Brito (2011)

3.2 Case studies: relations between degradations and their possible causes

In the examples under study, in the majority of cases of detachments and missing tiles, design and execution errors are supposed to be probable causes. Design errors are mainly localized close to windows: the loss of adherence could have been caused by water infiltration due to percolation from the sill and the mullions, in the point of junction between the wall and the window frame. Besides, as regard the upper part of the window, rainwater stops there causing the corrosion of the steel frame placed over it, since on that part of window it's not present a slope to let the water slide away.

Execution errors are mainly referred to the mortar used to place the tiles, which often having high thickness (around 40 mm) and being placed on several layers, creates various contact surfaces which are not always adherent among them.

Also the cases of cracking are supposed to be related mainly to design and execution errors: in this case they are due to the creation of excessive shear stresses between tiles and support, due to absence of expansion joints, to the wrong choice and laying of the adhesive and substrate.

As regards problems of discoloration and chromatic alteration, in the majority of cases, they are probably caused by environmental actions and lack of a proper maintenance.

4. Conclusion

The described research which has direct experimental application on the buildings inside Leonardo Campus of Politecnico di Milano, has been useful to assess the present conditions of the state of damage; it's now possible to evaluate the residual service life correlating the level of degradation to residual performances.

This analysis will be carried out through the *performance limits method*, which ties the estimated service life of component to its performances. The aim is to intervene by changing the boundary conditions and therefore by removing the risk factors or by flanking and reinforcing the fragile element (e.g. possible protective coatings for the mortar) so that to slow down the degradation growth and elongate the permanence of the element guaranteeing a proper level of performance.

In this specific case, the performance requirement is expressed in terms of the adhesion level of the cladding system and therefore the performance decay (and consequently the degradation growth) is evaluated in terms of tiles detachments.

In the following image it's possible to see a qualitative representation of the performance decay and degradation growth for adhered cladding systems, expressed as a function of time. The degradation level is divided in low, medium and high according to the entity, the probability and the superficial extension of the pathology. The graph provide useful information for the evaluation of the residual service life (and residual performance) of the component in order to plan maintenance interventions taking into account sustainability aspects along the whole life cycle of the building.

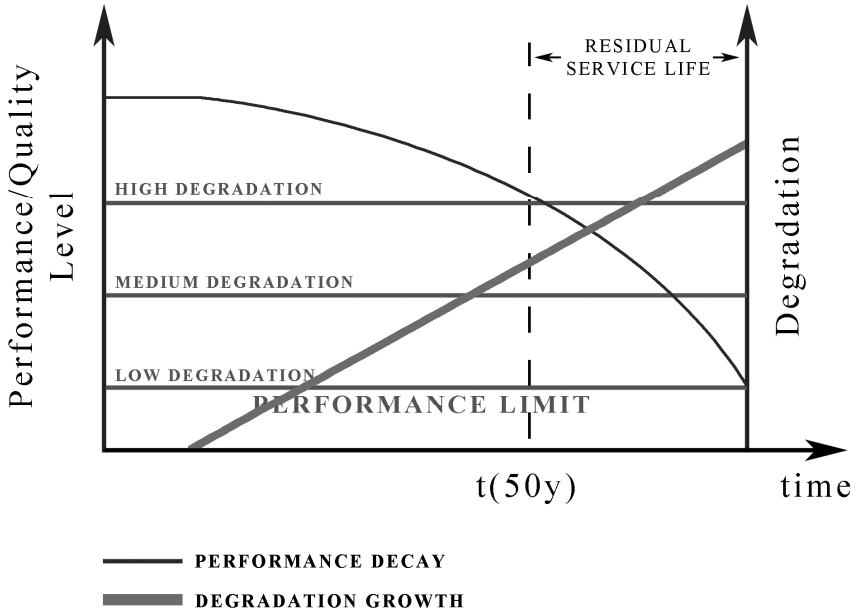


Figure 10: Qualitative representation of performance decay and degradation growth as a function of time

The next step of the research will be based on the development of a method for the evaluation of durability with the aim to identify and improve the application of the information on service life, keeping into account sustainability aspects. In addition, laboratory and in-situ tests will be performed in order to obtain further information as regards the initial performance and the performance decay trend during time [13].

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A Conceptual Decision Making Model For Design Information Maturity

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Abstract

The efficiency of a design process has a close relationship with effective information management. However, the increasing volume of digital information makes effective information management in construction organisations more difficult, in particular on retrieving high value, high quality and more importantly mature design information when it is needed. There is an urgent need to develop a tool that can assess or indeed increase the maturity of any design information for the ease of storage, retrieval and reuse with suitable information management tools. The engineering industry has been striving for this for many years, they have been attaining success on capturing design rationale. The aim of this paper is to demonstrate how the concept on capturing design rationale from the engineering industry and its tool called design rationale editor (DRed) can be incorporated as a new tool called DRed-based decision making model that can be used in the design stage of construction. It can capture and evaluate design rationale and hence help designers to make better and effective design decisions through the increased design information maturity. The definition or concept of information maturity in construction has indeed yet to be explored and will be included as a major future work, others include to demonstrate how design rationale can be captured and edited along the digital life cycle through the use of real case studies, and to address any issues and limitations on its applications in the industry.

Keywords: Design, decision-making, information management, maturity, modelling.

1. Introduction

The challenge in a construction project derives from different organisations relying on a large number of various interrelated data sources, without a proper way or tool to manage these sources in a convenient, integrated and principle norm (Franlin et,al 2005). In other words, a clear and concise understanding on the data or information received between different stakeholders such as designers, engineers and other construction professionals at the conceptual design stage are one of the key element to a successful project, as good design decisions can be generated in an early stage of a project (Raisbeck and Tang 2009). Indeed, “Good design decisions at an early stage can demonstrate a constructive approach to planning requirements and greatly reduce the risk of costly later revisions.” (RIBA 2011). Kats (2003) proclaimed that a slight increase in the upfront cost of 2% is to support sustainable design, which on average, leads to a building life cycle saving of total

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construction costs approximately 20%, which is equal to the initial investment of the construction project more than 10 times. Throughout the life cycle of a construction project, key decisions made at the design stage of the whole design process can generate significant impact on the product the way to be produced and marketed. These design decisions to be generated at the design stage have become more complex within the contemporary construction projects because the solution sets and information flow are becoming highly dynamic. In addition, the "process of elaboration and refinement of issue, alternatives, and decision criteria itself is an important component of the problem" (Tiwana and Ramesh 2001), which concerns not only the conventional objectives (cost, time and quality) but also the issues of environmental management and sustainable construction. Early development of design support systems (Adeli and Hawkins 1991; Berraris and Watson 1994; Kolodner 1991) are therefore conducted with the aim of assisting designers in the management of this extensive and complex information, and of providing some autonomous problem-solving abilities in the early design stages. Emphasis had also been put on providing more accurate and high value information for building performance analysis and evaluation (Klashner and Sabet 2006).

In recent years, the rapidly expanding demands of "data everywhere" or information overloads have led to a field consisted of interesting and productive efforts, but without a central focus or coordinated agenda (Franlin et al 2005). The application of digital design tools, such as Building Information Modelling (BIM) breaks down certain information flow barriers and at the same time bridges communication between extended design and construction teams. It is recommended to adopt BIM to meet the demand on "new levels of quality in construction and new services in order to deliver the 40-year carbon reduction programme" (BIS 2010). However, within the BIM application it is found that there are still some communication barriers among the stakeholders such as the designers, developers, planners and civil engineers on the deficiency of generating reliable information within and across project teams, when a mechanism for the justification (e.g. costs and benefits) on using BIM has to be provided (BuildingSMART 2010). "Extrapolating from US derived figures, the net benefits of BIM to the UK would account for between £1-2.5 bn p.a. in the construction phase." Commercial data from the UK construction sector also showed a consistent reduction of 8-18% of cost associated with design stages C to E of RIBA Plan of Work, including concept, design development and technical design, while the upside potential of saving could be as high as 40% (BIS 2011).

The difficulties of retrieving high value, high quality and mature design information during the design process can sometimes be considered as a major insufficiency of existing digital decision tool, which leads to the disparity between the reality and the prediction or simulation of any digital building models (Moffatt and Kohler 2008). During the design process of a construction project, stakeholders' decisions become highly subjective due to the increased problem complexity and additional project objectives (Nemati et al. 2002). In other words the capability of designers to retrieve and utilise information is critical to the outcome of a project in a design process. The volume of digital information has indeed been increased substantially; any characterised immature information (Hanssen 1997; Helms 2000) can confuse designers and result in the possibility of rework in the design process, and thus causes an improper decision being made that could cause fatal consequences. On the contrary, the provision of mature information can help designers make effective decisions in avoidance of adopting any unstable, imprecise and incorrect information that can facilitate effective information management.

The capture and evaluation of design rationale in the engineering industry have proved to be efficient on assessing design options (Bracewell and Wallace 2003; Bracewell et al. 2009). This technique can find out the reasons of selecting one option over another. It is said that the implementation of this technique offers not just the evaluated decisions only, but also provides visualisation and justification of any arguments among immature design decisions, and can possibly make a significant impact on a collaborative design process. This paper demonstrates the use of capturing and evaluating design rationale in the engineering industry or its tool called design rationale editor (DRed), in particular on how they can be incorporated as a tool (a DRed-based decision making model) to assess the design information maturity at the design stage of a construction project, in the end helping designers and other construction stakeholders to make better and effective decisions in a digital environment. The three major research questions are:

- What is information maturity in a design process?
- How can it be increased through the evaluation and capture of design rationale?
- Why is it important to adopt this developed model on collaborative design in construction project e within design stage?

2. Nature of information in construction

Construction is a process which consists of several identifiable stages i.e. preliminary design, conceptual design, detail design and construction (RIBA, 2011). These stages are too broad and consist of many sub stages dealing with lots of information in order to achieve completion of every stage. Hicks et al. (2002) said information is defined in two classes in engineering design: formal information (provides a specific, structured context and measure) and informal information (encompassing unstructured context, measure and description). Tang et al. (2007, 2008) and Zhao et al (2008) defined that the hierarchy consists of three stages in two main levels: recorded and personal (See figure 1). In analogue to the "Iceberg model" defined by Quintus (2000) that illustrates knowledge as explicit, implicit and tacit. Tang et al. (2007, 2008) defined "knowledge can be explicit (recorded or codified in some way), implicit (in the mind) or even tacit (cannot be recorded and codified in any format). Explicit knowledge can be stored as information".

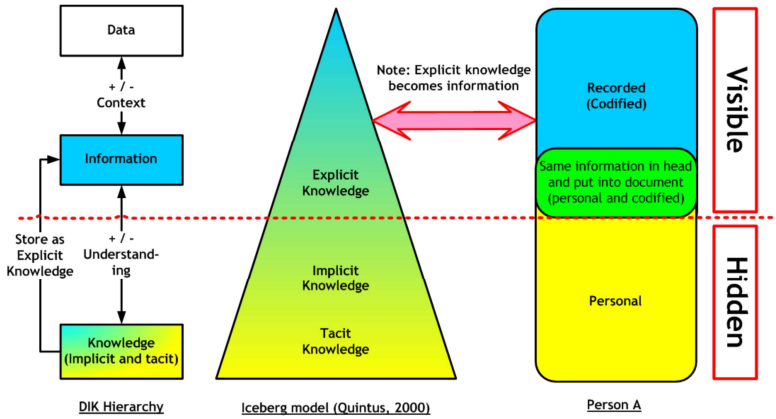

Figure 1 Codified and personal knowledge (Tang et al. 2007, Zhao et al. 2008)

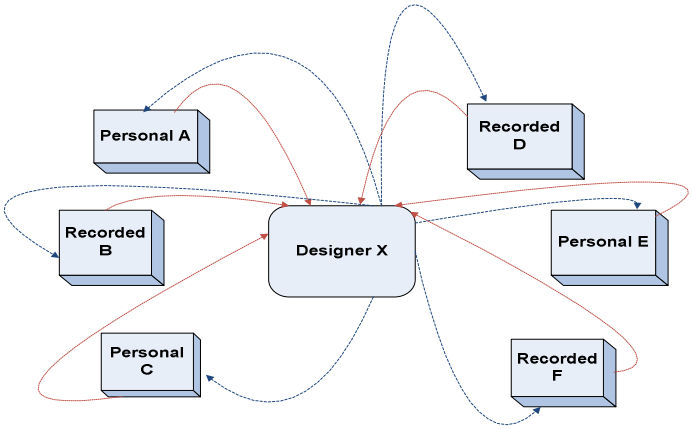

Figure 2 Personal and recorded information flow between stakeholders in construction

Designers are dependent on each other for information exchange: both recorded and personal. All design information is uniquely designed, structured and applied to complete a task in a project. Communication is a multidimensional flow of information exceptionally as shown in figure 2.

3. Nature of information in construction design process

Design is often described as a creative activity that is hard to support with exact science (Moran and Carroll 1996). A design process can be viewed as a set of inter-related activities, by different internal and external activities which are performed to increase knowledge, and increase certainty in relation to the design solutions. For example, designers need to cope with different requirements such as the size of beam, pillar, and space inside of the building to adapt different uses and scopes of the project. When a basic understanding of the task is achieved, designers have to choose appropriate methods. After that, when the decision on how to proceed is made, its evaluation will be taken place using tools, for example, BIM, CAD drawings and finite element analysis. Whether the design process is starting over again or not is subject to the decisions made satisfying the design requirements, otherwise a re-evaluation is necessary. Conceptual design process can be characterized by a series of actions including formulation, analysis, search, decision, specification, and modification. The actions characterised above at the early design stage of a project are shown to be highly interactive many years ago (Jense and Tonies 1979). In fact, the use of information management and technology tools on facilitating effective information management still need to be improved. The introduction of BIM helps address the iterations of redesign in order to refine or amend the functional requirements, design concepts and financial constraints of a project.

As the project moves on from conceptual design to detailed design, the design process becomes more structured. In the stage of detailed design, they are represented by specific steps with less random and uncertain design interactions. Since design problems are large and complex, they have to be decomposed to yield sub-problems in order that which the size can be solved. The integration of sub-problems often creates conceptual conflicts that must be identified and corrected. E.g. Darlington et al. (2008) discussed the foundations of a framework for information evaluation. It also identified and defined a number of important variables e.g. the objects of evaluation, the high-level operational contexts in which evaluation takes place, the motivations and post-evaluation actions associated with these contexts and how they and information entity attributes can be mapped on to the information life cycle. This leads to the questions of how good the value and quality (Tang et al.

2010) and more importantly how mature the design information is in order to avoid unnecessary design reiterations. A decision making tool is therefore needed to measure and increase design information maturity in a design process.

4. The concept of Information Maturity

“Right information needs to be available at the right time in the right format to the right person” (Winch 2002). The term 'right' highly relates how 'mature' the information is, which has a converse meaning against immature information (Hanssen 1997; Helms 2000; Grebici et al. 2006). There is little literature defining the maturity of information where immature information is defined as tentative, untested and possibly incorrect information. In construction, the lean management model proposed by Sacks and Goldin (2007) presented that this method facilitates the replacement of a fixed activities network to be scheduled for the purpose of works' completion dynamically. In order to achieve this goal, the schedule of the finishing process should be done according to the maturity level of the client’s and designer’s changes to design. In construction production phase, maturity is measured according to the state of readiness of a work package or a task (Sacks et. al 2010). Watson (1998) stated that in construction the accumulated data becomes information when it is mature enough and ready to be passed on from one discipline to another. Immature information will be flown from one stakeholder or knowledge broker to another. In this paper, in simple terms, ***mature information is defined as certain information (e.g. stable, precise and complete) that can be passed on to the next stage of a design process with the least possibility and probability of re-iterations and/or other associated uncertainties, which can cause significant impact on the collaborative design decisions among different designers.*** The demonstration of the idea of information maturity for decision-making derives from the design of “London tube map” which is shown in Figure 3 (a). The design of “London tube map” desperately is keen to provide the clearest information for passengers, no matter whoever originates, terminates or passes through from one stop, somehow a user can find out the fastest route to the venue easily with the least distance. In terms of the application of this “tube map” idea in assessing the level of information maturity for making the optimised decision, the design process as a whole will be fragmentised into a number of design packages, design options generated within each package will be assessed towards its information maturity level respectively, eventually the final optimised design decision will be made combined with the consideration of stakeholders’ preferences, project goals and expenditure. The concept can be interpreted in Figure 3 (b) about how the information to be assessed in relation to its maturity level.

The parallel coordinates plot as shown in Figure 3(b) provides an alternative view of the design space. The ranges of information maturity level for each design package are represented as a vertical axis (increasing from the bottom to the top). Each colour line represents a design option. As shown in the figure, the lines on the top over the red horizontal axis represent three design options (purple, red and blue) with relatively more mature information towards to the right hand side of this maturity map. Within all travel routes or design options, it takes into account all decision-making criteria that encounters certainly, uncertainty, risky, possibility and probability issues when assessing multiple design options. The point where each line intersects a vertical axis represents the level of the corresponding information maturity criterion of a particular design package. Visualising results in this form allows the designers to identify quickly the range of information maturity level. For example, it can see that the best designs at beam section have higher volume of

information maturity level above the red horizontal axis. The best design option for instance varies after passing through the entire column section, of which its maturity level is going down obviously. It indicates that the design options for column have high influence on the design performance.

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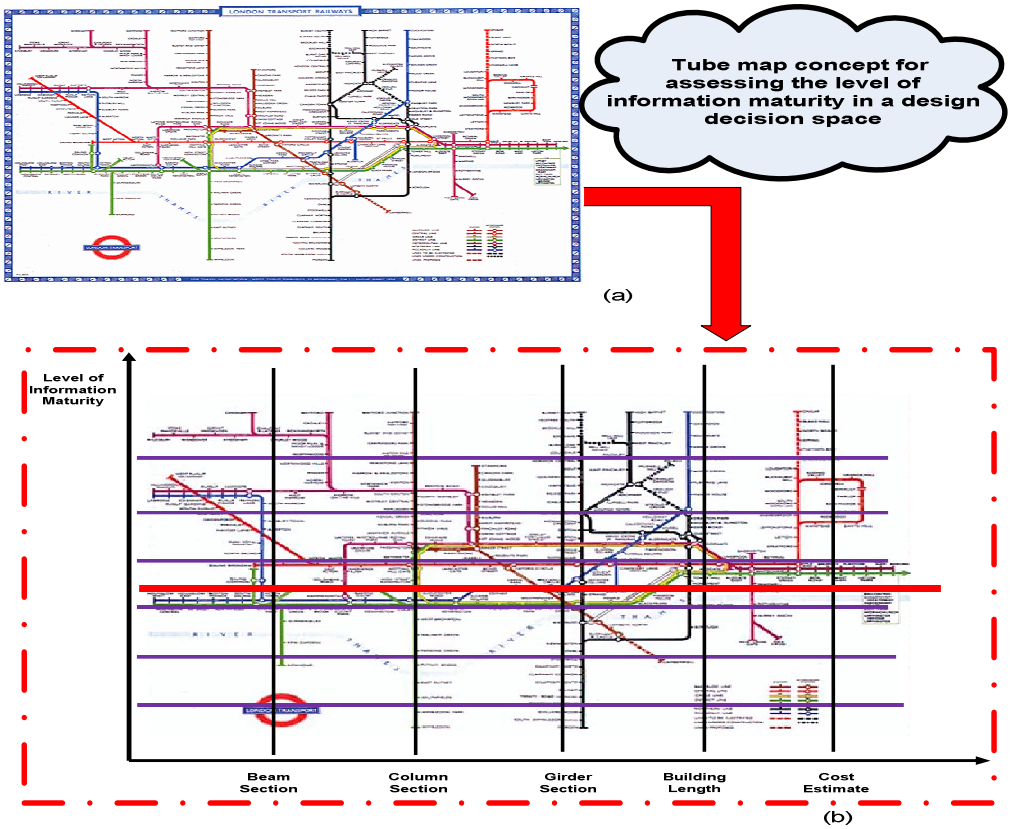

Figure 3 "Tube map" concept for assessing information maturity in a design decision space (Source from Google images: http://www.google.com/imghp)

In other words, the expected and targeted certainty among designers and other stakeholders on different design options (uncertainties) are lined up so that mature information is provided as an

input certainty for the stakeholders in the next stage of the project life cycle. For instance, the optimised design option would be interpreted as the mature one with the highest level of information maturity.

5. Design Rationale Editor (DRed)

The advantage of an accurate design maturity assessment facilitates less re-design, the organisations can measure their designs' maturity in process (O'Brien and Smith, 1995). The understanding of designers' interactive processes and thinking should bring up methods for maturity assessment which allow decision-makers and stakeholders to forecast the level of risk on releasing a design option (O'Brien and Smith, 1995). Cambridge Engineering Design Centre has carried out the research into information capture, storage and retrieval for 20 years. Lee (1997) did a review about the advantages on the available of design rationale capture tools while the pioneering work dated back to 41 years ago by Kunz and Rittel (1970) who developed Issue-Based Information system (IBIS). A tool called Design Rationale Editor (DRed) has been developed to assist the designers to structure their design thinking, to capture their rationale, and to reduce the need for paper work (Bracewell et al. 2009). DRed has been popularly adopted in Rolls-Royce in the design stage of production. The aim of this paper is to propose the use of this tool as part of the tube map idea and extend the development of it in relation to the definition of information maturity in construction, not only to capture the design rationale but also to increase the design information maturity. Once the design rationale comes into the design process, which becomes an important factor when making a final decision on which design option works and what does not. The major difference on using DRed is to ”understand design rationale for taking design decisions by weighting multiple aspects together” in three stages of the traditional design process in engineering. It is a linear process that consists of design task, its creation and evaluation (see figure 4).

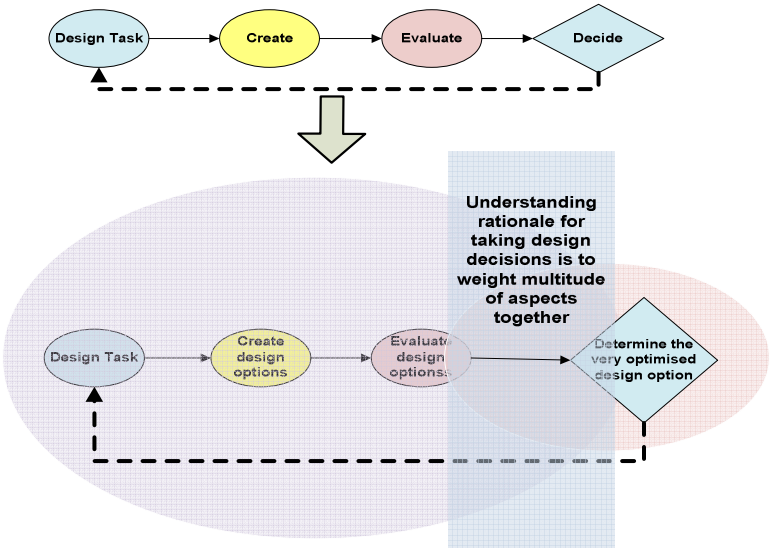

Figure 4 Traditional design process in engineering vs the use of DRed in a design process

DRed as a design rationale capture tool its potential has been proved to be able to improve the design process. Lee (1997) listed the advantages on using DRed that include the provision of better support for re-design, learning, reuse, maintenance, documentation, project management and collaborative work. It also allows "designers to record their design rationale at the time of its

generation and deliberation". Functionally DRed can be complemented with the analysis of BIM, CAD tools, Office, web and communication applications of which designers use to support their day-to day activities. As DRed facilitates the creation of an optimised design portfolio which is structured according to the dependencies in the design rationale, through the capture and evaluation of design rationales, it can finally increase design information maturity routinely in a design process.

6. A developing DRed-based decision making model

The design of a new facility often begins with the search of most relevant information for a design. In order to support collaborative design between designers, this section shows how the DRed can be incorporated as a tool to evaluate and capture design rationale of designers and hence to increase the maturity of design information in a design process. Obviously the relationship between designers and other stakeholders, such as clients, engineers, contractors, can be realised as both information provider and information user, so information maturity must respond to an agreed level of certainty between designers and other stakeholders. Figure 6 shows this proposed DRed-based decision-making model. The design rationale is displayed in a document “as a graph of nodes linked with directed arcs. The user creates the nodes by choosing from a predefined set of element types. The key element types are: issue, answer, and argument” (Bracewell et al. 2009). Questions to ask include:

- What design rationale is worthy to capture?
- In what form is it after captured?
- Once the design rationale has been identified, captured, evaluated and stored, how to share it with other for reuse?

As for the application of DRed, designers start on the basis of forming theories against the causes of the potential problems, and are keen to find out the evidence to support and object them. DRed can be used to capture the track of this diagnostic activity during its proceeding, and figure 5 shows the resulting chart with the diagnosis of changing curtain materials by the use of ‘traffic-light coloured’ system. All the elements in DRed chart are given a colour which represent the elements in various statuses. Decisions are captured by manual changes on the colour, for instance from red to green. The element with green colour means the designers are satisfied with the diagnosis result, which is precise, complete and correct (that is, mature) such as the issue “Design simplification weight and cost reduction” as shown in figure 5. Conversely if an element is not satisfied by the designers, it is marked as insolvable, which is displayed as red colour, e.g. the issue of “Risk of increased maintenance cost” in figure 5.

A designer’s diverse assumptions are captured and evaluated as answered elements, which go up along the upstream routine until the ultimate issue is eventually resolved. For a successful resolution to a design issue that relies on the number of answers of sub-problems being accepted, it is said that the more number of answers of sub-problems being sorted out, the higher percentage of the issue has been resolved. Hence the maturity of that piece of design information increases until it reaches its optimised level (see figure 6).

Through visualising the design rationale, the developed model can:

- monitor the design behaviour through assessment and capture immediate design thinking,

- and improve the 'richness and clarity' (Bracewell et al. 2009) of recorded information non personal as shown in figure 1 and hence increase the design information maturity. It helps line up and liaise the targets and expected certainty between designers and other stakeholders (see figure 6).

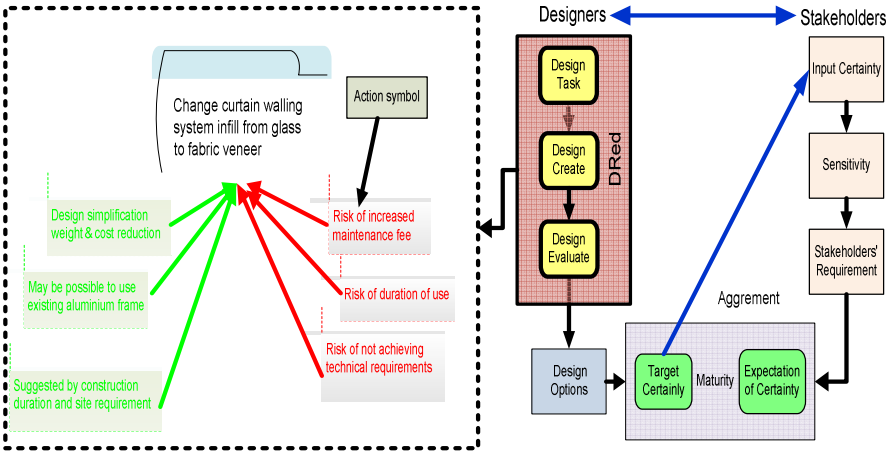

Figure 5 A demonstration of a DRed-based decision making model for changing curtain walling system in conceptual design stage

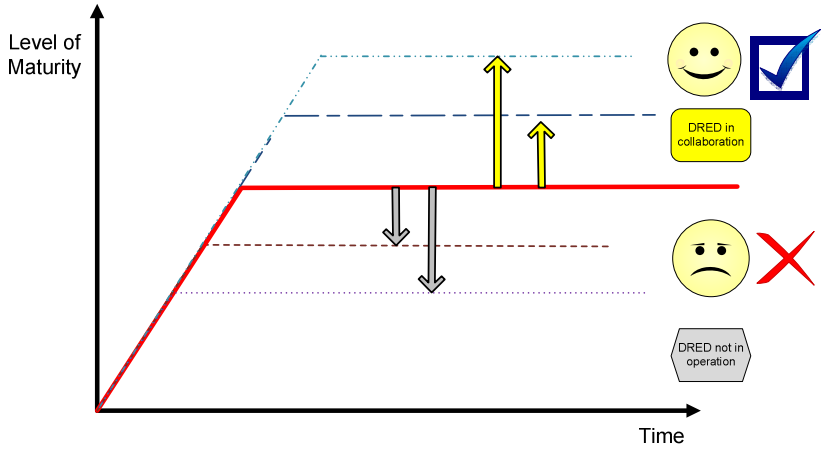

Figure 6 The impact of collaborative DRed on the information maturity of a design process

7. Future works

In this paper, the definition of design information maturity in construction has yet to be explored and will be included as the major future work, others include demonstrating how design rationale can be captured and edited along the life cycle in the BIM environment (e.g. through the pre-construction, construction, post-construction and facility management), by the use of real case studies. There is a need to address any issues and limitations on its applications in the industry, in particular:

- How should the design descriptions (in terms of richness of the recorded information) be associated with the levels of information maturity?
- Which attributes of mature information in each description should be included in the model?
- How can the measurement of future values of the information maturity be carried out?
- How should the design rationale evaluation be carried out with multiple designers?
- Which barriers have limited the application of this developed model, and how can they be overcome in the construction context?
- How does the model impact the design thinking and behaviour of designers?

Furthermore, acting too early or too late can turn a good decision into a mistake. This untimely information flow has been proved to affect the quality of decision-making in a design process (Whelton and Ballard 2002). The time of capturing design rationale needs to be explored in a greater extend. McKenna (1994) realised this kind of decision-making model as bounded rationality and suggested that it should include three investigation processes: sequential consideration of alternatives, using heuristics to identify the most appropriate alternatives, and choosing on the basis of the identification of the first acceptable solution.

8. Conclusion

Information is getting increase in the volume of digitalisation, while some of the intrinsic characteristics e.g. value, quality and as a whole the maturity of it needs to be explored in a design process. Particularly there is a need for a state of art construction form to maintain construction firms' competitiveness through assessing/increasing the productivity of designers or the costs and benefits of a design in a digital environment such as BIM. This paper shows that it is highly possible to develop a collaborative Design Rationale Editor (DRed) decision-making tool to facilitate designers in making effective decision in the design stage of a construction project. Through understanding the nature of information in construction reveals that the identification of mature (i.e. high value, high quality, least possibility and probability on design re-iterations or other associated uncertainties) information should be beneficial to bring out effective design decisions in the design stage of a project. However, the concept of information maturity in construction has not yet been explored. In particular, when facing uncertainty and design changes among designers and different stakeholders, the developed DRed-based decision making tool shows that it provides a systematic and informative way to show the optimised design decision through capturing and evaluating design rationale of designers, which is a concept adopted from the engineering industry. In conclusion, there is a need to apply the proposed model in construction to be embedded in the digital working environment, and hence to increase the information maturity level of design information among designers in order to facilitate effective information management.

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Temporary Housing Residents' Satisfaction Analysis: A Case Study in Southern Taiwan

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Abstract

As the world faces increasing threat of natural disasters, temporary housing has become an important transitional space to assist disaster refugees in rebuilding their lives. This study explores on how to measure the performance of temporary housing. After the 2009 Typhoon Morakot disaster in Taiwan, a non-profit organization in southern Taiwan constructed two types of single-story temporary houses. The participants were people who resided in these houses. This research first employed a social science study of questionnaire survey and participant observations on their life satisfaction. Engineering measurements to evaluate and compare these two environmental deficiency identified by the survey follows. The results showed that although most residents were satisfied with the overall environment, poor sound and heat insulation were common problems in temporary houses. In one type of the houses, indoor temperature may be higher than the outdoor temperature in summer. Both types of houses only have acoustic impedance between 15 to 30 dB for neighbouring unit partition walls, way below the standard for new buildings of 55 dB. It is considered that fast-build temporary houses that are improperly designed and constructed may not provide a suitable living environment for refugees to begin the recovery process inside.

Keywords: **living satisfaction, temporary housing, heat insulation, sound insulation**

1. INTRODUCTION

During the 2009 Typhoon Morakot disaster in Taiwan, consecutive rainfall over three days exceeded 2500 mm, the highest rainfall level recorded on the island. The compound disasters of flooding and landslides caused serious damage to the buildings in the mountains. Subsequently, numerous aboriginal tribes were resettled in temporary housing on the plain near the disaster-stricken mountain areas for a couple of years in preparation for permanent housing settlement. However, the temporary houses provided varied and the residents' living backgrounds were also different. This led to numerous problems in the temporary housing

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camp, which had not been considered beforehand, such as excessive building usage and living problems.

Although the public and private sectors were experienced with temporary housing because of the 1999 Chi-Chi earthquake disaster in Taiwan, the government had not established appropriate principles or guidelines for future applications. The government had been criticized previously for a lack of alertness and preparedness to respond to large-scale flooding. Therefore, after the Morakot flood, the central and local government debated whether to provide temporary housing and what form of temporary housing to construct (The Control Yuan of The Republic of China, 2000). Thus, when the decision to build a number of temporary houses was finally made, there was little time to develop a quality design.

A non-profit organization (NPO) in southern Taiwan assisted in constructing two types of single-story temporary houses namely remodelled military barracks with wooden roof trusses and prefabricated light-gauge steel houses. This study examines the residents' satisfaction of the living environment in them. We first conducted a questionnaire survey to explore the residents' level of satisfaction. After analyzing the survey results, we further quantified the negative factors that caused the refugees discomfort in the temporary houses using physical environment measurements.

2. RESEARCH SUBJECT AND METHODOLOGY

2.1 Subject

This study selected the Chung-Cheng Resettlement Center (CCRC) constructed by an NPO in Pingtung of southern Taiwan as the study site. This was because the CCRC provides 91 remodeled military barracks and 20 steel houses as temporary housing for aboriginal tribal families (Figs. 1). Every house is approximately 50 square meter and equipped with a living room, a kitchen, a bathroom, and three bedrooms. The remodeled military barracks, featuring wooden trusses and brick walls, were of a similar size and layout to the newly built light-gauge steel houses, enabling us to conduct a comparative study of the advantages and disadvantages these housing types. The CCRC houses 44 households (166 individuals) from Taiwu Township and 67 households (333 individuals) from Laiyi Township. The resettlement period was from January 1, 2010, through to December 31, 2011.Initially we explored the refugees' lives periodically; however, 12 months after resettlement, when their lives had somewhat stabilized, we conducted questionnaires with the refugees under the permission of the management committee.

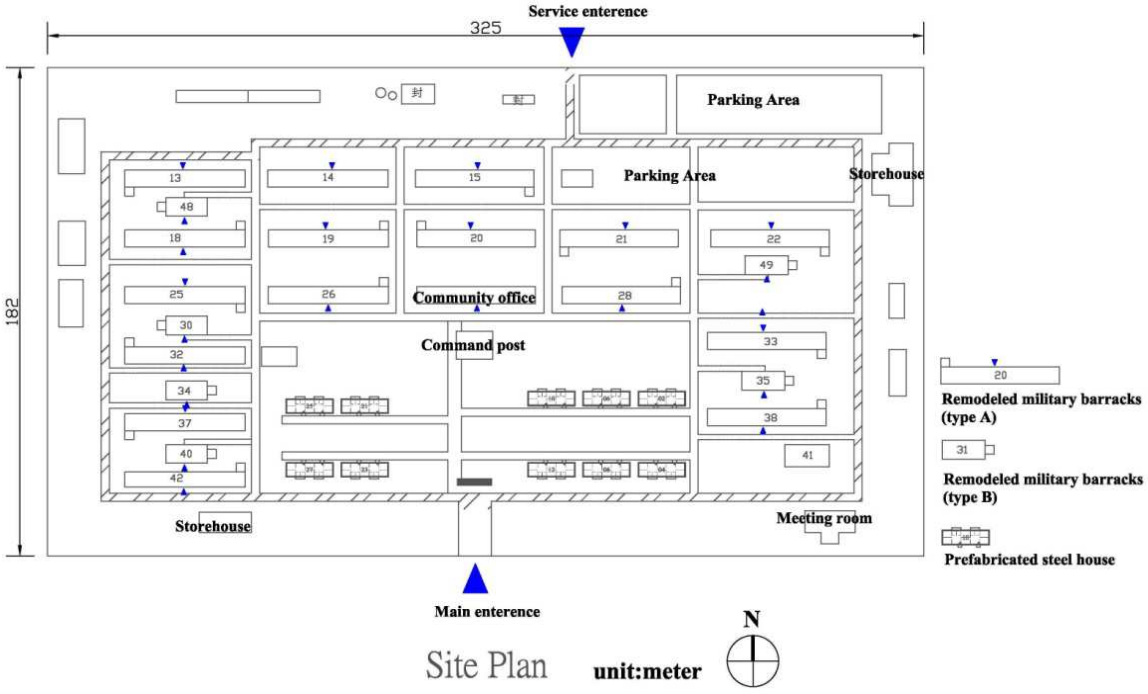

Figure 1.The CCRC Site plan

2.2 Methodology

As discussed previously, residents' safety, health, convenience, and comfort are the basic requirements for houses. We established 12 evaluation criteria for living environment by referencing the results of our literature review. After the questionnaire survey, we used SPSS version 10.0 and a t-test to analyze the questionnaire responses.

The survey results suggested that the residents were most dissatisfied with two items in the physical environment. Therefore, we endeavored to quantify this phenomenon by measuring the remodeled military barracks and the steel houses. Thus, we can collect quantifiable data to improve future temporary housing.

3. RESEARCH FINDINGS AND DISCUSSION

3.1 Residents' satisfaction level on living environment

We conducted the questionnaire using the census method, distributing questionnaires to 111 households. The survey period was one week from December 22, 2010, to December 28, 2010.We received 96 completed questionnaires for an overall response rate of 86.5%. The questionnaires that were incomplete or answered by minors, we eliminated. Thus, the number of valid questionnaires was 91, which accounted for 82% of the residents. Cronbach's α was 0.93, higher than 0.7, which indicates that the questionnaire survey had a high credibility.

1. Satisfaction level on living environment

The result for residents' satisfaction with the living environment was 3.74, which is between neutral and satisfied. The daylight criterion achieved the highest satisfaction level. These results suggest that temporary housing meets the refugees' needs to some extent. However, sound insulation receives the lowest satisfaction level, followed by waterproofing and indoor temperature. These results indicate that the quality of the living environment of temporary housing still requires improvements (Fig. 2).

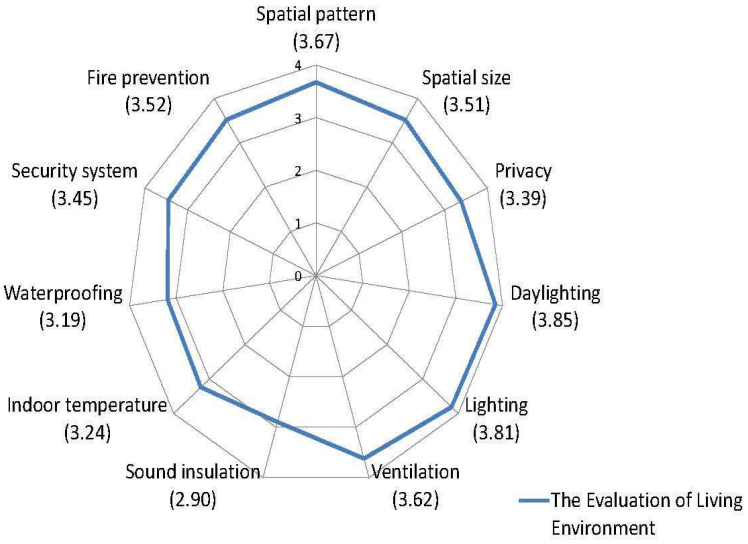

Figure 2.Analysis of the living environment of temporary housing

Residents living in the remodeled military barracks reported that on rainy days, the building had inundation problems. Following the onsite survey, we identified the primary factor contributing to the overflow of water was poor drainage systems, which could not drain at sufficient speed, causing inundation. Thus, 12 residents residing in remodeled military barracks experiecened water overflowing into their houses because of heavy rain. In contrast to the remodeled barracks, inundation did not occur in the newlybuilt steel houses because the design included a raised foundation and a comprehensive drainage system. In March 2011, the drainage problem was significantly improved after the government approved an upgrade budget.

Seven residents stated that the sound insulation of the temporary houses was poor; the primary noise source was their neighbors. This occurred in both steel houses and remodeled military barracks units. To understand how this affected the residents, we conducted an acoustic assessment to evaluate the sound insulation of the unit.

Regarding the indoor temperature, four respondents complained of overheating inside both types of temporary houses. Because the fluctuation of the indoor temperature is related to the airflow, we conducted an onsite indoor temperature and airflow experiment to examine the thermal insulation performance of both housing types.

2. Analysis of various levels of satisfaction with the living environment

Comparing the satisfaction level of residents living in remodeled military barracks with that of residents living in steel houses, the mean satisfaction level for people living in remodeled military barracks was 3.52, and the standard deviation was 0.71.The mean satisfaction level of the residents living in steel houses was 4.49, and the standard deviation was 0.62.The independent samples t-test showed that the residents living in steel houses were more satisfied with the living environment compared to their counterparts.

We then further analyzed the living environment evaluation criteria individually. The mean of the evaluation criteria for the steel houses was higher than that of the existing remodeled military barracks. The difference analysis conducted using a t-test found no obvious differences. This indicates that the satisfaction of residents living in steel houses is higher than that of the residents living in remodeled barracks.

According to the evaluation result, the sound insulation criterion achieved the lowest satisfaction level among residents of both the existing remodeled military barracks and the newly built steel houses. Refugees residing in both housing types experienced excessive indoor temperatures. Relevant authorities should examine the factors contributing to overheating problems and develop countermeasures to reduce these problems (Fig. 3).

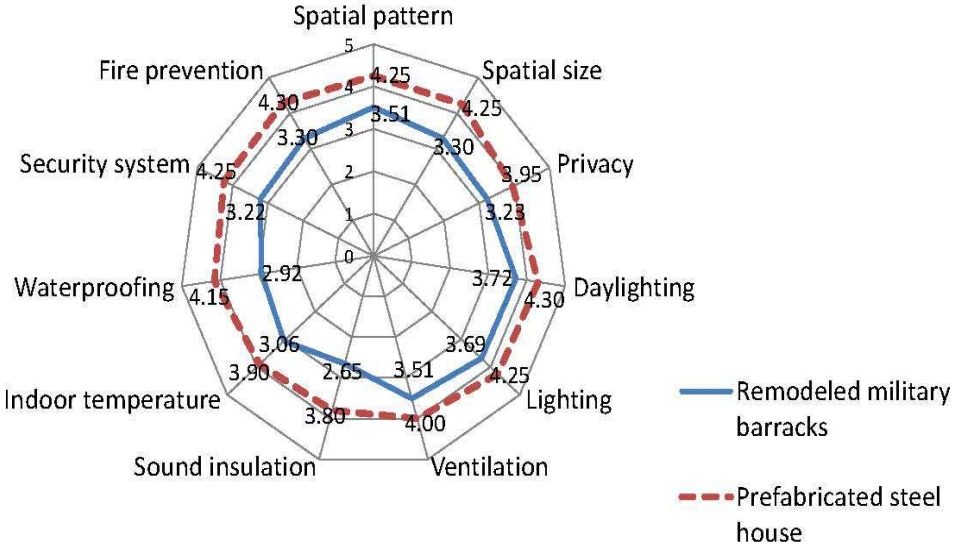

Figure 3.Temporary housing residents' evaluation of the living environment

3.2 Physical environment impact factors of different forms of housing

1. Sound environment analysis

We conducted an onsite test of the internal partition walls between two units of remodeled military barracks and steel houses to quantify the sound insulation performance.The sound insulation testing was based on EN ISO 140-4: 1998. We selected one remodeled military barracks and one steel house partition wall for testing (Figs. 4 and 5).The test result indicated that the transmission loss through the partition walls of the remodeled military barracks was 26 dB at 500Hz. At low-frequency

between 63.80 and 100 Hz, the resonate pattern was obvious, and the sound insulation volume decreased. The transmission loss of the steelhouse was 15 dB under 500 Hz, and the resonate pattern appeared at 125, 160, 2500, and 3500 Hz. The sound insulation volume also decreased. However, building codes in Taiwan only regulate the elements, materials, and thickness of the sound proofing walls; they do not specify the sound insulation performance level.Thus, we compared the data obtained in this study with that of commonly used 15-mm-thick RC partition walls in a laboratory to assess the sound insulation performance of the temporary houses (Fig. 6).

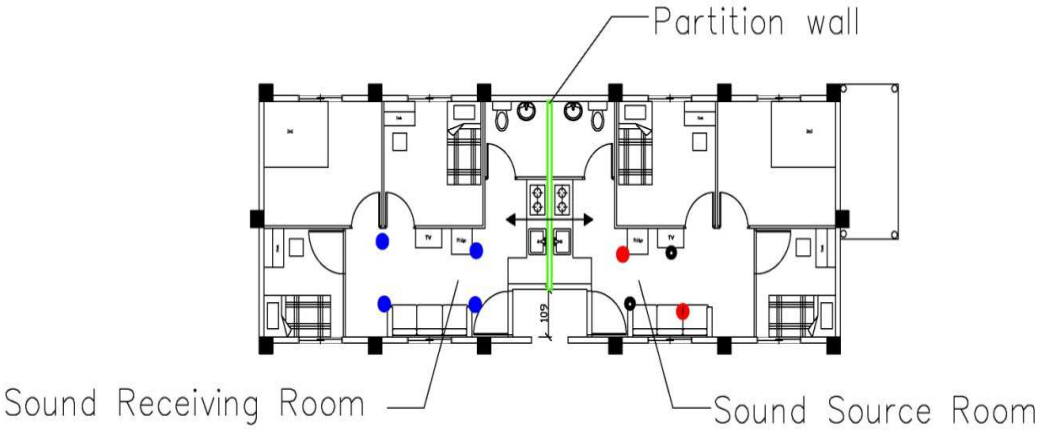

Figure 4. Layout of the sound insulation test performed in remodeled barracks

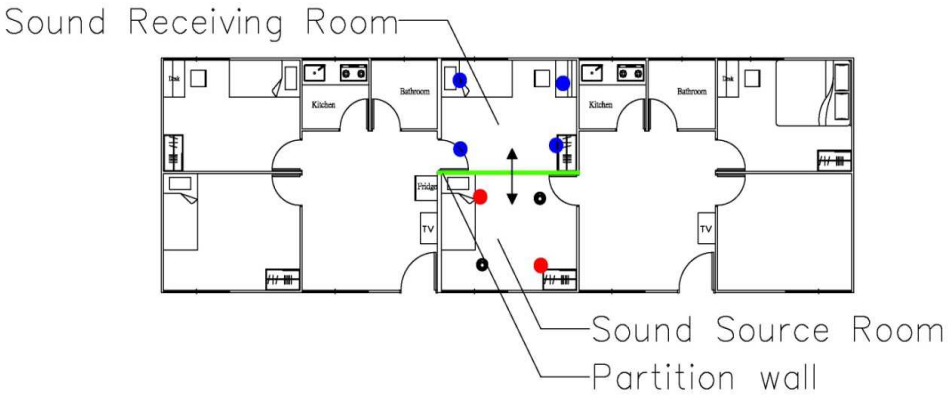

Figure 5. Layout of the sound insulation test performed in a steel house

Regarding the airborne sound insulation of buildings and building elements, the basic sound insulation level of internal walls must reach D-40, which means that noise at 125 Hz should be reduced to 25 dB, 500 Hz should be reducedto 40 dB, and 2000 Hz should be reduced to 50 dB, according to the JIS A 1416. The results of the onsite tests on the internal walls of the remodeled military barracks revealed that the transmission loss was 15 dB at 125 Hz, 23 dB

at 500 Hz, and 36 dB at 2000 Hz. The test result on the internal walls of the steel house revealed that the transmission loss was 2 dB at 125 Hz, 13 dB at 500 Hz, and 27 dB at 2000 Hz. Both housing types have a transmission loss that is significantly lower than the minimum standard; thus, they do not meet the JIS requirement.

We also applied EN ISO 140-4 to compare the sound insulation performance of various construction methods. For the normalized level difference, the Dn value of the remodeled military barracks was 29 dB, the prefabricated steel house was 15 dB, and the 15-cm RC wall was 50 dB. The value for the 15-cm RC wall was significantly higher than that of the other two building types, demonstrating the low sound insulation capability of the temporary houses. Similar results were obtained for the standardized level, DnT, and apparent reduction index R as shown in Fig. 6.

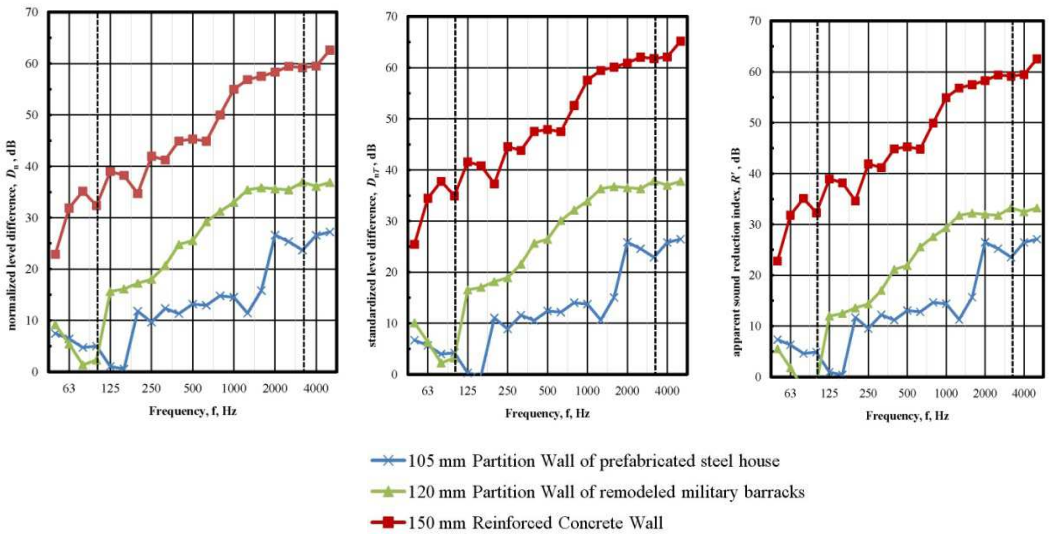

Figure 6. Comparison of the sound insulation performance of temporary houses

The sound insulation performance exhibited a resonate pattern under 100 Hz. This means that the thickness and weight of partition walls of the remodeled military barracks were insufficient, resulting in low-frequency resonance. This also led to the poor sound insulation performance of the partition walls. The wooden frame of the partition walls were composed of 25 × 45 mm square timbers. The centre of the walls was filled with 64K rockwool. The walls are flanked by 12-mm magnesium oxide boards. The thickness of the internal walls was approximately 7.5 cm.

Another reason for the poor sound insulation performance was that the suspended ceiling was constructed before the partition walls because of the limited timebefore the refugeesmoved in. Therefore, the partition walls did not reach the roof; instead they terminated at the soffit of the suspended ceiling. Additionally, the opening between the trusses above the suspended ceiling was not filled with sound-proofing rockwool nor equipped with flanking plates. Thus, the truss opening above the partition walls may provide an acoustic transmission passage. All these problems resulted in poor sound insulation and frequent noise interference among different units in the same building (Fig. 7).

The thickness of the internal wall in the steel house was 5 cm, and the main element of the wall is polyester foam. The wall was flanked by two 0.3-mm steel plates.The material of the wall also had a poor sound insulation performance. Furthermore, the material was not sufficiently thick or heavy, resulting in poor soundproofing in the steel house. Another disadvantage is that above the suspended ceiling, similar to the remodelled barracks, the partition wall plate only reached the bottom cord of the space truss. The opening in the truss was not equipped with sound insulation blanking plates. The sound may transmit through the truss opening and the wall plates. A schematic diagrem of the sound transmision through the truss opening and the wall plates is shown in Fig.8.

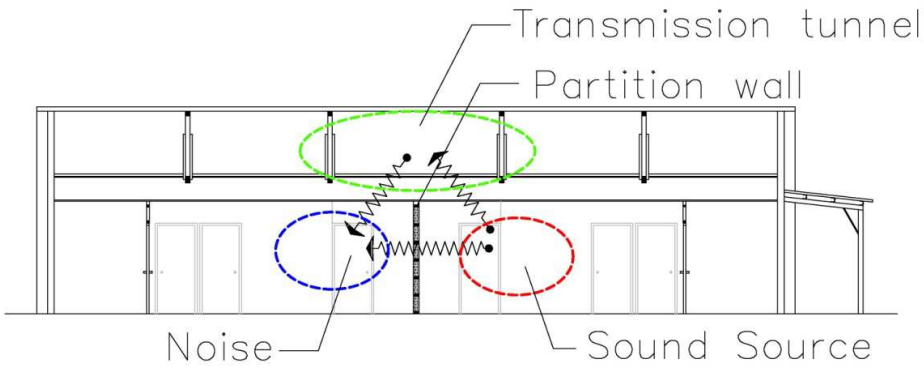

Figure 7. Sound transmission profile of the remodeled military barracks

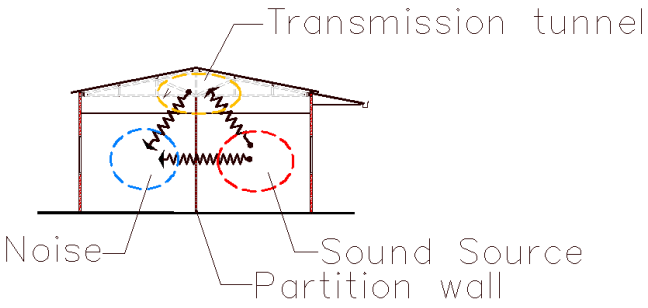

Figure 8. Sound transmission profile of the steel house

2. Thermal environment analysis

According to the questionnaire survey, overheating of the indoor environment was the second major problem experienced by the temporary housing residents. Therefore, this study investigated the fluctuations of the indoor thermal condition during August, the hottest month in Taiwan. We measured and recorded the internal and external temperature and humidity of the remodeled military barracks and the prefabricated steel house for one week in August 2011. The measurement time step was 10 min. All doors and windows were closed to create a windless experimental environment. The weather during the study period was sunny, which

is typical of the area.

Our records show that the average outdoor temperature in a typical summer week during the study period was 27.95℃, the highest temperature was 32.29℃, and the lowest was 24.1℃. Under the same weather conditions, the highest indoor temperature of the remodeled military barracks was 31.79℃, and the lowest was 25.11℃. The highest indoor temperature of the steel house was 34.97℃, and the lowest was 27.19℃. The average indoor temperature of the remodeled military barracks was lower than the average outdoor temperature, and the variation range was narrow, indicating that the existing reconstruction had some shadding effect. Conversely, the indoor temperature of the prefabricated steel house was higher than the outdoor temperature. This explained the unbearably high temperatures in the steel houses and why residents were extremely uncomfortable. These results also indicate that the shading performance of the steel house requires further improvements (Fig.9).

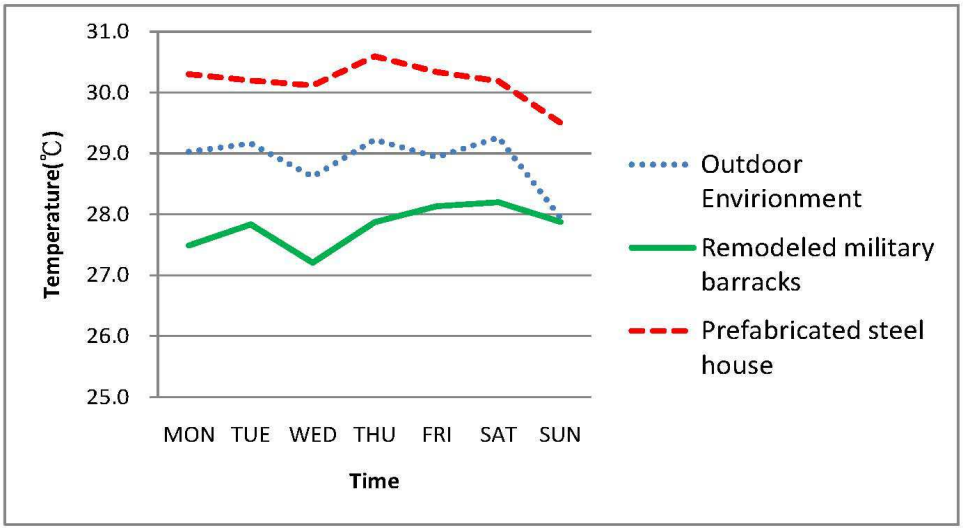

Figure 9. Comparison between the indoor temperatures of the temporary houses

4. CONCLUSION

Temporary houses not only relieve the tremendous stress felt by refugees of major disasters, but are also a starting point for post-disaster recovery. Thus, the condition of the living environment affects both the residents' satisfaction with their quality of life and their post-disaster recovery. This study conducted questionnaire surveys in a campground with two types of temporary houses to evaluate residents' satisfaction with their living environment. The results indicated that the residents of both types of houses were fairly satisfied with the overall living environment and particularly satisfied with the access to daylight, the lighting, and the layout. Through a detailed analysis of the survey results, we found that the residents were least satisfied with the sound insulation and heat dissipation performance.

The poor sound insulation performance causes noise disturbance to neighboring households. Onsite sound insulation measurements indicated that both temporary housing types have minimal acoustic impedance between housing units. The three main factors that contributed to the poor performance were inappropriate choice of partition wall material, inadequate wall thickness, and the existence of an acoustic transmission channel above the suspended ceiling.

Poor heat dispersal resulted in overheated rooms, which also received a low satisfaction score from the residents. Using temperature measurements, we identified that the performance of the steel house was worse than that of the remodeled barracks because the average indoor temperature was always higher than the outdoor temperature.

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Green Building and Universal Design Decision-Making of Educational Facilities in a Multiple Stakeholder Environment

Scott Kelting[1]

Abstract Title

This research is a retrospective case study designed to document the green building and universal design decisions made by the project delivery team and stakeholders. For this study, project delivery team members and key stakeholders agreed to extensive interviews about the decisions made during the design, construction, and post occupancy phases of two new major public educational facilities. The design and construction of public education facilities represent a significant opportunity to study multiple stakeholder decision-making in complex public organizations. Moreover, from a practical standpoint, such research might be particularly useful for addressing rapidly emerging trends in development and deployment of green building and universal design decisions. Each step of the project delivery process typically requires many decisions, which can often be complex. In the absence of other considerations, however, the final drivers of decisions are cost, function, and aesthetics. This study used a retrospective case study as part of an exploratory qualitative research strategy for examining the multiple stakeholders involved in the decision-making that occur in complex public organizations. This study was aimed at documenting some practical features of the actual decisions made in this particular case. Results indicate project delivery team members', their characterization of the primary decision driver, and the decisions made related to green building and universal design in educational facilities.

Keywords: multiple stakeholder decision-making, green building, universal design, higher education organizations, educational facilities

1. Introduction

Often times, an important first step for architects and constructors is gaining an understanding of their client prior to beginning the design and construction of new facilities. Educational leaders are many times the decision makers for the client in the design and construction of new public educational facilities. Educational organizations require educational leaders with the ability to not only see what is required in the present but also to have a vision for the future and to make the decisions necessary to meet future needs (Razik and Swanson, 2010). Additionally, educational organizations are complex. The

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complexity of these organizations may add challenges to the architects and constructor's ability to understand who the decision makers are and what is driving their decisions about green building and universal design. Decision making in complex organizations, such as universities, involves many people who represent a diversity of constituencies, i.e. multiple stakeholders (Brazer and Keller, 2006). Some of these stakeholders may be from outside the university's organization while others exist within the organization, creating added complexity to the organization and decision making process.

The process of making decisions is a major and frequent aspect of leadership in educational organizations. Literature on organizational effectiveness in education listed improving the quantity and quality of resources as one of the three variables that help students reach high standards (Corcoran and Goertz, 1995). An educational facility is a prime example of one of these resources. Educational leaders' guidance in the decision making process may create the conditions under which stakeholders can recognize the importance of classroom design and an improved use of resources (Corcoran and Goertz, 1995). The design and construction of educational facilities has an impact on the teaching and learning that take place in the completed facility – an important factor because an education organization's core goals center on teaching and learning. These decisions are high stakes decisions because of the relative performance of the outcome of these decisions. Once an educational facility is constructed, it is difficult to make changes to the decisions made about its' design. These decisions are many times permanent and are literally grounded in concrete for an indefinite period of time.

An educational leader may plan for, or participate in, the building of a new educational facility only once in his or her career, if that. Therefore, many educational leaders do not have training in managing the planning process of new school facilities. When decisions deviate from routine, educational leaders seek information from multiple stakeholders prior to making decisions (Brazer and Keller, 2006). Many times, these stakeholders have multiple objectives with varying degrees of influence and collaboration that impact the decision making process (Brazer and Keller, 2006).

Many university communities include different people involved in different decisions, from teachers and students to the community. Due to university bureaucracy, the decision-making process seems to defy "logical" decision-making models (Reitz, 1987). Educational leaders could face an endless number of decisions, and many decision-making models lack the conceptualization of decision-making processes that link theory with practice (Brazer & Keller, 2006). Recent literature has recognized voids in educational decision making and has created areas of inquiry out of these voids to develop a model that future researchers can apply. The general conceptual framework focuses on multiple stakeholders, levels of collaboration, "the concept of coupling between decision makers and stakeholders, and feedback in many different directions as decisions evolve" (Brazer & Keller, 2006, p. 2). Different organizations within the university are parts of a system that have linkages, or couplings, to each other. Some of these couplings are tight and some are loose, meaning that directives and actions are not always linear (Brazer & Keller, 2006). An example of this in the university setting would be the university educational leaders who may not always understand the mission of each individual college's specific goals for teaching and learning.

Often, educational facilities in higher education are designed 5-10 years in advance of actual construction. With timelines this long, emerging trends are rarely considered, much less planned. This typically leads to decisions made about changes in the design of educational facilities throughout the project delivery process. Design decisions based on emerging trends, such as green building and universal design, are not easy decisions to make. This can be even more challenging when there is a team of people involved in decisions that may have different drivers for making their decision making.

This study used a retrospective case study as part of an exploratory qualitative research strategy for examining who the key decision makers were in the multiple stakeholder environment that involved the decision-making of two new green public education facilities. This paper is empirical in design as it is intended to specifically focus the decisions made about green building and universal design. Practical features of the actual decisions made during the design, construction and post occupancy phase were documented and are reported. Additionally, this study describes the project delivery team members' characterization of their primary decision drivers. Each step of the project delivery process typically requires many decisions, which can often be complex. In the absence of other considerations, however, the final drivers of decisions are cost, function, and aesthetics.

1.1 Green building and universal design

Green building is an important area educational leaders need to understand in order to make decisions about the design and construction of educational facilities (Earthman, 2009). Historically, until the latter part of the 20th century, the majority of educational facilities were constructed with minimal concern for their impact on the environment (Earthman, 2009). A combination of events led to the current trend of green facilities. The movement to construct high-performance "green" facilities has experienced unprecedented market growth and continues to become a more mainstream practice for constructing schools in the United States.

The United States Green Building Council (USGBC), a widely recognized green building certification organization, categorizes the three primary benefits of green building as: economic, environmental and health. "The economic benefits are: reduced operating costs, enhanced asset value and profits, improved employee productivity and satisfaction, and optimized life-cycle economic performance. The environmental benefits are: protected ecosystems, improved air and water quality, reduced solid waste, and to conserve natural resources. Health benefits are: Improved air, thermal, and acoustic environments, enhanced occupant comfort and health, and minimized strain on local infrastructure" (USGBC, 2009). A recent study interviewed K-12 educational leaders' and found they perceived energy savings strategies to be more important than indoor environmental quality in the design and construction of new schools (Kelting and Montoya, 2011) even though indoor environment quality such as thermal comfort, indoor air quality, acoustics and lighting correlate with an improved learning environment (Bosch, 2006).

Due to the increasing diversity of people in the higher-education environment, facility designers have become aware of the importance of applying universal design concepts to

create an inclusive environment. Diversity has extended beyond gender and nationality to include physical differences as well (disabilities). This transition has brought awareness that the facility should be accessible to all students. Universal design generally extends beyond building codes due to the benefits educators have found. Four areas to consider as best practices when including universal design into the project delivery process are general design standards and processes, site and facility planning, facility systems, and functional areas (Tepfer, 2001). Participatory design is an example of a general design standard that allows educators to voice their opinions on student needs during the design of the facility. Examples of site and facility planning include the building's location on the campus and its orientation on the site in relation to the existing built environment. Accessible routes for everyone to enter the facility serve as the foundation of site planning and selection. Indoor environmental quality is an example of facility systems the universal design should take into account. Both acoustics and indoor air quality are examples of the indoor environmental quality. Finally, classrooms are prime examples of the functional areas the design process should include.

1.2 Decision drivers

The recent economic climate in the United States of America makes the cost of new higher-education facilities increasingly important. Educational facilities need to meet minimum requirements mandated by federal and local jurisdictions. Many educational leaders and stakeholders have goals to design above and beyond these minimum requirements to provide a more effective space for learning to occur. Educational leaders and stakeholders must make decisions on the appropriate way to spend the money allocated to the facility. Different individuals in these groups may have differing opinions and different decision-making criteria on the best use of the money allocated to the new facility. For example, the educational leaders and multiple stakeholders may have differing opinions about whether function or aesthetics is more important. A person concerned about facility operational costs, for instance, may want fewer windows in the design of the facility to lower energy costs. Other decision makers may have more concerns about the facility's aesthetics and therefore want to add more windows to improve its appearance from both the exterior and interior. Another decision maker may also want more windows for the function of creating more daylight, ventilation, and views for learners. These conflicting perspectives may drive decisions on spending.

The facility's function hinges on many factors, including the ability to accommodate the activities that will take place within the facility and the facility's ability to accommodate the diverse student body in a safe environment. One of the main functions of a higher-education facility is to improve student learning, however. This function breaks down into many different areas: the location and orientation of the facility, the indoor environmental quality (e.g., lighting, thermal comfort, and indoor air quality), and the furnishing and equipment (e.g., desks, computers, projectors, and storage areas).

Although cost and function are important, the facility's aesthetics also play a crucial role. Many facilities are designed to remain consistent with or complement their surroundings, making them places that please the general public. Interior finishes and exterior finishes

(e.g., paint, tile, window coverings, and exterior siding) are often a high priority for educational leaders and stakeholders involved in the decision-making process. This fact often becomes particularly evident with owners and with facility occupants who may influence or take part in the owner's decision-making process. One of the main reasons interior and exterior finishes are a driving factor in decision making is that they impact perception of the facility's overall quality. The quality of the facility also depends on aspects not visible at the end of construction (e.g., structural integrity, mechanical and electrical systems, plumbing, and exterior envelope); the perception of quality may center on these finishes, however, making them a driver of many decisions.

2. Methodology

This retrospective case study is designed to research and analyze the decisions made on the design and construction of a new higher-educational facility, as characterized by the educational leaders and stakeholders. This study is retrospective because it studies the decisions that have already been made during the project delivery of completed educational facilities. The central instrument for data gather was semi-structured interview with a set of guiding questions.

A preliminary investigation assisted the researcher with identifying the primary decision makers during the design and construction of the selected higher-education facility. Merriam (2009) refers to network sampling as a type of investigation wherein interviewees refer the researcher to other potential interviewees for the study. The researcher used network sampling by starting with the previously identified interviewees and listened keenly for other people who may have played a key role in the educational leaders' decision-making process that would add to the findings of this study. If the following conditions occurred during an interview, the researcher made a decision to interview additional people accordingly: The interviewee mentioned someone as a key influencer in the educational leaders' decision making, and these individuals were willing to participate in the study. Two interviewees gave contradicting information, which led the researcher to interview a third party to sort out the contradiction. An interviewee provided insufficient detail and referred the researcher to another source for additional information.

The researcher created and read transcripts from the interviews and then color-coded the transcripts to identify all the responses that pertained to decisions made by the interviewees. The researcher extracted this information from the transcripts by quoting and summarizing the interviewees, then subsequently organizing this information organized by phase, organization, green building and universal design. After creating tables to summarize all documented decisions, the researcher coded the tables with the decision drivers of cost ("c"), function ("f"), and aesthetics ("a")

This research took place at a completed four-year university facility in the United States that has been occupied within the past two years. These two four-story facilities both obtained a Leadership in Energy and Environmental Design (LEED) Silver certification and used a design-bid-build project delivery approach. One facility was designed and constructed for education faculty and students and the other was designed and constructed for social

science faculty and students. To maintain confidentiality, this study used pseudonyms for the two buildings: Building A for the education building and Building B for the social sciences building. Each of the facilities has a floor plan designed to accommodate the specific use of the facilities for the goals and missions of its occupants.

3. Research Questions

Many times the educational leaders are the final decision makers and do not have training to manage the planning process of new school facilities. The lack of training provided for many of today's emerging trends, such as green building, creates a larger need for educational leaders to seek information from multiple stakeholders prior to making decisions. Who are the numerous people participating in the decisions over time? What drives the decisions educational leaders and stakeholders use to make decisions about green building? What decisions do they make? The answers to these questions may be useful for educational leaders who may be involved in future projects. In addition, this information may assist the multiple stakeholders understand the decision making environment of universities. To answer these questions, this study described the decisions made about the emerging trends of instructional technology.

This study attempted to answer the following questions:

1. Who are the key decision makers and stakeholders?
2. What decisions were ultimately made (during the design, construction and postoccupancy phases), relative to green building and universal design, as characterized by the educational leaders and stakeholders at a higher education institution?
3. How did the educational leaders' and key stakeholders' characterize their primary reasons for green building and universal design decision making?

4. Results

The educational leaders originally selected for interviewing were the dean and assistant dean from Building A, as well as the associate vice-chancellor and facilities manager from the university's campus design and facilities department. The key stakeholders identified were the architect, and the constructor. The network sampling led the researcher to additional interviewees. The people identified were from Building B, the university's Office of Budget and Planning, and the Design and Facilities Department. The network sampling revealed that key decision makers from Building B were part of the overall project and part of the decision-making process. The individuals recognized as playing a key role in the decision-making process in Building B were the provost, and the three deans from different units within the college. Only one of the three deans participated in the study. The university employee identified as playing a key role in the decision-making process was the director of design and construction. The interview process for both buildings uncovered a complex web of additional stakeholders, including additional staff, the fire marshal, the building inspector, Building A and B's information technology directors, donors, the university's board of directors, faculty, and students. The researcher created a table that summarized the decisions made by each organization and coded each decision by phase (see table 1).

Table 1: Summary of Design Decisions Made about Green Building and Universal Design as Characterized by Building A, Building B, and Entire Project Respondents

Respondent/Organization	Decisions Made About Green Building
Building A	LEED Certification (F) Natural ventilation with operable windows (F) Daylighting (F) Outdoor learning garden (F) Addition of window coverings (F)
Building B	LEED Certification (F) Natural ventilation with operable windows (F) Lack of life-cycle analysis (C) Addition of window coverings (F)
Entire Project	LEED Certification (F) Natural ventilation with operable windows (F) Outdoor learning garden (F) Low volatile organic compound paints, carpet, and landscaping (F) Installation of Marmoleum flooring (F) Installation of Cherry Wood Handrails (A)
Respondent/Organization	Design Decisions Made About Universal Design
Building A	Central entrance (F) Public social spaces (F) Clear circulation or way-finding (F) One elevator (C)
Building B	Two elevators (F) Corridor widths (F)
Entire Project	One elevator for Building A (C) Two elevators for Building B (F) Toilet layouts (F) Corridor widths (F) Meet building code (F) Unclear circulation in building B and clear circulation in building A (F)

The researcher created an organization chart displaying the various key decision makers (see figure 1).

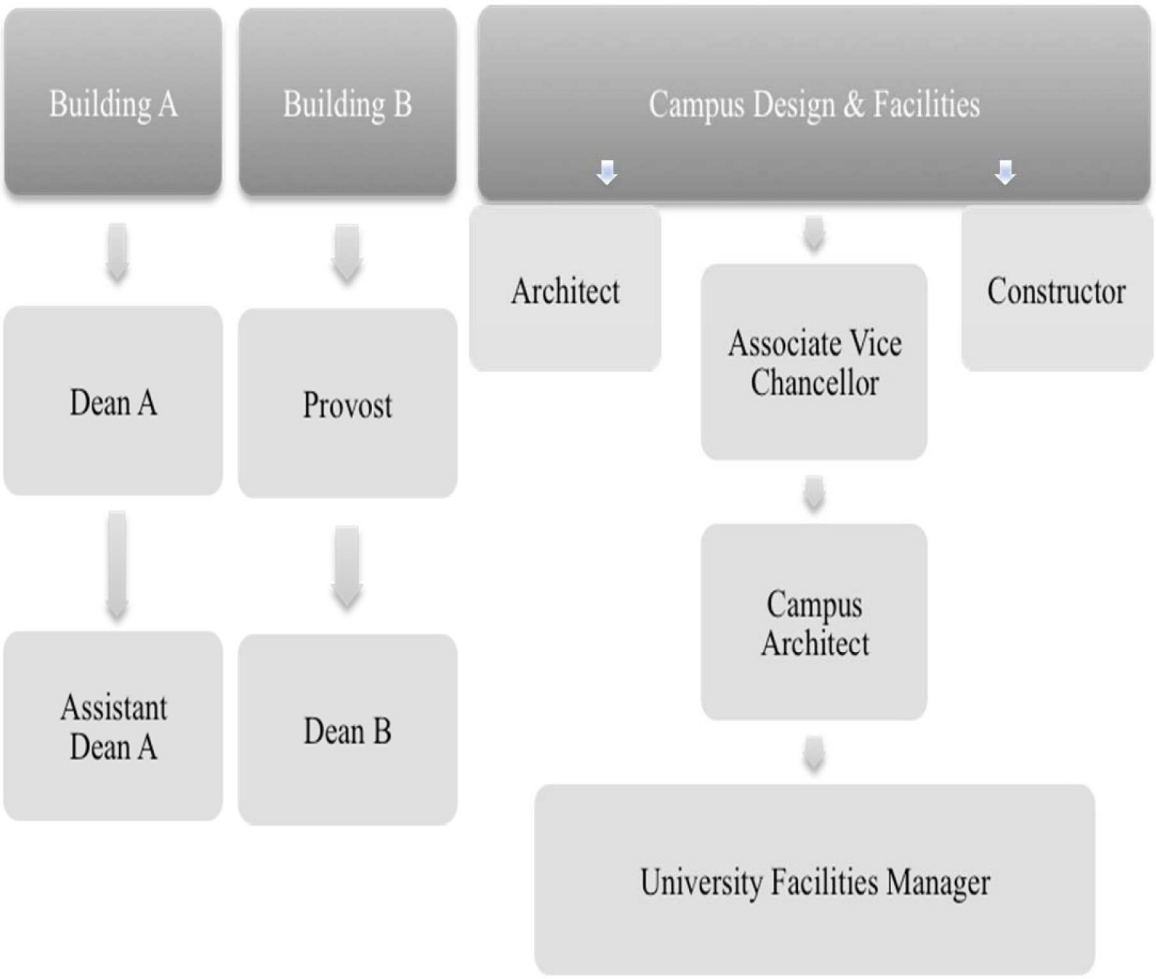

Figure 1: Decision Makers and Their Drivers for Green Building Decisions

5. Discussion

Three complex organizations emerged from the data. The first two organizations are Building A and Building B with the educational leaders and stakeholders specifically associated with each building. Building A was a small organization with one dean and two departments. Interviewees characterized Dean A as having provided a vision for the decisions made in a collaborative process. Building B's organization was much larger than that of Building A, with a history of department advocacy, and therefore more complex. The interviewees characterized the decision-making process as top down, and they described little collaboration. The third organization included educational leaders and key stakeholders who were not associated with either building but were involved in the decision making for the entire project. This organization is called the Design and Facilities Organization.

Not every educational leader has the ability to provide a vision for an organization that will guide the decision making process to meet future needs. The associate vice chancellor reported that Building B did not have a central vision and Building A did. The associate vice

chancellor discussed that it has not been the university's policy to provide guidelines for the learning spaces of new educational facilities. As a result of Building B's final design, the associate vice chancellor has established four additional architectural guidelines to assist with providing a central vision for future projects: 1) central lobby with an identifiable front door, 2) clear circulation to help create an easily navigable building, 3) social spaces for the faculty, staff, and students, 4) and an outdoor learning garden that aligns with the building's purpose. These guidelines are a part of the university's physical design framework which provides guidelines to educational leaders and stakeholders involved in the decision making process of new educational facilities.

The educational leader decision making process for "Green building" refers to the LEED silver certification. LEED certification aims to improve three areas: 1) energy, water, and atmosphere reduction; 2) improved indoor environmental qualities; and 3) a stewardship to resources and their impact (USGBC Research, 2009). The data analysis found the green building decision making processes and the decisions to be relatively the same. The researcher attributes this to the decision support system of the LEED rating guidelines that were used. Both Building A and B were part of the same LEED rating guidelines used to make design decisions for the entire project.

The researcher was surprised that the primary decision driver for both buildings was functionality. However, Dean B indicated that the green decisions did not take into account life cycle cost analysis of the building. One advantage of green building is energy efficiency. Many times, achieving high levels of energy efficiency comes with upfront costs.

To learn about the impacts multiple stakeholder decision-making has on future higher-education facilities the researcher recommends a post occupancy evaluation of the facilities in this study as further research. This recommendation for future research resulted from some of the respondents' characterization of the end product expressed during the interviews. Assistant Dean A said, "I would say, 'knock on wood, but there's been very few complaints." However, the researcher was approached by other occupants who learned about this study and one mentioned that the natural ventilation resulted in uncomfortable conditions because the rooms reached temperatures that were too warm. As a result, blinds were purchased for the windows. Site visits revealed that these blinds were often times closed during the day, which eliminated the both the views, and the natural daylight that was originally designed for the new green educational facilities

6. Conclusion

This study identified who the key decision makers were in the multiple stakeholder environment that involved the decision-making drivers of two new green public education facilities and documented some practical features of the actual decisions made during the design, construction and post occupancy phase. The primary decision driver was functionality. The network sampling utilized in this study identified a multiple stakeholder environment that included architects, constructors, and many educational leaders from different organizations within the university as being key decision makers about green building. The methods used to better understand the complexity of these organizations in

this particular case study may be utilized by both architects and constructors to assist them in understanding who the decision makers are and what is driving the decisions about green building and universal design. Not every educational leader has the ability to provide a vision for an organization that will guide the decision making process to meet future needs. The associate vice chancellor reported that Building B did not have a central vision and Building A did. The associate vice chancellor discussed that it has not been the university's policy to provide guidelines for the interior spaces of new educational facilities. As a result of Building B's final design, the associate vice chancellor has established four additional architectural guidelines to assist with providing a central vision for future projects

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Assessing Outstanding Payment Issues in the Hong Kong Construction Industry

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Abstract

In Hong Kong, multi-layered sub-contracting is common, with sub-contracts typically providing 'pay-when-paid' arrangements for progress payment. When no payment is made by the employer to the main contractor, all lower-tier sub-contractors and suppliers suffer. To help resolve payment disputes, relevant professional institutions and organisations have suggested the security of payment legislation. Nevertheless, any new legislation requires strong justification to earn legislative councillors' support. Therefore, the main objectives of this study are to (1) assess the durations, amounts and major causes of outstanding payments, (2) identify the common methods adopted to resolve payment disputes, including the assessment of their effectiveness and (3) evaluate whether some common legislative provisions adopted in overseas countries can effectively secure payments in the construction supply chain. This study was conducted by questionnaire with main contractors, sub-contractors and suppliers as the target respondent. Of the 1,000 questionnaires dispatched, 423 were returned, of which 23 cases were subsequently identified as incomplete. Hence, there were 400 successful cases representing an overall response rate of 40%. It was found that while the delay in progress payments was not intolerable, the delay in the settlement of final payments was very long. Many respondents identified variation as the most common source of disputes, generating difficulties in work measurement and valuation along with entitlement to interim payments and final accounts. The amount of the outstanding payment reported by respondents was very serious. With the exception of negotiation, the adopted common dispute resolution methods were considered ineffective for resolving payment problems. The respondents also believed that some of the common legislative measures adopted in overseas countries could promptly resolve the majority of payment disputes in the local construction industry.

Keywords: Outstanding Payment, Dispute Resolution Method, Security of Payment.

1. Introduction

The construction industry has a low capital support and heavy reliance on cash flows to sustain business. Operating under a hierarchical chain of contracts within the construction industry, the financial failure of any one party such as the employer or main contractor can have a domino effect on lower-tier parties in the contractual chain. Extremely tight margins in

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the industry, restricted cash flows and payment default can force the lower-tier parties to carry bad debts or, if the burden of debt becomes too much, force such parties into insolvency. Nevertheless, some lower-tier parties are reluctant to take the necessary actions available under the contract due to the high cost and time delays involved and concern regarding future work opportunities. Under such circumstances, they may choose to waive their legal rights when faced with promises of future payment (Royal Commission into the Building and Construction Industry, 2002).

Given the seriousness of payment problems, the governments in the United Kingdom, Australia, New Zealand, Singapore and Malaysia have passed specific legislation to help secure payments along the construction supply chain. As the next section reveals, the payment problem in Hong Kong may be more serious than in these countries. Some professional institutions, associations and contracting organisations have recommended that the government pass similar legislation. Nevertheless, any new legislation requires strong justification to earn legislative councillors' support. Therefore, the main objectives of this study are to (1) assess the durations, amounts and major causes of outstanding payments, (2) identify the common dispute resolution methods adopted to resolve payment disputes and assess their effectiveness and (3) evaluate whether some common security of payment legislations adopted in overseas countries would effectively secure payments in the local construction supply chain.

2. Review of Payment Issues in the Hong Kong Construction Industry

Cash flow is the lifeblood of main contractors, subcontractors and suppliers because their businesses' viability tends to depend more on cash flow than profit margin. However, most contracts in the Hong Kong construction industry contain a 'pay-if/when-paid' provision. When the payment is not forthcoming from an employer, all lower-tier subcontractors and suppliers suffer, even though the default is solely due to the main contractor.

In 2001, the Construction Industry Review Committee (CIRC) noted that some overseas countries such as the United Kingdom and Australia had enacted a security of payment legislation to deal with payment-related issues in their construction industry. For instance, the Housing Grants, Construction and Regeneration Act 1996 in the United Kingdom provides the right to progress payments through payment claims for the completed work. Other legislative provisions include prohibiting the conditional payment (i.e. 'pay-if-paid' and 'pay-when-paid' clauses) in a construction contract, providing a right to refer any dispute arising under the contract to adjudication, requiring security for disputed amounts following adjudication, and allowing to suspend performance of obligations for non-payment after adjudication. The CIRC recommended that the need for enacting security of payment legislation be considered, given overseas experiences (CIRC, 2001).

In response to the CIRC's recommendation in 2004, the HKSAR government took the view that security of payment legislation was unnecessary under local circumstances; instead, a voluntary adjudication was introduced in public work contracts to help resolve disputes. Although the objectives of this voluntary adjudication are to achieve a 'simple, speedy and…

effective method of resolving disputes', it cannot improve the payment problem for a few reasons. First, it is limited to government projects and does not apply to projects in the private sector. Second, even in a government project, the voluntary basis means that one party can request adjudication and the other can refuse. Third, it does not apply to subcontractors and suppliers. Finally, it does not affect the unfair 'pay-if-paid' or 'pay-when-paid' contractual provision. In other words, the payment problems in local construction industries have remained unresolved since the CIRC report.

Many of the payment problems that have occurred overseas have also occurred in Hong Kong. However, there are also specific problems in the local construction industry. Many clauses in the standard forms of contract are amended to allocate most risks to main contractors, who have no choice but to accept these inequitable contract provisions in view of the keen competition for any project. When a risk event occurs, some main contractors look for ways to make contractual claims that will allow them to recover their losses, whereas architects and engineers in the same situations are pressed by their employers into a harsh position in which any delay or extra cost is either the main contractor's or their responsibility. Under such circumstances, architects and engineers may not act impartially and fairly when administering the contracts. When a dispute arises, the current adjudication process does not resolve the cash flow problem of lower-tier parties in a speedy and cost-effective manner because it is complex and akin to short form arbitration.

According to a survey of outstanding payments jointly conducted by the Public Opinion Programme and the Construction Industry Council (2010), the top ten most serious problems faced by main contractors, subcontractors and suppliers in the private sector were 'delayed resolution of dispute', 'delayed settlement of final accounts', 'various unreasonable obstacles for payments', 'have to continue works even when arrears are not settled', 'disagreement on substantial completion of works', 'delayed certification of interim payments', 'unreasonable allocation of risk', disputable or wrongful contra-charges', 'contracts contain payment terms like "pay-when-paid" or "pay-if-paid"' and 'failure of agreement on variations'. To understand the payment issues in detail, it is necessary to assess the duration of delays in progress and final payments, along with the major causes of outstanding payments and their corresponding amounts.

Moreover, main contractors, subcontractors and suppliers tend to resolve payment disputes through commercial negotiation. While mediation and arbitration are typically specified in contracts as the dispute resolution methods, these are not considered effective enough in securing payments. Common reasons may include concerns about breaking up the business relationship with their clients; imbalance in negotiation positions; mediation's voluntary, non-binding nature; and the fact that arbitration is costly and time-consuming. At present, adjudication is not common in the local construction industry. Before introducing new legislative measures, it is essential to re-examine the effectiveness of the current methods adopted to resolve payment disputes.

A review of the security of payment legislation in the United Kingdom, New South Wales and Singapore indicates that there are some common legislative provisions. These include the provision of default payment periods if the contracts do not contain any payment schedule,

the prohibition of conditional payment terms such as ‘pay-if-paid’ or ‘pay-when-paid’, the right to suspend work, the right to adjudication for prompt resolution of construction dispute and recovery of payment and the enforcement of adjudicators’ decisions. Before introducing the security of payment legislation, it is important to assess whether these legislative provisions can effectively secure payments in the local construction supply chain.

3. Research Method

3.1 Research Design

This study was conducted using an email questionnaire survey consisting of seven questions. Questions 1-4 collected information on the durations, magnitude and causes of outstanding payments. Questions 5 and 6 collected details on the common methods adopted to resolve payment disputes and their effectiveness. Question 7 elicited information on the effectiveness of some common security of payment legislative provisions for enhancing payment practices, the details of which are as follows.

1. As the timeliness of settling payments is a major concern, question 1 assessed the extent of delays in receiving progress payments from main contractors, subcontractors and suppliers. Respondents were asked to provide information on the interim payment period specified in the contract and the actual period taken to settle the interim payment. As interim payment is a generic term, this study includes a single or one-off payment, a milestone payment and other progress payments.
2. If there are more contractual disputes, the contracting parties take a longer time to agree on the final account. Question 2 assessed the extent of delays for final accounts. The respondents were asked to provide information about the final account period specified in the contract and the actual period taken to settle the same.
3. Question 3 assessed the amount of outstanding payments withheld by upper-tier contracting parties. A snapshot approach was adopted, whereby respondents were asked to provide data on the amount of payments applied and the corresponding amount actually received. The difference between these two payments can be construed as the estimated amount of outstanding payments. In addition, the respondents were asked to provide data on the total amount of annual business receipts. Different grossing-up factors were calculated for different respondents, taking into sampling fractions and response rates. The total amount of outstanding payments could thus be estimated.
4. Question 4 identified the causes of major payment disputes between the contracting parties. Nine major types of payment disputes were identified, including (a) disagreement on workmanship and quality of work done, (b) disagreement on measurement and valuation of variations, (c) disagreement on, and delay in, the settlement of progress payments, (d) disagreement on claims for prolongation of or disruption to the progress of works, (e) disagreement on amount of liquidated damages, contra charges or set-offs, (f) disagreement on issuance of certificate of practical/substantial completion of the works including delay in release of retention money, (g) disagreement on issuance of certificate for making good defects including delay in release of retention money, (h) disagreement on, and delay in, settlement of final account, and (i) disagreement on noncompliance with specified standards. The respondents were asked to provide a breakdown of the

total amount of outstanding payments previously reported based on these nine causes of payment disputes.

5. Question 5 identified common methods adopted for the resolution of payment disputes. The respondents were asked to report the approaches they adopted for the resolution of payment disputes from amongst six methods: (a) dispute resolution adviser, (b) commercial negotiation, (c) mediation, (d) adjudication, (e) arbitration and (f) litigation. Choosing more than one method was allowed because more than one dispute can be encountered in a contract. A distribution analysis of the dispute resolution methods adopted was then prepared to indicate the relative frequency of use.
6. Question 6 evaluated whether the common dispute resolution methods could effectively resolve the payment problems. The respondents were asked to evaluate whether the six identified dispute resolution methods were 'effective' or 'not effective', considering the cost, time, binding/non-binding effect and any other relevant considerations.
7. Question 7 evaluated the potential effectiveness of common legislative provisions, if adopted, to secure payments along the construction supply chain. Five common security of payment legislative provisions used in overseas countries were identified, including the (a) right to progress payments, (b) right to suspend works for non-payment, (c) prohibition of conditional payment provisions, (d) right to rapid adjudication and (f) enforcement of adjudicators' decisions. Because the security of payment legislation is still under consideration, a brief description of these legislative provisions was provided in the questionnaire. The respondents were asked for their opinions on the effectiveness of these legislative provisions, expressed in percentages of the total amount of outstanding payments withheld.

3.2 Data Collection

The target respondents consisted of three groups: main contractors, subcontractors and suppliers. The security of payment legislation in many countries also includes professional consultants, but they are excluded from this study because they do not suffer payment problems to the same extent when compared to the main contractors, subcontractors and suppliers who undertake the physical construction. This study's sampling frame was based on various government registers such as the Registered General Building Contractors and the List of Approved Contractors for Public Works (for main contractors), Registered Specialist Contractors (for subcontractors) and the List of Approved Suppliers of Specialist Contractors (for suppliers). The data were collected between early June and the end of September 2012. Of the 1,000 questionnaires dispatched, 423 were returned, of which 23 cases were subsequently identified as incomplete. Hence, there were 400 successful cases representing an overall response rate of 40%.

4. Findings and Discussion

Table 1 shows the distribution of respondents in respect to the number of questionnaires delivered and successfully returned. The overall response rate was 40% (42.5% for subcontractors, 40% for suppliers and 35% for main contractors). Statistically, the sample sizes for main contractors and subcontractors are acceptable. However, because there are a

relatively small number of returned cases from suppliers, the results derived are subject to a relatively larger sampling error. The key findings of this study are summarised below.

Table 1: Distribution of respondents

Type of respondents	No. of questionnaires delivered	No. of questionnaires completed	Response rate
Subcontractor	600	255	42.5%
Main contractor	300	105	35.0%
Supplier	100	40	40.0%
Overall	1000	400	40.0%

4.1 Delay in Settlement of Interim Payments

The interim payment period specified in the contract and the actual period taken to settle the same are shown in Table 2. The average interim payment periods were 31, 38 and 36 days for main contractors, subcontractors and suppliers, respectively, whereas the average actual periods taken to settle interim payments were 42, 52 and 52 days as reported by main contractors, subcontractors and suppliers, respectively. In other words, there were average payment delays of 11, 14 and 16 days for main contractors, sub-contractors and suppliers, respectively, due to various disputes and delays. This finding indicates that upper-tier parties did not fulfil their contractual obligations to make interim payments within the specified periods. Nevertheless, respondents generally considered such delays to be less serious; rather, they were more concerned with the amount of payments being withheld and how to resolve such withholding.

Table 2: Delay in settlement of interim payments

Durations taken for settlement of interim payment (days)	Main Contractor	Subcontractor	Supplier
Interim payment periods specified in the contract	31	38	36
Actual interim payment periods taken	42	52	52
Difference	11	14	16

4.2 Delay in Settlement of Final Accounts

The final account period specified in the contract and the actual period taken to settle the same are shown in Table 3. The average final account periods were 12, 12 and 6 months for main contractors, subcontractors and suppliers, respectively, whereas the average actual periods taken to settle final payments were 24, 21 and 9 months as reported by main contractors, subcontractors and suppliers, respectively. In other words, the average delays in the settlement of final accounts were 12, 9 and 3 months for main contractors, sub-contractors and suppliers, respectively. This finding also suggests that upper-tier parties could not fulfil their contractual obligations to settle final accounts within the specified

periods. The respondents generally considered these delays to be unreasonably long and reported serious affects to cash flow due to a low profit margin, a high percentage of retention monies and a long period of final measurement and valuation.

Table 3: Delay in settlement of final accounts

Durations taken for settlement of final account (months)	Main Contractor	Subcontractor	Supplier
Final account periods specified in the contract	12	12	6
Actual final account periods taken	24	21	9
Difference	12	9	3

4.3 Estimated Amount of Outstanding Payments

Based on the amount of payments applied and the corresponding amount of payments actually received, the amount of outstanding payments and its corresponding percentage were calculated as shown in Table 4. The percentages of outstanding payments were 8.5%, 11.6% and 4.8% for main contractors, subcontractors and suppliers, respectively. Taking the amount of outstanding payments as a percentage of the total business receipts reported by respondents, the total amount of outstanding payments per annum was estimated to be HK$11,500 million for main contractors, HK$11,000 million for subcontractors and HK$500 million for suppliers. It is noted that the security of payment legislation in the United Kingdom and New Zealand (but not Australia, Singapore or Malaysia) does not cover supply contracts, probably because payment problems in these two countries are not serious. This finding indicates that suppliers also suffer from serious payment problems (4.8%), although the extent is less severe than that experienced by main contractors (8.5%) and subcontractors (11.6%).

Table 4: Estimated amount of outstanding payments

Estimated amount of outstanding payments	Main Contractor	Subcontractor	Supplier
Outstanding payments (HK$ million)	$11,500	$11,000	$500
Business receipts (HK$ million)	$135,000	$95,000	$10,500
Outstanding payment as percentage of business receipts	8.5%	11.6%	4.8%

Remark: The amount of outstanding payments to main contractors, subcontractors and suppliers are susceptible to overlapping due to conditional payments in the subcontracting chain. Adding the two figures would result in double counting.

The respondents considered their profit margins in many projects to be far below the percentages of outstanding payments. Operating under this business environment, they had to balance the negative cash flows during the course of the contract and could only realise the profit after the settlement of the final account. Given the substantial amount of outstanding payments, coupled with the considerable delay in settlement of final accounts mentioned above, the security of payment in the local construction industry should be improved by some means.

4.4 Major Causes of Outstanding Payments

Table 5 provides a breakdown of the total amount of outstanding payments (i.e. the difference between payments applied and payments received) into nine identified cause categories. The three most common causes, as reported by main contractors and subcontractors, were 'disagreement on measurement and valuation of variations' (37% for main contractors and 30% for subcontractors), 'disagreement on, and delay in, settlement of final account' (20% for main contractors and 22% for subcontractors) and 'disagreement on, and delay in, settlement of progress payments' (18% for main contractors and 20% for subcontractors).

Table 5: Breakdown of major causes of outstanding payments

Major causes of outstanding payments	Main Contractor	Subcontractor	Supplier
Disagreement on measurement and valuation of variations	37%	30%	-
Disagreement on, and delay in, settlement of final account	20%	22%	25%
Disagreement on, and delay in, settlement of progress payments	18%	20%	40%
Disagreement on claims for the prolongation of and disruption to progress of works	7%	5%	-
Disagreement on issuance of certificate of practical completion of works including a delay in the release of retention money	6%	7%	
Disagreement on workmanship and quality of work done	5%	7%	-
Disagreement on issuance of certificate of making good defects including delays in the release of retention money	4%	5%	-
Disagreement on amount of liquidated damages, contra charges or set-offs	3%	4%	5%
Disagreement on noncompliance with specified standards	-	-	30%
Total	100%	100%	100%

Due to high land costs, many clients set a tight schedule for both design and construction so that completion can be achieved as soon as possible to generate income. Under the clients' pressure, some projects are inevitably tendered based on incomplete designs and/or specifications. As a result, architects and engineers are required to issue a large number of variations during the construction stage. Disputes often arise in relation to the procedural requirements in respect of the notice of claims, discrepancies among drawings, specifications, bills of quantities and other parts of contract documents, different interpretations between the work specified in original contract documents and the work changed by architects and the measurement and valuation of some variations. All of these disputes lead to underpayments to main contractors and subcontractors. In addition, interim payments, which typically include the estimated values of works done, preliminaries, materials on- and off-site, re-measurements and contractual claims, are generally evaluated

on the conservative/low side. There are various reasons behind. For instance, because so many variations are issued each month, quantity surveyors do not have sufficient time to accurately measure and evaluate all variations. As a result, only approximate values of these variations are included in interim payments. These values are, in many cases, under- rather than over-estimated by quantity surveyors. Furthermore, if there are serious delays in the settlement of variations, contractual claims and other disputes, these will also result in more serious delays in the settlement of final accounts.

The three most common causes of outstanding payments reported by suppliers were ‘disagreement on, and delay, in settlement of progress payments’ (40%), ‘disagreement on noncompliance with specified standards’ (30%) and ‘disagreement on, and delay in, settlement of final account’ (25%). As most supply contracts contain the ‘pay when/if paid’ clause, this seriously affects the timely settlement of both interim and final payments received by suppliers. In addition, one of the major disputes is whether the materials supplied comply with the specified standards. They cannot normally get payments unless this type of dispute has been resolved.

4.5 Methods for Resolving Payment Disputes

A distribution analysis of the methods adopted to resolve payment disputes is shown in Table 6. The three most common methods, as reported by main contractors, were ‘commercial negotiation’ (55%), ‘mediation’ (15%) and ‘arbitration’ (10%). Indeed, these three dispute resolution methods are commonly specified in most local construction contracts. So it is rational that main contractors would first try to settle disputes through commercial negotiation. If unsuccessful, they would then pursue mediation. If the disputed amount is relatively small, then the dispute can be satisfactorily resolved through mediation. Main contractors still suffer from cash flow problems during the mediation process, which may take few months. However, if the amount in dispute is substantial, it is not likely that the dispute will be resolved by mediation because the losing party may subsequently refer the case to arbitration for a final decision. Nevertheless, arbitration is considered both costly and time-consuming. In many cases, both parties in arbitration have incurred significant legal costs that may not be affordable for small main contractors.

Table 6: Methods adopted to resolve payment disputes

Methods adopted to resolve payment disputes	Main Contractor	Subcontractor	Supplier
Commercial negotiation	55%	65%	70%
Mediation	15%	15%	17%
Arbitration	10%	7%	2%
Litigation	8%	6%	10%
Adjudication	7%	4%	1%
Dispute resolution adviser	5%	3%	-
Total	100%	100%	100%

The three most common methods reported by subcontractors for resolving disputes were ‘commercial negotiation’ (65%), ‘mediation’ (15%) and ‘arbitration’ (7%). Compared with main contractors, subcontractors relied more on commercial negotiation to resolve payment disputes, suggesting that subcontractors rely heavily on cash flows to sustain their businesses. Even if they have strong cases to succeed, they may choose to waive certain legal entitlements for the sake of promptly settling the disputes. Arbitration is considered a last resort for resolving payment disputes.

The three most common methods reported by suppliers for resolving disputes were ‘commercial negotiation’ (70%), ‘mediation’ (17%) and ‘litigation’ (10%). Compared with main contractors and subcontractors, suppliers relied even more on commercial negotiation to settle payment disputes for reasons similar to subcontractors. However, if commercial negotiation and mediation are not successful, suppliers prefer to litigate rather than arbitrate because most supply contract disputes are relatively straightforward and litigation is better than arbitration in terms of the time and cost involved.

4.6 Effectiveness of Payment Dispute Resolution Methods

The effectiveness of the six common payment dispute resolution methods is illustrated in Table 7. The majority of the respondents considered commercial negotiation to be the most effective method, ranging from 80% for main contractors, to 85% for subcontractors and 90% for suppliers. Slightly more than half of respondents considered mediation an effective method, ranging from 55% for main contractors, to 65% for subcontractors and 60% for suppliers. Realising that any formal dispute may break up the business relationship with their clients, main contractors, subcontractors and suppliers prefer to resolve their payment disputes through informal commercial negotiation whenever possible and, if not successful, they would then pursue formal mediation. As lower-tier parties are often in a weak negotiation position, they are sometimes forced to compromise by waiving certain entitlements if the disputes can be settled promptly. Therefore, while commercial negotiation appears to be very effective in dealing with payment disputes, it may not be a fair and equitable solution.

Less than half of the respondents considered adjudication an effective method, ranging from 42% for main contractors, to 45% for subcontractors and 40% for suppliers. First, there are better methods, such as mediation, and second, adjudication is operated in a similar process as the short-form arbitration, which in many cases cannot resolve the disputes in a timely and cost-effective manner. Dispute resolution advisers are only available in government contracts and are not applicable to subcontractors and suppliers, which limits the applications. Other dispute resolution methods, such as arbitration and litigation, were considered ineffective because they were time consuming or expensive. Arbitration or litigation might only be used in cases where the amount in dispute is very substantial. Under such circumstances, no party can afford to lose their cases.

Table 7: Effectiveness of payment dispute resolution methods

Effectiveness of payment dispute resolution methods		Main Contractor	Subcontractor	Supplier
Commercial negotiation	Effective	80%	85%	90%
	Not effective	20%	15%	10%
Mediation	Effective	55%	65%	60%
	Not effective	45%	35%	40%
Adjudication	Effective	42%	45%	40%
	Not effective	58%	55%	60%
Dispute resolution adviser	Effective	32%	-	-
	Not effective	68%	-	-
Arbitration	Effective	20%	17%	12%
	Not effective	80%	83%	88%
Litigation	Effective	8%	6%	15%
	Not effective	92%	94%	85%

4.7 Effectiveness of Security of Payment Legislative Provisions

The effectiveness of each of the security of payment legislative provisions expressed in terms of percentages of the total amount of outstanding payments is shown in Table 8. For main contractors, the three most effective legislative provisions for resolving payment disputes were the 'right to rapid adjudication' (50%), the 'right to suspend works for non-payment' (20%) and 'enforcement of adjudicators' decisions' (12%). For subcontractors and suppliers, the three most effective legislative provisions were the same, i.e. the 'right to rapid adjudication' (40% for subcontractors and 45% for suppliers), 'prohibition of conditional payment provisions' (20% for subcontractors and 18% for suppliers) and the 'right to suspend works for non-payment' (17% for subcontractors and 15% for suppliers). The use of 'others' suggests that these legislative provisions would not resolve all payment problems. If the amount in dispute between parties is substantial, one or both parties may refer the case, at the beginning or after the adjudication, to count or arbitration proceedings for a decision. Nevertheless, past experiences in overseas countries indicate that the security of payment legislation can resolve the majority of payment disputes.

Table 8: Effectiveness of security of payment legislation

Effectiveness of security of payment legislation	Main Contractor	Subcontractor	Supplier
Right to rapid adjudication	50%	40%	44%
Right to suspend works for non-payment	20%	17%	15%
Prohibition of conditional payment provisions	-	20%	18%
Enforcement of adjudicators' decisions	12%	10%	8%
Right to progress payments	10%	7%	5%
Others	8%	6%	10%
Total	100%	100%	100%

For all types of respondents, the right to adjudicate disputes is the most important provision in the security of payment legislation. Based on that legislative provision in overseas countries, adjudicators' decisions are binding unless and until the underlying dispute is resolved in count or arbitration proceedings. The decisions are enforceable even if there are errors of law or fact provided that the adjudicator acted within his jurisdiction and reached his decision in accordance with the principles of natural justice. Following service of the referral, the adjudicator in the United Kingdom must reach a decision within 28 calendar days. This requirement makes it easier for the lower-tier parties to recover their payments without a substantial delay.

The rationale behind the right to suspend is to prevent main contractors and subcontractors from having to continue working without payment, essentially enabling them to legitimately cease the works without fear of breaching the contracts. Suspension also provides an incentive to the upper-tier contracting parties to pay fairly and on time.

Conditional payment terms such as 'pay-if/when-paid' are prevalent in the local construction industry. Arguments in favour of such terms include freedom of contact and allocation of risks. However, the prohibition of conditional payment is based on the principle that a minimum level of clarity and fairness should be maintained in a contract so that the crystallisation of payments due does not depend on factors external to the contract and beyond the power of subcontractors or suppliers to fulfil. This legislative provision would effectively prevent the upper-tier contracting parties from withholding any payments on the grounds that they have not received a payment from a third person, thus protecting the smaller, more vulnerable subcontractors and suppliers in the supply chain.

5. Conclusions

Many of the respondents attributed variations as the most common source of disputes because they generate difficulties in measurement and valuation of the works done as well as agreeing on the entitlement to interim payments. A payment schedule is usually specified in a contract, but there are always delays due to slow certification, conditional payment terms and variation disputes. While respondents could generally get paid from interim payments, they were left in uncertain positions when facing the unduly long time lag in the settlement of final accounts. Under the current settings, the respondents tended to resolve their payment disputes through informal commercial negotiation because the other dispute resolution methods specified in the contract were considered to be ineffective. Under such situations, it was not uncommon that they would have to compromise by accepting a final account less than the amount that they were supposed to be entitled. The total amount of outstanding payments was reported to be substantial which should warrant the introduction of legislative measures to secure payments in the construction supply chain. The respondents also believed that some of the common legislative measures adopted in overseas countries could effectively resolve the majority of payment disputes along the construction supply chain. The way ahead is to consider the exact scope and details of the security of payment legislation appropriate for the local construction industry. This would be a good area for further research.

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Environmental Sustainability: A Framework for Environmental Assessment Schemes

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Abstract

Rising environmental issues in all socioeconomic systems have led to continuous discussions on the concept of Sustainable Development (SD). The construction sector and the built environment have been accused of causing a range of environmental problems and are faced with the challenge of translating strategic sustainability objectives into concrete actions at project level. There is an increased involvement of accreditation bodies, both commercial and governmental research and administrative organizations, in the introduction of third party environmental assessment schemes to assess and promote sustainability performance in construction and the built environment. However, these are not without criticisms and previous studies have identified a range of shortcomings related to criteria selection, weighing, coverage, and methodological transparency. Also, no theoretical base has been established for environmental assessment schemes, and it is evident that theory lags behind practice. To contribute to efforts to address this gap, this paper proposes a theoretical framework for Environmental Sustainability (ES) which can be used as a base for selecting, and giving weights to the criteria in environmental assessment schemes. The literature on SD and ES was reviewed to understand their objectives and relevant aspects which should be applied at the project level. While the concept of SD is always defined as the balance between three sectors; economic, environment and social, the Environmental Economists have begun to emphasize the importance of ES. Based on this emphasis, the paper discusses the interactions between the natural environment and the economic system to highlight the important requirements of ES which are to be addressed on today's construction and built environment projects and a theoretical framework is presented.

Keywords: Sustainable Development, Economic system, Environmental goods and services, Environmental Sustainability, Environmental Assessment schemes

1. Introduction

People experience the clear symptoms of environmental un-sustainability today: climate change, ozone layer depletion, pollution, resource depletion, food shortages, health problems, and so on. Most of these are results of growing economic activities which are not compatible with the capabilities of the natural environment which provides all the goods and

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services to almost all economic activities. These rising environmental issues in all socioeconomic systems have led to continuous discussions on the concept of SD. The construction industry and the built environment have been accused of causing a range of environmental problems including excessive consumption of natural resources and the pollution of the natural environment throughout their life-cycle (Sev, 2011). Therefore, the demand for a sustainable built environment has increased (Abdalla et al., 2011) and the industry is now faced with the challenge of translating strategic sustainability objectives into concrete actions at the project level (Ugwu and Haupt, 2007).

In this vein, environmental assessment methods play an essential role in evaluating and therefore encouraging the implementation of the sustainability principles in construction and built environment projects and a number of methods have been developed for evaluating the sustainability performances of those projects. Crawley and Aho (1999) note that environmental assessment methods range from life cycle assessment (LCA) methods to environmental impact assessment (EIA) methods. While the former consider the building or other construction project as a product and assess the life cycle environmental impacts, non-site specific, the latter evaluate the broader impacts of construction projects on the environment. Moreover, Crawley and Aho (1999) observe that between these two are environmental assessment methods such as Building Research Establishment Environmental Assessment Method (BREEAM) in the UK, Leadership in Energy and Environmental Design (LEED) in the USA, Building and Construction Authority Green Mark (BCA-GM) in Singapore, and National Australian Building Environment Rating System (NABERS) in Australia.

Cole (2005) shows that the terms ‘method’ and ‘tool’ are used interchangeably to describe building environmental assessment techniques and also the terms ‘certification’, ‘rating’ or ‘labelling’ are also used interchangeably to indicate extended outputs from the assessment process. Cole (2005) considers ‘tools’ to describe a technique that predicts, calculates or estimates environmental performance characteristics of buildings or construction products which is similar to that of LCA methods explained by Crawley and Aho (1999). Cole (2005) uses the words ‘method’, ‘system’ or ‘scheme’ to describe assessment techniques relating to scoring performance and derivation of weightings which is the focus of this paper and are referred to as ‘environmental assessment schemes’. Since the introduction of the UK’s BREEAM in 1990, the first environmental assessment method worldwide for buildings (Haapio and Viitaniemi, 2008; Abdalla et al., 2011), there has been increased involvement of accreditation bodies, both commercial and governmental administrative and research organizations in the introduction of third party certification (Cole, 2005; Xiaoping et al., 2009) to assess and promote sustainability performances in construction and the built environment (Glavinich, 2008; Abdalla et al., 2011). Environmental assessment schemes have been formulated not only to be used to assess buildings but also infrastructure projects which cover a wide range of projects in the built environment. These schemes include Civil Engineering Environmental Quality Assessment and Awards Scheme (CEEQUAL) in the UK, BCA Green Mark for Infrastructure in Singapore, and the Australian Green Infrastructure Council rating system.

Despite the increased interest in, and development of, environmental assessment schemes worldwide, these are not without criticisms and previous studies present a range of shortcomings in these schemes. These include lack of overall transparency (Inbuilt, 2010 cited by Alyami and Rezgui, 2012), failure to cover some important criteria (Haapio and Viitaniemi, 2008; Abdalla et al., 2011), lack of an objective basis for the weighting system (Alyami and Rezgui, 2012) and lack of a clear path towards establishing an applicable environmental assessment method (Alyami and Rezgui, 2012) for a specific sector in a specific region. Also no theoretical base has been established for environmental assessment schemes in general (Cole, 1998; Retzlaff, 2009). Thus, in this area, theory lags behind practice. Crawley and Aho (1999) identified methodological transparency as an important requirement in developing environmental assessment tools, from both a philosophical and a practical point of view. However, previous studies have followed a process of listing sustainability criteria and sub-criteria under broad categories (such as project management, energy, materials use, ecology, waste and so on) and ranked them with expert evaluation. These rankings are not based on a theoretical base for ES and their assessment over actual environmental impacts are not transparent.

To contribute towards efforts to address this gap between theory and practice, this paper proposes a theoretical framework for ES with direct relevance to the construction and built environment items which can be used as a base for selecting and weighting the criteria in environmental assessment schemes.

2. Method and layout

Owing to the importance of the natural environment for almost all socioeconomic activities, the literature on Environmental Economics related to interactions between the economic system and the natural environment was adopted as the main basis for this research. These interactions were reviewed to determine a set of requirements that should be considered in order to achieve ES.

3. Sustainable development

SD is often presented as comprising three sectors; economic, environmental and social and often presented as three equal-sized interconnected rings (Giddings et al., 2002) as shown in Figure 3.1.a. Giddings et al. (2002) pointed out several weaknesses of the ring model which shows three rings in a symmetrical interconnection that leads one to assume the the three sectors are separate or even autonomous from each other. Furthermore, Giddings et al. (2002) claims that the model shows possible trade-offs that can be made among the three sectors, similar to that of the concept of “weak sustainability” which assumes that man-made capital can be used to replace or substituted for natural resources and systems (Neumayer, 1999 cited in Giddings et al., 2002; Daly, 1994) which is far beyond the reality considering real physical environmental limits.

In reality, the economic system depends on society and the environment and both the economic system and society depend on the natural environment ultimately. The natural environment is the core of any economy and economies cannot be sustained without

environmental goods and services. Therefore, ES is a necessary condition for economic sustainability (Thampapillai, 2002). Thus, the separation in the ring model underplays the fundamental connections between the economy, society and the environment (Giddings et al., 2002) and it is suggested that the nested model (Figure 3.1.b.) represents the reality of the relationships between economy, society and the natural environment better than the ring model (Giddings et al., 2002).

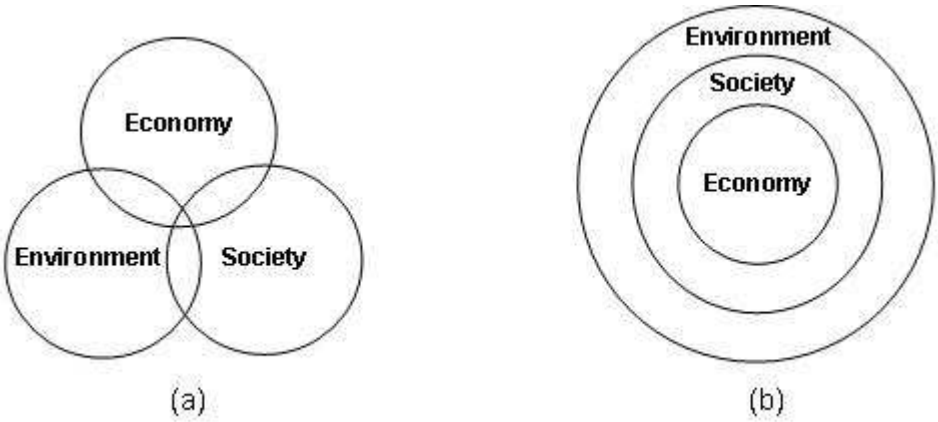

Figure 3:1 Ring model and Nested model (Giddings et al., 2002)

It has been realized today that the term “economic” does not just mean the happenings in the flow of money but also changes in human well-being which comprise not only monetary wealth but also many other services provided by the natural environment. Therefore, effective sustainability approaches need to address the relationships between ecosystems and economic systems (Jansson et al., 1994). The literature on the interactions between the ecological system and the economic system is reviewed in the next section.

4. Interactions between natural environment and economic system

The major interactions between the economic system and the natural environment are discussed to establish the requirements for ES for the proposed model.

Turner et al. (1994) explain the multi-functional nature of environmental resources with a wide range of economically valuable functions and services. Holding similar views, Common and Stagl (2005) and Asafu-Adjaye (2005) illustrate four interactions between human economic activities and the natural environment as (i) resource extraction from the environment for production and consumption, (ii) waste disposal to the environment as a result of both production and consumption, (iii) provision of amenity services, and (iv) life support services by environment. Pearce and Turner (1990) and van den Bergh (1996) also support these interactions. In addition to these four interactions, Hanley et al. (2001) explain an important interaction, the impacts from the economy to the biodiversity of the natural environment.

Including but going beyond these widely discussed interactions, de Groot (1992) developed a system to better explain functional interactions between human society and the natural environment as shown in Figure 4.1 which can be used for assessing the full value of natural systems to human society including both positive and negative aspects.



Figure 4:1 Functional interactions between society and environment (de Groot, 1992)

The main focus of de Groot (1994) is the function concept as an important element which defines environmental functions as "the capacity of natural processes and components to provide goods and services that satisfy human needs directly and/or indirectly" (de Groot, 1992). Also under the 'natural capitalism' phenomenon introduce by Lovins et al. (1999), the value of ecosystem services is identified as the largest component of capital. They propose four major shifts to economic activities in order to reduce wasteful and destructive flow of resources from depletion to pollution by reducing resource usage and hence, extraction and waste generation, and at the same time, restoring, sustaining and expanding natural capital to offset environmental impacts caused by economic activities. The latter is also emphasized by Daly's (1994) notion of moving from an empty world to a full world.

Table 4:1 Summary of literature review of economic - ecosystem interactions

Interactions	Sources
1. Use the environment as a source of land	Pearce and Turner (1990); de Groot (1992); Turner et al. (1994);
2. Use the environment as a source of materials and energy resources	Pearce and Turner (1990); de Groot (1992); Daly (1994); Turner et al. (1994); van den Bergh (1996); Lovins et al. (1999); Hanley et al. (2001); Thampapillai (2002); Common and Stagl (2005); Asafu-Adjaye (2005)
3. Use the environment as a sink for disposing of waste	Pearce and Turner (1990); de Groot (1992); Daly (1994); Turner et al. (1994); van den Bergh (1996); Lovins et al. 1999); Hanley et al. (2001); Thampapillai (2002); Common and Stagl (2005); Asafu-Adjaye (2005)
4. Use the environment as a flow of amenities and life support services	de Groot (1992); Turner et al. (1994); Hanley et al. (2001); Thampapillai (2002); Common and Stagl (2005); Asafu-Adjaye (2005)
5. Invest in natural capital to maintain it	de Groot (1992); Thampapillai (2002)
6. Invest in natural capital to enhance it	de Groot (1992); Daly (1994); Lovins et al. (1999); Thampapillai (2002)
7. Conserve biodiversity	Hanley et al. (2001)
8. Suffer from environmental hazards and risks	de Groot (1992)

Daly (1994) explains that when natural capital is utilized to produce man-made capital continuously, natural capital become scarce and therefore investment in maintaining natural capital stock is of immense importance. Thampapillai (2002) presents two forms of investment in natural capital; restoring lost (non-functional) endowments and maintaining existing (functional) endowments. Thampapillai (2002) emphasizes the need for sharing of income within the economic system with the natural environment to achieve equilibrium between the environment and the economic system.

Table 4.1 summarizes these interactions between the economic system and the ecosystem. Since the concern of this study is in the form of proposing changes to the current patterns of economic activities to achieve sustainability, the interactions are listed from the perspective of activities in the economic system.

5. Theoretical framework for environmental sustainability

In this section, each interaction is defined for the purpose of the current study and major interactions will be determined which provide the basis of the theoretical framework for the assessment of ES of construction and built environment projects.

5.1 Use environment as a source of land

Although land could be considered as a unique resource that it is perfectly inelastic in supply and available to society as a fixed total quantity (Hanley et al., 2001), with the rapidly growing development activities, there is greater concern about changing land quality (FAO, 1997). The way land is used highly affects the future availability of productive land and other natural features inherent in those areas in terms of both quantity and quality.

Therefore, proper management in land use to minimize these effects is considered as one of the major requirements for ES. Here, one aspect is to minimize the need for acquiring new productive land and another aspect is to consider the composition of the land; whether it is a greenery area, wetland, marshy land and so on. During project development and operation, concern must be given in reducing damage to the selected land area and the neighbouring land. These requirements are considered in the proposed theoretical framework.

5.2 Use environment as a source of materials and energy

The environment provides inputs to the economic system; raw materials and energy resources (Hanley et al., 2001) for both production and direct consumption (Common and Stagl, 2005; Asafu-Adjaye, 2005). The earth is considered as a closed system in terms of materials and receives a limited amount of outside energy (solar energy) within a certain period. Therefore, natural resources are considered as scarce resources and with growing economic activities they become more scarce. Harnessing excessive amount of materials and energy resources may reduce the available stocks (Hanley et al., 2001) and cause damage to the environment depending on the type of source and method of extraction. The selection of materials and energy sources and quantity of usage should be decided depending on the potential for the natural growth of different materials and energy sources;

whether non-renewable, exhaustible or renewable (Turner et al., 1994; Hanley et al., 2001). Effective usage would reduce the demand for new materials and energy resources and also the attention should be paid to select the material sources with minimum environmental impacts during extraction and usage. For example, quarries developed in national parks will damage the biodiversity and amenity flow (Hanley et al., 2001) rather than one in a brownfield area. Logging in a rainforest largely impacts biodiversity compared to a logging in a planted forest. It might involve the extraction of the same amount of materials by quantity but it would cause different harms.

Therefore minimizing the usage of materials and energy resources by quantity and minimizing damages during extraction and usage are considered as major requirements for ES in the proposed framework.

5.3 Use environment as a sink for disposing of waste

The economic system uses materials and energy during production and consumption. In production processes, useful products are made and residuals are also generated. When these residuals are not inserted again into the economic system by reusing or recycling, they become waste (Common and Stagl, 2005). Similarly, useful products become waste after consumption. Waste cannot be destroyed in an absolute sense as explained under the first law of thermodynamics, and it is not possible to recycle all waste as explained under the second law of thermodynamics. Therefore, at least some of it will eventually be discharged into the environment (Turner et al., 1994; Thampapillai, 2002). The natural environment has an ability to handle these wastes up to a certain extent which is known as “assimilative capacity” (Thampapillai, 2002). When the disposal of the waste is continuous and intense, this capacity may be exceeded, and the natural environment is no longer able to fulfil its functions as a waste sink (Thampapillai, 2002). This will also affect its other functional performances as well and consequently, imposes limits to the economic activities (Turner et al., 1994; Common and Stagl, 2005). Both the quantity of waste and the quality of waste should be considered. For example, the discharging of non-treated water into a river system is more harmful than that of the same quantity of treated effluent.

The proper usage of the natural environment as a sink for disposing of waste in terms of waste quantity and harm is a major requirement for ES and is considered in the proposed theoretical framework.

5.4 Invest in natural capital to maintain it

It is not possible to attain a target of zero harm to the environment with economic activities. Therefore, a way to compensate the environment should be involved in the economic activities. Thampapillai (2002) suggests that the final output of the economic system (sum total of all income from goods and services) should not be exclusively used up in consumption and investment within the economic system. Instead, a part of this final output must be invested into the environment. Similar to that of the equilibrium of input and output flows between households and firms, the equilibrium between the economic system and environmental system (Thampapillai, 2002) should be attained. One form of investment in

natural capital is maintaining the flow of services from endowments that currently provide services (functional). This is similar to offsetting wear and tear of capital goods. An example of this would be periodically treated a river which is getting polluted but still providing services.

Another form of investment in natural capital is to restore the flow of services from endowments which have ceased to provide services (non-functional). This includes restoring previously damaged or lost endowments such as rivers rendered unusable due to algal blooms, reforestation of areas that had been cleared for years (Thampapillai, 2002). Daly (1994) emphasizes the importance of investment in natural capital to enhance its stock, in order to cope with the increasing demand for environmental goods and services.

Therefore, investing in natural capital to maintain its status and to enhance its stock is considered as important requirements for ES and are considered in the proposed theoretical framework.

5.5 Impact biodiversity

According to Hanley et al. (2001), biodiversity loss involves more than the loss of particular species. Direct impacts such as loss of genetic materials for food crops or as a source of medicine, loss of a range of ecosystem services and, impacts on non-use benefits such as aesthetics can also be experienced. Biologically diverse ecosystems provide a greater flow of ecosystem services than non-diverse systems (Parker and Cranford, 2010). Also, diversity provides an important property of natural systems which is known as ‘resilience’, the ability to withstand shocks such as drought and fire (Hanley et al., 2001). Although natural resources are conserved in terms of quantity of total natural capital stock, the diversity of that natural capital stock is of immense importance in order to continue the functionality of the life-supporting ecosystems (Wilson, 1988 cited in Jansson et al., 1994). Hence, conserving biodiversity and reducing negative impacts on biodiversity are regarded as major requirements for ES in the proposed theoretical framework.

5.6 Use environment as a flow of amenities and life support services

People derive utility in terms of happiness and satisfaction (Common and Stagl, 2005; Hanley et al., 2001) through amenity services provided by the natural environment including sightseeing, sunbathing, wilderness recreation and so on (Hanley et al., 2001; Common and Stagl, 2005). Negative impacts on natural resources due to improper land selection, depletion of resources, pollution and loss of biodiversity disturb the functioning of ecological systems and these amenities. Also the natural environment provides biophysical necessities of life such as food, energy, mineral nutrients, air and water (Jansson et al., 1994) through life support services including climate regulation, operation of the water cycle, regulation of atmospheric composition, nutrient cycling, and so on (Hanley et al., 2001). Maintaining the life support services of the environment are important for the survival of humankind.

Since, land use, resource use, waste disposal and loss of biodiversity which are discussed in the sections 5.1 to 5.3 and 5.6, are the causes disrupting the amenities and life support

services and controlling those causes during development activities will help continuing the amenities and life support services as well.

5.7 Suffer from environmental hazards and risks

Since this study is focused on ES from the perspective of protecting and enhancing the natural environment, the environmental hazards and risks affecting the economic system from the environment are not considered in the proposed theoretical framework.

5.8 Theoretical framework

Considering the impacts on the natural environment due to economic activities, nine requirements were determined which are important to achieve ES as listed below.

ES1a – Minimize land use in terms of area

ES1b – Minimize qualitative damages to the environment due to land use

ES2a – Minimize use of materials and energy sources in terms of quantity

ES2b – Minimize qualitative damages to the environment due to the usage of materials and energy sources

ES3a – Minimize waste disposal to the environment in terms of quantity

ES3b – Minimize qualitative damages to the environment due to disposing of waste

ES4a – Invest in natural capital to maintain it

ES4b – Invest in natural capital to enhance it

ES5 – Conserve biodiversity

These are the factors to be considered when assessing the environmental performance of development projects, thus providing the theoretical base for Environmental Assessment Schemes which are assessing such projects.

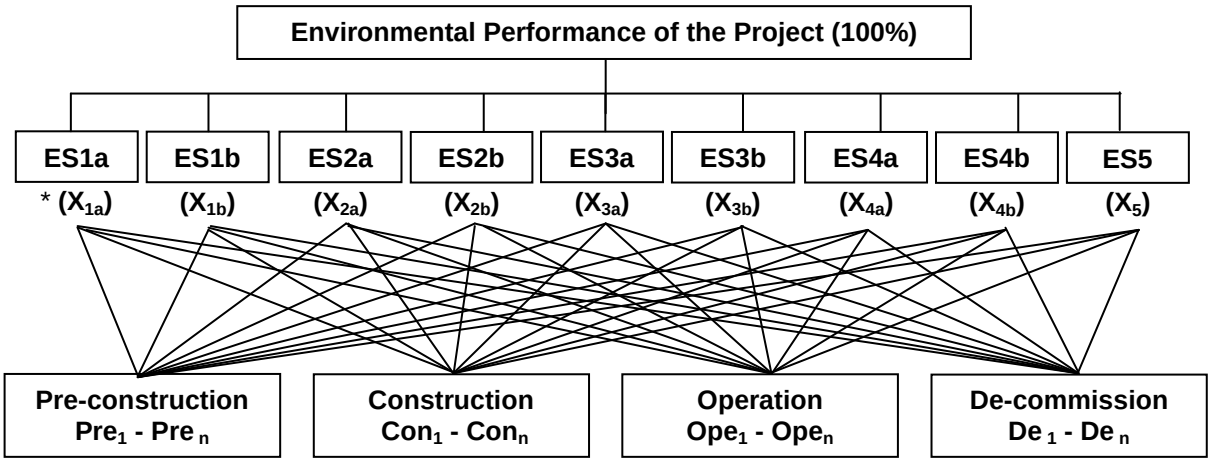

Figure 5:1 Framework for evaluating environmental sustainability

* 100% = $X_{1a} + X_{1b} + X_{2a} + X_{2b} + X_{3a} + X_{3b} + X_{4a} + X_{4b} + X_5$ = Total assessment score

Pre_1 - Pre_n - Criteria in the pre-construction stage

Con_1 - Con_n - Criteria in the construction stage

Ope_1 - Ope_n - Criteria in the operation stage

De_1 - De_n - Criteria in the de-commissioning stage

When developing an environmental assessment scheme for a specific sector in a specific region, the percentage importance of the total score for each factor from ES1a to ES5 for that region should be evaluated first. Then the potential environmental issues and potential positive impacts should be identified at each stage of the project from pre-construction to de-commissioning. Next, the criteria should be determined based on these issues and potential positive impacts and the importance of each criterion at each stage against ES factors (ES1a to ES5) can be evaluated. Finally, a summated value can be assigned to each criterion based on their contributions towards achieving ES. Thus, the theoretical framework of ES factors provides a basis for determining weights for criteria rather than using a simple interval scale to assign weights, or assigning equal values to all criteria.

6. Further research

The proposed framework can be applied in the development of environmental assessment schemes for different types of construction and built environment projects. Likely or existing environmental problems and positive impacts at each stage of a project in the particular sector in the particular region can be identified through a field survey. Then the criteria can be determined and weights assigned to them based on their importance towards the attainment of each ES factor. Systematic, multi-criteria ranking techniques such as Analytic Hierarchy Process (AHP) can be applied in undertaking such an evaluation.

7. Conclusion

Environmental assessment schemes play an important role in the implementation of the sustainability principles in construction and the built environment and a number of such schemes have been introduced around the world. However, there are several criticisms including the absence of a theoretical base for selecting and assigning weights to the criteria for environmental assessment schemes. These schemes need to identify projects with better environmental performance and therefore the weights for each criterion should reflect its contribution towards the achievement of environmental sustainability. Considering this requirement, this study proposed a theoretical base for ES which can be used as the basis for determining weights for the assessment criteria. Also, it presents a systematic method for developing environmental assessment schemes using the proposed theoretical base.

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Seismic safety of places of worship in Italy's Gran Sasso and Monti della Laga National Park

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Abstract title

The abundance of historic architectural heritage within Italy and its vulnerability to earthquake heighten the need for a risk analysis aimed at preserving buildings and their contents. In particular, churches are often more vulnerable than other buildings, even in the case of brief tremors. The reasons for this increased vulnerability are due to structure and peculiar geometrical proportions: presence of large open areas without internal walls to provide bracing, absence of intermediate ceilings, thinness of walls and certain vaulted structures, presence of thrust-exerting elements (arches, vaults). These features of churches, along with the use of architectural and structural criteria that are recognisable and comparable, albeit within the unique nature of each object, has led to a quest for specific procedures to assess seismic vulnerability, these being different to those utilised for ordinary buildings. The method involves dividing the building into macroelements, i.e. architectural sections of recognisable construction technique and showing similar seismic response (facade, apse, bell tower, etc.). The way in which damage can occur and the collapse mechanisms that the earthquake can provoke are therefore identified for each macroelement.

A specific risk analysis of places of worship has been carried out as part of the European project RECES modiquss "The network of small old town centres as a model of urban quality and sustainable development" - INTERREG IIIA Adriatic cross-border programme. Research has been concentrated on places of worship located in an area comprising six communes of the L'Aquila province in central Italy. Many of the churches involved underwent a vulnerability analysis. The earthquake that struck central Italy on 6th April 2009 seriously damaged many of the churches surveyed prior to this event. It is now possible to compare the damage suffered and the mechanisms unleashed with the mechanisms predicted during survey and analysis.

Keywords: seismic vulnerability, churches, collapse mechanisms, damage, macroelements.

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[2] Architectural firm Proteo Associati
[3] Italian National Research Council
[4] Italian National Research Council

1. Introduction

The abundance of historic architectural heritage within Italy and its seismic vulnerability, i.e. its susceptibility to damage or alteration following an earthquake, heighten the need for a risk analysis of certain areas aimed at preserving buildings and their contents. A specific risk analysis of places of worship was carried out by the L'Aquila branch of the National Research Council Construction Technology Institute (NRC CTI) as part of a European project whose objectives included knowledge, protection and enhancement of cultural heritage, including in support of socioeconomic development linked to sustainable tourism. Research concerned places of worship located in an area comprising six communes of the L'Aquila province: Barisciano, Calascio, Castelvecchio Calvisio, Castel del Monte, Carapelle Calvisio, S. Stefano di Sessanio. This area forms one of the Cultural Tourism Districts of the Gran Sasso and Monti della Laga National Park called Terre della Baronia. This survey of places of worship has led to the identification and registration of 64 elements, some in a state of ruin, comprising churches, convents and chapels (figure 1).



Figure 1. San Cipriano Church in Castelvecchio Calvisio

Some of the churches involved, representing the largest part of the sample, underwent a vulnerability analysis. The sample consists of 33 mainly aisleless churches of various size and complexity. The method used is about the study of building and the analysis of seismic risk with a quickly form and an analytical method, according to the indications of the Italian rule for cultural heritage.

The earthquake that struck central Italy on 6th April 2009, in particular the city of L'Aquila and the above-mentioned communes, has enabled a check to be carried out on the effectiveness of the forecasts made and methodology used.

2. SAMPLE TYPE ANALYSIS

The different types of construction were identified, these ranging from a simple chapel to very large churches (see table 1 and figure 2). The higher the surface area, the greater the building's structural complexity. The sample surveyed comprises 73% aisleless churches and 24% with two naves or three aisles. 70% are buildings with vaulted structures. Domes are present in only 24% of the sample. Projections and gables are found in 64% of the sample and mainly feature bell gables and gable façades, whilst 21% have a bell tower. 36% of the sample have an apse and 12% a transept. Only 6% of the churches have a prothyron.

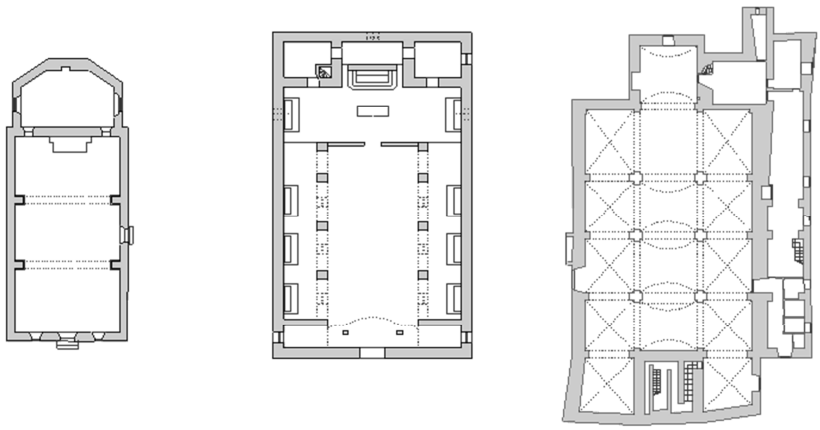

Figure 2. Plan of the Santa Maria della Pietà di Collerotondo church, Santa Maria ab Extra church, both in Barisciano, and the San Marco Evangelista church in Castel del Monte

Various types of façade are to be found (figure 3), the most characteristic and at the same time most vulnerable feature, but all meet standard architectural criteria. The rectangular façade typical of L'Aquila (45% of sample) is the most common, whilst 24% of the churches surveyed have a gabled façade and in 21% of cases it follows the outline of the roof. This last-mentioned type is a feature of aisled churches or those having side chapels. It is worth noting that 39% of the sample have a façade with gables and other projections that can be particularly vulnerable in the event of an earthquake.



Figure 3. Façade of the churches of Santa Maria di Valleverde in Barisciano, Madonna del Lago in S. Stefano di Sessanio and Santa Maria and San Vittorino in Carapelle Calvisio

3. SEISMIC VULNERABILITY ANALYSIS

An in-depth study was conducted into the construction of each of the churches, this considering the following aspects:

- its history, using available bibliography and archive material from the L'Aquila Heritage Commission;
- comprehensive geometric, technological and material characteristics survey based on direct observation and the survey and archive material available from the L'Aquila Heritage Commission (figure 4);
- survey of cracks and deformation**.**

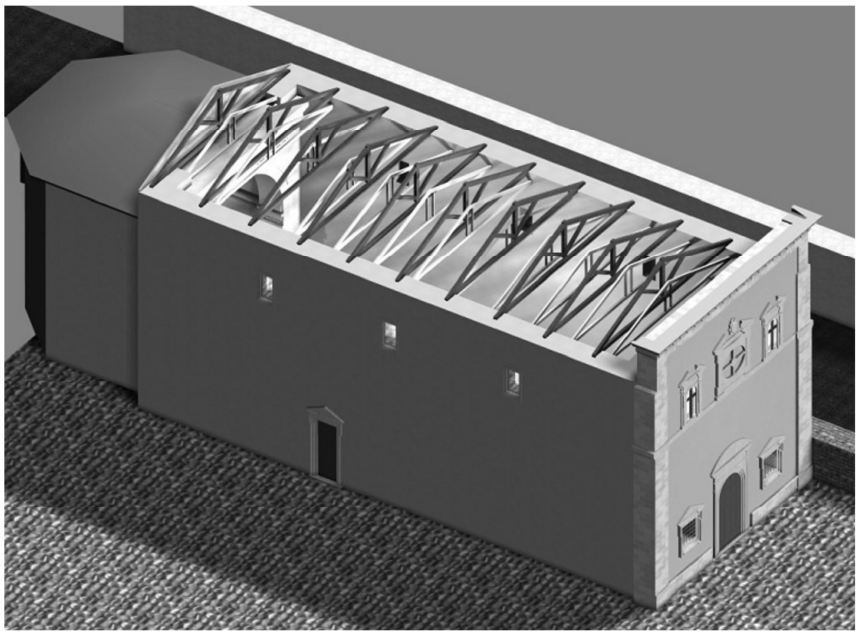

Figure 4. Santa Maria di Valleverde church in Barisciano, axonometric projection

In addition, these churches also underwent a data sheet survey using the "Level II churches damage and vulnerability survey sheet". The survey method is based on identifying 28 possible damage mechanisms affecting a series of the church's macroelements and analysing the factors that can facilitate or prevent the activation of such mechanisms. The procedure leads to the creation of a vulnerability index i_v ranging from 0 to 1, using a suitable combination of points awarded to the various seismic vulnerability and protection elements. This index offers comparison of the degree of vulnerability of churches of different shapes and sizes, allowing a sort of hierarchy to be established (see fig. 5).

For each damage mechanism considered, its frequency of activation was calculated along with the damage level as a percentage of all the churches surveyed. The information provided by the data sheets highlights the absence of seismic damage. When present, damage is limited and does not exceed level 3. Indeed, the main problem was caused by lack of maintenance, as noted during surveying.

N	COMUNE	DENOMINAZIONE CHIESA	navata unica	due navate	tre navate	pianta centrale	facciata	protiro	campanile	vela	cappelle	abside	transetto	corpi annessi	volte	cupola	lanterna	posizione
1	Barisciano	S. Maria della pietà	X				X			X				X				isolata
2	Barisciano	S. Maria di Capo di Serra		X			X			X					X			estremità
3	Barisciano	S. Maria del Carmine	X				X			X	6	X		X	X		X	nel contesto
4	Barisciano	S. Maria di Valleverde	X				X		X			X		X				corpi annessi
5	Barisciano	Immacolata Concezione	X				X			X	1			X	X	X		nel contesto
6	Barisciano	S. Flaviano			X		X		X		12	X	X	X	X	X	X	corpi annessi
7	Barisciano	Oratorio del SS.Rosario	X							X		X		X	X			estremità
8	Barisciano	S. Colombo	X				X			X	4	X		X	X			corpi annessi
9	Barisciano	S. Martino	X				X				4			X				estremità
10	Barisciano	Madonna del Rosario	X				X							X				corpi annessi
11	Barisciano	S. Maria ab Extra			X		X		X			X	X	X	X	X	X	isolata
12	Carapelle Calvisio	S. Pancrazio	X				X			X	10			X	X			isolata
13	Carapelle Calvisio	S. Francesco	X				X			X	1			X				nel contesto
14	Carapelle Calvisio	S. Vittorino	X				X								X			isolata
15	Carapelle Calvisio	S. Maria e S. Vittorino		X			X			X	3	X			X	X		nel contesto
16	Castelvecchio Calvisio	S. Cipriano	X				X			X		X		X				isolata
17	Castelvecchio Calvisio	S. Giovanni Battista		X			X			X	1			X	X			estremità
18	S.Stefano di Sessanio	S. Stefano Protomartire	X				X		X					X	X			isolata
19	S.Stefano di Sessanio	Madonna del Lago	X				X	X		X	2			X	X			isolata
20	S.Stefano di Sessanio	S. Maria in Ruvo		X			X			X		X		X				nel contesto
21	S.Stefano di Sessanio	Anime S. del Suffragio	X								1			X				nel contesto
22	Castel del Monte	S. Marco Evangelista			X				X				X	X	X	X		nel contesto
23	Castel del Monte	S. Maria del Suffragio	X				X			X				X	X			corpi annessi
24	Castel del Monte	S. Donato	X				X				6	X			X			isolata
25	Castel del Monte	S. Maria delle Grazie	X				X			X					X			isolata
26	Castel del Monte	S. Rocco				X	X			X						X		estremita
27	Castel del Monte	S. Caterina		X			X								X			nel contesto
28	Calascio	S. Maria delle Grazie	X				X	X	X			X		X	X			corpi annessi
29	Calascio	S. Antonio Abate	X				X			X				X				corpi annessi
30	Calascio	S. Nicola di Bari	X				X		X		4	X	X	X	X	X		nel contesto
31	Calascio	S. Leonardo	X				X			X				X	X			corpi annessi
32	Calascio	Madonna delle Grazie	X				X			X				X	X			isolata
33	Calascio	S. Francesco	X				X								X			isolata

Table 1. Types of church forming the sample

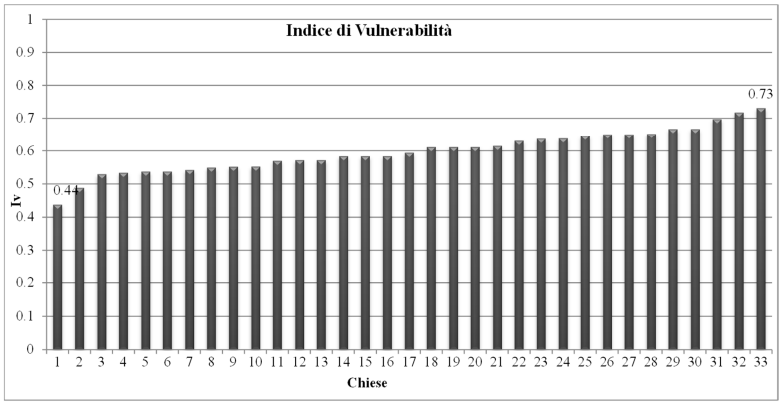

Figure 5. Vulnerability indices

By assessing the damage mechanisms that can be activated in the presence of a certain macroelement, it can be noted that façade mechanisms are likely in almost all the churches (97%). This shows that the sample is composed of buildings that are either isolated or form part of complexes in which such macroelement can be identified. The highest damage level, and thus mechanism activation, is also found: 24% overturning of façade, 15% top, 27% in-plane mechanisms. The cases noted of overturning are characterised by the presence of vertical cracks on the side walls close to the façade, mainly due to poor bonding between masonry walls. Cracks relating to a mechanism at the top of the façade is almost always due to either the fact that façades project above the top of the roof and are pounded or the thrust of nave vaults. On the other hand, in-plane mechanisms are helped by the presence of various openings in the façade, some of notable size. The greater possibility of activating a

transverse response (100%) as opposed to mechanisms connected to nave vaults (70%) underlines the absence of vaulted structures in some churches that instead have timber trusses or beams resting on stone cross arches. In this case, the damage is to be found above all in the vaults (mechanism activated in 21% of cases) with cracks in the keystone or on the lunettes, mainly due to the absence of suitable protection to dampen thrust. The mechanism in the roofing is also likely to be activated in almost all the buildings analysed (97%). Some of the roofing structures are constructed using timber trusses, but most are made using reinforced concrete. In 88% of the sample, interaction is possible between the individual structures forming the building as a whole.

4. MASONRY QUALITY ANALYSIS

Masonry quality was assessed by referring to the “Level I data sheet for assessing masonry type and quality”. Using the data contained in the survey sheets for the sample considered it has been possible to carry out a statistical survey with regard to the presence of the different construction parameters that can be found in the various types of masonry. A total of 67 masonry structures have been identified and these can be broken down into four types specified by current technical standards (figure 6). The data sheets serve the dual purpose of facilitating the collection and filing of information and allowing immediate identification of the masonry’s specific characteristics and determination of the main types. By analysing the data concerning their constituents, it can be seen that the masonry structures are all composed of elements of a calcareous nature with lime mortar.

Tipologia muraria	Numero casi	Percentuale
A. Muratura in pietrame disordinata	53	79%
B. Muratura a conci sbozzati	5	7%
C. Muratura in pietra a spacco con buona tessitura	3	4%
E. Muratura a blocchi lapidei squadrati	6	9%
Totale	67	100%

Table 2. Masonry types

The breakdown of the different types (table 2) shows that most of the sample belongs to type A, whilst there are no examples of type D. Type E often regards the façade, this being built with large blocks of limestone that are carefully squared in order to produce a building of striking architectural impact.

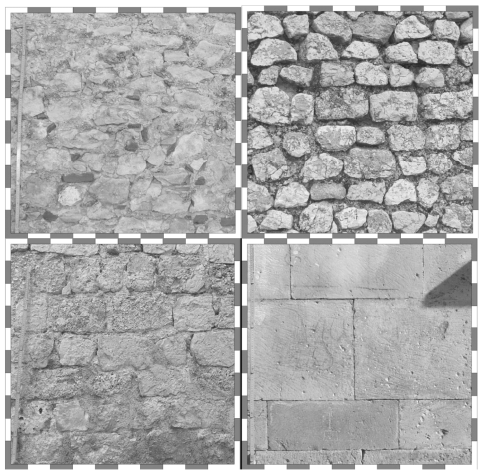

Figure 6. Sample of masonry types: starting from top left A, B, C, E

Thermal imaging was carried out on some of the buildings in order to assess, without touching plastered surfaces, the elements required for characterization of structural members such as: the vertical arrangement of the masonry structure, presence of gaps/irregularities and substructures, vault type, degree of instability and details of the cracks. Thermal imaging was carried out by a workgroup led by Prof. Ermanno Grinzato. The thermal images produced enabled direct verification of the quality of the information that can be obtained (figures 7, 8).



Figure 7. Santa Maria di Valleverde church in Barisciano, thermograph and photo



Figure 8. Madonna del Lago church in Santo Stefano di Sessanio, thermograph and photo

5. ANALYTICAL VULNERABILITY ASSESSMENT

5.1 LV1 assessment level

The analytical vulnerability assessment of the churches in question was carried out in accordance with the procedure specified in the "G*uidelines for the assessment and reduction of the seismic risk to cultural heritage*". Initially, the simplified LV1 model proposed by the above-mentioned guidelines was applied. This model, based on statistical data collected from previous Italian earthquakes, enables an estimate to be made of the peak ground acceleration corresponding to the Ultimate Limit State (ULS) and Damage Limitation State (DLS) as a function of the vulnerability index i_v calculated with the damage and vulnerability survey sheet using the following expressions:

$$a_{SLD} = 0{,}025 \times 1{,}8^{2{,}75-3{,}44 i_v}$$

$$a_{SLD} = 0{,}025 \times 1{,}8^{5{,}1-3{,}44 i_v}$$

The structure's safety index at the Ultimate Limit State represents the ratio of structural capacity to seismic demand and can be calculated as:

$$I_s = \frac{a_{SLU}}{\gamma_I S a_g}$$

where: a_{ULS} is the ground acceleration that will lead to the ultimate limit state being reached; S is a parameter that takes account of the stratigraphic profile of the underlying subsoil and morphological effects; γ_I is the importance coefficient that takes account of the building's position and its cultural importance. a_g is the reference acceleration for the site. This is the same for the Damage Limitation State. This purely statistical approach may be considered correct since it refers to the analysis of a specific area. It allows drawing up of lists of priority and programming of more detailed assessments in the best possible manner with a view to implementing preventive measures. Indeed, the use of a single model for assessments of this type allows more objective comparison as far as seismic risk is concerned. Reference accelerations for the communes in which the places of worship are located were taken from current technical standards. Safety indices at ULS and DLS for the churches in question are given in the following table and graphs (table 3, figure 9).

As confirmation of that previously noted in the case of minor earthquakes, it is worth pointing out that these structures are more susceptible to DLS than ULS. It may be noted that ground acceleration values corresponding to the ultimate limit state (ULS) are fairly high. Indeed, mechanisms will generally be activated at lower values, although higher acceleration levels are needed before causing the structure to collapse.

In order to make a more accurate forecast as to the seismic risk for these buildings, more in-depth studies and processing are required, applying the LV2 second level procedure based on the analysis of individual mechanisms.

N	Chiesa	Comune	S	γ_i	Fc	a_{SLD}	a_{SLU}	Is_{SLD}	Is_{SLU}
1	S. Cipriano	Castelvecchio Calvisio	1.25	0.65	1.12	0.05 g	0.21 g	0.63	1.00
2	S. Rocco	Castel del Monte	1.25	0.65	1.12	0.04 g	0.17 g	0.54	0.86
3	S. Maria delle Grazie	Calascio	1.25	0.65	1.12	0.04 g	0.17 g	0.53	0.84
4	S. Caterina-Cong. della SS Annunziata	Castel del Monte	1.25	0.65	1.12	0.04 g	0.16 g	0.52	0.83
5	S. Antonio Abate	Calascio	1.25	0.65	1.12	0.04 g	0.17 g	0.52	0.83
6	S. Francesco d'Assisi	Calascio	1.25	0.65	1.12	0.04 g	0.17 g	0.51	0.82
7	S. Stefano Protomartire	S. Stefano di Sessanio	1.25	0.65	1.12	0.04 g	0.17 g	0.51	0.81
8	S. Donato	Castel del Monte	1.25	0.65	1.12	0.04 g	0.15 g	0.49	0.78
9	S. Maria delle Grazie	Castel del Monte	1.25	0.65	1.12	0.04 g	0.15 g	0.49	0.78
10	Immacolata Concezione e Cappella	Barisciano	1.25	0.65	1.12	0.04 g	0.16 g	0.49	0.78
11	S. Pancrazio	Carapelle Calvisio	1.25	0.65	1.12	0.04 g	0.16 g	0.47	0.76
12	S. Maria di Capo di Serra	Barisciano	1.25	0.65	1.12	0.04 g	0.16 g	0.47	0.75
13	Madonna delle Grazie	Calascio	1.25	0.65	1.12	0.04 g	0.15 g	0.47	0.75
14	S. Maria del Suffragio	Castel del Monte	1.25	0.65	1.12	0.04 g	0.15 g	0.46	0.74
15	S. Maria di Valleverde	Barisciano	1.25	0.80	1.12	0.05 g	0.19 g	0.45	0.72
16	S. Colombo	Barisciano	1.25	0.65	1.12	0.04 g	0.15 g	0.45	0.72
17	S. Leonardo	Calascio	1.25	0.65	1.12	0.04 g	0.15 g	0.44	0.71
18	S. Maria Ab Extra	Barisciano	1.25	0.65	1.12	0.04 g	0.15 g	0.43	0.69
19	S. Francesco	Carapelle Calvisio	1.25	0.65	1.12	0.03 g	0.14 g	0.42	0.66
20	S. Maria del Carmine	Barisciano	1.25	0.65	1.12	0.03 g	0.14 g	0.41	0.66
21	S. Giovanni Battista	Castelvecchio Calvisio	1.25	0.80	1.12	0.04 g	0.17 g	0.41	0.65
22	Madonna del Rosario	Barisciano	1.25	0.65	1.12	0.03 g	0.14 g	0.41	0.65
23	S. Vittorino	Carapelle Calvisio	1.25	0.65	1.12	0.03 g	0.13 g	0.40	0.64
24	S. Maria della Pietà	Barisciano	1.25	0.65	1.12	0.03 g	0.13 g	0.40	0.64
25	Anime Sante o del Suffragio	S. Stefano di Sessanio	1.25	0.80	1.12	0.04 g	0.16 g	0.39	0.62
26	Oratorio Confraternita del SS. Rosario	Barisciano	1.25	0.65	1.12	0.03 g	0.12 g	0.37	0.58
27	S. Martino	Barisciano	1.25	0.80	1.12	0.04 g	0.14 g	0.35	0.56
28	S Nicola di Bari	Calascio	1.25	0.80	1.12	0.04 g	0.14 g	0.35	0.55
29	S. Marco Evangelista	Castel del Monte	1.25	0.80	1.12	0.03 g	0.13 g	0.35	0.55
30	S. Maria in Ruvo	S. Stefano di Sessanio	1.25	0.65	1.12	0.03 g	0.11 g	0.35	0.55
31	Madonna del Lago	S. Stefano di Sessanio	1.25	0.80	1.12	0.03 g	0.13 g	0.32	0.51
32	S. Maria e S. Vittorino	Carapelle Calvisio	1.25	0.80	1.12	0.03 g	0.13 g	0.32	0.51
33	S. Flaviano	Barisciano	1.25	0.80	1.12	0.03 g	0.12 g	0.28	0.45

Table 3. Safety indices

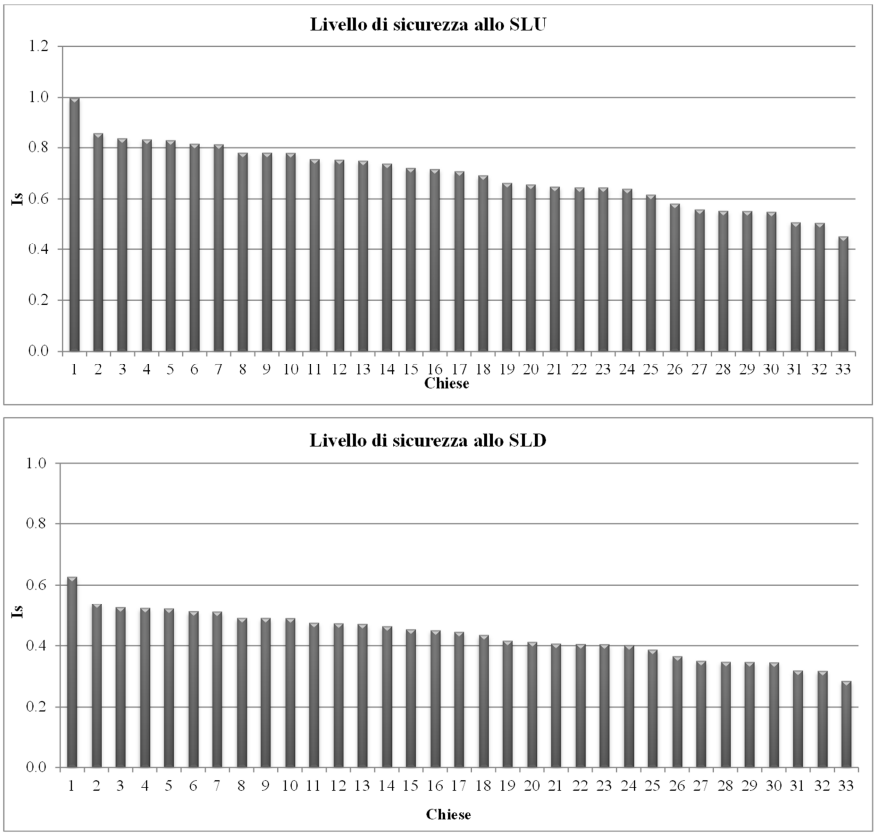

Figure 9. Safety indices at ULS and DLS

5.2 Linear kinematic analysis

As regards places of worship, the guidelines prefer kinematic analysis methods (linear and non linear) applied to the various macroelements that thus become the reference structural units. This highlights the need to utilise local models and assessments rather than complex models.

As previously stated, during the course of the research project, besides collecting historical records regarding the churches in order to have a better idea of past events, comprehensive surveying was also carried out along with observation and cataloguing of the types of vulnerability present.

Observing a church's alteration, disrepair and damage processes reveals the essential characteristics that condition its seismic vulnerability. The weakest parts of the structure are identified, those that could collapse when the earthquake strikes, thus indicating the ways in which the earthquake will be able to cause damage. This involves a preliminary qualitative analysis that is swiftly followed by a quantitative assessment of stability.

The aim of the qualitative analysis is to highlight the mechanisms whose presence and activity are revealed by some degree of damage for which they are directly responsible and identify the mechanisms most likely (figure 10) to be activated in the future based on observation of the churches' structural features, type and vulnerability attributable to specific characteristics or else statistically common. Having ascertained the mechanisms already activated or likely to be so, linear kinematic analysis was carried out in accordance with technical standards.

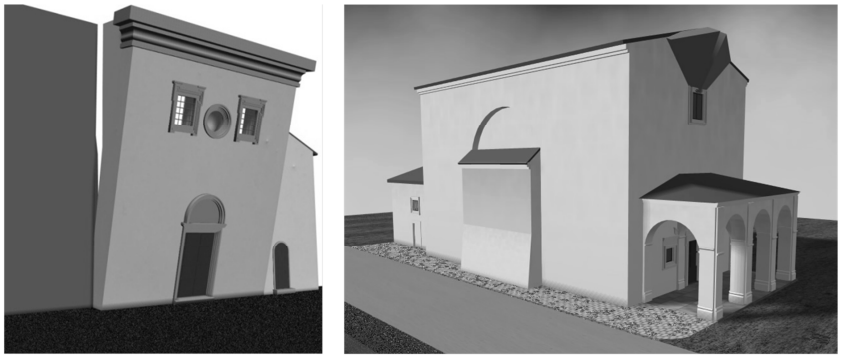

Figure 10. On the left the San Francesco church in Carapelle Calvisio (AQ), façade overturning mechanism; on the right the Madonna del Lago church in S. Stefano di Sessanio, tympanum overturning mechanism with formation of oblique hinges.

6. CONCLUSION

As previously stated, the seismic vulnerability study of the sample described was carried out over the two-year period 2007-2008.

The earthquake on 6th April 2009 struck all communes in the Baronia di Carapelle area to a lesser or greater degree. With the exception of Calascio, all communes fall within the "*seismic footprint*".

The churches studied have suffered varying amounts of damage, in some cases severe (figure 11).



Figure 11. Example of damage suffered by the churches: starting from top left the churches of Santa Maria e San Vittorino (Carapelle Calvisio), San Marco Evangelista (Castel del Monte), Madonna del Rosario and Santa Maria del Carmine (Barisciano)

Damage assessment was carried out using the church seismic damage survey sheet that considers the same macroelements and damage mechanisms as the vulnerability survey sheet. The method associated with the survey sheet provides for the calculation of a damage index i_d (ranging from 0 to 1) representing the church's average damage level (fig. 12).

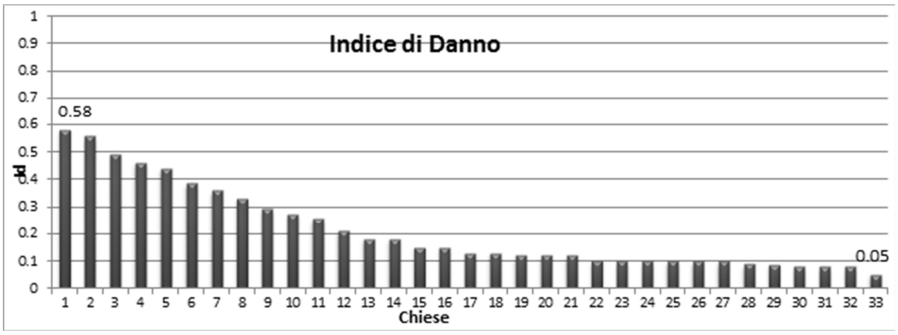

Figure 12. Damage indices for the sample of churches

It can indeed be noted that there is good correspondence between mechanisms deemed more hazardous (see table 8) and those in which the highest damage level was found.

DAMAGE MECHANISMS	Possible activation (%)	D0(%)	D1(%)	D2(%)	D3(%)	D4(%)	D5(%)
1. Overturning of façade	97%	79%	12%	6%	6%	0%	0%
2. Mechanisms at the top of the façade	97%	88%	9%	3%	3%	0%	0%
3. Façade in-plane mechanisms	97%	79%	15%	6%	6%	0%	0%
4. Prothyron or narthex	6%	94%	0%	6%	6%	0%	0%
5. Nave area transverse response	100%	79%	3%	12%	12%	0%	0%
6. Shear mechanisms in the walls	100%	88%	9%	3%	3%	0%	0%
7. Colonnade longitudinal response in aisled churches	21%	97%	0%	3%	3%	0%	0%
8. Nave vaults	70%	82%	9%	6%	6%	0%	0%
9. Aisle vaults	18%	24%	0%	3%	3%	0%	0%
10. Overturning of transept end walls	12%	24%	3%	0%	0%	0%	0%
11. Shear mechanisms in transept walls	12%	27%	0%	0%	0%	0%	0%
12. Transept vaults	12%	24%	3%	0%	0%	0%	0%
13. Triumphal arches	36%	79%	3%	3%	3%	0%	0%
14. Dome-drum	21%	85%	0%	0%	0%	0%	0%
15. Roof lantern	9%	85%	0%	0%	0%	0%	0%
16. Overturning of apse	36%	79%	3%	0%	0%	0%	0%
17. Shear mechanisms in presbytery or apse	73%	91%	0%	6%	6%	0%	0%
18. Presbytery or apse vaults	64%	85%	6%	3%	3%	0%	0%
19. Mechanisms in roofing (side walls)	97%	88%	3%	6%	6%	0%	0%
20. Mechanisms in roofing (transept)	9%	97%	0%	0%	0%	0%	0%
21. Mechanisms in roofing (apse and presbytery)	73%	85%	0%	3%	3%	0%	0%
22. Overturning of chapels	36%	85%	0%	3%	3%	0%	0%
23. Shear mechanisms in chapel walls	42%	88%	0%	0%	0%	0%	0%
24. Chapel vaults	42%	85%	0%	3%	3%	0%	0%
25. Interaction at plan and elevation irregularities	88%	91%	3%	0%	0%	0%	0%
26. Projections (bell gable, spires, pinnacles, statues)	64%	94%	0%	0%	0%	0%	0%
27. Bell tower	24%	94%	0%	0%	0%	0%	0%
28. Bell gable	30%	94%	0%	0%	0%	0%	0%

Table 4. Damage mechanisms and damage percentage

The earthquake of 6 April 2009 has allowed us to verify the validity of scientific method used for the risk analysis of the churches in the "restricted area". The next phase of research will be directed toward a consolidation of the procedures in order to allow vulnerability assessments of the churches on a large site. The processed data can be used to study risk analysis. More over they can be useful to the building owners as a guide to restore the cultural heritage.

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Discussion of Facilities Management as lead user and innovation driver towards improvement of energy efficiency and user comfort of buildings

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Abstract

The target of this paper is to discuss user-driven innovation as a new approach towards the improvement of energy efficiency and user comfort of buildings. This approach contributes to the general need for the improvement of building energy performance in buildings. Reducing energy consumption, greenhouse gas emissions and increasing the share of renewable energy is not only a technical challenge, but also of high national and international importance. Facilities Management (FM) is addressed as having the lead user role referring to approaches of the social science and management discipline. Users can contribute to the advancement of knowledge on building energy performance. These approaches are based on the state of the art innovation theory. The focus is set on Eric von Hippel's user innovation methodology. It was conceptually applied on FM as lead user in the building context. In addition, literature research revealed other examples of user driven innovation referring to research and practice in the field of energy efficiency improvement. These are presented as a contribution to the discussion and highlight different perspectives.

Facilities Management has so far not been considered as lead user of energy-efficient and comfortable buildings. Moreover, the complex interaction between the building itself and its' management and usage overburden the existing lead user theory. Thus, further research is mandatory to transfer lead user theory from product innovation towards service innovation, especially for sectors with high levels of complexity.

Keywords: Facilities Management, user-driven innovation, energy efficiency, lead user, building energy performance.

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1 Introduction

It is widely acknowledged that “buildings account for 40% of total energy consumption” (DIRECTIVE 2002/91/EC, p13). As a consequence of this, the EU is targeting reduction of energy consumption as well as promoting the use of energy from renewable sources in the building sector. The European approach is to prioritise the improvement of the energy performance of buildings, with a focus on technical innovation, “taking into account outdoor climatic and local conditions, as well as indoor climate requirements and cost-effectiveness” (DIRECTIVE 2002/91/EC, p17). The objective of this paper is to discuss how far improvements of energy efficiency and user comfort can be considered as more than a technical challenge. The consideration of outdoor climatic factors, local conditions, and indoor climate requirements are essential for the design of a building’s construction and its’ technical services. The motivation for this paper is the assumption that an understanding of how a building is used might be more important for efficient energy management in a day-by-day and long-term perspective. Literature research on the state of the art on user-driven innovation towards energy efficiency improvement has been conducted. Referring to methodologies from social science and management theory the question comes up as to how far FM can be considered as an innovation driver towards the improvement of energy efficiency and user comfort. The purpose is to extend the scope of building energy performance. A better understanding of the behaviour of building users and FM decision-making on a strategic, tactical and operational level is needed.

Referring to common FM terminology a building can amongst other things be considered as a “Facility” and the person who is responsible for the management of the building therefore as a “Facility Manager”. However the FM discipline refers to a much broader field of work. FM includes all kinds of support facilities and services which develop and improve the organisation’s primary activities from a day-by-day and lifecycle perspective. Energy management is only one of the service processes which supports the user’s primary activities. FM services are referring to owned or rented space and infrastructure. FM interacts with the client organisation on a strategic, tactical and operational level (Atkin and Brooks 2009, Cotts et al. 2010, Barret & Baldry 2003, Junghans 2012a, EN 15221-1). Could FM therefore be considered as a lead user for energy-efficient building management and energy-efficient building design and construction?

Research from the social sciences has shown that the way a building is taken into use is important for the fulfilment of its’ technical possibilities (Aune & Bye 2005). Findings from real estate management related research similarly point out that, from an environmental perspective, the management and maintenance of buildings have an impact on building performance (Kyrö et al. 2010). Atkin and Brooks (2009) consider energy efficiency as long having been recognised and practiced from a FM perspective. They highlight recent changes towards a “wider environmental concern” and the adoption of a “whole-life perspective of buildings and other facilities” (p120). Borgers et al. conducted a systematic review of literature on user innovation (2010). They discussed state of the art user-driven innovation with a focus on the role that users play during innovation. Referring to the pioneers of innovation theory, they point out that users have been considered in the context of innovation since the 18th century. “The role that these users play during innovation of the

products that they ordinarily buy from producers has been the subject of research since at least Adam Smith" (p857) Borgers et al. recognised that the literature on the role of users during innovation has significantly grown. They studied 106 references in total. Among those were 52 references with publication dates since the year 2000. A major focus was the work of Eric von Hippel. This was studied with 16 references published between 1976 and 2007. (Borgers et al. 2010, pp872-875) The diffusion of innovation theory by Rogers can be considered as theoretical basic knowledge and was first published in 1962. "He [Everett Rogers] argued that diffusion was a general process, not bound by the type of innovation studied, by who the adopters were, or by place or culture." (Rogers et al. 2007, p2)

The following section gives a brief description of user-driven innovation theory, highlighting the management approach by Eric von Hippel (1988) in which user innovation projects have been primarily targeted to enhance the development of innovative products. User-driven innovation from the aforementioned social science perspective emphasises the needs of end-users and underlines the importance of developing an understanding for the social construct aside the technical innovation itself.

2 Methodology of user-driven innovation theory

Eric von Hippel (1988) introduced the term 'lead user'. He defines a lead user of a new or enhanced product, process, or service according to two characteristics: 1) "Lead users face needs that will be general in a marketplace, but they face them months or years before the bulk of that marketplace encounters them, and 2) Lead users are positioned to benefit significantly by obtaining a solution to those needs." (von Hippel 1988, p107)

Churchill, von Hippel and Sonnack (2009) developed the lead user approach further and applied it as a research method for the conducting of lead user projects with four main research phases:

"1. Selection of the Project Focus and Scope: This is the preparatory phase of a lead user project. A management group first decides the new product or service area that will be the focus of the innovation initiative and selects the core team that will implement the lead user study. This project team then does the practical work required before launching the actual lead user study in the next phase.

2. Identification of Trends and Needs: The core project team begins the lead user study by doing an in-depth investigation of trends and emerging market needs. By the conclusion of this phase, the team will have selected the specific need related trend(s) that will drive concept generation in the next phases.

3. Collection of Needs and Solution Information from Lead Users: This phase begins the concept generation phase of the project. The project team interviews lead users to gain deeper insight into emerging needs and to acquire new product and service ideas. By the end of phase three, the team will have generated preliminary concepts.

4. Concept Development with Lead Users: A select group of lead users and technical experts join the project team and other company personnel for a workshop to do intensive product or service concept development work, usually over a 2 or 3 day period. The outcome of this workshop is typically a new product or service concept – or sometimes, several of them. The project team then refines these concepts and develops a business "case" which is presented to management for its review." (Churchill et al. 2009, p10)

Targeting the discussion on FM driven innovation towards the improvement of a buildings energy performance, phase 3 "Collection of Needs and Solution Information from Lead Users" is considered as the most essential. Regarding this phase it is recommended to define and study three different types of lead users: 1) Lead users in the target application and market; 2) Lead users of similar applications in advanced /analogue markets; 3) Lead users in respect to important attributes of needs faced by users in the target market.

Churchill et al. (2009) demonstrate the application of the different types of lead users by using an example taken from the field of medical instrument development:

"Suppose that a manufacturer of medical X-ray systems decides to form a lead user project team to identify concepts for new products in that field. The team researches the target market and finds two important trends. One trend is towards images with higher resolution; another was towards better methods for recognizing subtle patterns in images that are medically important – for example, patterns that indicate possible early-stage tumours. In this example, the team might go on to identify and learn from the three types of lead users as follows: 1) Lead users in the target application and market – These might be medical radiologists working on applications in medical imaging that are very demanding with respect to images of high resolution and pattern recognition. 2) Lead users of similar applications in advanced 'analogue' markets – These could be users in more demanding but related markets such as engineers who create images of microscopic patterns developed on semiconductor chips. 3) Lead users with respect to important attribute of needs faced by users in the target application – These could include pattern recognition specialists in fields other than imaging such as pattern recognition in sound or mathematics." (Churchill et al. 2009, p9)

The example relates to product innovation and represents a continuation of earlier research by von Hippel (1988), in which he examined the role of users in product development in the fields of scientific instrument innovation and semiconductor and electronic assembly manufacturing equipment. This systematic approach was used before to identify relevant case studies on user innovation towards improvement of building energy performance and to structure case studies referring to four market development phases: lead users, early adopters, routine users, and laggards (Junghans 2012b).

3 Conceptual application of user-innovation theory considering Facilities Managers as lead users

The following conceptual application of von Hippel's lead user theory was developed to initiate a user-driven research project. It is a fictive consideration referring to the author's

experience from earlier studies on energy efficiency improvement of buildings (2009). However, the exemplary application aims to study FM as having the lead user role, intending the improvement of energy efficiency and user-comfort of buildings. Regarding von Hippel's lead user approach, lead user projects are structured into four project phases. (Churchill et al. 2009, p10) The four project phases are applied as follows:

1) Preparing for the lead user project: The starting point is the preparation of the lead user project on behalf of the client and initiation of the project team ("client" in this example are owners of, or investors in public office buildings). FM can be regarded as both client and lead user. The driving need for innovation is to utilise FM's experience within the operation and use-phase of buildings to improve energy efficiency by better integration of energy-efficient buildings and energy-efficient management. To initiate the project team the main stakeholders in the operation and use of a building have to be considered.

2) Identifying trends and key customers' needs ("key customers" in this example are public departments): The main task of the project team is the identification of trends and key customer needs. The trends should have a strong connection both to the energy efficiency of a building as well as the way it is managed and used, and to needs for further improvement of energy efficiency. Regarding the state of the art in energy efficiency improvement of buildings and statistics about energy consumption, two preliminary trends were identified: 1) Reduce the steadily increasing demand for electricity for basic functions, such as heating, cooling and ventilation. 2) Increase the possibility to control energy consumption by changing user needs, for example user specific technical equipment.

3) Understanding the needs and solutions of lead users ("lead users" in this example is the FM supplier): The understanding of the needs and solutions of lead users supports the identification of appropriate innovation types.

3.1 Lead users in the target application and market – whose objective is to strengthen the demand perspective in the target application and market (e.g. reduce building demand for electricity and increase control of energy consumption). In-house FM of public office buildings are considered as lead users in the target application and market. The objective is to strengthen the demand perspective in the target application and market. The demand is determined by the need for energy-efficient improvements and the target application market is described by in-house FM services. In-house FM of a public office building is, therefore, considered as lead user in this category.

3.2 Lead users of similar applications in advanced analogue markets – who add higher demand perspectives similar to the target application, but in an advanced analogue market (e.g. reduce building demand for electricity and improve cost efficiency, increase control of energy consumption considering changing user demands). External FM service providers as lead users of similar applications (to target application and market) in advanced analogue markets. Advanced analogue markets add higher demand perspectives in similar applications and have higher standards for the measurement and control of costs and quality. External FM service providers consider FM a core activity and make it their business. This branch is referred to in the European standard definition (EN 15221). The definition

describes the target of FM service integration, within an organisation as, to maintain and develop the agreed services which support and improve its core activities (EN 15221). In order to do this, FM should interact between end-users and clients on strategic, tactical, and operational levels. External FM service providers who might be involved or contracted in public-private-partnership (PPP) or private owned office buildings, are therefore considered as the focus group in this category.

3.3 By helping us understand specific areas of demand and need lead users can help us gain a deeper understanding of the problems faced by users in the target market. This knowledge can then be transferred into other areas of application. One aspect that could be examined is the energy management in hospitals which has high requirements for continuous availability and constant quality of power supplies. FM with high service intensity and supporting large and complex building and operational systems, for example hospitals, can be considered as lead users with respect to important attributes of problems. Studying FM in hospitals highlights important aspects of the demand perspective in respect to energy efficiency, with the highest requirements regarding energy supply of constant quality for 24 hours per day, 7 days per week, and 365 days per year. FM in hospitals is therefore considered as lead user in this category.

4) Improving approaches to problem solving by involving lead users and experts to maximise the likelihood of success

As a result approaches to problems solving will be improved with lead users from in-house and external FM and architects and engineers as well as client, key customer and end-user representatives.

4 Examples of user-driven innovation with focus on Facilities Management and energy efficiency improvement of buildings

4.1 Consideration of FM as lead users of buildings

FM can be considered as a building user amongst other users and has been discussed as having a kind of lead user role, without using the term ‘lead user’ specifically, by Olsson et al. (2010). The authors pointed out that, Facility managers are working in the building and that they are working with supporting facilities services. Facility managers use buildings and facilities and act on behalf of the users. They simultaneously link the ‘supply side’ and the ‘demand’. FM are the section of users who are characterised in the context of buildings as follows: “Owners; facilities management and service personnel (who operate buildings) [Facility Manager]; management of the organization(s) based in a building; service providers; service receivers and indirect service receivers.” (Olsson et al. 2010, p28)

The role of FM in general is defined by the European standard definition of facilities management (EN 15221-1). “Facility managers are responsible for the integration of processes within an organization. They act as a link between the demand and supply side on a strategic, tactical, and operational level.” (Junghans 2012a)

4.2 Norwegian study on energy-efficiency potential and barriers of buildings

On behalf of a large Norwegian Real Estate Property and Asset Management organisation engineers and consultants conducted a study addressing energy-efficiency potential and examining barriers for improvement in commercial buildings in Norway (Multiconsult and Analyse&Strategi 2011). The aim of the study was to quantify the potential for energy savings towards the year 2020 targeting all commercial buildings in Norway. The results were structured into theoretical, technical, financial and real potential. Referring to the calculation method used, based on square meters and technical standards for the key input factors, the technical potential was calculated as the portion of the theoretical potential that is technically feasible. Economic potential was calculated as the share of the technical potential that is economically feasible to implement. The real potential for energy efficiency was described as the proportion of the economic potential that naturally occurs, but is limited by various barriers.

A qualitative, survey-based evaluation was conducted to find out more about the various barriers and how to deal with them. Respondents of the survey were particularly concerned with the economic barriers, and least concerned with the technical barriers. Attitudes and knowledge barriers were also considered as very important. Another result was the respondents' lack of knowledge about the effects and benefits of energy efficiency. This was considered as a possible reason why negative attitudes persist, and myths about lack of profitability continue to exist. Many survey respondents believed this was due to lack of knowledge, which in turn can be the cause of other types of barriers, such as financial barriers.

Case studies, focus group interviews and workshops contributed to the analysis which demonstrates that part of the real potential is limited by these barriers, and the type of institutions in society that can reduce these barriers with the various measures. Main barriers for existing buildings were practical barriers, economic barriers and knowledge barriers. For new construction the barriers were financial and knowledge. The overall result of the study finds the greatest potential for improvements in energy efficiency in existing buildings, it is therefore important to concentrate measures here. (Multiconsult and Analyse&Strategi 2011, pp1-12)

The initiation of the focus groups led to discussion about who should be represented. The client preferred participants who showed why decision-makers choose particular measures. Decision-makers in the examined case study were building owners. The contractor was of the opinion that it would also be appropriate to include people with technical management responsibilities, because they were supported by more detailed information on barriers related to specific measures in the building, assuming that they had a more practical approach. (Multiconsult and Analyse&Strategi 2011)

The study also included an approach with reference to diffusion of innovation theory by Rogers. The authors considered it as important to refer to market development and to group decision-makers based on the theory of diffusion of innovation. Participants were therefore asked to answer a short questionnaire in which they categorised themselves by whether

they perceived themselves as, respectively: 1. Innovators, 2. Early users, 3. Early majority, 4. Late majority, 5. Last few. The answers to this survey, as well as additional observation of the participants in the focus groups gave input to this part of the study. (Multiconsult and Analyse&Strategi 2011) However, the authors commented on the achieved results and mentioned potential weaknesses of the approach later in their report. “Participants perceive themselves as innovative and early users. Based on the discussions in the focus group, we (Multiconsult and Analyse&Strategi) believe, however, that participants may seem somewhat more conservative than they express themselves, because participants experience many economic barriers, which may indicate that they are not willing to take risks and thus are not innovative” (Multiconsult and Analyse&Strategi 2011)

4.3 Strength and weaknesses of interaction between energy users and energy efficiency practitioners

Heiskanen et al. (2012) explored the interaction between energy users and energy-efficiency improvement measures in the context of a European research project. They underlined the usefulness of the user-driven approach referring to user-driven projects.

User-driven projects (or pilot projects) are considered as “ideal in many ways” (p6). Strengths are that, “end-users know their needs and circumstances and can contribute to context tailored designs” and “end-users are motivated and engaged from the start and do part of the work.” (p5). Weaknesses were found in that, “End-users may not be fully aware of their behaviour and all the factors underlying it” and, “Up-scaling from small user-driven pilots to broader groups of end-users can be difficult.” (p5)

In addition, strength and weaknesses of three other approaches, i.e. surveys and interviews, prior research, and familiarity and informal interaction can be summarised as follows:

Surveys and interviews were regarded as, “obviously useful” and categorised as “formal, dedicated research” (p6). The strength of this method is, “the systematic approach to data collection” and “the possibility to poll representative samples” (p5). Weaknesses are that surveys and interviews, “do not always feed into program design” and, “Surveys may be designed to confirm existing preconceptions, may fail to bring up new insights” as well as, “Conducting good research is expensive and requires specialised skills” (p5).

Prior research, particular theoretical perspectives, were summarised as, “previous experience” and considered as, “obviously useful” and, “speeds up the learning phase” especially if previous experience with the same user-group was available (p6). The strength of using previous experience is that the, “theoretical base can guide observations and help to make sense of energy-related behaviour” (p5). Examples were explored referring to hands-on activities and experiments. Weaknesses of this method are the “commitment to prior findings or theories may lead to overlooking contextual particularities” (p5). In addition, an “overly theoretical background can lead to complex and confusing designs” (p5).

Familiarity and informal interaction with the target end-user group can be based on face-to-face contacts or membership in the user community (p6). “Informal interaction allows a rich

exchange of information" and "Immersion in the user community helps to understand users' every day routines" as well as, "Familiarity creates trust" (p5) were considered as strengths. Weaknesses are that, "much time and commitment is needed to build up the necessary level of familiarity" and, "Contacts can be biased: some end-users are more familiar than others" (p5).

5 Discussion of FM as having lead user role

How far can FM be regarded as lead user and innovation driver towards improvement of buildings energy performance?

Discussion of FM driven innovation as the topic of this paper seems to be in line with the suggestion of Borgers et al. (2010) to transfer user innovation theory into other management fields. "We believe it is useful to provide a comprehensive review of the role of users in the innovation process and to link the notion of users as innovators to other literatures in the field of management." (Borgers et al. 2010, p858). As underlined by Borger et al. (2010), it was Eric von Hippel (1988) who introduced the notion of a user as a source of innovation in the 1980s. He described the user as one of the four sources of innovation, beside manufacturers, suppliers, and others. If the user is considered as a building's user, the following key questions, by von Hippel (1988, p3), relate to the categorisation of the different functions of a building and address the potential benefit of innovation, "Do they benefit from using it? They are users. Do they benefit from manufacturing it? They are manufacturers. Do they benefit from supplying components or materials necessary to build or use the innovation? They are suppliers." Based on lead user theory by von Hippel (1988) the main research approach is how whether FM as lead user fulfils the following criteria.

1) Does FM face needs months or years before the bulk of that marketplace encounters them, and

2) Is FM positioned to benefit significantly by obtaining a solution to those needs?

From a FM perspective, needs regarding the improvement of a building's energy performance are faced by integrating user demand and service delivery. FM gains benefit from achieving cost reduction and user satisfaction, as well as ensuring a healthy and safe environment. FM is involved in the whole life-cycle (Atkin and Brooks 2009) and interacts with the client organisation and service provision on strategic, tactical and operational levels (EN 15221-1). Thomzik et al. (2011) identified non-residential buildings in several categories as most relevant for the FM industry, such as: educational buildings, heath care buildings, light industry and workshops, retail and storage buildings, buildings for sports, culture, and recreation, housing for institutional owners, and other types of non-residential buildings. Building engineering services like heating, ventilation, air conditioning and cooling (HVAC), lighting, power, transportation, fire and security systems are consuming significant financial resources up to, "more than half of the capital cost" in the construction phase and require controlling during building operation and use. "Control over these installations is vital if the

facility is to perform optimally and not exceed targets for energy consumption or reduce user comfort, amongst other concerns." (Atkin and Brooks 2009, p146).

While the general perception is focused on the improvement of building energy performance and technical innovation for buildings and technical infrastructure as stated in the EU definition, "energy performance of a building" means the calculated or measured amount of energy needed to meet the energy demand associated with a typical use of the building, which includes, inter alia, "energy used for heating, cooling, ventilation, hot water and lighting" (DIRECTIVE 2002/91/EC, p18). FM driven innovation can be considered as targeting improvement of building energy performance referring to the complexity of the building lifecycle and including the understanding of how a building is used and managed.

6. Conclusion

Lead-user theory was introduced in management discipline in the 1980s, however, examples of user innovation projects are still targeting the development of industrial or consumer products, like for example CAD software, pipe hanger hardware, outdoor consumer products, 'Extreme' sporting equipment. (von Hippel 2005, p36).

The social science perspective on user-driven innovation highlights the need to understand end-users and consider the social construct alongside technical innovation. Heiskanen et al. (2012) point out that "information about users' needs and manufacturers' capabilities is highly contextual, tacit and difficult to transfer from one site to another"(von Hippel 2005). They explain that this problem of common understanding hinders the uptake of innovative solutions. Referring to Rohracher (2001) they highlight "Energy efficient building solutions" as examples for innovative solutions that fail to address users' concerns and practices. Limited uptake and effectiveness are considered as consequence of this. (Heiskanen et al. 2012, p2)

Until now FM has not been considered as a lead user of energy efficient and comfortable buildings. However following the research on, "diffusion of innovation" (Rogers et al. 2007) and, "user-driven innovation", referring to Borgers (2010), Churchill et al. (2009) Heiskanen et al. (2012), Rohracher (2001), the understanding of the innovation user and the consideration of the social context aside, the technical innovation is of high importance for a successful innovation implementation.

Von Hippels lead user approach does not yet meet all the requirements of service innovation within such complex systems like building-management-use settings. This shows a need for further research to transfer lead user theory from product innovation towards service innovation.

Future research might further develop the "user-driven innovation approach" into an "innovation-driven user approach". This means implementing social science knowledge into management concepts to actively support the communication and diffusion of innovation. Future research questions could be: Is social context supporting the improvement of building

energy efficiency and user comfort? Is the social perception of technical innovation measurable? And, if it is measurable, can it be managed by FM?

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The Role of the DQI in Managing Stakeholder Requirements in Construction Projects

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Abstract

The Design Quality Indicator (DQI) tool was developed to allow stakeholders connected with a construction project to define indicators that can used to assess the design and construction quality of a building. While it is primarily focused on design quality issues, it also fosters communication and the management of expectations among stakeholders at various stages of a project. This paper explores how the DQI contributes to the management of stakeholder requirements on construction projects. A review of stakeholder management principles in construction is followed by an overview of the DQI tool with respect to its underlying philosophy and practical application on projects. Case studies on how DQI was used on particular projects and the perceptions of users are then presented and discussed against their potential contribution to stakeholder requirements management. The paper concludes with insights into the possibilities and constraints in the use of the tool.

Keywords: **Clients, Construction Projects, DQI, Stakeholder Requirements Management**

1. Introduction

The development and delivery of construction projects involves various stakeholders who influence or are affected by such projects. While the client, as promoter of the project, is central to this process, the needs and expectations of many other groups (e.g. users, designers, legal authorities, the general public, etc.), which can sometimes be contradictory, need to be incorporated and/or accommodated in a project (Kamara et al. 2002). The effective management of these stakeholders is therefore now considered as a key ingredient to project success (Newcombe, 2003; Olander, 2007; Chinyio and Olomolaiye, 2010).

The categories of stakeholders and their relative influence on a project varies depending on the type of project and stakeholder. They can be individuals or groups, or they can be internal to the client organisation, or external to it. A key strategy for their effective management on a project is the identification and assessment of their relative importance on a project (Olander, 2007). Various approaches for stakeholder have also been proposed (e.g. Chinyio and Akintoye, 2008; Manowong and Ogunlana, 2010; van Gunsteren, 2011). This paper explores the role of the Design Quality Indicator (DQI) tool in managing stakeholder requirements in construction projects. DQI was developed in the UK to allow stakeholders connected with a project to define and assess the design and construction

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quality of a building. Whilst it is primarily focused on design quality issues, it also fosters communication and the management of expectations among stakeholders at various stages of a project (the focus of this paper is on the latter and not on assessing design quality outcomes). A review of stakeholder management in construction is followed by an overview of the DQI tool with respect to its underlying philosophy and practical use at various stages of a project. Case studies on how it was used on particular projects and the perceptions of users are then presented and discussed against the principles of stakeholder management. The paper concludes with insights into the possibilities and constraints in the use of the tool.

2. Stakeholder Management in Construction

The importance of stakeholders and the need for their management on construction projects is now becoming well recognised. At the very least the regulatory requirements imposed on projects through, for example, the planning and development control process in many countries, requires the consideration of interests other than those of project promoters. But usually, given the complex and uncertain nature of construction projects, the active consideration of stakeholder requirements is necessary for project success (Newcombe, 2003; Olander, 2007; Van Gunsteren; 2011). Stakeholders "are persons or groups with legitimate interest in the procedural and/or substantive aspects of corporate activity" (Amaeshi, 2010:16). From a construction project perspective, Olander (2007:279) defines a stakeholder as "a person or group of people who has a vested interest in the success of a project and the environment within which the project operates, [with] vested interest…defined as having possession of one or more of the stakeholder attributes of power, legitimacy or urgency." These, and the many other definitions of the concept, suggest that there are different types (e.g. individual or group) and categories (e.g. with respect to the relative influence on a project) of stakeholders. These categories include: internal and external stakeholders (i.e. those actively involved in project implementation, and those directly affected by the project, respectively) (Olander, 2007; Leung and Olomolaiye, 2010); and primary and secondary stakeholders (i.e. those with whom a firm has a fiduciary obligation to, and those where such obligations do not exist, respectively) (Amaeshi, 2010). Other categorisations by Newcombe (2003); Smyth (2008) and Chinyio and Akintoye (2008) are more generic and relate to how the relative influence of stakeholders can be mapped. An example of this, which is illustrated in Figure 1, compares the power to influence against the level of interest of stakeholders as a way to determine the strategies for their management.

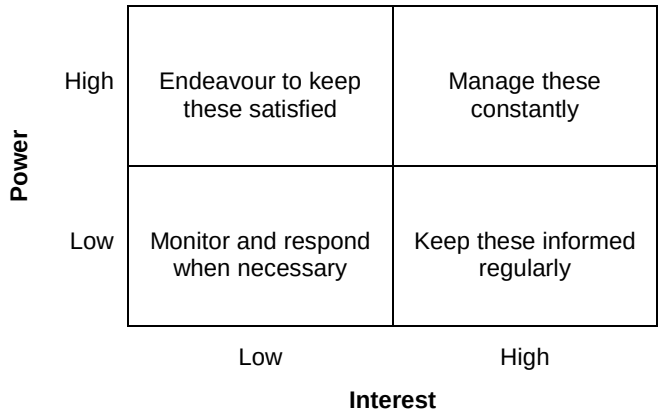


Figure 1: A power-interest grid for assessing stakeholders (Chinyio and Akintoye, 2008)

The management of stakeholders is usually underpinned by a number of paradigms. Amaeshi (2010) identifies three interrelated perspectives: the descriptive, instrumental and normative perspectives. The descriptive perspective, as the name suggests merely describes what the corporation is, and the interactions with its stakeholders. The instrumentalist perspective goes beyond mere description by looking at consequences of stakeholders (i.e. their relative influence) on the interests of the firm. Stakeholder management strategies arising from this perspective are usually driven by the firm's self-interest, characterised by a one-way, top-down communication, without any real voice being given to stakeholders. The normative perspective is underpinned by morality; that the engagement with stakeholders is the right thing to do. The premise is that: "the interests of all stakeholders are of intrinsic value [and] each group of stakeholders merits consideration for its own sake and not merely because of its ability to further the interests of some other group, such as the shareowners" (Amaeshi, 2010:16).

Smyth (2008) makes reference to utilitarian approaches to stakeholder management (similar to the instrumentalist perspective above), and proposes an 'ethics of care' approach (similar to the normative perspective that "provides an alternative moral philosophy based upon outcomes for managing stakeholders" (p. 634). He argues that since power carries responsibilities, it is not helpful to map interests of stakeholders against power; but rather, it is more ethical to map interests against responsibility. He therefore recommends that "stakeholder management theory needs to move away from approaches underpinned by skewed utility and from self-interested power-based analysis towards recognition of responsibilities for ethical care employing proactive management, [such as] …relationship management" (Smyth, 2008:641).

It is acknowledged that because of the competing (and often contradictory) needs of stakeholders on a project, stakeholder management is more about managing expectations rather than achieving consensus. A first step to stakeholder management therefore involves the identification and assessment of the relative importance (prioritisation) of stakeholders on a project (Manowong and Ogunlana, 2010). This mapping is seen as an on-going process since the relative influence of a particular stakeholder can change over the lifecycle of a project (Newcombe, 2003; Chinyio and Akintoye, 2008). Depending on the type and importance of stakeholders, various levels of stakeholder management can be adopted. These include: informing, consulting, involving, partnering/collaborating, or a mixture of all of these (Manowong and Ogunlana, 2010). A range of approaches (or tactics) can also be adopted. Research by Chinyio and Akintoye (2008) on practical approaches adopted by some UK construction organisations identified, what they classify as, underlying approaches (e.g. developing a systematic way to engage with and manage stakeholders, providing top-level support, being proactive, maintaining existing relationships and responding to power-interest dynamics) and frontline approaches (e.g. effective communication, use of trade-offs, incentives, concessions, workshops, and various people skills). One of the conclusions from their research was that approaches for engaging with stakeholders need to be varied. This paper therefore introduces the Design Quality Indicator (DQI) and its potential for stakeholder management on construction projects.

3. The Design Quality Indicator (DQI)

The Design Quality Indicator (DQI) is "an assessment tool for evaluating the design quality of buildings" (Whyte and Gann, 2003:387). It was developed in the late 1990s (and launched in 2002) by the UK Construction Industry Council (CIC), as a counter to the dominance of process measurement in terms of Key Performance Indicators (KPIs) that did not consider building design quality (Gann et al; 2003; Odgers and Samuel, 2010) (There are separate DQIs for schools and healthcare buildings, launched in 2005 and 2012, respectively). The motivation for DQI stemmed from the realisation that good design has a positive contribution to the quality of people's lives, and those who are affected by such designs should be involved in defining and assessing that quality (CABE, 2006). The DQI focuses on "engaging the whole stakeholder community in setting and assessing design priorities throughout the building process" (http://www/dqi.org.uk). It combines objectivity and subjectivity in assessing priorities, and thus sits in the middle between the judgement-based and rational (measurement) approaches to quality assessment (Gann and Whyte, 2003).

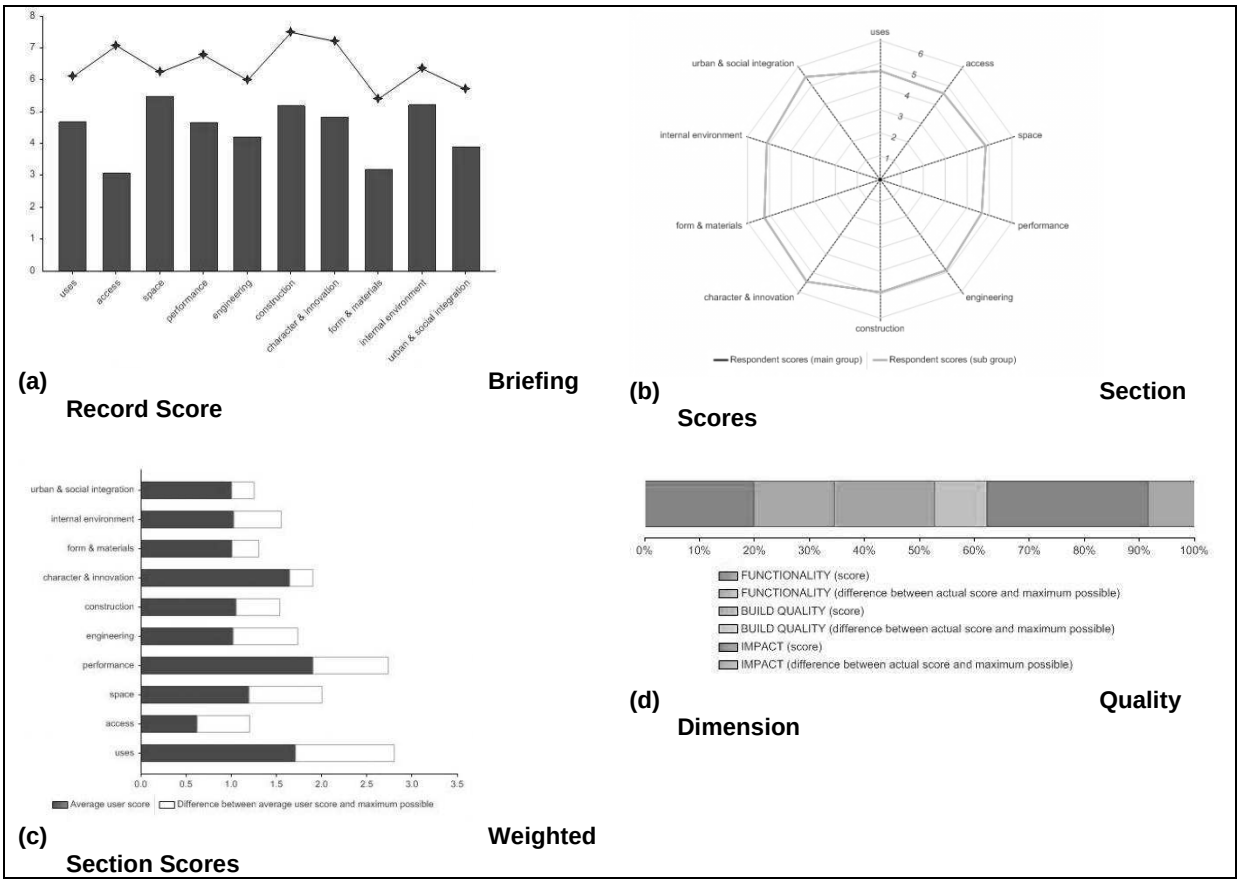
The definition of design quality adopted in the DQI is based on Vitruvius's principles of *Utilitas* (Commodity), *Firmitas* (Firmness) and *Venustas* (Delight). The respective terms used are: **Functionality** (the way the building is designed to be useful), **Build Quality** (the construction and performance of the building), and **Impact** ('wow' factor; the building's ability to create a sense of place and a positive effect on the local community and environment). Functionality is defined with respect to: *access*, *space*, and *uses*; Build Quality aspects are: *performance, engineering*, and *construction*; Impact with respect to: *urban and social integration*, *internal environment*, *form and materials*, and *character and innovation*.

The setting and assessment of design priorities is based on a standard set of questions (the DQI questionnaire – 99 questions for standard DQI, and 113 for DQI for Schools – DQIfS) under each of the quality areas (i.e. access, spaces, etc.) outlined above (e.g. "the building should provide good access for everyone;" "the building should be easy to operate", "the building should be a pleasure to use", etc.). The whole process involves a DQI Leader (somebody within the project team who champions the process), project stakeholders (users, clients, members of the design team, contractors, community members, etc.), and an independent DQI Facilitator (trained and approved by the CIC to run DQI workshops). There are four stages in the process: briefing, mid-design, ready for occupation, and in-use. During the briefing stage the key aspirations for the project are developed through discussion and consensus. Stakeholder views and priorities are recorded in the online DQI Briefing Record. Priorities are defined by assigning either 'Required', 'Desired', 'Inspired' or 'Not Applicable' to each of the statements on the DQI questionnaire. A 'Required' tag (e.g. against the statement: "the building should provide good access for everyone") indicates that minimum standards and regulations will satisfy that aspiration. A "Desired" tag implies a design intervention beyond minimum standards (or where there are no defined minimum standards); an 'Inspired' tag implies a greater level of design innovation far beyond minimum standards (Table 1). A typical Briefing Record will have a greater proportion of 'Required' statements compared to 'Desired' and 'Inspired' statements. The graphical representation (line graph in Figure 1a) provides the basis for assessing the design and completed building in subsequent stages of the DQI process.

Table 1: The language of the DQI Tool (Source: http://www.dqi.org.uk)

	Required	Desired	Inspired	*Not Applicable*
Articulated by demand side	Compliance with standards, regulations and quantified minimum targets	Setting targets for building performance beyond the minimum required	Inspiring goals and standards. Reference to special buildings	*Because of the scope of the project, cannot be achieved*
Achieved by supply side	Working to accepted good design and construction practice	Integrated design solutions to practical matters	Imaginative synthesis of design strategies to create a special ambience and response of delight.	*Is not achievable*

During the mid-design, ready for occupation and in-use stages, the DQI assessment tool, which contains the same set of questions in the DQI questionnaire, but worded slightly differently (e.g. the statement on access mentioned above becomes: "the building provides good access for everyone", in the assessment tool). Instead of 'required' (etc.) tags, each statement has a likart scale where respondents have to tick one of eight options (strongly disagree, disagree, tend to disagree, tend to agree, agree, strongly agree, not applicable, don't know). The assessment can be done on paper or directly online, but all results have to be entered online to allow comparison with the briefing record. The scores of each respondent are aggregated and represented in various output graphs, illustrated in Figure 1. Table 2 contains the descriptions of each graph.



(a) **Briefing Record Score**

(b) **Section Scores**

(c) **Weighted Section Scores**

(d) **Quality Dimension**

Figure 1: DQI Output Diagrams (source: http://www.dqi.org.uk)

Table 2: Description of DQI Output Diagrams

Diagram	Description
Briefing Record Output	This graph compares the results from the DQI assessment with the Briefing Record profile. The target line is the maximum the design can achieve. The bars display the results from the assessment and highlights how well the design has been judged to perform against the target. The height of the bar (i.e. how near or far it is from the target line) is a measure of how well that aspect of the design is meeting the target.
Section Scores	"This is a spider diagram scaled between 0 and 6. It displays the average of respondents' answers to each section. The higher the score (the further out) the better the respondents felt the design was achieving that characteristic."
Weighted Section Scores	"This graph shows the 10 sections of the main headings. It takes into account the weightings allocated to all the sections and the overall weightings and sets these against the individual responses made in each. This graph allows you to see what the most important sections are (overall length of the white line). The green line indicates how well the design is performing in each section."
Quality Dimensions	"This graph illustrates the overall DQI and is scaled between 0 and 100%. It visualises two sets of results; firstly it takes into account the overall weightings allocated to Functionality, Build Quality and Impact, and secondly its sets these against the individual responses made to the statements within those three fields."

Each stage of the DQI process is usually implemented via a workshop that is facilitated by the DQI Facilitator, in close collaboration with the DQI Leader, and can last from between 2hours to a full day, depending on the stage of assessment, number of participants and type of project. Increasingly the mid-design stage assessment has also been used as part of a bid-evaluation process.

4. Research Methodology

The objective of the research reported in this paper was to explore the role of the DQI tool in managing stakeholder requirements (the issue of design/project outcomes with respect to design quality was beyond the scope of what is being reported here). It is based on case material from DQI workshops for two projects. Given that the DQI process stipulates the involvement of a cross-section of project stakeholders, the key question was therefore around the perception of these participants on the relevance of the tool in enhancing their engagement with the project. The key source of data was therefore based on the standard feedback questionnaires completed by each participant at the end of a DQI workshop. The questionnaire asks participants to rate (from excellent, very good, satisfactory, unsatisfactory, poor) the appropriateness of the DQI tool, the format of the DQI session, and the quality of facilitation. Space is also provided for respondents to include qualitative comments on each section, and on the overall process. A description of the workshop process and the feedback scores and comments from two projects (A and B) (described in Table 3), are presented here. Some of the comments have been slightly altered to maintain anonymity and/or aid clarity, by the insertion of a [square bracket]. The outputs from each workshop, spread of stakeholders, and feedback scores will provide the basis for analysis. Lack of space prevents the inclusion of a wider variety of projects. However, the selected projects and type of stakeholders are relatively diverse enough to provide some insights into the process and its relevance in the management of stakeholder requirements on projects.

Table 3: Details of project cases

Project	Type	Brief Description	DQI Workshop	No. of Participants
A	A Fire and Rescue Authority, Private Finance Initiative project	The project involved the construction of 4 new community fire stations and a community life skills centre	Briefing Workshop (15 July 2008)	18
B	County Council Primary School	A replacement new-build primary school, to be built on the existing site of the school	Mid-Design Workshop (23 May 2011)	22

5. Findings from Cases

5.1. Project A: DQI Briefing Workshop

The objective of the workshop was to develop consensus among various stakeholders associated with the project, about their aspirations for the project, and to specify which aspects of the design are Required, Desired, or Inspired. The development of the Briefing Record and associated aspirations for the project was done in two stages. The first (pre-workshop) stage involved members of the project team and it was focused on scoring the briefing record (i.e. specifying which statements in the DQI questionnaire were Required, Desired or Inspired). The second (main workshop) stage involved discussions by representatives of various stakeholder groups around the key questions in the DQI questionnaire, and specific issues brought forward from the pre-workshop stage. The intention was to modify the briefing record developed in the pre-workshop stage following discussions in the main workshop, but this proved not to be necessary. The first half of the main workshop focused on assessing existing fire stations and included a tour of the [Project A] station (the venue for the workshop) (A formal assessment (as suggested in the DQI guide) was not conducted, due to time constraints, but the key questions in the DQI questionnaire were used to 'assess' existing facilities). The second half focused on defining aspirations for the new fire stations and life skills centre. The categories of stakeholders and a analysis of the feedback questionnaire, are provided in Tables 4 and 5, respectively.

Table 4: Stakeholders represented at DQI workshop (Project A)

Type	Local Residents	Fire-fighters	Other fire service staff	Project staff	Fire service union	Total
Number	5	5	5	2	1	18

The briefing record developed from the workshop showed that 59.6% (59) of the statements were considered to be *required*; 29.3% (29) were *desired*, and 11.1% (11) of the statements in the questionnaire would be *inspired* for the project. With respect to the statements within each section, 66.7% of Functionality statements were considered to be required; 76.3% of statements under Build Quality were considered to be required; and 35.3% of Impact statements were considered to be required. The key measures that would define the success of the project included the following:

- The need for community fire stations that are welcoming to their respective communities;

- Need for sufficient, fit-for-purpose spaces that are well planned and efficiently arranged, and fully dictated by the operations and activities of a community fire service
- Buildings that complement and are sympathetic to their immediate surroundings
- Need for robust ('fire-fighter proof) buildings that incorporate sustainable green solutions, future proof to prevent/minimise further development but adaptable to changing needs.

Table 5: Analysis of Feedback Questionnaire (Project A)

Ratings	**Appropriateness of DQI Tool**		**Format of DQI Session**		**Quality of Facilitation**	
Excellent	2	11.1%	1	5.9%	2	11.1%
Very Good	10	55.6%	11	64.7%	11	61.1%
Satisfactory	6	33.3%	5	29.4%	5	27.8%
Unsatisfactory						
Poor						
TOTAL	**18**	**100%**	**17**	**100%**	**18**	**100%**
Specific Comments	Perhaps would have been useful for a short introduction of sites being considered Facilitated some interesting debate. Seemed to get everybody on board Not sure the exercise will produce the best results Enabled many views and points to be made It was a useful way to identify important needs A large number of varying views to be considered Briefing questionnaire provided a good basis to discuss any project to build Questionnaire good. Powerpoint slides confused some due to terminology Focus on key personal issues		Some sections after lunch would be better if shorter – more punchy (loosing concentration) Very unusual mix of participants who arrived [and] left throughout the workshop Not always clear about the point of the discussions – all ideas were important to the people who put them forward. Difficult to support vision from functionality Good variety of representation Works well but external stakeholders can find it difficult to engage in full process		Session had views from residents that I found useful Ideal to see operation and layout of fire station. Lecture room not ideal for event due to road noise, heat, lack of ventilation Not completely aware of the sensitivities of the location decisions Went over the same priorities in the morning and afternoon. I thought it unfair that priorities were recorded whilst most fire fighters were out on a shout DQI presentation was rushed	
Any other (general) Comments	After speaking to residents from [Site X], it would be interesting to hear issues from other residents on their thoughts on the station moving Important to continue process & involvement Very useful to hear and understand other stakeholders issues. I look forward to end result Very helpful I think hopefully!! Excellent refreshments. Friendly atmosphere. Glad to be involved – keep consultation going! Group discussion (6) very constructive, prior to this was probably more for other parties than myself I hope all the opinions expressed will be considered for the next stage of this process Good to listen to individual perspectives					

5.2. Project B: DQI Mid-Design Workshop

The objective of the workshop was to assess the design for [Project B], against the aspirations for the project that were established at a previous Briefing Workshop (held in February 2011). The workshop started with a brief overview of DQIfS (DQI for Schools), a review of the key outputs from the Briefing Workshop, and an explanation on how the assessment questionnaire was to be completed. This was followed by a presentation on the design for the School with opportunities for questions from participants. After the presentation, participants completed the assessment questionnaire and then discussed positive and negative aspects of the design. The categories of stakeholders present are presented in Table 6.

Table 6: Stakeholders represented in DQI workshop (Project B)

Type of Stakeholder	Direct Users			Non-Users			Total
	Pupils	Teaching staff	Other staff (incl. Head Teacher)	Client	Governors	Design/ Project Team	
Number	7	3	5	1	3	3	22

The Briefing Record used as the basis for the assessment had been developed by a cross-section of (and is an aggregation of the views of) stakeholders. Given the number of questions on the DQIfS questionnaire (113), the seven (7) pupils (Table 6) who were present were asked to complete a selection of questions from the questionnaire (i.e. the key questions in the questionnaire and those statements that were prioritised as "inspired" in the Briefing Workshop). A "Don't Know" response (a valid response) was put for all questions not answered to ensure that each pupil had enough responses for their scores to be included in the overall results; this did not affect the overall result.

A key question that provided the focus for this workshop was: "to what extent have …aspirations for the project been addressed in the design?" The assessment scores showed that there was a very positive evaluation of the design. The key priorities set out at the Briefing Workshop focused mainly: space, 'wood' (materials), character and history (statements in the DQIfS questionnaire that were tagged as "inspired" also focused on space and "impact" issues; some "build quality" statements were also tagged as "inspired"). Space and "build quality" aspects were given high priorities during this workshop but "impact" aspects (e.g. "form and materials" and "character and innovation") were considered to of low priority (relatively). There was therefore consistency between the priorities set at the Briefing and Design workshop for space and "build quality" aspects, but an apparent inconsistency in the priority of the "impact" aspects of the design. The inconsistency might be due to the fact that "impact" issues (e.g. character, wood) were not the real priorities of all participants. However, given the positive scores and overwhelming support for all aspects of the design, it was concluded then that the design for [Project B] that was presented during the workshop, closely matched the aspirations for the project, especially in those aspects (e.g. spaces) that were of priority to the majority of users. A summary of responses from the feedback questionnaire is provided in Table 7.

Table 7: Analysis of Feedback Questionnaires (Project B)

Ratings	**Appropriateness of DQI Tool**		**Format of DQI Session**		**Quality of Facilitation**	
Excellent	3	13.6%	2	9%	6	27.3%
Very Good	13	59.1%	18	82%	12	54.5%
Satisfactory	6	27.3%	1	4.5%	4	18.2%
Unsatisfactory			1	4.5%		
Poor						
TOTAL	**22**	**100%**	**22**	**100%**	**22**	**100%**
Specific Comments	Good discussions				Well organised and well-led by [XXXXX]	
Any other (general) Comments	I have enjoyed these sessions as [it's] important to share as much as possible of the new build with the community. Thank you for your work. A very good show It seems that the officers have taken note of the wishes and concerns of the staff, governors and children A very useful, enjoyable and relevant process for all participants involved. Thank you. A lot to cover in just 2 hours – session could benefit by being 2.5-3 hours duration					

6. Discussion

Both workshops for Project A and B were successful in meeting the objectives of those workshops (i.e. developing a briefing record, and assessing the design for a project). In Project A, all respondents rated as satisfactory (or better) the appropriateness of the DQI tool (66.7% rated it as very good or excellent), the format of the session (70.6% rated it as very good or excellent), and the quality of facilitation (72.2% rated it as very good or excellent). The satisfaction levels are also comparable in Project B, where 21 out the 22 participants who completed the feedback questionnaire rated as 'satisfactory' (or better) the appropriateness of the DQI tool (72.7% rated this as very good or excellent), the format of the DQI session (91% rated this as very good or excellent), and the quality of facilitation (81.8% rated this as very good or excellent); only 1 respondent (a pupil) rated the format of the DQI session as "unsatisfactory". The qualitative comments (Tables 5 and 7) were also generally very positive, although there were a few negative comments (e.g. lecture room not ideal, not being clear about discussions/confusing PowerPoint slides – Table 5). However, comments like: "briefing questionnaire provided a good basis to discuss any project build"; "very useful to hear and understand other stakeholders' issues…" (Table 5); "it seems that the officers have taken note of the wishes and concerns of the staff, governors and children" (Table 7), suggest that participants felt this was a good way to engage stakeholder views.

The evidence from the two cases presented therefore suggests that the DQI tool does indeed enhance engagement with stakeholders. However it should be noted that the use of the DQI tool is not the only stakeholder engagement activity that takes place. There are several other interactions between the project team and stakeholders, although this tends to be organised with individual stakeholder groups. The DQI thus provides an avenue for engagement with a cross-section of stakeholders. Also, the success of a DQI workshop

largely depends on the skills of the facilitator and the willingness (and ability) of the DQI Leader to involve as wide a cross-section of stakeholders as possible (i.e. to adopt the normative perspective or 'ethics of care' approach described by Amaeshi, 2010 and Smyth 2008, respectively). One of the comments in Table 5 ("I thought it was unfair that priorities were recorded whilst most fire fighters were out on a shout") referred to a point in the workshop when a number of fire-fighters who were on call, had to leave the workshop to respond to an emergency. The DQI Leader was unable to get station managers to send only participants who were off duty. It needs to be pointed also that the DQI process doesn't involve the identification and mapping of stakeholders (Manowong and Ogunlana, 2010), and therefore does not cover all aspects of stakeholder management.

7. Conclusion

This paper has explored the role of the Design Quality Indicator (DQI) tool in the management of stakeholder requirements in construction projects. The outputs and feedback comments from two cases (DQI workshops for specific projects) were used to explore the potential of the tool in stakeholder requirements management. It is observed that while the DQI does not cover every aspect of stakeholder management, it thus provide a good avenue for aggregating the views of stakeholders around the crucial issue of building design quality, and in providing a robust baseline (briefing record) for subsequent assessment of the design and building. The successful use of the tool however, appears to depend on the quality of facilitation and the willingness of project leaders to genuinely engage with stakeholders. The genuineness of engagement applies to all approaches to stakeholder management, and is not unique to the DQI. A final point to note is that the usefulness of the DQI (as presented from the cases above) was not assessed against other approaches; as the aim was not to compare the DQI against other methods. Further research is clearly required to establish this. The paper also did not address the issue of final design/project quality outcomes (as it was focused on stakeholder engagement); further research is therefore required to determine the measurable benefits on the use of DQI, and the contribution of stakeholder engagement in enhancing building design quality. The DQI however, thus have a role in the management of stakeholder requirements and expectations on construction projects.

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A New Model of Productivity Management as an aid to Deadline Management

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Abstract

Most problems involving owners and contractors are caused by failure in meeting completion deadlines in construction. The consequences of these delays are social stress and financial damages. Minimizing the causes of delay systematically and efficiently has always been a key demand in construction and, therefore, a theme of great interest to the Academia. In 2007, one of the biggest companies of the world (with investments higher than 200 billion dollars in the 2009-2014 period) took on this challenge. From a partnership with two Brazilian universities, a new model of productivity management was developed and effectively implemented to aid the deadline management in the construction works of this company. The purpose of this article is to present this management model, namely GEPOP, highlighting some of the achievements associated with its application. Presently, the model has been deployed in a significant number of construction sites of the company and it has promoted substantial changes in the relationship between owners and contractors regarding deadline management.

Keywords: productivity, management, construction, delays, deadline

1. Introduction

The delays in the conclusion of construction activities in Brazil have caused great concern. Losses from those delays both affect owners and contractors. Owners witness the postponement of their expected share of the results and, therefore, the reduction of the business attractiveness rates. Contractors witness the reduction of their profits, which affect their company's financial health and, in extreme cases, cause the fall of its market value.

When delays become a reality and financial losses are the immediate consequence, conflicts between owners and contractors may be staged in court. In these extreme cases, lawsuits are founded on the bad management of resources in construction sites. Then, a relevant question

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arises: why is such a problem not properly addressed in its origin, that is, in the construction site?

The answer seems to be in the manner how that management is performed. Today, construction management is distant from production. With the advent of subcontract (systematically practiced for more than 20 years), construction supervisors have become "contract supervisors". They do not focus on production, or production management anymore. They have become deadline managers, deadline "jugglers". In the Engineering, Procurement and Construction (EPC) contract model, the responsibility for meeting deadlines is delegated to Contractors. Owners are just supposed to demand the achievement of deadline goals. However, when deadlines are not achieved, it is a problem to know how to proceed: take a reactive or a proactive position.

As delays are systematic, another problem is to determine their cause. One usual justification for delays is the "insufficient resources" - either in quantitative or in qualitative terms. Another one is the labor poor qualification.

It is true that labor scarcity has consequences on productivity. In the past decade, there were lines of workers at the doors of Brazilian construction sites. The large supply allowed for selection, and the most qualified were chosen. Nowadays, the large demand favors a situation in which both well and poor qualified workers are employed. The reflex on productivity is certain. However, this is not the only cause of the deterioration of productivity. It is very easy and, at the same time, very irresponsible to follow this path.

Simply accepting that the amount of resources is insufficient - when instantaneous observations ("Activity Analysis" models) show low rates of labor occupied in direct work - does not seem to be the path to the mitigation of delays either.

The biggest Brazilian owner in terms of volume of construction works in the 2007-2014 period has reacted to the systematic delays in construction in different ways. In one of these approaches, initiated in 2007, it was proved that the delays of the construction activities are a direct consequence of the inefficiency in the use of resources. From this moment, a new approach for the mitigation of delays was conceived. In this perspective, the owner does not only demand the accomplishment of deadline goals, but also plays a direct and proactive role in production, favoring success with deadlines.

2. Objective

This work has the purpose of presenting a Model of Productivity Management capable of contributing to the mitigation of one of the main damages caused by the loss of labor efficiency: delays in construction activities.

3. Background

3.1 A scenario of incomplete information in Brazilian construction enterprises

Brazilian owners have revealed major advances in the management of costs and deadlines lately and a gradual change towards a culture of knowledge management. However, some barriers for an effective knowledge management must be considered: i) the insufficiency of databases; II) the lack of experienced professionals to consolidate the databases; III) the scarcity of available time from supervisors and foremen to collect data; IV) the inexistence of forums for the dissemination of good practices; v) the scarcity of available time for the dissemination of the lessons learned.

The analyses of the owners' management systems reveal that their management of knowledge is not solid yet. One aspect that stands out is the fact that feedback is still limited (information does not flow naturally). There is a general perception that supervisors could have a more decisive performance in the collection of productivity indices and, therefore, participate in a more decisive manner in the consolidation of the owners' planning.

Regarding the contractors' management system, there are no evidences that it operates with more complete information than that of the owners'. Therefore, the expectation of a more consistent planning from contractors is optimistic.

In fact, there are complaints between both owners and contractors. Some examples of the complaints frequently reported by owners are i) the inexistence of commitment with the owners' objectives; ii) the mobilization of management teams with inadequate abilities and competences; iii) the inexistence of a previous mobilization; iv) the lack of a robust planning before the beginning of the construction activities; vi) the inadequate preparation of cost-based schedules; vii) the inconsistent analysis of risks (i.e. the non consideration of risks to the planning by means of multiplying indices).

As the evidences above show, it is possible to understand why deadline and cost problems have become usual in the present Brazilian scenario. The lack of information creates space for the establishment of common sense (and some myths), such as i) safety requirements exert a major impact; ii) owners' requirements are very rigid; iii) contractors' costs are very high; iv) contractors are incompetent; v) contractors do not know how to plan.

Common sense reflects personal experiences; it does not represent the overall Brazilian reality. In practice, it works as a “cognitive shortcut”. Therefore, it is not enough to i) identify the factors influencing productivity; ii) evaluate the independent and joint impact of the influencing factors; iii) discriminate the actors responsible for the factors; iv) support management processes of continuous improvement.

Thus, a management model capable of providing a scenario of complete information, driven by the improvement of productivity is imperative if one considers i) treating the information as an organizational asset (source of competitive advantage) and ii) facing the loss of information as the loss of a financial resource (liability).

Productivity has been commonly associated with the contractors' inability, even though it is generally accepted that owners' actions can influence contractors' performance. Although sensitive to those actions, owners have no idea of the magnitude of their impact on productivity.

ARAUJO et al. (2012) argued that productivity has been usually treated by owners as a matter of increasing the amount of resources. If production is low, the main action to be taken is to increase the amount of resources. Such action can generate conflicts of interests between the actors involved, leading to: i) contractual dispute; ii) extra costs; iii) stress.

The pessimistic scenario presented in Figure 1 corroborates the value of information for companies. Silva (2005) argues that there is a natural tendency to measure the value of information by how much additional gain it brings. For this author, the broadest and most correct concept considers the opportunity cost – i.e. how much the lack of information would cost. In this sense, measuring the value of information is a process similar to those involved in insurance or advertisement – how much "not having it" costs. In this broader approach, information is treated as a resource, possessing cost and value, return rate, opportunity cost. Irrespective of the type of organization - private or public - administrators come from, they make their decisions of investment adopting the principle of the economic rationality: to get the most out of a certain amount of resources or to reduce this amount to achieve a certain result. For this analysis, opportune and quality information is crucial for an efficient administrative performance.

Moresi (2000) believes that the importance of information for organizations is universally accepted. Its management and use are directly related with the desired success. In many organizations, it is considered and used as a structuring factor and a management tool. Thus, an organization effective management requires an objective and precise perception of the values of information and of the information system.

The present authors, therefore, recognize i) the negative implications of the current scenarios of incomplete information in Brazil, worsened by technical, management and commercial significant difficulties during the implementation of new investment portfolios; ii) the existence of difficult scenarios for owners, considering an unknown set of factors to be conveniently evaluated and faced; iii) the value and the power of information. These authors see the Model of Productivity Management as a powerful tool to promote invaluable feedback in the enterprises.

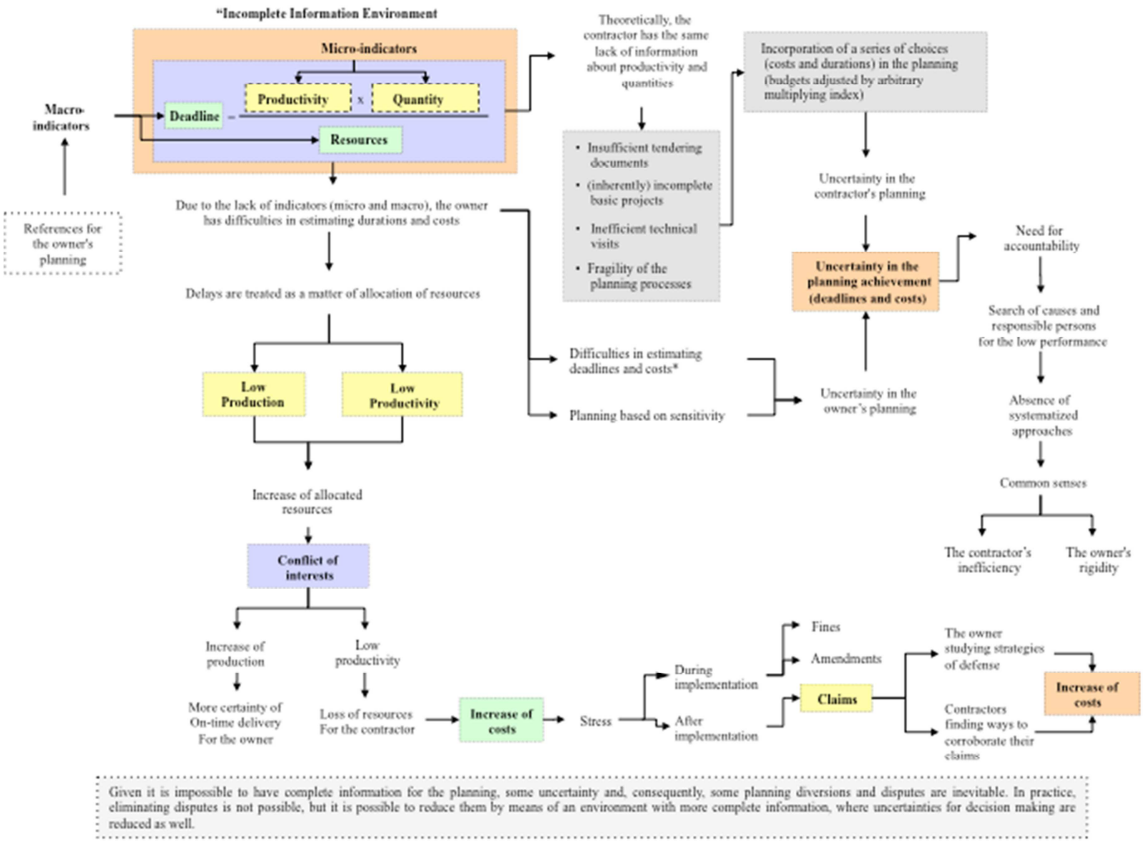

Figure 1: Scenario of incomplete information

3.2 Concern with the corroboration of claims

Recently published works about productivity loss in the construction sector reveal that discussions and reflections about this theme are almost exclusively turned to the contractors' and owners' concern with disputes. Owners desire to find ways and mechanisms to corroborate their claims, and contractors try to defend themselves, aiming at rejecting those claims.

Discussions about productivity losses, as a result, are reactive and usually promoted when construction activities are already finished. Disputes usually end up in court, with the parties justifying themselves before the judge, and their resolution address financial questions only.

The works reviewed (Thomas (1992); Dieterle and DeEstephanis (1992); Thomas and Napolitan (1994); Singh (2001); Swartzkoph (2004); Thomas (2009); Thomas (2010); Dieterle and Gaines (2011); Guevara (2012)) make evident the concern in systematizing the collection of productivity loss evidences in construction activities to justify future claims. The present authors believe that

the resolution of productivity losses must happen in the construction site, as soon as it is diagnosed.

4. Contextualizing the model of productivity management

THOMAS 2010 questioned why the loss of labor efficiency (LOE) damages is so difficult to recover. The reasons pointed by the author refer to the difficulties in justifying productivity losses. He presents and analyzes two broad categories of actions related to evidentiary justification that can be taken to improve contractors' chances of recovering LOE damages.

The above questioning led to the reflection on one previous question: why is loss of work efficiency not mitigated in its origin so that disputes in courts could be avoided? The answer to such a question was very simple: Why not?!!

Then, the development of a model of productivity management began. Its success would ease THOMAS' concerns and all the other previously cited authors'. And that is possible simply because it deals with productivity losses in an opportune place and moment: in the construction site, as soon as it is made evident.

The intended result with the application of the model is the mitigation of construction delays. The adopted path necessarily leads to the treatment of Loss of Labor Efficiency or loss of productivity, and the word treatment is especially important here. The model of productivity management does not aim at collecting evidences to justify losses of productivity for the future use of this information. The success of the model is exactly the mitigation of productivity losses at the moment it occurs.

Particularly for EPC contracts, the scenario of productivity loss is no different. They require extensive knowledge and expertise and, rationally, they should not demand owners' detailed supervision of the resources employed by contractors. However, the systematic delays have made owners review their supervision measures.

The first observations reveal idle resources and symptomatic delays. Productivity losses are usually justified by the observation in site of idle labor force or by the low rates of occupation in direct work, measured by the Activity Analysis.

Thus, from the observation of the primary justification (idleness) and of the significant evidence (construction delays), the largest Brazilian construction owner, in EPC contracts, started the development of a new model to treat productivity losses in partnership with two Brazilian universities - UERJ and UFRJ. This model was called Productivity Management Model - GEPOP.’

5. Model of Productivity Management: premises

The Productivity Management Model - GEPOP - considers the reestablishment of crucial information channels to the success of construction projects. Productivity management is based, therefore, in the collection, availability and use of information during construction.

The productivity improvement depends more and more on the capacity of production units to diagnose and combat their inefficiency at the exact moment it occurs. The faster information and knowledge are generated, made available and transmitted, the greater the benefits of their use. The units of production strategically supported by the Productivity Management Model start to count on scenarios of complete information, interrupting the undesired flow previously presented in Figure 1.

There is a major effort to produce better information to support the internal decision making in the production environment. The Model of Productivity Management brings tools (ARAUJO and SAMPAIO 2012) capable of offering information with a high level of detail (ARAUJO et al. 2012) and specific measurement of productivity, labor and other factors associated with productivity losses. The benefits are organized as follows:

1. identify, systematically and independently, the influence of the main actors interested in the productivity;

2. evaluate the impact of contractors' actions on productivity in a quantitative and qualitative manner;

3. contextualize the impressions, perceptions and common senses in light of the data collected in the construction sites;

4. corroborate or reject the impressions, perceptions and common senses;

5. stimulate the collection of productivity measures in owners' construction and assembly services;

6. motivate actions for continuous improvement from the main actors involved;

The Model of Productivity Management assumes that:

1. productivity is influenced by all the stakeholders involved, and the improvement of productivity requires coordinated actions, involving, necessarily, owners (client and engineering) and contractors;

2. the levels of adherence and commitment of stakeholders managers are directly proportional to the success in the critical analysis of the revealed productivity losses;

3. the reduction of uncertainty regarding deadlines and costs demand, in turn, a better knowledge management, allied to a competent management of risks in qualitative and quantitative terms;

4. the implementation of productivity management, founded on a database of productivity measures, constitutes a relevant part of this effort;

5. the validation of the information that will feed into the database must be made by a reputable and independent organization;

6. the quality of the information (evaluated by parameters as data consistency, veracity and reliability) is directly associated with the quality of the improvement actions;

7. it is essential that the information on productivity is made available all the time, allowing for a continuous monitoring of everything that happens in the construction site.

As a result, the potential benefits of the implementation of a Productivity Management Model as a structured program are:

1. support cost management processes;

2. support deadline management processes;

3. support risk management in the processes above;

4. increase the overall reliability of the planning process;

5. early identification of productivity losses;

6. mitigation of the impact of productivity losses;

7. increase the reliability of budgets;

8. mitigate the direct and indirect impacts of productivity losses, including contract disputes;

9. support internal processes of continuous improvement.

The adoption of the Productivity Management Model is not a guarantee of productivity improvement. However, the improvement of productivity will hardly be carried out without such a management model.

It is important to consider that the purpose of a productivity management model is to enable the control of productivity. The control of productivity will be possible from the analyses of the

information made available by the measurement systems. The improvement of productivity will happen through the beneficial cycle promoted by the systematic use of the information generated in this process.

Measuring productivity is the initial step of a Productivity Management Model. Perhaps, the fact that only this step is considered important explains the poor development of that type of model and, therefore, the absence of control mechanisms. Having the best system of productivity measurement is not enough. The effective and systematic control of productivity is equally important. To illustrate the importance of the use of the available information for control, some real cases will be discussed in the next session.

6. Model of Productivity Management: application

The application of the Model of Productivity Management is aimed at the improvement of productivity in the ongoing construction contracts. For that, the model enables a thorough analysis of productivity by means of the concept of “productivity stratification” (Araujo et al. 2012). The presentation of the U.R. in “fractions” enables the examination of productivity losses, as its exceeding factors are revealed, identified and quantified all at once.

At this point, it is necessary to analyze the productivity metrics, look deeply at the results for the different categories, compare them with the results obtained in other sites, evaluate daily metrics and the main occurrences and causes for productivity losses. This step should be taken by owners and contractors together. Then, actions should be defined and implemented in order to increase construction productivity, and good practices should be identified. That is the moment to involve all the stakeholders who work to the success of the project.

The Model was applied in three projects involving piping assembly and piping welding. They illustrate improvements and the specific actions behind those improvements.

The first success case of piping assembly is related to a large project in the Refinery of Rio de Janeiro. For this project, the construction productivity was evaluated in three different periods and the increase rates were 64% within three months and 22% two months later (Figure 2). To the first case, the owner gave a great contribution by adapting its safety requirements: improvement of conditions for measuring workers' blood pressure, with exams valid for three days. Workers received a stamp with the expiration of the exam. The gain provided by the Contractor was based on some actions, such as: i) improvement of the communication (all foreman have radio communicators, facilitating the tracking of work areas); ii) better distribution of tasks (distributed on the previous day); iii) reduction of the number of workers per foreman; iv) improvement of the logistics of construction sites (collective ladders instead of sailor ladders).

The second case (Figure 3) is related to another large project: the construction of the Petrochemical Units in Rio de Janeiro. In this case, there was a 60% increase in pile installation

within two months. The productivity program contributed to faster solutions, by promoting the adoption of some main actions: i) the replacement of equipment due to frequent failures; ii) the replacement of the concrete supplier due to frequent delays; iii) the strengthening of support activities (a bulldozer was dedicated to improve the working conditions on the ground).

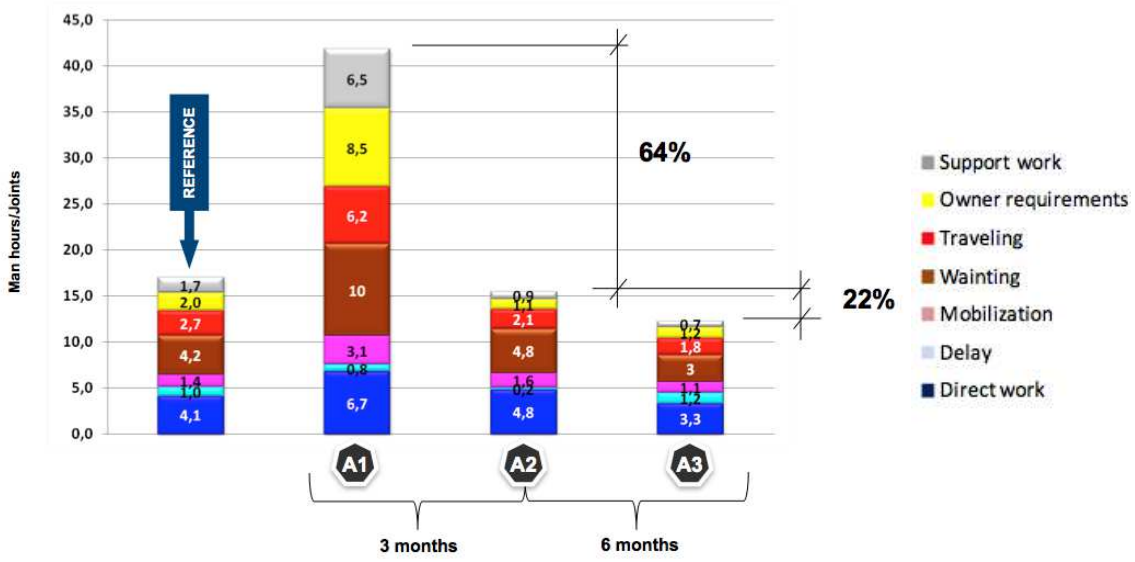

Figure 2: Case 01

The systematic monitoring of productivity, as evidenced in Figure 3, allows for comparisons of the construction phases in consecutive periods. This monitoring takes into account the performance in consecutive periods or internally determined references. This type of comparison promotes ACTING, which is a driver for the structuring of the management model. The diagnosis of a period presents points to be debated, demanded and treated. The diagnosis of the following period makes evident the effectiveness of the implemented actions. The repetition of this beneficial cycle is expected to promote a standard behavior of the productivity trend curve: downward. A behavior different from that must be investigated, justified, treated and combated. It must never be ignored.

The third success case (Figure 4), involving piping welding, is related to the Refinery of Campinas. It presented a 63% increase within four months. The main actions implemented in Campinas were i) integration of the teams (planning, production and quality control teams); ii) Improvement of the weekly schedule of activities; iii) definition and monitoring of weekly goals for welding and inspection of joints; iv) reduction of rework; v) implementation of a Weekly Management Productivity Meeting (one hour) with owner and contractor teams.

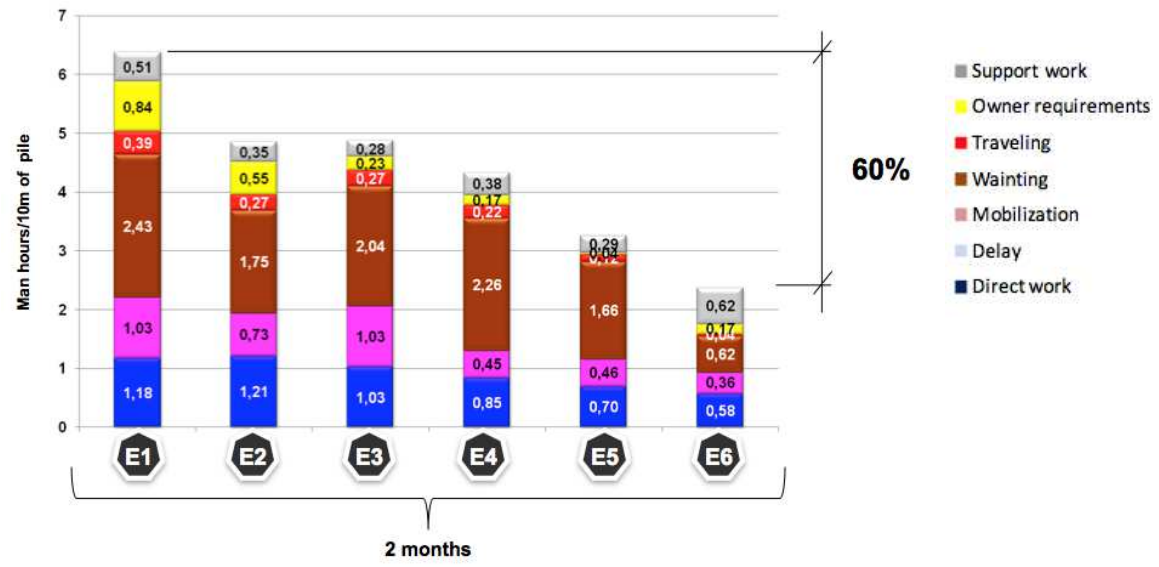

Figure 3: **Case 02**

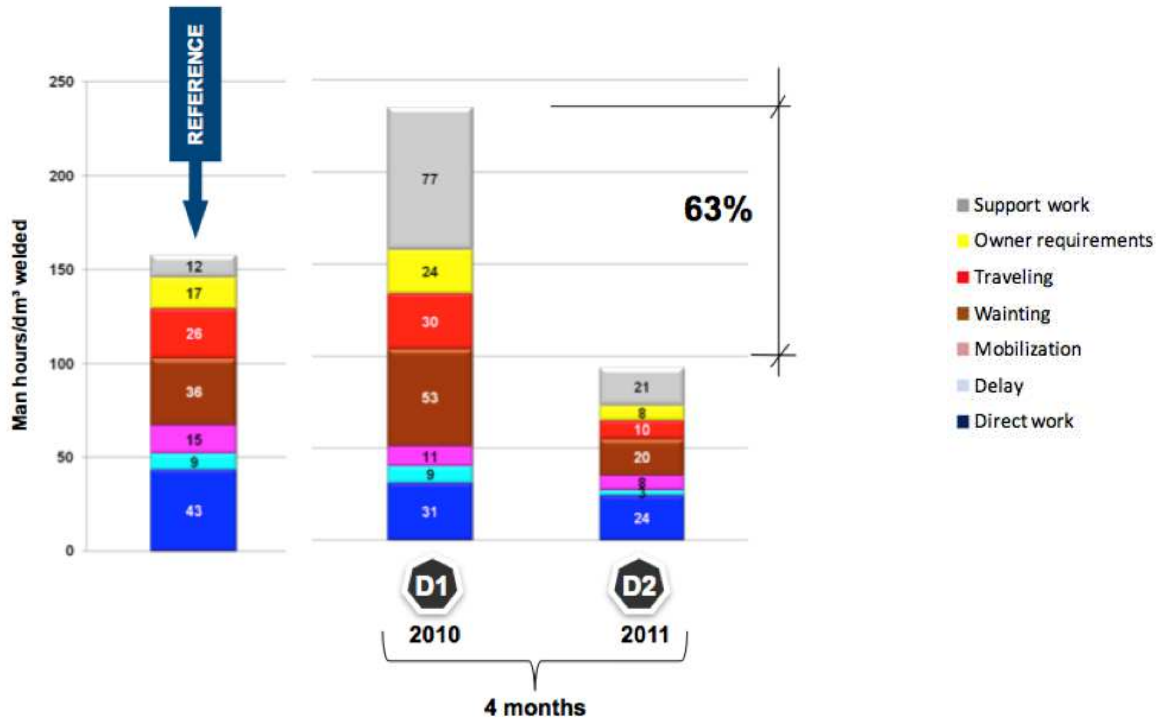

Figure 4: Case 03

In all the three cases the productivity was improved. And this was possible due to the vailability of information, which necessarily included the following actions: obtaining, making available and using the information during the construction activities in an effective manner.

7. Conclusions

The largest construction owner in Brazil faces productivity control in its EPC contracts as a crucial measure for the mitigation of delays in construction. The Productivity Management Model was conceived to support the management of deadlines in construction works. It considers the availability of information and the proactive use of this information during construction activities. Once productivity losses are estimated, it becomes easier to identify the factors that cause them.

The implementation of this Model enables the control of productivity losses. From the relationship between deadline management and productivity losses demonstrated by ARAUJO et al. 2012, it is possible to state that productivity control is essential to the management of deadlines.

However, some difficulties should be considered. The main difficulties detected in this research were i) lack of comparative references, particularly external metrics; ii) lack of access to the estimated and planned metrics; iii) inability to access the programming activities in order to check the commitment with the tasks that are being executed.

Conversely, the benefits obtained from the implementation of the Model and the effective use of the information available were i) recognize that both owners and contractors have to improve the planning process and optimize site logistics; ii) demonstrate that it is possible to implement improvements in ongoing projects and therefore increase their productivity; iii) actuate directly on the improvements, as soon as the productivity losses are identified and quantified; iv) collect metrics and establish references using comparison charts and starting an internal benchmarking process; v) identify and disseminate best practices that contribute to the increase of productivity.

The major benefits were i) disseminating the productivity culture in both owners and contractors organizations; ii) increasing profitability for contractors; iii) meeting project cost and time targets and, ultimately, the construction result.

8. Acknowledgment

The authors acknowledge the unlimited incentive and support of the Petrobras engineering staff for the development of this work.

The authors acknowledge Dr. Leonardo Melhorato Grilo for the invaluable contributions to this work.

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Theoretical Framework for Stakeholders' Disaster Response Index in the Built Environment

S. Mohammad H. Mojtahedi[1], Bee Lan-Oo[2]

Abstract

Disasters are becoming increasingly frequent, expensive and devastating globally. They also jeopardize society, performance of economy, built environment, and other socio-economic and physical determinants. While disasters cannot be eliminated, resilient built environment are those where disasters are effectively managed by stakeholders. Therefore, it is important to measure stakeholders' approaches against disasters in the built environment. A widely used measure is to create a composite index. The aim of this paper is to propose a theoretical framework using stakeholder and decision-making theories in the development of stakeholder disaster response index. Stakeholder theory determines power and legitimacy of stakeholders whether they have tendency towards proactive or reactive approaches. Decision-making theory, on the other hand, provides optimized decisions for stakeholders in order to minimize all negative consequences of disasters. Furthermore, stakeholders take rational behaviors in reactive approaches in recovery and post-disaster reconstruction activities. With a sound theoretical framework, the anticipated benefits of the resultant stakeholders' disaster response index include: (1) direct comparison of different stakeholders' approaches against disasters in the built environment; (2) high-level disaster management planning decisions; and (3) development of stakeholder disaster management procedure.

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Keywords: built environment, decision-making theory, disaster response index, stakeholder management theory

1. Introduction

The natural hazard becomes a natural disaster as soon as human beings, infrastructure, or other forms of tangible or intangible capital is threatened and/or destroyed by that hazard (Alexander, 1997). However, it is noted that some scholars believe that 'Natural Disaster' is now largely considered to be a misleading concept (Bosher 2008; Mileti 1999; Winser et al. 2004). O'Keefe et al. (1976) suggested that some radical rethinking on the nature of "natural" disasters is necessary. Natural disasters can occur when natural vulnerability and human vulnerability have the same coordinates in space and time (Alcantaraayala 2002; Alexander 1997, 2000; Smit et al. 2000). The crucial point about understanding why disasters occur is

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that it is not only natural events that cause them, but they are also the product of the social, political, and economic environment. In this paper we focus on disaster as a general concept which covers natural, technological, and man-made hazards.

Disasters affect not only communities, but also physical assets and the built environment due to lack of stakeholders' awareness before, during and after natural disasters (Bosher et al. 2009). Although there have been efforts to measure different aspects of natural disaster management including preparedness, resilience, mitigation efforts, social vulnerability, and hazard exposures, there is little work on stakeholder approaches against disasters in the built environment. There are potential benefits from measuring stakeholders' approaches, such as a clearer understanding of their preparedness, and providing a means to encourage stakeholders that are more vulnerable and less prepared to improve their preparedness efforts. Better measurement also may lead to more efficient allocation of scarce resources, and assist in assessing risk more effectively and accurately.

An overview of literature related to preparedness indices in disaster management indicates that previous research efforts have dealt mainly with emergency management theory, and socio-economic conditions (e.g., Haque 2003, Ibarrarán et al. 2007, Kahn et al. 2005). Indeed, there is no solid foundation of emergency management theory to guide the development of disaster response indices (Covington and Simpson 2006). Increasingly, few studies have focused on stakeholders' roles and reaction behaviours against disasters in the built environment (Roberts 2008). The aim of this paper is to propose a theoretical framework using stakeholder and decision-making theories in the development of stakeholder disaster response index. Stakeholder theory determines power and legitimacy of stakeholders whether they have tendency towards proactive or reactive approaches. Decision-making theory, on the other hand, provides optimized decisions for stakeholders with considering expectation, asset integration, and risk aversion. We hypothesise that the ideas of both stakeholder and decision-making theories would pave the way to develop stakeholder disaster response index remarkably. In this, first we review the concept of both theories, and then we borrow ideas from both theories to support the theoretical framework of stakeholder disaster response index.

2. Impact of natural disasters on the built environment

The built environment, defined by the facilities and civil infrastructure systems that people use, is the fundamental foundation upon which a society exists, develops, and survives. Built environment is at risk from the impacts of natural disasters associated with climate changes. Natural disasters affect built environment not only in developing countries but also in developed countries. The estimated damages from flooding in UK is around £270 million and around 80,000 urban properties in UK are presently at risk from flooding (Wilby 2007). According to the Department of Climate Change and Energy Efficiency 2011, between 187,000 and 274,000 residential buildings in Australia are exposed to the combined impact of inundation and shoreline recession associated with sea level rise. Furthermore, between 27,200 and 34,500km of transportation infrastructure is potentially at risk from floods associated with sea level rise and climate changes. The average value of exposed residential buildings and transportation infrastructure is $65 and $60 billion, respectively. In

2009, natural disaster costs US$ 41.5 billion, which the costliest disaster was winter storm Klaus, which caused damages totalling US$ 5.1 billion in France and Spain (Bureau of Transport Economics (2001). The database has also recorded that Hurricane Katrina solely caused damages amounting to almost US$ 137 billion in United States in 2005. The issue of climate change and natural disasters are remarkably crucial in the built environment. The climate risks most frequently addressed in existing studies are associated with sea-level rise, and water resources (Nicholls 2004). Anticipated consequences of climate change for cities include fewer periods of extreme winter cold; increased frequency of air and water pollution episodes; rising sea levels and increased risk of storm surge; and changes in the timing, frequency and severity of urban flooding (Wilby 2007). These events and changes will, in turn, have both direct and indirect impacts on the built environment (Wilby 2007). A review on literature by Hunt and Watkiss (2010) suggests that there has been little study pertinent to impacts of disasters on energy sectors and transport infrastructure. Roberts (2008) argue that the principle vulnerability of the built environment and infrastructures to climate changes is derived from extreme events; including floods and storms and to a lesser extend heat-waves and drought. New buildings will have to be designed to cope with the effects of disasters associated with climate change. Stakeholder approaches towards natural disasters in order to mitigate the consequences of disasters are firmly recommended in the built environment (Moe and Pathranarakul 2006, Bosher et al. 2009).

3. Stakeholder approaches to managing disasters in the built environment

Stakeholders' approaches toward natural disaster management can be classified into pro-active and reactive approaches. Moe and Pathranarakul (2006) described that pro-active approach refers to those activities such as mitigation and preparedness that are planned and conducted before the natural disasters by stakeholders in order to tranquilize the adverse impacts of natural disasters effectively. In contrast, responses and recovery activities which are conducted by stakeholders during and after natural disasters is called reactive approach.

Although there are two approaches to tackle the natural disasters; reactive and proactive approaches, most studies have claimed that the stakeholders often resolve the predicaments arisen in natural disasters by reactive approaches (Bosher et al. 2009, Brilly and Polic 2005, Loosemore and Hughes 1998). It is also noted that few studies exist on stakeholders' approaches toward natural disaster management in the built environment. Loosemore (1998) investigated reactive crisis management in construction projects. Brilly and Polic (2005) studied a case in Slovenia to provide an integrated flood mitigation decision making process with considering stakeholders' approaches. Moe et al. (2007) proposed a balanced scorecard technique with considering pro-active and reactive approaches to provide a continuous assessment of performance in each life-cycle phase in natural disaster management project. Bosher et al. (2009) claimed that there is a need to proactively address strategic weaknesses in maintaining the built environment from a range of disasters. They also emphasized that there is still insufficient evidence that key construction stakeholders are playing an active role in mitigating flood risk. The pre-construction phase of building's life cycle has been identified as the most critical stages in their study when key stakeholders such as architects/designer, structural and civil engineers, urban planners, specialist

contractors and emergency/risk managers need to adopt natural disaster mitigation strategies. Their survey on the integration of disaster risk management in UK's built environment indicated that knowledge and awareness of integrated disaster risk management is poor, they also concluded by some key recommendations as: (i) built environment stakeholders need to become more immersed in group decision making; (ii) professional training for stakeholders such as architect, planners, engineers, developers, etc pertinent to risk and hazard awareness should be systematically organized; and (iii) performance-based contracting, and product or service oriented procurement decision should be taken in order to make designers and contractors think about long-term implications and performance of buildings and structures they design and construct. Development of indices is highly required in the built environment to measure stakeholders' responses against disasters. For this, we need to shape theoretical framework to justify the feasibility and reliability of disaster response index in the built environment.

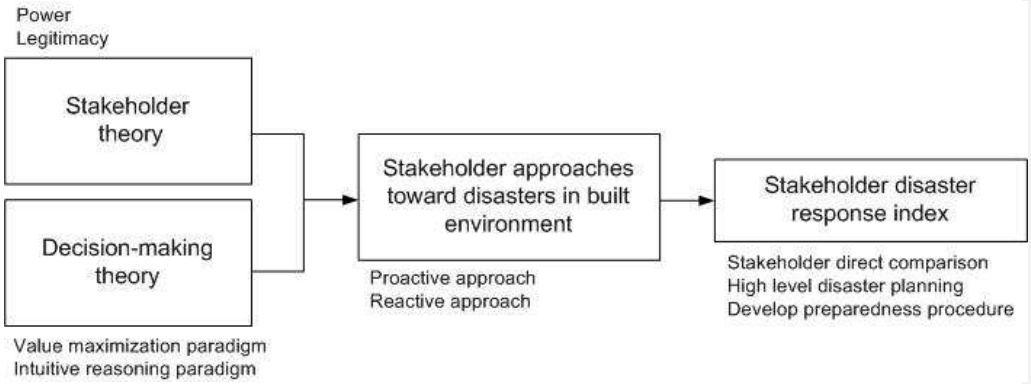
4. Theoretical framework

Disaster response indices play an important role to measure stakeholders' disaster preparedness, resilience, mitigation efforts, social vulnerability, and hazard exposure. Davidson and Lambert (2001) explained that natural disaster indices are appealing because they summarize a substantial amount of technical information in a way that people can easily understand. Indeed, indices have become more widely applied in social capital and capacities, and measure quality of life, human development, social vulnerability, emergency preparedness (Davidson 1997, Davidson and Lambert 2001, Simpson and Katirai 2006). Disaster response indices have remarkable benefits as following (Cutter et al. 2003, Davidson and Lambert 2001, Simpson and Katirai 2006): (1) providing a more dynamic picture of disaster; (2) comparison of vulnerability between different communities; (3) efficient allocation of scarce resources; (4) assessing disaster risk more effectively and accurately; (5) understanding community preparedness. They also support disaster resource allocation, high level planning decisions, public education efforts and disaster risk assessment (Davidson and Lambert 2001).

Apart from the benefits of disaster response indices, there have been numerous issues pertinent to the theoretical aspects in developing disaster response index (Covington and Simpson 2006). Few scholars have applied theories and paradigms in measuring disaster preparedness. These theories include: practice-based theory and a theory-based practice (Gillespie and Streeter, 1987) and planning perspective (Perry and Lindell, 2003) and It is noted that the most frequently used is the emergency management theory (e.g., Dynes 1994, McEntire 2001, McEntire 2002). However, emergency management theory doesn't seem to provide a solid foundation to guide the development of disaster preparedness indices, emergency management theory has three fundamental problems for developing disaster response indices as follows: (1) we are really interested in disasters, not emergencies; (2) the focus on emergency makes the field reactive and limits its applicability to first responders; (3) emergency management may imply that we have total control in our ability to deal with the adverse occurrences we call disasters. Hence, emergency management is both a misnomer and an oxymoron. But a suitable replacement has not been found, and one may never be accepted due to the increasing professional recognition of the

name emergency management (Covington and Simpson 2006). In this paper, we combine stakeholder and decision-making theories to support the proposed theoretical framework for developing stakeholder disaster response index.

Figure 1 shows the proposed theoretical framework to develop stakeholder disaster response index by considering decision-making and stakeholder theories in the built environment. An important matter for the disaster management team is to identify and analyse those stakeholders who can have an influence over disaster management phases. This paves the way for managing a process that maximizes stakeholder positive input and minimizes any adverse or negative consequences. Furthermore, disaster management is a decision-making process. In a decision making process we are supposed to choose one or



some choices over different alternatives with considering deficiency of knowledge and uncertainty about the future. The built environment decision making process requires a profound integrated understanding of how to avoid and mitigate the effects of risks and disasters (Bosher et al. 2009).

Figure 1: Theoretical framework for developing stakeholder disaster response index

5. Stakeholder definition and theory

Any kind of entity can be a stakeholder in managing disasters. Local people, groups, organizations, institutions, societies, and even the natural environment are generally thought to qualify as actual or potential stakeholders. First definition of stakeholder is attributed to Freeman (1984). He borrowed the notion of memo from Stanford Research Institute in 1963. The memo defined that stakeholder is an entity without whose support the institution would not survive. He also described that the purpose of stakeholder management was to devise methods to manage the myriad groups and relationships that resulted in a strategic fashion. Harrison et al. (2010) claimed that stakeholder theory should be considered the decision makers' roles, their decisions and who takes advantages of the outcomes of those decision. Stakeholders have an interest in the actions of an organization and they have ability to influence it or they can be affected by the achievement of the organization's objectives (Freeman 1984, Savage et al. 1991). Stakeholders experience or anticipate experiencing the harm and benefits of an organization (Donaldson and Preston 1995). Although there have been a few other stakeholder definitions, the latest describes stakeholder who has input in

decision making as well as who benefits from the results of decision makings (Phillips 2003). Stakeholder theory is a theory of organizational management and business ethics that addresses morals and values in managing an organization. This theory was originally detailed by Freeman (1984), and it has been a popular heuristic for describing the management environment for years. Stakeholder theory argues that institute's welfare is optimized by meeting the needs of the institute's key stakeholders in an appropriate way. Increasingly, stakeholder theory offers power and legitimacy attributes which are not found in other theories of the organization (Mitchell et al., 1997).

It is important to categorize stakeholders into different groups. Mitchell et al. (1997) classified stakeholders into seven main groups as; (1) dormant stakeholders; (2) discretionary stakeholders; (3) demanding stakeholders; (4) dominant stakeholders; (5) dangerous stakeholders; (6) dependent stakeholders; and (7) definitive stakeholders. Although dormant stakeholders have little or no interaction with the firm the main criteria in dormant stakeholder is to possess power to impose their will on an organization. Discretionary stakeholders hold the attribute of legitimacy, but they have no enough power to affect a firm's decisions. Demanding stakeholders possess urgent claims but having neither power nor legitimacy. Dominant stakeholders have enough power and legitimacy to direct a firm's decision making process. Coercive behaviours making stakeholders dangerous to the firm (Mitchell et al., 1997). The identification of stakeholders who are involved in disaster management depends on the type of the built environment. Furthermore, the number of stakeholders increases when disasters affect the built environment. A generic set of stakeholders in managing disasters in the built environment would include local government, prime (general contractor), subcontractors, suppliers, architects/designers, structural and civil engineers, urban planners, emergency relief organizations, financial institutions, insurance companies and affected local community (Bosher et al. 2009; Moe and Pathranarakul 2006).

In Freeman's (1984) stakeholder theory, power and legitimacy are two distinctive stakeholder's attributes. The power of stakeholder allows them to mobilize social and political forces and to withdraw resources from the organization (Post et al. 2002, Olander 2007). Legitimacy gives opportunity to stakeholder to abide some sort of beneficial or harmful risk pertinent to organization (Mitchell et al. 1997, Olander 2007). These suggest that power and legitimacy provide them to take proactive or reactive approaches in decision making process. Therefore, stakeholder theory could be a pivotal pillar for supporting the theoretical framework in the development of disaster response index in examining their proactive or reactive approaches against disasters. Power and legitimacy help stakeholders to bring about the outcomes they desire; hence, these attributes are very crucial for stakeholders to take proactive approaches against disasters in the built environment. In other words, combination of power and legitimacy can create authority for stakeholder's firm to take proactive responses independently. However, decision making process definitely influence stakeholders to migrate from proactive approach to reactive response, or vice versa. In the next section we explain how decision making theory can affect the stakeholders' approaches toward disasters in the built environment.

6. Decision making theory and paradigm

Decision making has always been the significant matter for all humans. We need to make decision individually and in groups constantly. In a decision making process we are supposed to choose one or some choices over different alternatives with considering deficiency of knowledge and uncertainty about future (Shih, 2007). There are two distinguished decision making paradigms namely: value maximization paradigm and intuitive reasoning paradigm (Ariely 2008). The first paradigm assumes that humans have great tendency towards to maximize the value of selected alternatives based on their desires. The latter paradigm assumes that humans' decisions are influenced by complicated factors. Therefore, in value maximization paradigm people have rational behavior but in intuitive reasoning paradigm humans might involve irrelevant factors in their decision making process (Levy 1992, Ariely 2008). Based on the concept of expected utility, the value maximization paradigm proposes that a decision maker will choose the alternative that maximizes the weighted factors obtained by utility functions. Von Neumann Morgenstern Theory (VNMT), under the value maximization paradigm, explains that a person or unity is rational if and only if their behavior maximizes the expected value of the set of possible outcomes (Neumann and Morgenstern 1944). Prospect theory introduced by kahneman and Tversky (1979) significantly advanced decision making theory. This theory enrich value maximization paradigm by addressing three principles: (1) expectation, (2) asset integration, and (3) risk aversion. The overall utility of a prospect is the expected utility of its outcomes, and a prospect is acceptable if the utility resulting from integrating the prospect with one's assets exceeds the utility of those assets alone. Moreover, most people will prefer an alternative with expected value X over any riskier alternative with equal expected value X (Senior 2012). In decision making process, alternatives encounter dominance and conflict conditions (Shafir et al. 1993). A condition of dominance emerges when an alternative is perceived as superior to another in all significant features. In contrast, a conflict condition arises when one alternative may be superior to another in only some dimensions.
Altay and Green (2006) conducted a comprehensive review on operation research and decision making in disaster management. They found that most researchers have focused on mitigation, preparedness, and response and recovery phases of natural disasters. For flood disaster, Akter and Simonovic (2005) proposed a flood management decision making methodology to capture the views of multiple stakeholders using fuzzy set theory and fuzzy logic. More important, decision making theory facilitates to select appropriate exposures and pertinent variables in the development of stakeholder disaster response index. The use of decision making techniques can be dated back to four decades. Since then, the theory and applications have been developed significantly (Shih, 2007).

Based on value maximization paradigm, it is hypothesized that stakeholders who are involved in the built environment would try to choose proactive approaches against disasters in order to minimize all negative consequences of disasters. Similarly, stakeholders would take rational behaviors in reactive approaches in recovery and post-disaster reconstruction activities. However, understanding stakeholders' decision making in disaster management can be attributed to intuitive reasoning paradigm. Stakeholders might choose irrelevant factors in their decision making process. For instance, in multi exposure analysis of disasters, one location (e.g., state, city, suburb) would be dominant compared to another

location if the former is perceived to be superior to the latter in all significant aspects. Finally, by borrowing the ideas from both the stakeholder and decision making theories, we would be able to justify the development of stakeholder disaster response index that measures stakeholders' response approaches against disasters in the built environment as shown in Figure 1.

7. Conclusion

This paper examined the stakeholder and decision-making theories in the proposed theoretical framework for the development of stakeholder disaster response index. The proposed theoretical framework synthesis the two theories in examining stakeholders' response approaches against disasters in the built environment. Through stakeholder theory, we determine power and legitimacy of stakeholders whether they have tendency towards proactive or reactive approaches. Through decision-making theory, we are able to provide optimized decisions for stakeholders in order to minimize all negative consequences of disasters. Furthermore, stakeholders take rational behaviors in reactive approaches in recovery and post-disaster reconstruction activities with considering expectation, asset integration, and risk aversion.

With a sound theoretical framework for the development of stakeholders disaster response index, the resultant index facilitates: (1) direct comparison of different stakeholders' approaches against disasters; (2) high-level disaster management planning decisions; and (3) development of stakeholder disaster management procedure.

The next stage planned for this study involves validating the proposed theoretical framework with profound quantitative analysis by gathering relevant data from disaster management databases and in-depth interviews with stakeholders who are involved in managing disasters in the built environment.

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Green Office Interiors in Australia: Lessons Learnt

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Abstract

In 2003, the Green Building Council of Australia (GBCA) launched their Green Star rating tools for various types of buildings in order to promote green building practice in Australia. Of these, the Green Star-Office Interior rating tool is designed for building owners, tenants and interior designers to assess the environmental impact of an interior fitout. It covers a number of categories, including Management, Indoor Environment Quality, Energy, Transport, Water, Materials, Land Use and Ecology, Emissions, and Innovation. This paper reviews the usage of the Green Star system in Australian office tenancy fitouts and the potential challenges associated with Green Star-Office Interior implementation. This involves the analysis of score sheets of 66 office interior projects across Australia that achieved Green Star certification. The percentage of green star points obtained within each category and sub-categories (credits) for each project are investigated to illustrate the achievement of credits. The results show that Emission-related credits and Innovation-related credits are the easiest and most difficult respectively to obtain. It is also found that 6 Green Star office interior projects perform especially better in the categories of Energy and Ecology than 4 and 5 Star projects. The investigation of point frequency in each category provides prospective Green Star applicants with insights into credit achievement for future projects.

Keywords: Sustainable building, GBCA, Green Star, Office interior

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1. Introduction

There has been a widespread acceptance of the need for sustainable development in recent years. As the biggest energy consumer and greenhouse gas emitter, the building sector plays a vital role in achieving environmental, economical and social sustainability goals (WBCSD, 2007; Zuo et al., 2012). Office buildings account for a significant proportion of the building stock. According to the Property Council of Australia (2012), the gross floor area of office buildings in major cities nationwide is more than 23 million m2. These office buildings consume a significant amount of water, and electricity and produce more than 60 metric tons of CO2 equivalent greenhouse gas. Additionally, as most employees spend long hours in offices each day, it is very important to provide a sustainable indoor environment to maintain their health, well-being, and performance.

To promote sustainable practices in office buildings, the Green Building Council of Australia (GBCA) has released three rating tools for office buildings, i.e., Green Star-Office Design, Green Star-Office As Built, and Green Star-Office Interior. Unlike the Green Star-Office Design and Green Star-Office As Built, which assess the sustainability performance of the whole office project, the Green-Star Office Interior assesses the sustainable attributes of interior fitouts in office buildings. While it is primarily applied when the construction of an office tenancy fitout is completed, it can also be used during the interior design stage to ensure green features are incorporated at early stage. Since its release in 2005, more than 60 office fitouts have secured Green Star–Office Interior certification. It is expected the Green Star–Office Interior tool will provide greater opportunity to building occupants to enjoy the social, environmental and economic benefits of a Green Star fitout (GBCA, 2012).

However, obtaining Green Star interior certification for office buildings involves significant challenges. The rating system evaluates the sustainability performance of interior fitouts against as many as nine categories (management, water, indoor environment quality, etc.), each of which pose different requirements and challenges to the applicants. It normally requires the applicants to invest additional resources in order to obtain the Green Star certification. Additionally, considering the large stock of office buildings across Australia, the number of Green Star-Office Interior buildings is relatively small, which to a large extent echoes the difficulty in securing this certification.

Therefore, this paper aims to provide an understanding of the level of difficulty involved in securing GBCA Green Star Office Interiors certification. The frequency of green star points obtained within each category and sub-categories for 66 projects are investigated to illustrate the challenges and achievements involved. Although the number of certified projects is comparatively small from which to obtain general conclusions for the industry, the investigation of points frequency for the rating categories will provide potential applicants “with information on credits awarded in the past, and insight into credit implementation in future projects with similar goals” (Silva and Ruwanpura, 2009).

2. Green Star-Office Interior Rating Tool

Built on existing green building rating tools, such as the BREEAM in Britain and LEED in North America, Green Star is a "national, voluntary environmental rating system that evaluates the environmental design and construction of buildings and communities", which was launched by the GBCA in 2003 in order to promulgate sustainability features in the Australian property industry. It helps to define and evaluate green buildings by establishing a common language and standard of measurement (GBCA, 2012; Zuo et al., 2012)

The Green Star-Office Interior evaluates the environmental initiatives of a Class 5 office tenancy fitout against the nine categories of Management, Indoor Environment Quality, Energy, Transport, Water, Emission, Materials, Land use & Ecology and Innovation, with 3 to 34 points available. Each of these nine categories includes a different number of sub-level indicators that address different aspects of green features. Within the office interior rating system, a total of 144 (unweighted) points are distributed to eight categories (shown in Table 1). With the application of environmental weightings, the number of total points is then converted into a maximum of 100. In a similar manner to other Green Star rating tools, five extra points are available for the Innovation category if the office interior project adopts innovative strategies and technologies exceeding the Green Star benchmarks and environmental design initiatives.

Table 1 Summary of indicators and points for Green Office Interior V1

Categories	Number of indicators	Points available (un-weighted)
Management	6	15
Indoor Environment Quality	15	34
Energy	4	16
Transport	3	10
Water	1	14
Materials	11	33
Land use & Ecology	6	19
Emissions	2	3

After receiving the application document from project teams, the GBCA commissions a panel of third-party Certified Assessors to assess whether all the claimed indicators meet the requirements outlined in the Technical Manual. Project teams are then notified of their final score based on the recommendation of the Assessment Panel. If the scores are within the range of the Green Star levels, the project team receives the corresponding rating certificate together with an award letter, marketing kit and relevant Green Star logos. There are three different "Star" levels, comprising:

4 Star: 45 – 59 points, indicating "Best Practice"

5 Star: 60 – 74 points, indicating "Australian Excellence"

6 Star: 75-100 points, indicating "World Leader"

3. Method

To investigate the potential challenges in implementing the LEED rating system in the Canadian property sector, Silva and Ruwanpura (2009) conducted a comprehensive review of the percentage of points obtained within each LEED indicator in 42 newly built projects. This helped to understand how the projects utilized the green rating tools and provided insights for improving the application of sustainable features for future sustainability development.

In a similar way to Silva and Ruwanpura (2009) and Xia et al. (2012, 2013), we examine here the point frequency for each evaluation category within the Green Star-Office Interior. The score-sheets of 66 projects provided by GBCA are used for this analysis, with the point frequency being calculated by dividing the points obtained (PO) by the points claimed (PC) for each category, as:

$$\text{Point frequency} = (PO/PC)*100 \text{ percent}$$

It would be reasonable to assume that those categories with lower point frequency pose more challenges to the applicants.

4. Data Analysis

4.1 Project Landscape

According to the geographical distribution of the 66 projects shown in Table 2, New South Wales and Victoria account for the majority of the Green Star-Interior certified projects. Most of these projects were awarded as 4 or 5 Star, with only 4 buildings (6% in total) obtaining a 6-Green Star certification (Table 3).

Table 2 Number of certified projects across Australia

Locations	Number of education projects	Percentage (%)
New South Wales (NSW)	24	36
Victoria (VIC)	22	33
Queensland (QLD)	8	12
South Australia (SA)	8	12
Australia Capital Territory(ACT)	2	3
West Australia (WA)	2	3

Table 3 Number of projects for each Green Star rating

Green Star rating	Number of education projects	Percentage
4 Star	27	41

5 Star	35	53
6 Star	4	6

4.2 Overall Percentage Awarded: Point Frequency in Rating Categories

The point frequency for each rating category is shown in Fig 1. This ranges from 100% in the Emission category to 28% in the Innovation category. These different percentages largely reflect the different levels of challenges faced by project teams.

The Emission category is regarded as the easiest one to achieve as all the applicants were awarded all the points claimed. According to the rating system's Technical Manual, the Emissions category encourages the use of refrigerants that do not contribute to ozone depletion. Additionally, it recognises the use of thermal insulation that is free of ozone-depleting substances. With the wide recognition of the importance of ozone protection and the technology development in HVAC of thermal insulation systems, nearly all the applicants managed to avoid the use of ozone-depleting substances.

The Management category addresses the adoption of sustainable development principles throughout the project development process. With 94 percent of the claimed points being awarded, most of the applicants have adopted sustainable principles and guidelines during the project planning, design, construction, commission, and operation stages. The Management category includes 6 sub-categories with a total of 15 unweighted points. The major reason why the Management category is comparatively easier to achieve appears to be due to most of the indicators being descriptive, operatable and document based, and do not require much additional time and effort. For example, three points are awarded where it is demonstrated that there is a Tenant Guide.

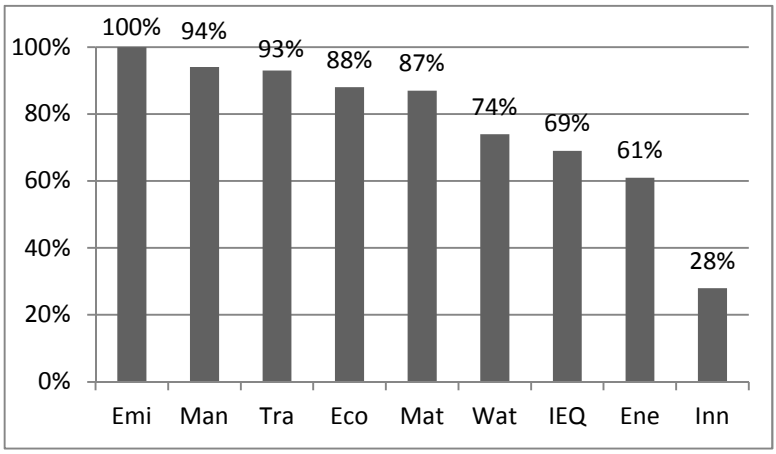

Fig. 1 Point frequency for Green Star-Office Interior rating categories

The category of Transportation encourages and recognizes tenancies with a proximity and good access to public transport networks, utilization of alternative modes of transportation by limiting available parking space, and provision of cyclist facilities. With 93% of the point frequency, most of the projects obtained a sound achievement in this aspect. This is

understandable as most of the official buildings are located within urban areas with easy access to public transportation, and provide cyclist facilities for the tenants.

The categories of Ecology and Material obtained more than 80 percent of the claimed points. These encourage the selection of buildings for tenancy that incorporate environmental impact management, have efficient and flexible layout, reduce material waste, and adopt reuse initiatives and efficient management practices. Considering most of the Green Star office interior buildings already have a 4 Star Office-As Built or higher certification, the point frequencies of Ecology and Material in this rating system is normally higher.

The categories of Water, Indoor Environmental Quality (IEQ), and Energy were awarded a comparatively lower rating of 74 percent, 69 percent and 61 percent respectively. The category of Water aims to encourage and recognise the use of water efficient fittings and appliances that result in reduced potable water consumption. Given the percentage of points awarded in this category (74 percent), it can be concluded that it is not easy to provide water efficient office fitouts. IEQ is important for office occupants as they spend a long time in the building. This category addresses the ventilation rates, carbon dioxide monitoring and control, daylight and electric lighting, external views, personal comfort control, noise level and indoor planting. Most of the measurement is technique oriented and requires significant resource investment. The Energy category, on the other hand, with 61 percent of points awarded, encourages the reduction of greenhouse emissions by addressing energy efficiency, energy improvement, electrical sub-metering, and light switching flexibility.

With only 28 percent of the claimed points awarded, the Innovation category obtained the lowest frequency of points. This category, with a total of 5 points available, includes three subcategories of innovative strategy and technologies, exceeding the Green Star benchmark, and environmental design initiatives. Obviously, the Innovation category is the most challenging to applicants as it requires significant environmental benefits. Additionally, a close look at the three subcategories reveals that they are not clearly defined, which is likely to discourage interested applicants.

4.3 Cross-sector Comparison: Green Star Ratings

The distribution of the point frequency within different categories for 4 Star, 5 Star, and 6 Star office interior projects is shown in Fig 2. This shows that projects with higher certification levels generally have higher points frequency within most of the rating categories. In particular, for the Energy category, the point frequency for 6 Star office interior projects is 32 percentage points higher than for 4 Star and 16 percentage points higher than 5 Star projects. Similarly, the Ecology performance at the higher level of Green Star-office interior projects is much better than at the lower level.

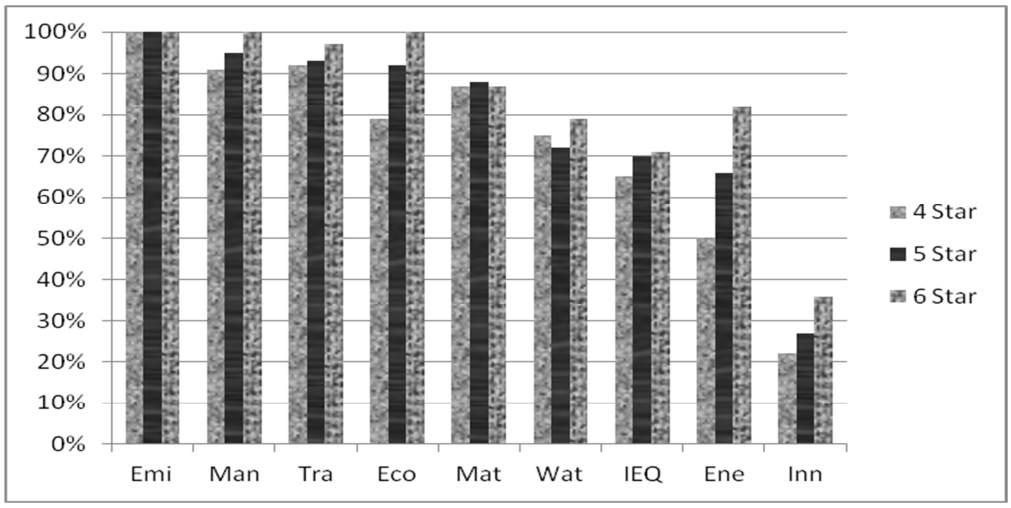

Fig. 2 Percentage of point awarded for different categories

For the Material category however, the 5 Star office interior buildings have a better performance than the 6 Star buildings. The Water category also has a higher point frequency of 4 Star-office interior than the 5 Star equivalent. Also notable is that all the projects achieved the full percentage in the Emission category, while Innovation remains as the most challenging category, with the certified projects obtaining less than 40 percent of the claimed points.

5. Discussion

The Green Star-Office Interior rating system was developed to assess the sustainable features of interior fitout projects. It provides project teams and tenancy occupants with perspectives and guidelines to evaluate the sustainability of the working environment in addition to helping reduce the environmental impact of office buildings.

The comprehensive review of the scoresheets of all office interior projects certified by the GBCA indicates that New South Wales and Victoria account for the majority of the Green office interior projects, which is nearly 70 percent of the total number in Australia. This largely reflects the higher acceptance of sustainability for indoor working environments in this region. Additionally, only 6 percent of these projects achieved a 6 Green Star rating, which is regarded as “World Leader” level in sustainable development. Future studies will be conducted to investigate the specific challenges involved in achieving this level of green office interior buildings in Australia.

The lower point frequency for certain categories largely reflects the challenges facing project teams during green practice implementation. Water, IEQ, Energy and Innovation are the most difficult categories for applicants. There are several possible reasons for this. First, some of indicators within these categories are quite vague and uncertain, and are likely to discourage applicants unless they have clear vision of the possible outcomes. Second, achieving these categories is more expensive than others, and requires larger amount of resources in order to obtain the points. Finally, regional differences may also cause the difference of point frequency. For example, office buildings in drought west Australia

normally obtain fewer points in the Water category, while buildings in cold areas have a lower point frequency in the Energy category. As a result, the overall performance of these two categories is less satisfactory than others.

6. Conclusions

The past decade has witnessed a strong growth of green buildings from both the theoretical and practical perspectives. In Australia, a variety of rating tools for different types of buildings have been developed by the GBCA. This study critically analysed the scoresheets of office interior projects certified by the GBCA. The results showed that Emission, Management, and Transport related credits are the most frequently obtained in GBCA Green Office Interior buildings. This indicates that these categories are comparatively easier to achieve. However, innovation remains the least frequently obtained credit. In other words, it is hard to achieve in practice and poses a challenge to most of the applicants

This study is the first to review the project performance in the implementation of Green Star office interior projects and the analysis of points awarded in each category gives potential applicants a general picture of the challenges involved in making successful applications. It will help developers and project teams in better understanding the rating scheme and providing a better working environment for the occupants of offices. Future studies will be conducted to investigate the underlying causes of the different levels of success in applications in individual rating categories.

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Investigating the role of the external environment to influence clients' health and safety (H&S) performance in the construction industry

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Abstract

Construction Clients have been identified in many studies to be of great importance to H&S performance in the construction industry. However their participation in H&S implementation remains below the expected and meaningful level. The situation in Southern Africa is not any different from the rest of the world. Therefore developing strategies that enhance clients' H&S culture would ensure a gradual and sustained improvement of H&S in the construction industry.

As a result it was imperative to investigate the feasibility of the postulation that the external environment has a positive influence on construction clients' H&S culture and performance. The study, which was conducted in Botswana and South Africa, utilised the Delphi and structural equation modelling techniques in order to model and validate the said postulation.

Findings from the Delphi study were that the external environment had a significant impact on client H&S performance. Further, clients were 'very likely to' implement H&S elements when influence from the external environment factors was evident. The validation from the structural equation modelling technique further indicated that the influence of the external environment on clients was statistically significant.

Therefore this paper will report on findings from an investigation on the influence of the external environment on clients' H&S performance. The study will highlight the point that environmental influence on clients is vital in order to achieve an improved H&S performance in the construction industry.

Keywords: Clients, external environment, health and safety, performance.

1. Background to the study

It is estimated that the construction industry employs about 180 million people, or seven Percent of global employment (ILO, 2005; Murie, 2007). Despite its size in terms of the

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workforce, the construction industry for example in the European Union causes about 20 to 25% of all fatal accidents (Dias, 2004; Karjalainen, 2004; Ringen & Englund, 2006). The construction sector does not have a good record and its H&S performance can best be described as poor (Haslam et al., 2005).

In the construction industry, the risk of a fatality is said to be at least five times more likely than in other manufacturing based industries (Sawacha et al., 1999; Loughborough & UMIST, 2003). According to Bomel (2001) the construction industry is a hazardous environment. Workers in the construction industry are more at risk of an accident, ill health and or even a fatality at work place than other manufacturing based industries (Loughborough & UMIST, 2003; Hoonakker et al., 2005). Generally construction sites are still one of the most dangerous workplaces because of the high incidence of accidents (Teo et al., 2005; Kines et al., 2007).

The poor record on H&S presented at the global level, is also evident in the construction industry in Botswana and South Africa. The industry in Botswana and South Africa, rank among the worst performing industries (Van Ooteghem, 2006; CIDB, 2008). In South Africa, the construction sector had the third highest number of fatalities per 100,000 workers (CIDB, 2008). This industry has also experienced an increase in the number of accidents that were reported between the periods 2004 to 2008. The CIDB reported that both fatal and non-fatal accidents increased from 224 to 578. In comparison to other manufacturing based industries, the construction industry ranked first in terms of an industry with the most accidents (CIDB, 2008).

Consequently, the issue of Health and safety (H&S) performance improvement in the construction industry has received considerable attention in recent years. For many large construction organisations it is a top priority (Choudhry, Fang, & Mohamed, 2007). This has been in part due to the introduction and the pressure from the legislative environment (Mitropoulos, Abdelhamid & Howell, 2005), coupled with increased personal responsibility of senior managers and organisations for H&S (Fitzgerald, 2005), a need to develop a good or better image of the construction industry (Misnan & Mohammed, 2007) and in certain ways to address the H&S record which in comparison to many industries is undesirable (Mohamed, 2002; Loughborough & UMIST, 2003; Behm, 2005; Haslam, Hide, Gibb, Gyi, Pavitt, Atkinson & Duff, 2005; Kulchartchai & Hadikusumo, 2010). For larger multi-national organisations, the need for H&S improvement is a corporate social responsibility issue and therefore corporate organisations are working at improving their H&S performance (Smallman, 2001).

It is economically important that H&S should be improved in the construction industry. Poor H&S performance is costly and can impact negatively on an industry and indeed on an economy. It is estimated that the costs of accidents account for about four Percent of the global Gross Domestic Product (GDP), (ILO, and 2003). Egan (1998) estimates that accidents can account for about three to six Percent of total construction project costs. Studies conducted in Europe among members of the European Union in 2002 on costs of accidents, revealed that as a percentage of the GDP, H&S costs could be as high as eight-and-a-half Percent (Karjalainen, 2004). In the United Kingdom (UK), the Health and Safety

Executive (HSE) report of 2008/09, indicated that 1.2 million people who had worked during that year were suffering from an illness, both long- standing and new cases caused or worsened by their current or past work, equating to 3,900 per 100, 000 people or three-and-nine-tenths Percent (HSE, 2010). In terms of costs, occupational ill health and injury accounted for almost three Percent (Wright, 2007). In South Africa, it was estimated that occupational injuries and diseases accounted for about three-and-a-half Percent of GDP (Republic of South Africa, 2003). In Botswana, the Botswana Federation of Trade Unions (BFTU) estimates that occupational injuries and fatalities account for over three Percent of GDP (BFTU, 2007). H&S performance improvement is therefore a fundamental issue because it is aimed at eliminating or reducing the risk of accidents and its severity in the construction industry.

Therefore, H&S performance improvement in the industry should be a priority. It is warranted that research should be encouraged on this matter given the importance and dangerous nature of the industry. In addition, much research on H&S performance improvement in the industry is justified to improve conditions in which construction workers operate.

Consequently, a number of studies have been conducted on the subject of H&S performance improvement. However most studies on H&S performance have tended to focus on understanding the causal factors underlying construction accidents, such as the studies conducted by Mansingh & Haupt (2008), Bomel (2001), and Loughborough University & UMIST (2003). Other studies have focused on addressing H&S at the construction stage and on issues such as the use of incentives to improve contractor performance (Tang et al. 2008), and designers' roles and responsibilities (Kartam, Flood & Koushki, 2000). Furthermore, studies that address procedures and systems at the construction stage as well as behavioural issues surrounding workers have been conducted (Goodrum & Gangwar, 2004; Cameron & Duff, 2007).

Further studies have been conducted on improving H&S performance through improving the H&S culture of mostly contracting organisations (Dingsdag et al., 2006; Chinda & Mohamed, 2008; Zhou, Fang & Wang, 2008). The studies on H&S culture have been complimented by studies on behaviour based H&S performance (Duff, Robertson, Phillips & Cooper, 1994; Lingard & Rowlinson, 1997; Petersen, 2000; Keil Centre, 2000; Cooper, 2009) and H&S climate (Zhou, Fang & Mohamed, 2011).

Despite these numerous studies on H&S performance improvement in the construction industry, few studies have addressed the role, contribution, responsibilities and influence of construction clients on H&S performance and how clients themselves may improve on their H&S performance. There is little evidence to show that adequate research has been conducted on the role of construction clients apart from one study conducted by Huang and Hinze (Huang & Hinze, 2006; Lingard et al., 2009). However, the study by Huang and Hinze, evaluated the influence of clients on contractor's H&S performance (Huang & Hinze, 2006). The current study sought to evaluate the influence of the external environment on clients' H&S performance. The rationale behind the study was that, in order for the clients to influence contractor or indeed project H&S performance positively, they need to be

motivated to have a good H&S performance. The motivators could be internal or external. The current study evaluated the external motivators.

1.1 The study

A confirmatory factor analysis of the postulated model was conducted. The model comprised two latent factors namely, the external environment and the client culture. The external environment being the exogenous variable and client culture was postulated to be the endogenous variable. The indicator variables of the external environment factor were: legislative (LGN), economic (ECON), social (SOC), professional bodies (PR) and materials and technology (TEC). The theorised model is presented in Figure 1. The theory and basis of the model was derived from literature and a Delphi study. Delphi results have been analysed and presented separately due to limitation of space in the current paper.

Data for the current study was obtained from a questionnaire survey conducted in Botswana and South Africa. Respondents to the survey included construction professionals from, client designer and contracting parties. A total of 281 responses was realised from the survey and 238 responses were analysed. Out of the available 281 cases, 43 cases were skipped because of missing variables.

The model had 57 dependent and 58 independent variables. It also had 108 free parameters. The number of fixed non-zero parameters was 64. The covariance matrix of the model was analysed using the robust maximum likelihood estimation method. Raw data was used for the analysis.

1.2 Findings

1.2.1 Hypothesised relationships

The model generally postulated that the external environment had a direct positive influence on client H&S culture (H1).

Specifically, the model hypothesized that the external environment had a direct positive influence on the following factors of client H&S culture, namely:

1. Leadership – CLLP (H1a);
2. Involvement –CLIP (H1b);
3. Procedures – CLPP (H1c);
4. Commitment – CLTP (H1d);
5. Communication – CLNP (H1e); and
6. Competence – CLCP (H1f)

1.2.2 Goodness-of-fit statistics - RML method

The sample data on the model yield an $S-B\chi^2$ of 2523.9043 with 1218 degrees of freedom. The associated p-value was determined to be 0.000 with a sample of 238 cases. The normed chi-square index, which is the ratio of the scaled chi-square ($S-B\chi^2$) to the

degrees of freedom yield a value of 2.072. This value was lower than the upper limit value of 3.0 and therefore indicative of a reasonable fit of the model.

The robust CFI index was found to be 0.844. The CFI index was less than 0.900 which is the lower limit value for model acceptance. However, a two statistic strategy is considered satisfactory to accept or reject a model (Hu & Bentler, 1999). Therefore RMSEA and SRMR statistics were used to decide on the acceptability of the model.

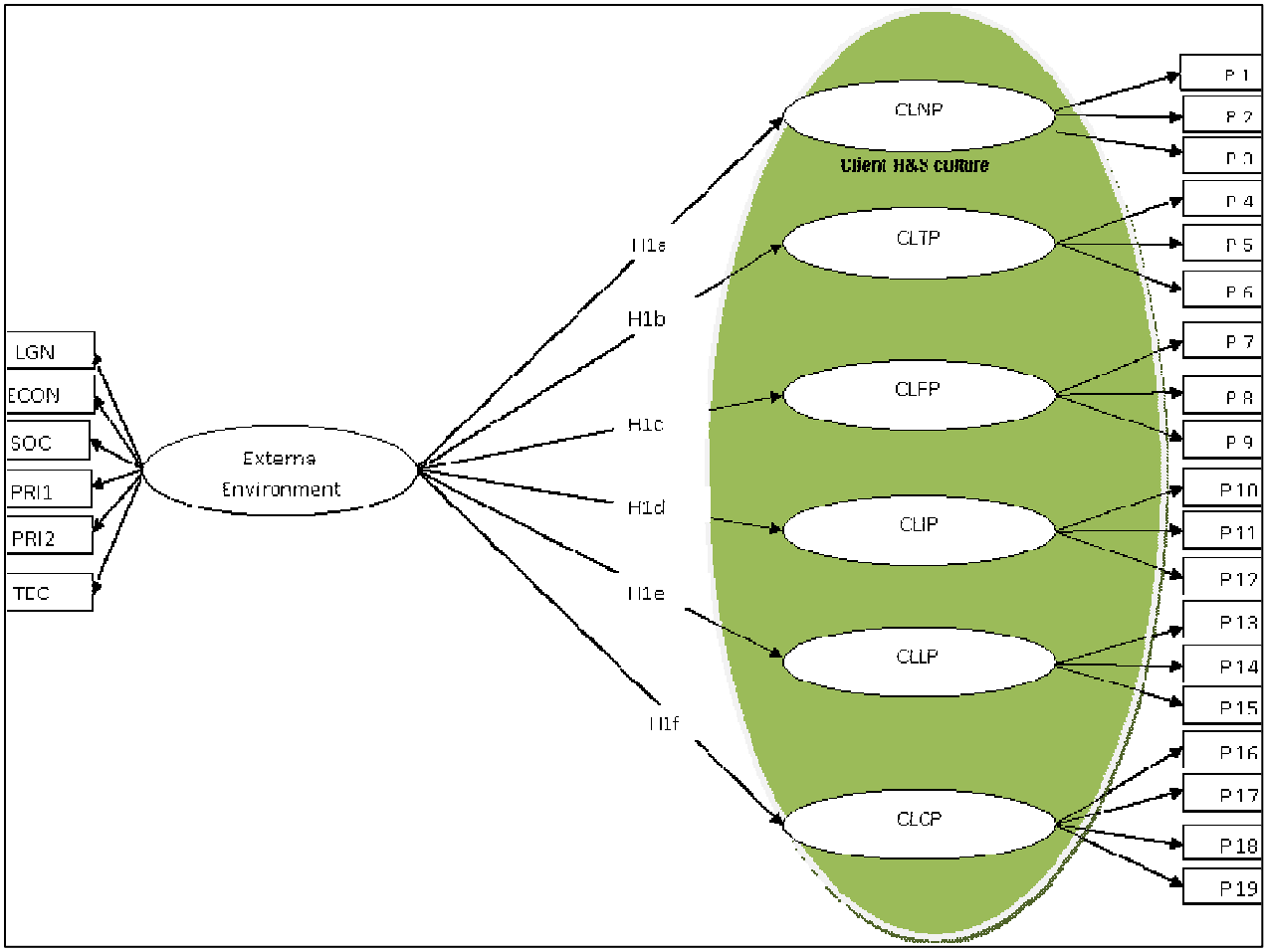

Figure 1: Hypothesised model of external environment's influence on client H&S performance

The robust RMSEA with 90% confidence interval was found to be 0.067. (Lower bound value = 0.063 and upper bound value = 0.071) The RMSEA index was just above the upper limit of 0.050 for the model to be described as good. However the value of 0.67 indicated that the model was acceptable. In addition, the absolute fit index, SRMR, was found to be 0.074. The SRMR fit index indicated an adequate fit of the full structural model to the sample data.

All the indexes with the exception of the CFI met the condition for model acceptance. Although the fit index CFI did not matter so much in the two fit statistic strategy, its value of 0.844 was not far from the lower limit value of 0.900 for model acceptance. See Table 1.

Table 1: Robust fit indexes for SEM Model 1.0

Fit Index	Cut-off value	Model 1.0	Comment
χ^2		2523.9043	
Df	0≥	1218	Acceptable
CFI	0.9≥ acceptable 0.95≥Good fit	0.844	Inadequate
SRMR	0.08≤acceptable 0.05≤ Good fit	0.074	Acceptable
RMSEA	0.08≤acceptable 0.05≤Good fit	0.067	Acceptable
RMSEA 90% CI		0.063:0.071	Acceptable range

1.2.3 Hypotheses testing

The statistic reported on for hypothesis testing was the parameter estimate divided by its standard error and therefore it functioned as a Z-statistic to test that the estimate (which is the relationship strength between two variables) was statistically different from zero. The significance test was used to evaluate the hypotheses $H1_a$ to $H1_f$.

It was generally hypothesised that the external environment had a direct positive influence on client H&S culture (H1). Specifically the hypotheses were that the external environment had a direct positive influence on the six factors of client H&S culture, namely: leadership, involvement, procedures, commitment, communication and competence.

Results from the SEM analysis yield support for all the hypothesised relations, $H1_a$ to $H1_f$. The hypothesised relationships between the external environment and all endogenous factors of client H&S culture were found to be significant and they all had definite positive directions. The relationship between the procedures factor and the external environment was found to be the most significant. The parameter coefficient for this relationship was 0.933 and the Z-statistic was 10.610. Similarly, the relationship between the communication factor and the external environment was found to be statistically significant. This relationship had a parameter coefficient of 0.932 and a Z – statistic of 9.781. These values are presented in Table 2.

Therefore the general hypothesis that the external environment had a direct positive influence on client H&S culture could not be rejected (Table 2). In terms of the magnitude of the parameter coefficients, a comparison of these revealed that the influence of external environment on the commitment factor was found to be the lowest at 0.784.

Table 2: Model 1.0 factor loadings and Z-statistic

Label	Hypotheses External environment has a positive direct influence on the factors of client H&S culture namely :	Factor loading (λ)	Z- Statistic	Significant?
$H1_a$	Leadership	0.880	9.569	Yes
$H1_b$	Involvement	0.791	8.938	Yes
$H1_c$	Procedures	0.933	10.610	Yes
$H1_d$	Commitment	0.784	9.455	Yes
$H1_e$	Communication	0.932	9.781	Yes
$H1_f$	Competence	0.867	9.534	Yes

(Robust statistical significance at 5% level)

1.2.4 Solution evaluation of the model

The robust fit indexes of SRMR and the RMSEA met the cut-off index criteria and the parameter estimates were found to be statistically significant and reasonable. The postulated structural model was therefore acceptable and considered to adequately fit the sample data. Since the analysis was confirmatory, there was no need to further improve the fit of the structural model at this stage. Furthermore, the LM test did not indicate a significant evidence of model mis-specification. Byrne (2006) points out, that for most models, model improvement is merely an exercise that tries to fit small characteristic features of the sample and does not necessarily add value to that already fitted. Therefore the hypothesised model was accepted with its level of fit.

2. Discussion and conclusion

The general hypothesis was that the external environment had a direct and positive influence on client H&S culture (H1) and this hypothesis could not be rejected. All six specific hypotheses which collectively formed the H1 hypothesis could not be rejected. The specific hypotheses stated that the external environment had a direct positive influence on the factors of client H&S culture namely: leadership, involvement, procedures, commitment, communication and competence. The results indicated that at least 62.6% of variance in client H&S culture was explained by the external environment. The external environment's influence was weakest on client H&S involvement compared to the influence on other factors of client H&S culture. The effect was found to be strongest on the factor, procedures. Generally the findings suggested that clients were more likely to lead, be involved, set up procedures, be committed, communicate on H&S issues and develop competence in H&S as a result of the external environment influence. Specifically, the results suggested that it was possible for client H&S culture to be modified as a result of external environment's influence. It was this change in client H&S culture that was needed for H&S performance to be realised in the construction industry. Bomel (2001) observed that the culture of client organisations presented considerable opportunities for H&S improvement in the construction industry.

The implications of this finding are that clients may effectively participate in H&S management and if they do, they would influence project H&S performance continuously and

therefore lead to a general H&S improvement on construction projects. Research in Southern Africa has shown that despite the acknowledged significance of clients to H&S performance, clients have not participated significantly in H&S management (Kikwasi, 2008; Musonda & Smallwood, 2008; Musonda, Haupt & Smallwood, 2009). Similarly, a study conducted by Loughborough & UMIST (2003), established that clients give insufficient consideration to H&S despite their obligations under the CDM regulations. Bomel (2001) observed that the culture of client organisations presents considerable opportunities for H&S improvement in the construction industry. The findings in the current study were therefore significant in the sense that with an increased incentive to clients to participate in H&S management through their culture change resulting from all factors of the external environment, the much desired participation of clients in H&S management may be realised. Further, the findings make it possible for policy makers to address factors of the external environment namely, legislative, economic, social, professional bodies and materials and technology in such a way that the external environment enables or motivates clients' participation in H&S management.

The impact of legislation, which is one of the indicator variables in the current study, has been noted in other studies. INSAG (1991) argue that the manner in which people act is conditioned by requirements set at a high level such as legislation. Findings by CIDB (2008) in South Africa, also affirm the importance of legislation. The CIDB found that there was a general perception in the construction industry that the construction regulations promulgated in 2003 in South Africa seemed to have had a positive impact. This was also found to be the case in the UK concerning the CDM regulations (CIOB, 2009).

The other indicator variable used to describe the external environment in the current study was the economic factor. The use of economic incentives on organisations has been evaluated before. The European Agency for Safety and Health at Work (2010) observe that economic incentives can be effective in promoting H&S. Pan, Soetanto & Sidwell (2010) observed that the economic situation in the UK influenced the homebuilders (clients) to slow down on the use of cross walls precast technology despite the benefits that came with the new technology when the housing markets were promising. The clients' decision on the type of technology to use in this case was highly influenced by the economics despite the benefits including the H&S benefits that would have arisen. In this case, due to a lack of economic incentive in the method, H&S was the casualty. The situation described by Pan et al. (2010) lend support to the findings in the current study that the economic situation as is the case with the legislative framework had a significant influence on client decisions and hence client H&S performance.

An observation by Pan et al. (2010) on the influence of technology change, noted that clients, influenced by the new technology were forced to assume new roles such as producing outline designs, detailed design coordination, procurement and construction. In other words, they were influenced to change the way they did things as a result of technology. The technology and materials factor used to characterise the external environment in the current study seem to have an influence on client H&S culture. In a study by Pan et al. (2010), on projects where the new technology was deployed, an observation

was made that they had experienced a reduction in the H&S risk and also enhanced the building quality (Pan et al., 2010).

Worker unions (social), as a factor of the external environment, have also been found to influence H&S in the construction industry and therefore ties in with the findings of the current study. According to Fraser (2007), unions in Australia, influenced a significant improvement in regulations concerning workers' H&S. It would appear therefore that client H&S culture could be enhanced with an increased participation from the social economic environment such as the workers union.

Therefore the finding that the external environment exhibited a direct positive influence on client H&S culture not only collaborate what other authors have stated before but it also offered a platform and a set of minimum factors that may be required to be addressed in order to change or influence client H&S culture. It would seem that a single approach may not be so successful. The European Agency for Safety and Health at Work (2010), observed that incentives and legislation were complementary. For example, clients in the UK were slow to take up their responsibilities on H&S even though the CDM regulations required them to do so (Baxendale & Jones, 2000). It could be argued that what they probably needed was an incentive from the external environment as established in the current study. Economic, social, technology and the legislative environment all have to be supportive of client H&S culture.

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Mechanisms of trust and trust repair in relational contracting: a multiple perspective investigation of alliance projects

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Abstract

The softer social skills are a key element in the project manager's toolkit, and developing a sense of trust across a project team can be a critical contributor to the project's outcome. This is particularly important where the form of commercial engagement is relational in nature. Alliance projects in construction underpinned by "pain-share/gain-share" principles bring this importance to the fore, and yet little research exists in this field. This research was designed to reveal the intricacies of trust formation and maintenance in such an environment. Initially the concept of trust was deconstructed, analysed and synthesised into a series of identifiable personal attributes, attitudes and behaviours. Thereafter a model of characteristics was developed in order to code and analyse a series of 10 detailed interviews with multiple representatives from 9 firms and the client organisation, the preliminary results of which are presented here. The research confirmed the relevance of trust dimensions, along with an absence of strategies for trust building, maintenance and repair within project management practice. With adversarial dispute resolution prevalent, greater attention to trust and its dimensions would be highly beneficial for Alliance Project practitioners. Specifically, careful attention to project team member selection, strategies for relationship formation and trust building, and open and honest communication should be the focus for stakeholder education in this regard. Furthermore, the skills and traits ascribed to individual stakeholders were considered critical to project success, and included excellent communication skills, technical competence, fairness, integrity, honesty and benevolence. The risks inherent within an alliance project were also considered significant, with the establishment of trust early in a project facilitating a shared purpose and collaborative approach to problem solving which enhanced project outcomes. When trust did break down, the pre-existence of strong relationships was considered to be the main weapon against an adversarial based response, and there was little evidence of knowledge regarding methods of trust repair.

Keywords: Alliance project, trust, trust repair, relationships

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1. Introduction

The use of alliance procurement for the delivery of major public infrastructure projects has become increasingly prevalent in recent years. An alliance arrangement is a distinct form of relationship contracting (Thomson, 1998), in which the respective stakeholders are brought together for a specific project. Abrahams and Cullen (1998, p. 31) define project alliances as:

"An agreement between entities which undertake to work cooperatively, on the basis of a sharing of project risk and reward, for the purpose of achieving agreed outcomes based on principles of good faith and trust and an open-book approach towards costs".

The pain share/gain share arrangement in an alliance ensures mutual project goals remain the driving force for all parties. The agreement to operate on a no-dispute basis, which rejects litigation, is also fundamental, and while negative events and issues may still eventuate, it provides the understanding that resolutions should be reached collaboratively i.e. rejecting the adversarial approach synonymous with traditional procurement mechanisms. Given the absence of the strict control mechanisms that define traditional procurement contracts, together with the centrality stakeholder relationships, the influence of trust is a key component of project alliances.

Trust is considered to be a fundamental requirement for human interaction (Romahn & Hartman, 1999), and there is widespread agreement on the value of trust in human behaviour (Bigley & Pearce, 1998). For the purpose of this study, the definition of trust provided by Rosseau, Sitkin, Burt and Camerer (1998, p. 395) has been adopted;

"Trust is a psychological state comprising the intention to accept vulnerability based upon positive expectations of the intentions or behaviour of another".

It is Important within the context of this research to view trust as a psychological state rather than a behaviour. Moreover it is different to a cooperative relationship, which can exist without the presence of trust: it follows that compliance as a behaviour does not imply the existence of trust (Brewer & Strahorn, 2012).

While alliancing is not new in Australia, little research has been conducted in relation to trust in that context. This research illuminates the formation and maintenance of trust through the lived experiences of multiple practitioners within Alliance projects. A theoretical model of trust is developed to allow the analysis and coding of detailed interviews. These reveal the importance of project initiation, ongoing maintenance, and limitations to the appropriateness of the alliance approach.

2. Literature Review

Past research has resulted in varying definitions and models of trust, which have usually been developed within the specific construct of the discipline in which they are to be applied. Debate and ambiguity has ensued regarding unified definitions and models (Hartman, 1999; Mayer, Davis, & Schoorman, 1995): the subjective nature of trust has also limited the

possibilities for developing a universally applicable trust model (Becerra, Denzinger, & Kremer, 2001).

Focussing primarily within the discipline of management, this study has therefore aimed to identify aspects of trust that have general applicability within a project environment. A thematic review of existing models has facilitated the identification and exploration of common trust themes (Brewer & Strahorn, 2012), with the subsequent review of literature resulting in the theoretical model of trust, as included in table 1. A succinct examination of the respective main theme codes found to be relevant to the particular focus of this study is provided herein.

Table 1- Theoretical trust model, as extracted from literature (Brewer & Strahorn, 2012)

Human variables	**Attribution variables**
Relationships, trust and the project environment	Trustworthiness
Relationship interactions and trust	Reliable behaviour
The initial intent of project stakeholder	Communication
	Competence
	Benevolence
	Integrity
	Honesty
Contextual variables	**Trust failure**
Risk, vulnerability and uncertainty	Trust break down
Control mechanisms	Trust repair
A positive team environment	Trustworthiness factors and trust repair
Trust and project success	Social explanations for negative events
Trust and the temporary nature of a project	Apology or denial
Trust and the unique nature of a project	Competency or integrity trust violations
Trust and project management	Apology and internal or external attributions
	Reticence

2.1 Human variables

The human element of trust was prominent in the reviewed literature, with relationships central in this regard. A relationship is described as the condition in which one party is dependent on another party to realize its objectives (Sheppard & Sherman, 1998), and the presence of a relationship is a requisite condition required for the development of trust (Rosseau, et al., 1998). The ongoing interactions within a relationship are a key determinant of trust (Mayer, et al., 1995; Tomlinson & Mayer, 2009; B. Weiner, 1986), with time a defining feature in any relationship (Karlsen, Graee, & Massaoud, 2008). Project success is also considered to be strongly influenced by the trusting relationships between stakeholders (Pinto, Slevin, & English, 2008), however, in order to fully realise the benefits of a trusting relationship, trust must be mutual (Romahn & Hartman, 1999).

When interacting within a relationship, positive or negative experiences provide the foundation upon which individuals form casual attributions towards one another, with such ascriptions considered along dimensions of causality, controllability and stability (B. Weiner, 1986). Outcomes from this dimensional analysis subsequently initiate future expectations and emotional responses (Tomlinson & Mayer, 2009), facilitating the updating of trust between the parties, and determining the propensity for risk taking in the future (Mayer, et al., 1995).

Prior to any project specific relationship interaction, the initial intent and expectations of the parties involved are considered to be significant in terms of the ultimate success of a project. While a pre-emptive display of trustworthy behaviour in the preliminary stages of an exchange relationship is not without risk, the potential benefits of trust may be lost if a non trusting intent is displayed from the outset (Whitener, Brodt, Korsgaard, & Werner, 1998). Ultimately, an initial non trusting intent will be detrimental to project success (Munns, 1995).

As human interaction is founded on trust (Romahn & Hartman, 1999), an understanding of the variables pertinent in this regard is significant within the context of any project environment.

2.2 Attribution variables

The reviewed literature also had much to say regarding attribution variables as applied within the context of trust in the project environment. That is, variables which influence how individuals assign some quality or character to another person within the project team. Themes pertaining to trustworthiness and its constructs were particular prevalent in this regard. To be considered trustworthy, one party must demonstrate the willingness to act in the best interests of another party (McLain & Hackman, 1995), and to this end, the extent to which one party is more or less trusted will be determined by their characteristics and actions (Good, 1988). Important trust building mechanisms which are mutually related to a high degree (Lander, Purvis, McCray, & Leigh, 2004) include reliable behaviour, communication (Karlsen, et al., 2008), competence, benevolence, integrity, and honesty (McKnight & Chervany, 1995).

2.3 Contextual variables

Contextual variables were also found to significantly influence trust. Uncertainty and risk are inevitable in the project environment (Schwalbe, 2004), and it is trust that ultimately helps to overcome issues in this regard. To this end, trust and the resulting benefits can not come to pass without one party accepting a degree of risk, and within the project setting, an individual's positive motivation towards the overall objectives of a project are also reinforced by the presence of trust (Wong, Cheung, Yiu, & Pang, 2007).

The fulfilment of control mechanisms which control risk and protect stakeholder vulnerability has also been shown to activate trust in the project setting (Wong, et al., 2007), however, it should be noted that excessive control mechanisms can be counterproductive to the development of trust, and potentially lead to distrust among project partners (Pinto, et al.,

2008). As the enactment of any control mechanism bears a cost to the project bottom line, the influence of trust is also significant in reducing the need for control, by fostering stakeholder relationships whereby individuals are able to interact without concern of exploitation (Aubert & Kelsey, 2000).

Trust has also been shown to be crucial to maintaining a positive team environment (Delisle, 2004), and similarly, a healthy team environment will have a positive influence on all themes and dimensions of trust. Ultimately, trust is vital for facilitating cooperative processes (Kramer, 1999), and through improving relationships, trust has a strong influence on project success (Pinto, et al., 2008).

2.4 Trust failure

While the themes of trust are idealistically applicable to stakeholder interactions, the practical ramifications of the real world project setting are such that the potential for trust break down is ever real, with the need to repair lost trust consequently also significant. Relationships between respective parties within a project team will be impacted by a negative event and the subsequent break down of trust can have significant consequences (Lewicki & Bunker, 1996; Robinson, 1996), leading to reduced trust and the need for trust repair (Kim, Ferrin, Cooper, & Dirks, 2004). The perceived reason for a negative outcome will influence trust differently (Lewicki & Bunker, 1996; Sitkin & Roth, 1993), with factors considered according to internal, controllable or stable ascriptions afforded to the trustee (Tomlinson & Mayer, 2009; B. Weiner, 2001), with stability considered to be the most influential (B. Weiner, 2001). In terms of trust repair, despite efforts by the mistrusted party to demonstrate trustworthiness, low levels of trust can be reinforced by the significant information pertaining to the violation which remains (Slovic, 1993), and trust repair must not only restore positive expectations in a relationship, but also overcome negative expectations. The trust repair process therefore differs from initial trust development (Kim, et al., 2004).

3. Methodology

Through adoption of the ‘constructivist’ theory to consider the diverse real world perceptions (Cresswell & Plano Clark, 2007) of multiple industry stakeholders, this research aims to analyse the divergent perspectives and lived experiences of alliance construction practitioners within the construct of trust and its influence. Semi structured, in depth interviews were used to collect the data. Nine individual stakeholders from different sectors were interviewed, including three clients, two client consultant project managers, three contractors, and one engineering consultant. Each interview was conducted at a location chosen by the participant and was approximately one hour in duration. The questions aimed to firstly clarify the roles of the respective interviewees, and then targeted attitudes pertaining to stakeholder relationships generally, and then more specifically with consideration to alternative procurement methods. Subsequently, the interview data underwent a thematic analysis process to identify and abstract the main trust themes included in the developed theoretical model of trust as extracted from literature. The preliminary findings are presented herein.

4. Results and discussion

The evaluation of emerging concepts relative to extant literature is important to the development of new theory (Eisenhardt, 1989). Analysing the interview transcripts with reference to the main theme codes enabled the identification of trust-related issues, highlighting agreement or divergence from existing literature.

4.1 Human variables

Within the alliance environment, the importance of stakeholder relationships to project success was universally recognised by the interviewees. An understanding of factors pertinent to developing relationships was apparent, with communication, regular meetings, interaction outside the work environment, time, past exchanges, multiple interactions, team building, mutual trust, integrity, honesty, and the sharing of common goals, considered to be significant. Trust itself was also acknowledged, and in order to build stakeholder relationships, *"you have to be able to develop trust"* (Client #1: Director). However, providing the project objectives were being satisfied, the development of relationships and trust appeared to be an expected consequence of regular project processes, not requiring any defined trust-building strategy. Furthermore, while the importance of stakeholder relationships was readily apparent, the influence of trust was in some instances implicit only. As trust facilitates cooperative relationships (Misztal, 1996), and trusting relationships foster project success (Pinto, et al., 2008), an understanding of the need to actively pursue the development of both relationships and trust within the alliance environment would prove beneficial.

The Alliance environment was considered to be conducive to strong relationships; however, poor relationships did still eventuate, particularly following negative events which result in relationships becoming adversarial. In instances of conflict, strong relationships among the alliance team were considered fundamental to resolving disputes and arriving at mutually acceptable outcomes. Nonetheless, the presence of strong relationships within an Alliance was not considered to provide an absolute guarantee of project success.

The people themselves were considered to be significant to how relationships developed within an Alliance arrangement, with the personalities and individual attitudes involved considered critical in terms of project success or failure. *"It's all about people, individual people, and the relationships they build"* (Client Consultant #2: Senior Project Manager). *"Things succeed or fail on the personalities involved"* (Contractor #1: Estimating Manager). Attention must therefore be given to the appropriate selection of individual project stakeholders during the formation stage of any Alliance.

In terms of relationship interactions and trust, the interviewees highlighted how future actions and behaviours were driven by past experiences: *"we're all products of our experience"* (Client Consultant #2: Senior Project Manager). Negative outcomes were considered to be a key catalyst for future decision making, and hence, the exchanges between stakeholders were considered to be of particular relevance when things went wrong. Relationship interactions were shown to influence trust positively and negatively, with future risk taking

decisions affected accordingly. Interviewees particularly valued displays of engagement, ongoing interaction, informal communications, collaboration and actions that confirmed integrity, honesty, and competence. Stakeholder interactions were also shown to facilitate a shared understanding of project objectives, improve previously poor relationships, and reverse instances of distrust.

The initial intent of project stakeholders was considered to be significant in terms of project success. Past experiences mould preconceived intentions, and drive the future actions which underpin project relationships. Even in an alliance environment conducive to the development of good relationships, *"you can't teach an old dog new tricks"* (Client Consultant #1: Senior Project Manager), and an adversarial environment can eventuate. Consequently, an initial non trusting intent, and/or a failure to invest in the initial development of relationships is likely to result in adversarial exchanges, increased costs, and diminished project outcomes.

4.2 Attribution variables

Attribution variables essentially determine the level to which the respective parties deem each other to be trustworthy. Positive interactions and outcomes, common goals, time, and acting in the best interest of others, were all considered to be pertinent factors in the development and display of trustworthiness. By displaying trustworthy behaviour, exchange partners are able to interact with confidence, and *"build a level of commercial trust"* (Client Consultant #1: Senior Project Manager).

Reliable behaviour in which an individual substantiates through action, what (s)he has articulated with words (Karlsen, et al., 2008), was identified as being important in building relationships and trust amongst project stakeholders. Similarly, non-reliable behaviour was also found to result in a break down of trust and deterioration in relationships (Ho & Weigelt, 2002).

Communication aimed at developing and maintaining relationships was universally acknowledged, with the link between communication and trust also implicit. Central was the need for well-timed, correct and appropriate information transfer between stakeholders (Braendshoi, 2001), along with the recognition that the quality of the communication within the project environment is a critical determinant of project success (Packendorff, 1995). Openness, transparency, straightforwardness, frequency, and stakeholder dialogue and collaboration, were considered valuable. While formal communication methods were considered necessary, the benefits of informal communication in which stakeholders interacted on a face to face basis were emphasised. Better outcomes were reportedly achieved through person to person communication that facilitated a mutual understanding (Lander, et al., 2004).

The alliance environment was considered to encourage open communication between stakeholders. However, the absence of rules that explicitly dictated communication protocols meant that relationships and trust between stakeholders became increasingly critical. The role of effective communication in responding to negative events and resolving conflict was

clearly acknowledged. A lack of communication with secretive and non transparent behaviour was shown to negatively influence project relationships and trust, and subsequently contribute to poor project outcomes, or even failure of the alliance arrangement. (Aubert & Kelsey, 2000).

While the benefits of communication in developing relationships and trust were highlighted, the converse link between trust and communication was not. As trust can facilitate the exchange of information which is vital for effective and efficient communication (Aubert & Kelsey, 2000), increased efforts in the development of trust would be beneficial, as would an understanding that communication is the essence of trust building (Lander, et al., 2004).

Competence is a significant determinant of trust (Karlsen, et al., 2008; Lander, et al., 2004), and the ability of respective team members is an essential element of trustworthiness (Butler, 1991; Gabarro, 1978; Sitkin & Roth, 1993). Many of the interviewees acknowledged the importance of competence to the creation of trust within the alliance environment. The importance of competence when selecting alliance partners was strongly apparent. Any display of incompetence or poor performance was therefore considered to provide a strong negative influence on relationships and future interactions between stakeholders.

Benevolence is expressed as one party's belief that another party will act empathetically, and is considered a common attribute of trust (Lamsa & Pucetaite, 2006). The mutual goals inherent within an alliance arrangement were commonly identified by the interviewers as been significant in terms of encouraging benevolent behaviour, and developing and maintaining relationships between project partners. The common alliance goals were shown to allow interactions to proceed with confidence, with the link between trust and benevolent behaviour subsequently implied. Conversely a lack of benevolence reportedly resulted in adversarial interactions, poor relationships and lost trust, and ultimately a deterioration and failure of the alliance arrangement.

Integrity concerns the trustor's perception that the trustee will remain true to a set of principals which are acceptable to the trustor, with a degree of dependability towards the trustee subsequently implied (Mayer, et al., 1995). The importance of integrity to stakeholder relationships and project success was recognised by the interviewees. When collaborating within the alliance environment, a lack of integrity ultimately led to a break down in relationships, and a deterioration of the alliance arrangement.

The influence of honesty, a personal characteristic related to credibility that implies there will be no attempt to deceive (Munns, 1995), was similarly acknowledged. The interviewees highlighted the significance of "*acting honestly and fairly*" (Contractor #1: Estimating Manager), in building trust, developing and maintaining relationships, overcoming negative events, and achieving successful project outcomes within the alliance framework. A display of honesty from the outset of the project was considered to be of particular importance, with the damaging affects of dishonest behaviour also recognised.

4.3 Contextual variables

The issues of risk, and risk management, were commonly raised by the interviewees as been significant factors. It was accepted that a high risk profile is the key determinant for forming an alliance. The respective risk apportionment provided the framework for stakeholder relationships and interactions, and also drove future behaviour. When compared with traditional procurement alternatives, the interviewees believed that project risk was generally better managed in the alliance environment due to the common goals of stakeholders, which encourage good relationships: consequently trust was developed and maintained. Scenarios were also provided where the risk apportionment was shown to be a negative influence, leading to a *"level of resentment"* (Client Consultant #1: Senior Project Manager), and in some cases a failure of stakeholder relationships. Overall, the benefits of trusting relationships in managing risks were recognised, with the relationships and trust fostered within an alliance increasing the sense of common purpose and shared goals, and assisting the achievement of project objectives.

When considering control mechanisms and trust the alliance environment was found to be conducive to developing trusting relationships, removing the fear of litigation and motivating the resolution of disputes in a collaborative way. Nevertheless strong stakeholder relationships and trust were not guaranteed. The potential for conflict remained ever present, with issues of transparency, performance, a lack of urgency, excessive controls, value for money, and the pursuit of individual interests identified as issues that could strike at the core of trust between alliance partners. Ultimately, it was acknowledged that irrespective of the chosen control mechanism, *"if there is not a human connection… It won't work anyway"* (Client #3: Project Manager).

Maintaining a positive team culture was commonly believed to be important in terms of relationships and project success. A fully committed positive attitude held by all, combined with team building and collaborative problem-solving led by key stakeholders, was considered to be significant in this regard. *"When people cooperate, it generates a whole series of unrecorded costs and unrecorded benefits"* (Client Consultant #2: Senior Project Manager).

4.4 Trust failure

The influence of negative events on relationships and trust was universally recognised by the interviewees, with the break down of trust between project stakeholders shown to result in poor project outcomes and even a complete failure of the alliance arrangement. In this regard, a lack of transparency, poor performance, behaviour that lacked integrity and honesty, adversarial conflict resolution, unreliable behaviour, lopsided risk apportionment, and issues pertaining to time, cost and quality, were all considered to be significant factors in terms of damaging relationships, and resulting in a reduced level of trust.

The interviewees clearly identified the link between negative events and lost trust, however remained silent on the divergent influences on trustworthiness of the perceived reason for the negative outcome: i.e. The extent to which the cause is deemed internal, controllable

and stable to the trustee (Tomlinson & Mayer, 2009; B. Weiner, 2001). The stability dimension is considered to be the most important (B. Weiner, 2001). To this end, the interviewees failed to consider the damaging affects on relationships and project success of negative outcomes that are ascribed to typical and context specific behaviour, where it is perceived that given similar circumstances, the same results are likely in the future (Sitkin & Roth, 1993).

In terms of repairing lost trust between project stakeholders, the interviewees commonly expressed the belief that strong relationships provided the foundation for resolving conflict and overcoming negative events. Responding promptly and openly was considered to be important, as was communication, particularly personal communication delivered face to face. However, the interviewees failed to acknowledge the need to not only restore positive expectations in a relationship, but also overcome negative expectations (Kim, et al., 2004). Nor was any consideration given to addressing the negative perceptions lingering after a negative event, and the need to reverse the low levels of trust which would thus be reinforced (Slovic, 1993). In this regard, an understanding by construction practitioners of how the trust repair process differs from initial trust development (Kim, et al., 2004) is likely to facilitate a better response to negative events, in turn strengthening stakeholder relationships and improving project outcomes.

5. Conclusion

It was evident that whilst stakeholders in Alliance projects routinely encountered situations where issues of trust formed part of their lived experience, strategies for trust building, maintenance and repair did not form part of their project management practice. Repeatedly they alluded to situations that illustrated the centrality of trust-related issues, and implicitly the desirability for more effective approaches to combat negative outcomes in these situations. However, more often than not, the default position remained founded on adversarial dispute resolution, despite the explicit acknowledgement that alternatives were likely to result in better project outcomes.

Accordingly it was concluded that greater familiarity and comfort with trust concepts in general, and sensitisation to the importance of trust formation, maintenance and repair strategies could be highly beneficial for Alliance Project practitioners. Specific issues in this regard include: the potential for personality profiling during project team member selection; relationship formation and trust building strategies for team leaders during the project team's establishment phase; transparency and honesty in project team communications.

Any project team that was to be constructed with care would need to be complimented by the skills and traits ascribed to individual stakeholders. To this end, excellent communication skills, technical competence, fairness, integrity and benevolence, as well as transparent honesty were all identified as critical elements of project success.

Within the specific context of alliance projects, it was acknowledged that issues pertaining to risk identification, quantification and apportionment were inherently challenging, and had the potential to penalise parties unfairly where underhand or simply murky decision making and

risk apportionment was evident, particularly in the early stages of the project. Conversely, where trust was established initially, shared purpose and collaborative approaches to problem solving tended to follow, facilitating enhanced project outcomes.

Where trust did breakdown, familiar behaviours based upon adversarial dispute resolution was often the habitual response. The most effective weapon against this type of behaviour was found to be the pre-existence of strong relationships between key stakeholder players. Besides this, there was little evidence of knowledge of trust repair techniques.

The outcomes from this study have therefore provided enlightenment regarding the formation and maintenance of trust in the lived experiences of construction practitioners within alliance projects. With consideration to the mostly implicit recognition of trust and its dimensions, education of project managers in this regard is warranted, and could realise improvements to current practice. Given that the data source for this study investigates trust as a general factor of alliance stakeholder relationships, a more focused study is also recommended, and would provide further illumination of the influence of trust, and provide greater direction in terms of future project manager edification.

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Life Cycle Analysis for Sustainability Assessment of Road Projects

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Abstract

Road infrastructure has been considered as one of the most expensive and extensive infrastructure assets of the built environment globally. This asset also impacts the natural environment significantly during different phases of life e.g. construction, use, maintenance and end-of-life. The growing emphasis for sustainable development to meet the needs of future generations requires mitigation of the environmental impacts of road infrastructure during all phases of life e.g. construction, operation and end-of-life disposal (as required).

Life-cycle analysis (LCA), a method of quantification of all stages of life, has recently been studied to explore all the environmental components of road projects due to limitations of generic environmental assessments. The LCA ensures collection and assessment of the inputs and outputs relating to any potential environmental factor of any system throughout its life. However, absence of a defined system boundary covering all potential environmental components restricts the findings of the current LCA studies.

A review of the relevant published LCA studies has identified that environmental components such as rolling resistance of pavement, effect of solar radiation on pavement (albedo), traffic congestion during construction, and roadway lighting & signals are not considered by most of the studies. These components have potentially higher weightings for environment damage than several commonly considered components such as materials, transportation and equipment.

This paper presents the findings of literature review, and suggests a system boundary model for LCA study of road infrastructure projects covering potential environmental components.

Keywords: Sustainability, Environmental Indicators, Life Cycle Analysis (LCA), Global Warming Potential (GWP), System Boundary.

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1. Introduction

The Rio+20 UN Conference on Sustainable Development (UNCSD) held in Rio de Janeiro, Brazil in 2012 focused on “green economy”, to deliver equitable improvement in living standards without eroding natural resources. The green economy is an economy or economic development model based on sustainable development and knowledge of ecological economics (Brand, 2012). Construction and operation of various road infrastructure projects have been a great concern for green development as they comprise a big part of the development activities around the world. Different phases of a road infrastructure e.g. construction, use, maintenance and demolition have significant environmental impacts (Stripple, 2001). Sustainable development of road assets is, therefore, a growing international concern (Soderlund, 2008).

Sustainability in infrastructure comprises of three dimensions- environment, social wellbeing and economy (Shaw et al., 2012b). The changing climate phenomenon as a consequence of growing level of greenhouse gas (GHG) emissions is drawing more attention to the environment dimension. The identification of key environmental indicators is a complex exercise, which needs life cycle analysis (LCA) of the service or product system. LCA science of road infrastructure is at a nascent state. This paper reviews LCA studies with a view to develop a well-defined system boundary for future road projects towards green road development.

2. Sustainability of Roads

The emergence of “Green roads” concept initiates the development of various sustainability assessment schemes or tools in different parts of the world. Some of these schemes relevant to roads are: Invest (Australia), AGIC (Australia), GreenLITES (USA), Greenroads (USA), Envision (USA) and CEEQUAL (UK). These schemes are developed on sustainability indicators covering the three components of sustainability (Shaw et al., 2012a).

Road projects involve considerable land use, energy input and resource consumption, which often results in substantial impacts to environment and community. In addition, there are road characteristics e.g. road geometry, pavement structure and surface conditions and traffic congestion during road works, which impact fuel consumption patterns and consequent emission levels (Lepert and Brillet, 2009). The relevant conventional “environmental factors” are emission and pollution, air and water quality, biodiversity, habitat and species protection, landscape design and aesthetics. However, over the years new “environmental factors” like impact on communities in long run, climate change adaptation, efficiency in resource use, sources of materials, whole of life considerations, waste management and future proofing have been emerged, which implies a growing and complex boundary of the sustainability concept (Griffiths, 2008). Conventional environmental assessments often overlook this complexity, leading to conclusions based on incomplete study. As a result, recent studies have identified the need of a comprehensive life cycle assessment (LCA) framework for road projects to facilitate identification of improved sets of sustainability indicators for the environment component (Santero et al., 2011, Yu and Lu,

2012). This can generate comprehensive and scientifically-defensible strategies for lowering emissions, reducing waste, and minimizing energy, water, or natural resource consumption.

3. Life Cycle Assessment (LCA)

LCA is a systematic set of procedures for compiling and examining the inputs and outputs of materials and energy and the associated environmental impacts directly attributable to the functioning of a product or service system throughout its life cycle. The ISO-EN-UNE-14040 (2006) regulation defines life cycle as the ‘‘consecutive and interrelated stages of a product system, from the acquisition of raw materials or the generation of natural resources until its final disposal’’(p. 2).

Typically, upstream (extraction, processing, transportation and construction), service life (use and maintenance), and downstream (deconstruction and disposal) flows of a product or system are inventoried. Subsequently, global and regional impacts are calculated based on energy consumption, waste generation and a select series of other impact categories (i.e., global warming, ozone depletion, & acidification). This is often termed as a “cradle-to-grave” approach.

3.1 Road LCAs To-date

Recent trends indicate that sustainability is being considered in roadway construction and operation (Muench, 2010). Santero et al. (2011) compiled fifteen road LCA studies from 1996 to early 2010 conducted in Australia, Canada, Finland, Korea, Sweden, UK and USA with a view to identify their system boundary levels. The findings are:

- Materials extraction and production is included by all the LCAs (15).
- Transportation of materials is considerably less studied (9).
- Onsite equipment used in construction is covered by most of the studies (11).
- Traffic congestion due to road works is mostly omitted (3)
- The use phase is almost neglected (2 and partially).
- The complicated maintenance is portrayed as a simplified series of events over the analysis period (10).
- The End-of-life phase is least considered (1).

Based on above findings Santero et al. (2011) found that inclusion of only selected phases and components of the life cycle in a given analysis undermines the utility of the results, as the omitted elements often contribute significantly to the overall life-cycle impact and potentially change the conclusions from a given study. Muench (2010) and Chan et al. (2011) also identified the lack of a comprehensive system boundary for conducting proper LCA of road projects.

The variation in system boundary makes it difficult for proper comparison of the LCA studies and does not provide representative sustainability assessments of road projects. It is, therefore, important that sustainability related LCA studies use equal and consistent system boundaries (Klöpffer, 2003). This observation is also reflected in the “Agenda 21” of 1992 UN Conference on Environment and Development (UNCED), as it defines “S*ustainable*

construction as a comprehensive cycle from the extraction and beneficiation of raw materials, through the planning, design and construction of buildings and infrastructures, until their final deconstruction and management of the resultant waste" (p. 6).

Considering the above scenario, the road LCA studies published since 2010 are evaluated for the system boundary considerations and are presented in Table -1. It is seen that despite some improvement most of the recent road LCA studies did not consider phases like use, maintenance and end-of-life. The findings of the LCA studies are summerized in the following sections to draw a qaulititatve conclusion towards develpoing a road LCA system boundary.

Table 1: A list of published road pavement LCA studies with their system boundaries.

Authors	Location	Life-cycle components in pavement LCAs.						
		Material Phase		Construction Phase		Use Phase	Maintenance Phase	End-of-life Phase
(√ = Component Included)		Extraction & Production	Transportation	Construction Equipment	Traffic Congestion	Rolling Resistance, Albedo, Lighting, Carbonation Leachate	Material, Construction	Equipment, Transportation, Recycling
Zhang et al (2010)	USA	√	√	√	√	√	√	√
Muench (2010)	Different	√	√	√			√	
Cross et al. (2011)	USA	√	√	√				
Cass and Mukherjee (2011)	USA	√	√	√				
Tatari et al. (2012)	USA	√	√	√				
Yu and Lu (2012)	USA	√	√	√	√	√		√
Ting et al. (2012)	USA	√	√	√		√		

3.2 Research Methodology

There are varying analysis period from 20 years to 100 years considered for the road LCA studies, with 50 years as the most perferred one. Santero and Horvath (2009) states that using a 50 year analysis period allows the impact from each component to fully materialize. However, conversion of findings of LCA studies other than 50 year analysis period to a 50 year analysis period is not a simple arithmetic as the various factors include: maintenance considerations, use phase impacts, different traffic levels, different material compositions, varying transport and equipment requirements, varying layer thicknesses, and design parameters etc. This study, therefore, considers a qualitative approach for comparing different impact levels.

The findings of different LCA studies presented in tables, graphs, results' discussions and conclusions are evaluated following Seidel's noticing, collecting and thinking model for qualitative data processing (Seidel, 1998). The environment components covered by a LCA study is segregated into high impact (H) and low impact (L) based on relative levels of

impacts of the components for different environmental indicators covered by the study. From quantitative considerations, the general boundary is above average impact level for the 'H' category and below average impact level for the 'L' category, though the differences are generally high and easily visible from the graphs and tables.

Environmental concerns of road projects in general are resource depletion, human health, global warming, acidification, depletion of stratospheric zone, eutrophication, photo-oxidant formation and ecotoxic impacts (Häkkinen T, 1996). However, most of the studies consider energy consumption and global warming potential (GWP) as the two major environmental indicators. This study also includes these two types of indicators for assessing the impact levels of different road LCA components. Quality road material is a depleting resource because of demand from the growing massive built environment around the world. So, apart from energy use and emissions, the demand of virgin material in road projects is also an important environmental indicator. This study, therefore, considers material resources as an important indicator.

Only primary energy to assess the impact levels of LCA components are considered in this analysis, as most of the LCA studies exclude feedstock energy assessment. Bitumen possess significant feedstock energy and inclusion of feedstock energy in a comparative LCA study gives cement concrete pavement considerable edge over asphalt pavement because of its very high consumption level of non-renewable energy in the material component (Zhang et al., 2010, Yu and Lu, 2012). Since, the scope for bitumen to be used as an energy source is still limited, feedstock energy in road LCA studies are generally not considered.

3.3 Road LCA Components

The life cycle of a road pavement can be divided into five phases, which are materials, construction, use, maintenance and end-of-life. Each phase comprises of several environmental components as listed in Table -2. 'Transportation' and 'Onsite Equipment' components are common to all phases except the use phase. For the materials phase 'onsite equipment' is considered inbuilt with the 'extraction and production' component and for the construction phase 'transportation' is excluded as most of it usually considers under the materials phase. The components of the construction phase and the maintenance phase are the same except when the materials of the existing pavement are processed onsite (recycling). For a new road 'traffic congestion' is unlikely during the construction phase, while its intensity during the maintenance phase depends on the nature of intervention and scope for detouring.

The materials phase comprised of the total upstream supply chain required to deliver processed materials for road construction and maintenance activities and can be broadly categorised as extraction and production. As the primary component of any road pavement, this phase has been considered as fundamental to all the LCA studies irrespective of system boundary definition.

Table 2: Road life cycle assessment components.

LCA Phase		LCA Components
Materials	:	(a) Extraction and Production, (b) Transportation
Construction	:	(a) Onsite Equipment, (b) Traffic Congestion
Use	:	(a) Rolling Resistance (Roughness), (b) Rolling Resistance (Structural), (c) Albedo (Radiative forcing), (d) Albedo (Heat Island), (e) Signage and Lighting, (f) Drainage and Land Cleaning, (g) Carbonation, and (h) Leachate.
Maintenance	:	(a) Material (Onsite recycling), (b) Transportation (c) Onsite Equipment, (d) Traffic Congestion,
End-of-life		(a) Onsite Equipment, (c) Transportation, (c) Material (Recycling)

Transportation is required to carry materials from the extraction sources to the production plants. The factors to be considered are: mode of transportation (road, rail or water), location of the project, and the mass of material to be transported.

Onsite equipment (including trucks) and construction related traffic use non-renewable energy and make emissions during the construction, maintenance and end-of-life phases.

Implementation of road works under safe and efficient conditions often needs closure of one or several lanes; such situation temporarily disrupts traffic flow and may cause congestion during peak periods. On heavily-used routes, traffic congestion at work sites can drastically increase energy consumption and emissions (Lepert and Brillet, 2009).

Pavement surface roughness and structural properties related to rolling resistance accounts for about 12% of the total fuel consumption of vehicles (Chupin et al., 2012). The impact of rolling resistance becomes significant as it affects every vehicle using the pavement (Ting Wang et al., 2012). Increasing roughness causes more vibrations and reduces driving speed, and thus increases fuel use and emissions of vehicles (Yu and Lu, 2012). At low speeds and under summer conditions, changing stiffness and visco-elastic properties of asphalt pavement increases fuel consumption significantly (Chupin et al., 2012).

Akbari et al. (2009) estimated that for every 0.01 increase in albedo (solar radiation reflected off the surface) can offset 2.55 kg of emitted CO_2 for every square meter earth surface. The solar radiation absorbed by the pavement increases the ambient temperature, resulting in the urban heat island effect and increases the energy demand for cooling devices in urban areas.

Carbonation is a naturally occurring phenomenon that sequesters a portion of the CO_2 that was originally liberated from the limestone during cement production. The rate of carbonation varies based on concrete properties and the exposure to the environment.

Leachate is the substance drained out from some pavement materials that may contaminate water bodies and potentially pose a threat to drinking water.

Roadway signage and lighting is usually used in urban roads. The amount of lighting required varies based on the reflective properties of the surface material. Stripple (2001) reported the energy consumption to be as high as 12 TJ per km by this component when assessed for a period of 40 years.

Maintenance phase has the potential to be a significant contributor to the overall environmental impact, as effective maintenance can minimize environmental impacts by providing a smooth and robust pavement over a longer period, thus reducing the negative impacts of the use phase.

The End-of-life (EOL) phase includes environmental burdens of dismantling old pavement, processing materials for reuse and transportation (Yu and Lu, 2012). The scope for using materials from the old pavement to the new pavement relates EOL phase to the material phase and the construction phase.

3.4 Recent LCA studies

Santero and Horvath (2009) studied eight different components of road LCA using global warming potential (GWP) as measured by units of carbon dioxide equivalents (CO_2e) as the environmental indicator. The study presents (Figure-1) the range of GWP for different components based on a functional unit of one lane-kilometer with a standard lane width of 3.6m for an analysis period of 50 years. The thick, gray bars represent the probable ranges and the thin, black lines represent the extreme ranges. This study shows that components e.g. rolling resistance (roughness), rolling resistance (structure), traffic delay, albedo (radiative forcing), materials and transportation can have high impacts. On the other hand, onsite equipment, carbonation, albedo (urban heat island) and roadway lighting can have low level of GWP impacts.

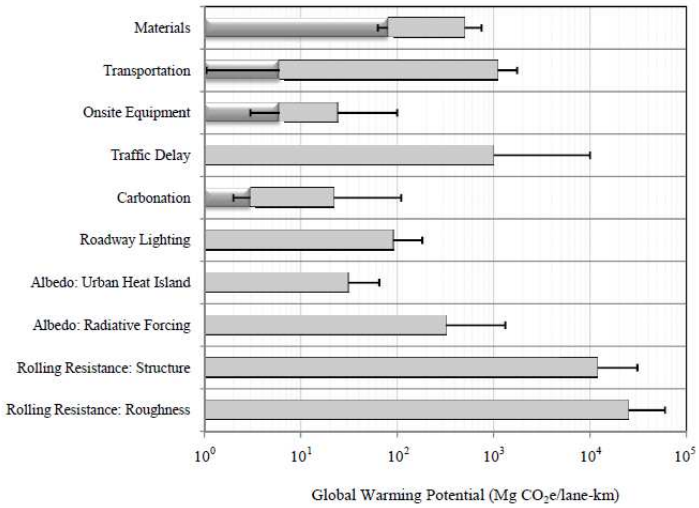

Figure 1: GWP impact ranges for components of pavement life cycle. (Santero and Horvath, 2009)

The other recent road LCA studies are discussed briefly below and the corresponding LCA findings are presented in Table- 3 considering environmental impact levels as high impact

(H) or low impact (L) from a qualitative point of view as stated in the section- 3.2: Research Methodology.

Zhang et al. (2010) studied LCA of three overlay options, (a) Engineered cementitious composites (ECC), (b) Portland cement concrete (PCC), and (c) Hot-mixed asphalt (HMA), on a badly cracked reinforced concrete pavement for an analysis period of 40 years with Michigan DOT maintenance strategies.

Muench (2010) reviewed 14 LCA papers published from 2000 to 2009 and studied ecological impacts of road construction and generalized maintenance projections.

Cross et al. (2011) studied LCA to compare the environmental burden relating construction of different reactive maintenance options using CIPR (cold in-place recycling), mill and fill with HMA and HMA overlay.

Cass and Mukherjee (2011) studied rehabilitation of a jointed plain concrete pavement using a hybrid LCA method. They found that the equipment and transportation components together represent only 6-10% of the total GHG emissions and the rest (90%) lies with the materials component.

Table 3: Qualitative impact assessment of LCA components.

Authors	**Indicators**		**Life-cycle components' impact levels**						**Legend:** H = High impact L = Low impact √ = Indicator Considered
	Energy Use	GHG Emission	Materials	Transportation	Const. Equipment	Congestion	Rolling Resistance	Albedo	**Remarks**
Santero and Horvath (2009)	-	√	H	H	L	H	H	H	Level assessed from the ranges as shown in Figure-1
Zhang et al (2010)	√	√	H	L	L	H	H	-	EOL studied for land filling only
Muench (2010)	√	√	H	L	L	-	-	-	Maintenance phase findings omitted for generalized values
Cross et al. (2011)	√	√	H	L	L	-	-	-	
Cass and Mukherjee (2011)	-	√	H	L	L	-	-	-	Study limited to construction phase only.
Tatari et al. (2012)	√	√	H	L	L	-	-	-	Resource consumption studied, which reflects similar findings.
Yu and Lu (2012)	√	√	H	L	L	L	H	H	EOL done for 10-20% recycling and found as low impact.
Ting et al. (2012)	√	√	L	L	L	-	H	-	Only preventive maintenance, so less material requirement.

Tatari et al. (2012) studied a hybrid life cycle analysis of continuously reinforced concrete (CRCP) and hot-mix asphalt (HMA) pavements for resource consumption and emissions up to the construction phase only.

Yu and Lu (2012) conducted LCA of three overlay options, a) 250 mm PCC replacing old PCC pavement, (b) 225 mm HMA replacing old PCC pavement, and (c) Crack and seat of existing PCC pavement followed by 125 mm HMA overlay (CSOL) with major preservation works over an analysis period of 40 yrs. The study shows that exclusion of usage module reduces energy consumptions for PCC, HMA, and CSOL options by 40%, 50%, and 44% indicating the significance of the use phase components.

Ting et al. (2012) conducted LCA case studies to evaluate the effect of rolling resistance on the life cycle performance of different pavement rehabilitation strategies. The study reveals significant energy and GHG savings with the reduction of rolling resistance.

The findings presented in Table- 3 identify materials (extraction and production), traffic congestion, rolling resistance and albedo as high impact components, while transportation and construction equipment as low impact components. The findings of Figure -1 (Santero and Horvath, 2009) for the transportation component differ with those of other studies, which is based on elaborated study considering cases like long-haul material supply, requirment of high emission road-way transportation, and large new construction using virgin materials etc. In addition, there are issues like noise and dust pollution, toxicity of tranport leachate, traffic safety, and LCA consideration of high transporation need of regular maintenace and operation activities. Therefore, this study recommends transportation as a high impact component. Most of the transporation component occurs under the materials phase, which includes transportation of materials from the sources (including part of the dismantled materials from the old pavement during the EOL phase) to the production plants and then from the production plants to the work sites. As such, for a simplified study envionmental impacts of transporation only for the materials phase can be considered.

It is also seen that the End-of-life (EOL) phase has not been considered by most of the LCA studies and hence less understood for a comparative assessment. This is in contrast to Rajendran and Gambatese (2007) study that EOL accounts for more than 50% of the total amount of waste generated over the entire life of a roadway. Ventura et al. (2008) found that except for the toxicity (human being) and ecotoxicity (other living species), all other impact indicators e.g. GHG emission, energy use, eutrophication, acidification, and tropospheric ozone formation shows a trend of decreasing potential environmental impacts with an increasing recycling rate. However, the toxicity levels in the storm water runoff are small and less likely to be injurious (Santero et al., 2011). As such, considering the depleting resources around the world and the level of waste generation, the ‘recycling’ activity of the EOL phase can be considered as a high impact component to promote extended use of recycled materials in future road works and thus resource preservation for future generations. Land and drainage cleaning component has not also been considered in any of the studies. It involves mostly onsite equipment use and likely of low impact category.

3.5 Proposed Road LCA System Boundary

Study of the road LCAs shows that low impact (L) environment components except ‘onsite equipment’ are hardly included in any LCA study. High impact (H) environment components are also less studied except ‘material’. The context of the studied road LCAs infers that inclusion of all the environment components in road LCA system boundary likely to be counter-productive in promoting LCA of road projects. The reasons are: (a) risk of data availability, (b) negligible influence of low impact components, and (c) longer LCA processing time with consequent delay in decision making . As such, a LCA system boundary comprising only high impact environment components will be more effective for extended and improved application of sustainability in road project development and management. Accordingly a road LCA system boundary comprising only high impact environment components as identified in this study is presented in Figure- 2.

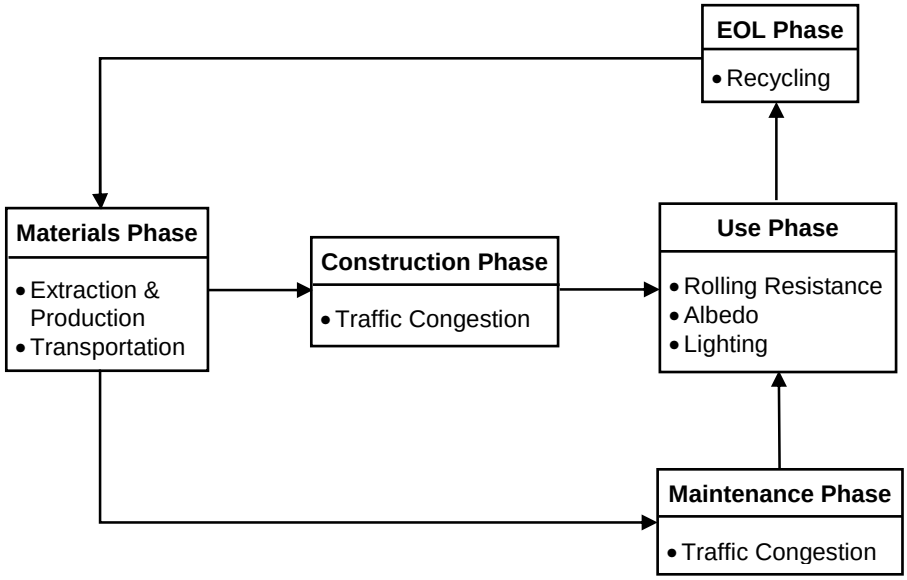

Figure 2: Proposed system boundary for road project LCA study.

4. Conclusion

To promote sustainable development of road infrastructure assets as part of global concern for green development, identification of key environmental indicators is paramount. Evolution of such indicators for the environment dimension of sustainability can only be possible through life cycle assessments of road projects. Such efforts have been frustrated to-date due to absence of any suitable system boundary covering most aspects of the life cycle of a road project. This research work on published LCA studies to date has identified the impact levels of various road LCA components through a qualitative assessment. Based on the research findings and the present practicies of road asset management, a comprehensive road LCA system boundary is presented. It is expected that future studies with possible quanititave assessment of various LCA components would improve the model further.

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Assessing Regulatory Framework Efficacy for Seismic Retrofit Implementation in New Zealand

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Abstract

Seismic retrofitting of earthquake-prone buildings has been a major challenge in many seismically active countries, including New Zealand. Earthquake losses can be minimised through the formulation and implementation of relevant regulatory frameworks such as policies, building codes and legislation. The recent Christchurch earthquakes have demonstrated the vulnerability of the New Zealand built environment to earthquake disasters, which suggest that existing regulatory frameworks may have been ineffective to reduce the impact of large earthquake disasters.

This paper examines the efficacy of existing regulatory frameworks in mitigating the risk posed by earthquake disasters to the community as whole. The multiple case study approach adopted in this paper, revealed significant barriers posed by the New Zealand Building Act and Territorial Authorities (TA) or local councils earthquake-prone policies, to seismic retrofitting of vulnerable buildings. These barriers include the seismic design philosophy and minimum strengthening requirements of the Building Act, timeframes allowed for strengthening and the lack of mandatory disclosure of seismic risks in TA policies. The research findings offer new insights into the impact of expert-driven regulatory frameworks on earthquake risk mitigation, and suggest a reappraisal of the some of the Act's provisions and the policy implementation approach adopted by various local TA.

Keywords: Efficacy, Seismic Retrofitting, Earthquake-prone Buildings (EPBs), Building Act (2004), Earthquake Policies, Territorial Authorities (TA)

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1. Introduction

The severity of past earthquake disasters has demonstrated the vulnerability of various communities, including in New Zealand to disastrous seismic events. Earthquake-related regulations such as policies, building codes and legislation are significant for disaster risk mitigation because property owners are mandated by these legislative frameworks to adopt mitigation measures (Burby and May, 1999). The New Zealand government enacted legislation in the Building Act (2004) and developed a building code, various building standards and policies, with the objective of reducing the level of earthquake vulnerability of the public. However, the recent Christchurch earthquakes caused significant widespread damage to buildings and infrastructure, 185 deaths, various causalities and a US$22 billion financial loss (Vervaeck and Daniell, 2011). Many unreinforced masonry buildings (URM) or parts of buildings collapsed and various modern building structures were critically damaged. 80 percent of the people who died from the earthquake disaster were members of the public, including pedestrians and motorists who were outside the collapsed or damaged buildings (Canterbury Earthquakes Royal Commission (CERC), 2012). This high percentage of fatality demonstrates that unstrengthen earthquake-prone buildings (EPBs) do not solely constitute a risk for the building owner or occupants but the whole community. These devastating impacts suggest that existing earthquake-related regulatory frameworks may be ineffective for ensuring public safety and recovery from a major earthquake event. The subsequent section provides an overview of New Zealand's earthquake mitigation policy and implementation process, to offer insights on seismic retrofitting of EPBs.

2. Seismic Retrofit Implementation in New Zealand

In New Zealand, compliance with earthquake-related regulations is mandatory. The Building Act (2004) recommended a seismic retrofit level of 33% of the code requirement for a new building, referred to as the New Building Standard (NBS), by targeting the most vulnerable buildings. This 33% NBS represents the minimum requirement necessary for ensuring safety in an earthquake event. A building having a structural seismic performance score less than 33% NBS is regarded as a high-risk building, a score greater than 33% NBS indicates a moderate risk, while 67% NBS or more is not considered a significant risk. However, 67% of the NBS was considered as a more suitable minimum seismic retrofit level because the Act's minimum requirement was found inadequate to eliminate the non-ductile failure mechanisms found in EPBs (New Zealand Society for Earthquake Engineering, 2006). Therefore, the New Zealand Society for Earthquake Engineering (NZSEE) considered a score of 67% NBS as a more suitable minimum level (New Zealand Society for Earthquake Engineering, 2006). Likewise, the Act stipulates that an existing building that requires alteration or a change of use must comply with the building code in the same manner as a new building (Sections 112-113). In compliance with the Act's regulations, seismic rehabilitation of EPBs often triggers other building code requirements such as fire performance and disability access. Cost implications due to these triggers often discourage building owners from voluntary seismic mitigation (Egbelakin *et al.*, 2011).

Further, the Act mandates local or territorial authorities (TA) to manage the mitigation of earthquake risks within their jurisdiction by developing and adopting a policy that specifically

addresses seismic risks. The Act allows the TA to determine the seismic strengthening level, policy implementation approach and timelines for strengthening the identified EPBs appropriate to their respective regions (Sections 131-132). Despite the NZSEE's recommendation of a higher seismic standard, 73% of the TA adopted seismic retrofit levels between 34% and ≤67% NBS, while 27% of TA adopted 67% NBS (Department of Building and Housing, 2005). Anecdotal evidence suggests that the retrofit levels adopted by the different jurisdictions relate more to available human and financial resources, political demands and earthquake experience than the region's seismicity. In addition, the TA could choose a passive, an active or a combined active-passive approach towards implementing their earthquake policy. The active approach includes a rigorous identification and detailed assessment of potential EPBs, followed by either retrofitting or demolishing identified EPBs within a time period of three to ten years. In the passive approach, seismic strengthening is only triggered only by an application for a building alteration, change of use and the extension of the building's functional life. A total of 45% of the TA chose the active approach, 32% chose the passive approach and 23% chose the combined active-passive approach (Department of Building and Housing, 2005).

Consequences from recent Christchurch earthquakes since September 2010 to date, which include loss of life, property and infrastructure damage, short and long term financial hardship, and disruption to normal social life within the wider community, suggest that the existing regulatory framework such as some of the provisions of the Building Act (2004) and TA policies, designed for earthquake risk mitigation has been ineffective in satisfactorily mitigating earthquake disaster impacts. This study sought to examine the efficacy of the current regulatory framework related to earthquake risk mitigation, and how it affects seismic retrofit implementation of EPBs in New Zealand. Efficacy of earthquake-related policies and legislation as conceptualised in this study, relates to the extent to which the formulation and implementation of these regulations affect earthquake risk mitigation in New Zealand, specifically the strengthening of EPBs. Assessing the efficacy of earthquake-related regulations has been attributed to risks perception, frequency of seismic retrofitting of EPBs, the community's level of acceptable risks and policy formulation and the implementation approach for treating unacceptable risks (Prater and Lindell, 2000; Comerio, 2004; Burby, 2005; Burby *et al.*, 2006).

3. Research Method

A multiple case study approach as referred to by Yin (2009), was adopted in this study due to the complexity of the research problem and the diversity of the different seismic risk regions in New Zealand. Semi-structured interviews and document analysis were used as the data collection techniques. Interviews allowed the different stakeholders involved in earthquake risk management to describe their experiences in the development and implementation of the relevant regulatory frameworks across different seismic risk regions. The evaluation of relevant regulatory documents highlights some of the constraints placed on the implementation of adequate risk mitigation measures by the existing legislative provisions.

Four cities in New Zealand were chosen as case studies, based on their seismicity, hazard factor, percentage of non-retrofitted and retrofitted EPBs, earthquake probability and likely severity. Similarly, participants were selected through a purposeful sampling procedure based on the research objectives and questions and because it allows the selection of relevant key participants involved in earthquake risk mitigation as the units of analysis (Babbie, 2008). The participants selected include building owners, engineers, architects and managers of governmental organisations that include city councils and territorial authorities (TA). Building owners include both persons who have or have not retrofitted their EPBs and may or have been not involved in recent Christchurch earthquakes. Other participants chosen for the interview have at least a minimum of two years' recent involvement in EPB retrofitting projects. These participants were selected in order to make use of their practical knowledge and experience to obtain information and gain a better qualitative understanding of the importance of the different aspects of seismic retrofit decisions. The use of multiple cases and the participant selection method ensure that data reliability and internal validity are strengthened. Forty-eight interviews were conducted and transcribed. All interview transcriptions were analysed thematically using NVIVO qualitative data analysis software. Both participants and industry experts reviewed the findings for confirmation and comments, to establish data validity.

4. Findings

Research findings from this study established that current regulatory frameworks, such as the Building Act (2004) and the TA earthquake-prone policies, pose barriers to seismic retrofit implementation in New Zealand. Key results are discussed in the following subsections within the context of the research investigation.

4.1 Provisions of Building Act (2004)

The findings in the current study show that certain provisions of the Building Act (2004) discussed below constitute potential impediments to the seismic strengthening of EPBs and for future pre-earthquake disaster mitigation in New Zealand.

4.1.1 Minimum Requirement for Life Safety

The minimum requirement of the Building Act (2004), as revealed in this study, serves as an impediment to seismic retrofitting of EPBs by building owners. The minimum requirement tolerates damage to the primary structure and to other building elements in the event of a major earthquake. It is apparent that the 151 deaths resulting from the collapse of the CTV building are perhaps an outcome from a rare event that was not anticipated by the Act's minimum requirement. In addition, hearings from the Canterbury Earthquakes Royal Commission (CERC) investigations suggest that the current minimum does not match the community's expectation of a building's performance in an earthquake (CERC, 2012). Moreover, the minimum earthquake performance level adopted by the Act and the differing New Zealand Society for Earthquake Engineering's (NZSEE) recommendation of a higher seismic performance level for EPBs, has created confusion and misinterpretation amongst building owners and other retrofit stakeholders regarding what retrofit level provides an

optimal result in terms of seismic strength and rehabilitation cost (Egbelakin *et al.*, 2011). Some building owners were found to have adopted the lowest cost-permissible retrofit level without considering the hazard implication of such a structural performance level (Hopkins, 2005). The recent Christchurch earthquakes resulted in enormous losses to both property owners and the country as a whole, which further demonstrates the implications of the Act's minimum requirement. Although the design of various contemporary buildings within the Christchurch CBD ensured that people could safely vacate them immediately after the earthquake, many buildings were considerably damaged and others needed demolition. Also, the Act's minimum requirement contributes to the TA's lack of commitment to earthquake hazard mitigation, which is evident in the implementation approach adopted in their policies, such as lack of public awareness programs and defined timelines for taking action with vulnerable EPBs. Most TA that adopted less than a 50% NBS are unlikely to have proactive risk-reduction programmes, as evidenced in the adopted policies, with 27% of the TA not specifying timeframes for strengthening identified EPBs, and 31% of the TA having no public awareness programmes to promote mitigation within their jurisdictions (Department of Building and Housing, 2005).

4.1.2 Change of Use Conditions

In compliance with the Act's regulations in sections 112 and 115, seismic rehabilitation of EPBs often triggers other building code requirements, such as fire performance and disability access. While it is reasonable to support the objectives of these sections, the cost implications of these triggers often discourage building owners from retrofitting their EPBs. There is thus a need for further research to investigate whether such requirements are justified in the interest of public safety and in relation to other relevant public policies. Similarly, Section 112 requires that a building that is altered shall comply structurally or seismically to the same extent as before the alteration. However, the categories of additions are not specifically covered. For example, a building with a score of 40% NBS could potentially be altered, provided that the resulting capacity is still not less than 40% NBS. Findings from this study showed that the implementation of Section 112 has significantly increased the proliferation of substandard structures within the community, leading to a growing level of vulnerability to seismic disaster. This is particularly evident in the number of collapses of masonry structures.

4.1.3 Lack of Mandatory Disclosure of Seismic Risks

Currently, none of the regulatory mechanisms relevant to earthquake risk mitigation in New Zealand specifically address whether the disclosure of building seismic risks should be mandatory or not. A lack of mandatory disclosure limits different stakeholders' knowledge and awareness of issues related to seismic risk, especially for participants within the property market. Findings from the qualitative study revealed that most of the stakeholders in the market have little or no knowledge about EPBs, seismic retrofit standards, legal obligations and potential liabilities relating to the changes in the Building Act (2004) and TA earthquake policies. Consequently, an insufficient weighting is attached to retrofit costs in investment and purchase decisions by potential buyers and vendors, due to failure to sufficiently account for the seismic rehabilitation costs necessary to strengthen the building,

which results in underinvestment in earthquake risk mitigation. Findings from this study show that mandatory disclosure of a building's seismic risks in relevant regulatory frameworks and property market transactions is necessary, to improve earthquake risk mitigation in New Zealand. For instance, mandatory risk disclosure would ensure that buyers, insurers and lenders are adequately informed, leading to an informed property market.

4.2 Provisions in Earthquake-Prone Policies (Prepared by the TA)

Some of the provisions of the TA earthquake provisions acting as obstacles to earthquake risk mitigation are discussed in this section.

4.2.1 Policy Implementation Approach

The policy implementation approach adopted by TA has several implications. Some of the TA have good programmes in place to mitigate earthquake hazard and risk, while others have done little, or lack adequate resources to implement mitigation measures. The passive mitigation approach adopted by some of the TA serves as an impediment to earthquake risk mitigation. Likewise, findings from the Christchurch earthquake disasters highlight the ineffectiveness of a TA policy taking a passive implementation approach, and the need to urgently implement consistent policies throughout New Zealand to address the potential threats posed to the community.

4.2.2 Timeframes for Retrofitting EPBs

Timeframes for strengthening EPBs vary widely among TA, ranging from 5-30 years depending on the building type and importance level (DBH, 2005). Most of the TA policies also allow for a possible time extension for strengthening EPBs. In the interim, people still reside and work in these vulnerable buildings and they could be susceptible to risks posed by a future disastrous earthquake. The Christchurch earthquakes provide an example of where longer timeframes impede the adoption of mitigation measures. Effective timeframes for retrofitting EPBs is necessary in TA policies, while considering regional hazard factor, resource availability and effective building life span.

5. Discussion of Findings

Certain provisions of the New Zealand earthquake-related regulatory framework pose difficult challenges for earthquake risk mitigation in New Zealand. Some of these constraints include the seismic design philosophy, minimum requirements of 33% NBS, timeframes, disability access and fire requirements in TA policies. The study findings show that the current approach to seismic design in the New Zealand Building Act (2004) is inadequate to ensure people's safety and economic recovery after earthquake disasters. Generally, most earthquake-related policies and legislation do not usually specify any applicable performance standards, but set out objectives that must be achieved or recommend minimum safety requirements, such as in the New Zealand Building Act. However, the New Zealand Christchurch earthquakes have demonstrated that such minimum requirements are not economically viable and do not meet the community's expectations of retrofitting

buildings only for life safety. Also, financial bail-outs from the Earthquake Commission, central government and private insurance companies are inadequate to cover associated expenses from the disasters. Furthermore, the Act's minimum requirement affects the TA' commitment to earthquake risk mitigation, which in most cases will not lead to consistent, strongly implemented, risk-reduction programmes across the medium-to high-risk jurisdictions. This finding is in line with the outcomes from Comerio (2004) and Prater and Lindell's (2000) research that concluded that the minimum requirements of most building-oriented legislative mechanisms are only intended to ensure public health and safety in an earthquake event, and in most cases would lead to a complete economic loss of the building.

Furthermore, decisions regarding the extent of mitigation programmes to be implemented are left primarily to TA. One outcome of such a model is that some districts have good programmes in place to mitigate earthquake hazards (the active approach such as in Wellington), while other communities have done little or lack adequate resources to implement mitigation measures (the passive approach such as in Lower Hutt and Christchurch). Several statements from the research participants revealed that the model of government in New Zealand indicates that city councils and TA do not receive substantial financial support, if any, from central government for reducing earthquake vulnerability. Evidently, there is a need for central government to provide additional resources to local councils and TA if New Zealand's non-tolerance for EPBs is to be increased.

Mandatory disclosure of seismic risks required by the Building Act (2004) could help improve the seismic rehabilitation of EPBs, as owners or developers would be obligated to disclose their building's seismic risks to prospective buyers or tenants at the point of sale or rent. For instance, the owner of the CTV building that completely collapsed in the February 2011 earthquake was unaware of the building seismic risks at the time of purchase. There is a possibility that if the CTV owner had been made aware of the extent of the building's vulnerability to earthquake risks, the cost of retrofitting could have been factored into the investment decision and retrofitting work carried out. Mandatory disclosure of seismic risks would provide a seal on potential EPBs, while communicating more accurate information to the stakeholders. Besides, some of the anomalies, such as lack of access to building risk information and poor risk communication associated with the building safety evaluation processes after the September 2010 earthquake, which contributed to increased disaster losses in the February 2011 earthquake would have been reduced if seismic risks disclosure had been mandatory.

6. Recommendations

Upon the appraisal of current regulatory frameworks and interview findings in four different cities in New Zealand, specific recommendations are presented in relation to the Building Act (2004) and TA earthquake-prone policies. Firstly, there is a need to review the Act's minimum requirement of 33% NBS for seismic retrofitting of EPBs. It is thus suggested that the earthquake-prone threshold should be increased to 67% NBS, as recommended by the New Zealand Society for Earthquake Engineers (NZSEE) (2006), or adjusted more effectively to accommodate occupancy levels in buildings used for commercial purposes.

Secondly, an appraisal of the policy implementation approach and timeframes adopted by some TA is necessary, to allow TA within low to high-risk zones to adopt an active implementation approach, coupled with proactive public awareness programmes and community engagement in order to improve commitment levels and to achieve consistent earthquake mitigation strategies across their regions. Finally, it is necessary to overlay most of the relevant policies and regulations related to natural hazard management and improved urban planning, such as the Land-use Planning and Resource Management Act (RMA) (1991), Civil Defence Emergency Management Act (2002) and historic preservation and disaster recovery with the seismic strengthening of EPBs, in order to promote earthquake hazard mitigation.

Overall, some of the recent devastating earthquakes, such as in Haiti in 2010, Indonesia in 2004 and also in New Zealand, have demonstrated the ineffectiveness of several earthquake regulatory frameworks devised for reducing disaster impacts. Hence the need to adopt proactive approaches to formulate, adopt and implement an effective mitigation policy. Thus, effective methods for reviewing present policies and regulations are necessary to improve earthquake risk and hazard in seismically active countries.

7. Conclusion

The research findings offer new insights into the impacts of expert-driven regulatory frameworks on earthquake risk mitigation. The Christchurch earthquakes have proven that this approach may not be effective in certain disastrous situations suggesting the need for strategies aimed at adequate pre-disaster mitigation strategies. Hence the need to re-examine the current seismic design philosophy that focuses only on life safety and possibly, the minimum acceptable earthquake-prone hazard level would be adjusted to community expectations of building performance in a seismic event. The findings from this study show that the Building Act and TA earthquake-prone policies would be enhanced by undergoing legislative reforms with regard to matters such as minimum requirements, strengthening targets, implementation approach and timeframes. It is important to acknowledge that seismic risk differs across all parts of New Zealand and such differences should be taken into account when determining the regulatory response for each region. Also, a review and realignment of all regulatory documents is necessary to present a robust framework where New Zealand communities such as Christchurch, can gradually recover after a major earthquake disaster, while planning for pre-disaster mitigation against future earthquakes. The findings suggest some practical changes for policies devised for earthquake risk mitigation, both in New Zealand and other seismically active countries.

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Improving Construction Productivity: Implications of Even Flow production principles

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Abstract

Subcontracting has been widely used in order to address the high level of variability and associated risks in the complex configuration of residential construction production systems. However, the explosion of subcontracting and the parade of trades have made the construction operations very fragmented, leading to lack of predictability and adequate control on schedules and quality. The present paper proposes a set of system configurations for residential construction. On this basis, after an extensive review of the efforts to model construction production problems, several discrete event simulation models have been developed so as to assess tangible performance measures. Comparing and contrasting the results, two attributes of the system were found to be critical to yield better performance measures. In the proposed flexible system design, fewer cross-trained subcontractors undertake integrated work processes. Also, the number of houses under construction does not grow infinitely and is proportional to the system capacity.

Keywords: Australian residential construction, even flow production planning, resource queue, specialized trade contractors, Work-in-process inventory

1. Introduction

To manage a construction system effectively, it is necessary to understand its configuration first. Residential construction is a sector with many similarities to manufacturing (Bashford, Walsh & Sawhney 2003). In other words, it is possible to look at residential construction as a production line, both sharing similar production problems. For example, in boom periods when the demand for building houses peaks, production homebuilding is flooded by large numbers of houses under construction. This increased level of work-in-process inventory (WIP) will lengthen the cycle time (CT), which is the average time between the start and end of construction operations. This is due to limited capacity of the construction systems.

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Furthermore, Events such as worker fatigue or illness, equipment breakdown and shortage of material supply may impose delays or interruptions on individual processes (micro level). Also, exogenous events of inclement weather conditions, inefficient construction management decisions and industrial actions may affect the operations at the macro level (Damrianant & Wakefield 2000). These reduce the output rate or throughput (TH) of the system.

To address the high level of variability and resulted risks, subcontracting has been widely used in the complex configuration of residential construction production systems. Homebuilders, who generally act as the construction manager, subcontract all of the production processes. In the most common scenario in the Australian residential construction, around 50 trade contractors are in charge of more than 100 building processes in order to build typical detached onsite houses. In this way, the risk of delays and late completion is generally avoided by the builder and is transferred to other stakeholders (Arashpour & Arashpour 2012). In fact, subcontractors are only paid upon the completion of a given activity. The explosion of subcontracting and the parade of trades have made the construction operations very fragmented, leading to a lack of predictability and adequate control on schedules and quality (Dalton, Wakefield & Horne 2011). The result is significant holding cost for capital that is generally borne by homebuyers due to extended cycle times.

Using the current system configuration, one solution, for instance, would be to pay attention to selecting the right subcontractor for the right activity. For example, Doloi, Iyer and Sawhney (2011), have linked contractors' performance on a project to a set of qualification criteria. However, although many attempts have been made by construction management professionals to improve the situation within the present system configuration, little attention has been paid to reconfigure the system, inspired by the principles of even flow production that have been successfully utilised in manufacturing for decades. Even flow production known as workflow-levelling strategy aims to decrease variability in the workflow for trade contractors.

On this basis, we analyse the implications of two even flow production principles: Maintaining a constant number of houses under construction (Constant work-in-process inventory (CONWIP)), and adding flexibility to movement of jobs (hand-offs) by means of integrating work processes and cross-training trade contractors. To achieve the aim, after an extensive review of the efforts to model construction production problems, several discrete event simulation models are designed and run in order to compare and contrast results and investigate significant changes in production parameters.

2. Review of efforts to model production problems

Construction production systems face several problems that directly affect their tangible performance measures. These problems include but are not limited to: Excessive work-in-process inventory (Love et al. 2002), lost throughput rate (AbouRizk, Knowles & Herman 2001), insufficient use of resources (Sacks et al. 2010), long cycle times (Bashford, Walsh & Sawhney 2003), interruptions and delays (Damrianant & Wakefield 2000) and inflexible production processes (Dalton, Wakefield & Horne 2011). To address these issues several

modelling initiatives have been developed in the construction literature that can be categorized into three main groups. Planning, monitoring and controlling of construction projects are facilitated by means of these models. Figure 1, illustrates a map of the construction management literature with regard to production problems and the modelling efforts to address them.

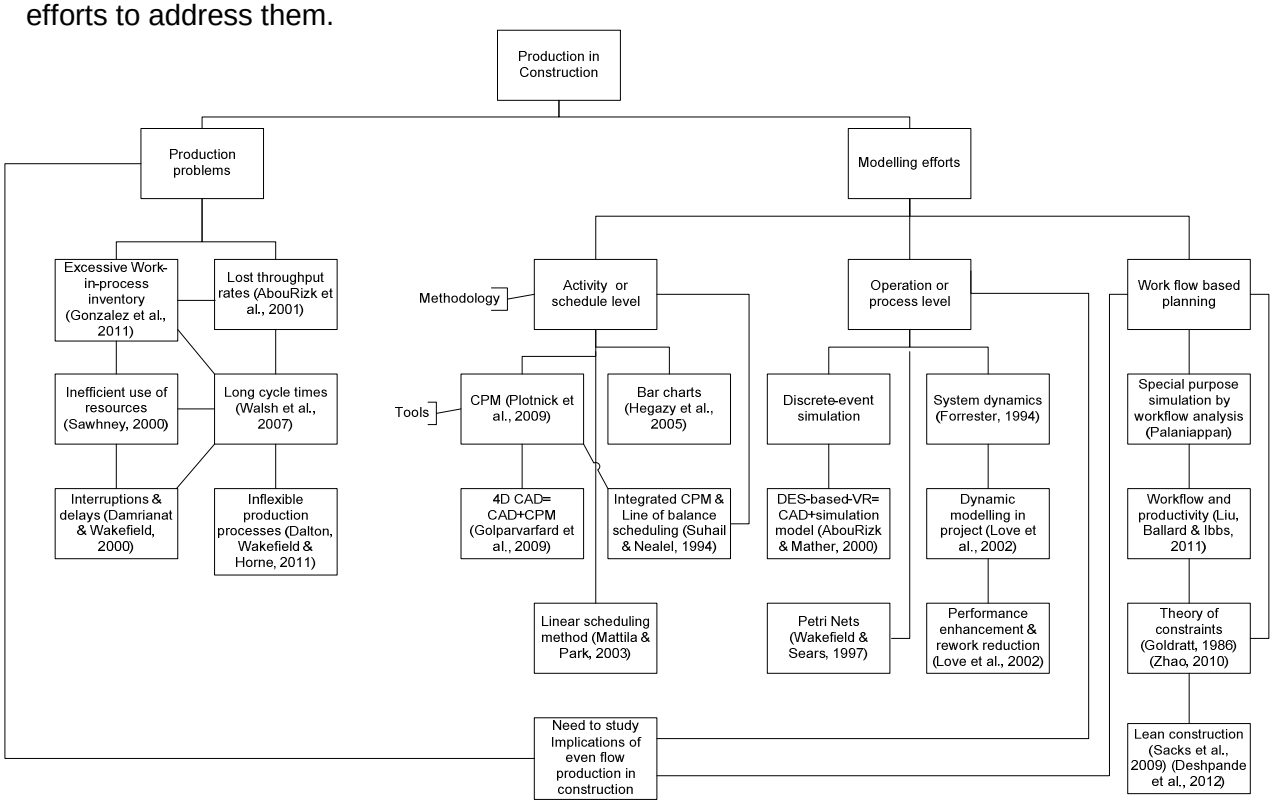

Figure 1: literature map on production problems and modelling efforts

2.1 Activity or schedule level modelling

The aim here is to analyse discretely evolving construction product and describe what is built where and when in order to study spatial and temporal interferences and optimal activity sequence (Kamat et al. 2011). Activity level visualization combines activity-based construction schedules, such as critical path method (CPM) or bar charts, and 3D computer-aided design (CAD) models of facilities in order to create four-dimensional (4D) CAD.

Four dimensional models in the augmented reality (4D AR) integrate as planned (expected) and as built (actual) visualizations to monitor and control construction performance using building information models (BIM). These models combine BIM, which represents the as-planned status of a project, and daily photographs taken in the site, which represent the as-built status of a project in order to track the physical progress of the project (AbouRizk, Knowles & Herman 2001). In this fashion, expected (as-planned) and actual (as-built) performance are compared in order to show what is expected to be built where and when, and the interactions among personnel, equipment and material. Using colour gradient spectra, the project performance measures such as Schedule Progress Index (SPI) and Cost Progress Index (CPI) can be visualised (Golparvar-Fard & Peña-Mora 2007). Also the construction sequences can be communicated. In this level of planning, BIM, which is typically used at design and preconstruction stages, is extended to the construction phase to

compare and contrast as-planned and as-built performances. This facilitates remote construction control decision making and also reduces the wasted time in contractor coordination meetings by cutting travel cost and time for project participants.

2.2 Operation or process level modelling

On the other hand, simulation modelling represents a framework to design, analyse and improve construction operations and processes. Dynamic operation level planning is rooted in discrete event simulation (DES) and combines operation planning tools (i.e. simulation models) and CAD models of static and dynamic entities . Here, the focus is to analyse interaction between resources, machines and materials in order to communicate not only what, where and when of the construction product but also who builds it and how. It depicts the continuous evolving products and processes (Kamat et al. 2011).

Designing construction processes is about comparing alternative construction methods, equipment, labour levels, temporary structures, and operating strategies to undertake the planned operations. Visualizing construction operations, project participants can graphically see (on the computer) the processes that would be done in the real site by conducting virtual walkthroughs. Virtual reality is a computer-generated environment that is sensory-immersive and responds to the user. Discrete event simulation and virtual reality can be combined to form what is called DES-based-VR. In the virtual reality environment, the logic of DES model can be validated and decision makers can provide feedback on the model.

Discrete-event simulation systems are characterized by their application breadth (general purpose or special purpose), flexibility (being programmable) and simulation paradigm, which can be either Process Interaction (PI) or Activity Scanning (AS). AS-based discrete-event simulation take the advantage of Activity Cycle Diagrams (ACD), to simulate complex construction operations (Martinez & Ioannou 1999). The logic behind this paradigm is that in manufacturing systems, materials arrive and undergo a fixed processing pattern; however, construction operations capture many interacting resources. Many construction simulation languages have been developed such as MicroCYCLONE, COOPS, CIPROS, and STROBOSCOPE.

However, construction operations can also be precisely modelled by means of other graphical and mathematical models. For example Damrianant and Wakefield (2000) used Petri nets to simulate and model construction systems. In this fashion, the user enjoys the flexibility in using both simulation-modelling constructs and user-written codes by general-purpose procedural languages (Arashpour, Wakefield & Blismas 2013).

2.3 Workflow based modelling

Flow variability in production systems can be the result of management decisions or randomness in process and demand. Subcontracting construction processes to several trade contractors makes the management of job movements (hand-offs) difficult. Several influences of workflow variability on project performance have been investigated in the construction management (CM) literature. For instance, Arashpour and Arashpour (2011)

and Liu, Ballard and Ibbs (2011) showed how labour productivity is directly correlated with some measures of workflow variability.

Other applications of workflow planning have been used to develop lean construction models. For example, Sacks et al. (2010) developed a framework to integrate lean management and building information modelling.

3. Research design

The purpose of this paper is to investigate the effects of two even flow production principles on production parameters in volume homebuilding sector. These two principles are using fewer but cross-trained subcontractors and limiting the number of houses under construction (work-in-process inventory). The positive effects of these principles have already been proved in manufacturing (Hopp & Spearman 2008). However, their impact on production construction has not been investigated yet. This investigation was conducted in order to bridge this gap.

Volume homebuilding in Australia was selected as the scope of this work. We designed four experiments by varying process times and their distribution, number of trade contractors, and rate of starting new homes. Care was taken to realistically model major production homebuilding elements. The experiments were simulated over 1000 working days using ARENA in order to compare and contrast associated performance measures. Figure 2 shows the base case involving 20 specialised subcontractors.

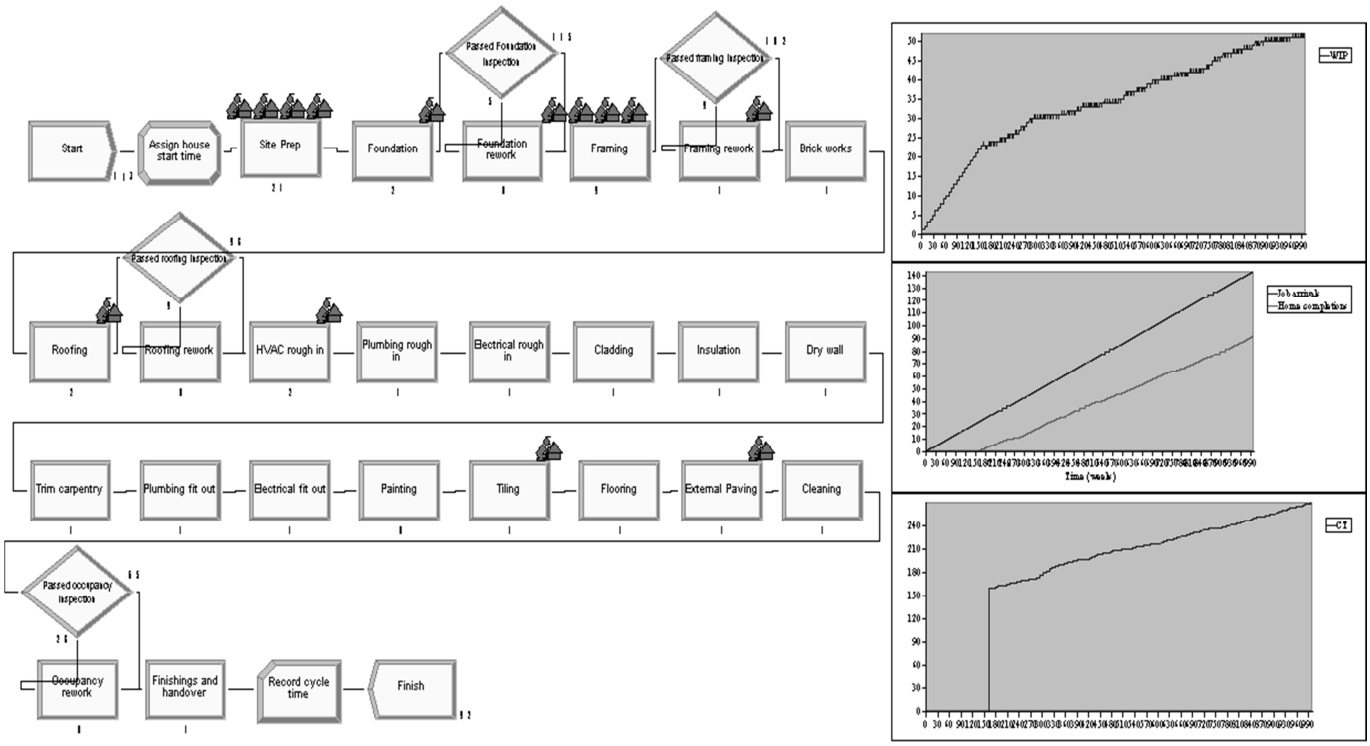

Figure 2: Interacting specialized trade contractors to build detached Australian houses

This simplified model of production homebuilding, which is similar to that of Bashford, Walsh and Sawhney (2003), was developed in order to demonstrate movement of jobs (workflow) among trade contractors and interaction of resources. These 20 major elements are similar to those of level 1 in the work breakdown structure (WBS).

The first simulation experiment, which served as our base case, involves deterministic process times for all processes. In experiment 2, new constructions are started without considering production limitations, which is a typical practice in push production. Therefore, probabilistic sales rates determine the start pace of new constructions. In contrast, the rate of starting new homes is controlled in experiment 3. That is, work-in-process inventory are constant (CONWIP) and stand at about 20 homes at all times. In experiment 4, 20 specialised trade contractors are replaced by 10 cross-trained contractors in order to explore whether or not this strategy would smoothen movements of jobs (hand-offs) among trade contractors.

4. Results and analysis

4.1 Deterministic process times- Base case performance

Having deterministic process times without any variability, the first experiment demonstrates the best case performance. Each of the 20 trade contractors in figure 2 need exactly seven working days to complete their processes and act as bottlenecks. Therefore, the throughput rate of the bottleneck (r_b) is 1/7 (house/day). Raw process time (T_0) is the average time that a single house takes to traverse the construction production line and is equal to 140 days in this case.

Production parameters can be computed by Little's law (Little 1961), which is a basic equation used in manufacturing:

$$TH = WIP / CT \qquad (1)$$

In equation 1, TH= output rate (throughput); WIP= number of houses under construction (work-in-process inventory); and CT= house completion time, respectively.

Also, the critical work in process inventory (W_0), which is the optimum number of houses under construction that yields the maximum throughput rate and minimum cycle time, will be:

$$WIP_{critical} = W_0 = r_b * T_0 \qquad (2)$$

$WIP_{critical}$ also results in the optimum utilisation of resources, which are trade contractors in our case.

An inventory of 20 houses under construction in the first experiment builds up no queues and results in the most efficient behaviour of the system.

4.2 Uncontrolled number of houses under construction (push production)

During construction boom periods, when demand for building new houses peaks, construction production systems are flooded by large number of houses under construction (work-in-process inventories). The intuition behind setting high levels of WIP is to increase resource utilisation and achieve throughput close to capacity. However, this approach will cause cycle times to grow infinitely because of the limited production capacity. Although adding resources may improve the performance measures of the system (Arashpour & Arashpour 2010), it would not financially or spatially be feasible in all cases.

Several real world production detractors are present in construction sites such as worker fatigue or illness, equipment breakdown, shortage of material supply and inclement weather conditions. To impose maximum randomness to production homebuilding, the process times were considered random and occurred according to exponential probability distribution. Having a mean value of seven days, the probability that a process can be done is proportional to the time. For example, there is about 35% chance for a given process to be done under three days: $F(3/7) = 1 - e^{-3/7} \approx 0.35$

Similarly, the probability that a process will take more than 14 days is:

$1 - F(14/7) = 1 - F(2) = e^{-2} \approx 0.14$

Considering exponentially process times, a given house to be processed by a subcontractor expects (WIP -1) / N other houses in the queue. Number of subcontractors (N) is equal to 20 in the present case.

In experiment 2, demand rates were considered random and occurred according to exponential probability distribution. In contrast to the previous case, new jobs are pushed into the system regardless of the current system state or WIP inventory level. The average level of WIP inventory reached a peak of 39 in the current case. Due to finite capacity of the system, the completion time of houses increased dramatically.

4.3 Constant level of work-in-process (CONWIP)

In designing experiment 3, care has been taken to maintain the constant number of houses under construction at all times. That is, new constructions are not started unless a completed house left the production line. In this event, T_i is the average time that each contractor takes to complete their construction process and will be,

$$T_i = t + \frac{WIP-1}{N} * t \qquad (3)$$

In equation 3, t= subcontractor processing time; and $\frac{WIP-1}{N}$ = queue time, respectively.

And, $CT = \sum_{i=1}^{N} Ti$ (4)

In this experiment, the throughput rate is more than push production in experiment 2. Also the average completion time for a house stood at 273 days, which is considerably less than 395 days in experiment 3. Figure 3 compares the levels of WIP versus throughput in these experiments.

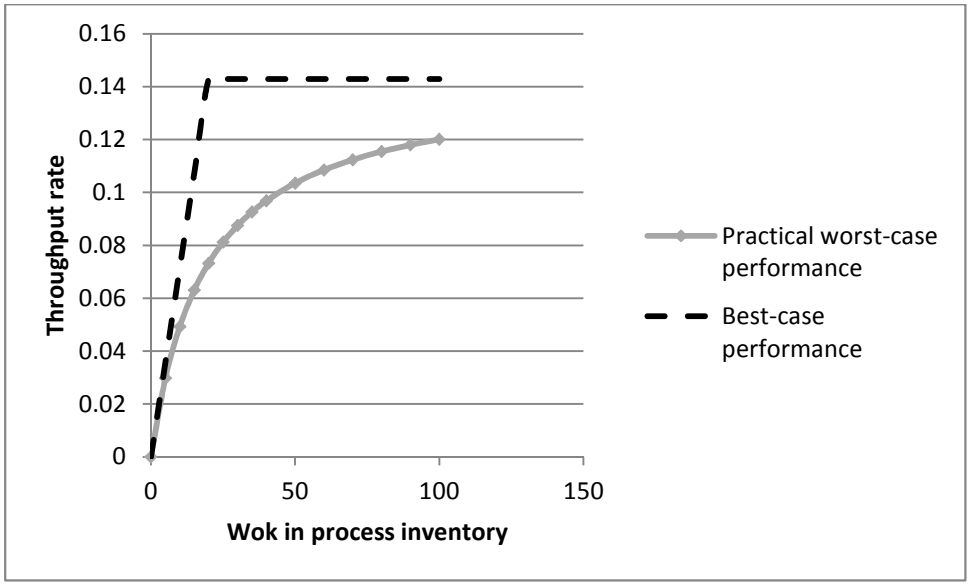

Figure 3: Work-in-process inventory versus throughput- Base case vs. push production

Based on the measurements, controlling number of houses under construction (work-in-process inventory) showed to have significant positive effects on production parameters in volume homebuilding sector.

4.4 Flexible system design with integrated work processes using cross-trained contractors

Excessive number of trade contractors in the system makes it difficult to manage handoffs among predecessors and successors. A solution would be to collapse work processes by using cross-trained processors (Arashpour, Shabanikia & Arashpour 2012). In other words, replacing single specialised trade contractors with parallel cross-trained contractors with the same capacity can improve performance. Such system designs used to be the common practice in the residential construction industry in the past, when a sole builder was in charge of all processes and was responsible towards the homebuyer.

In this scenario, 20 work processes were collapsed to create 10 integrated processes. The design is similar to that of Bashford, Walsh and Sawhney (2003). The process times were exponentially distributed and took twice longer than those in the previous case. That is, the first contractor, for instance, was in charge of site preparation and concreting the foundation slab. Therefore, instead of using two specialized contractors to cover site preparation and foundation processes, two cross-trained contractors that are able to cover both processes were employed. It was assumed that process times are twice longer than other experiments in order to have a fair cross-experiment comparison: t = EXP (7) + EXP (7)

As can be seen in table 1, number of completions in experiment four is almost the same to our base case. This indicates that reducing the number of interacting trade contractors along with controlling number of houses under construction can reduce the workflow variability and improves tangible performance measures volume homebuilding.

5. Discussion

Data obtained in previous studies indicated that workflow-levelling methodology known as even flow production can improve production efficiencies considerably. According to Bashford, Walsh and Sawhney (2003), even flow strategies affect both completion time and management efforts. In our study, a series of simulation experiments were used to implement two initiatives of constant level of work-in-process (CONWIP) and also integrated work processes. Table 1 shows the results obtained from production homebuilding simulation over 1000 working days.

Table 1: System description and tangible performance measures

Parameters	Experiment 1	Experiment 2	Experiment 3	Experiment 4
Process time distribution	deterministic	Probabilistic	Probabilistic	Probabilistic
Production line status	Balanced	Balanced	Balanced	Balanced
System description	Best performance	Push system	CONWIP	Integrated process+ CONWIP
Raw process time (T_0)	140	alters	alters	alters
WIP_0	20	20	20	20 (jobs)
Average WIP inventory	20	39	20	19
Avg. subcontractors' time	7	20.6	13.65	7 (days)
Completion time (CT)	140	395	273	127 (days)
Job completion intervals	7	15.4	13.7	7.14 (days)
Throughput rate	0.14	0.065	0.073	0.128 (job/week)
Number of completions	124	65	111	123
Number of system states	1	$9.4 * 10^{14}$	$6.9 * 10^{10}$	10^7

As can be seen, the first experiment yielded the best throughput rate because there was no variability in process times. This best case performance served as the benchmark in order to evaluate production parameters in other experiments.

The push production approach used in experiment 2 downgraded all tangible performance measures in volume homebuilding. The average process time for each subcontractor reached a peak of 20.6 days resulting an average completion time of 395 days for a house. In fact, increasing the number of houses under construction in resource constrained scenarios causes long delays and less output rate.

Controlling number of houses under construction (constant work-in-process inventory) resulted in close to ideal number of 111 completions. This is consistent with results obtained in previous studies (Bashford, Walsh & Sawhney 2003). Furthermore, a dramatic improvement in production parameters was observed when integrated work processes were used together with CONWIP strategy in experiment 4. Completion intervals, for example, were shortened considerably. Using cross-trained contractors decreased the complexity of the system by means of reducing the number of system states. Information about the number of jobs, which are being processed or are in a queue to be processed by trade

contractors, can be stated in matrices called system states. Table 2 illustrates possible system states for 10 contractors working on a constant level of 20 houses under construction.

Table 2: Possible system states (10 cross-trained contractors and 20 houses under construction)

System state	Vector	System state	Vector
1	(20, 0, 0, 0, 0, 0, 0, 0, 0, 0)	101	(18, 1, 1, 0, 0, 0, 0, 0, 0, 0)
2	(0, 20, 0, 0, 0, 0, 0, 0, 0, 0)	102	(18, 1, 0, 1, 0, 0, 0, 0, 0, 0)
3	(0, 0, 20, 0, 0, 0, 0, 0, 0, 0)	103	(18, 1, 0, 0, 1, 0, 0, 0, 0, 0)
4	(0, 0, 0, 20, 0, 0, 0, 0, 0, 0)	104	(18, 1, 0, 0, 0, 1, 0, 0, 0, 0)
5	(0, 0, 0, 0, 20, 0, 0, 0, 0, 0)	105	(18, 1, 0, 0, 0, 0, 1, 0, 0, 0)
6	(0, 0, 0, 0, 0, 20, 0, 0, 0, 0)	106	(18, 1, 0, 0, 0, 0, 0, 1, 0, 0)
7	(0, 0, 0, 0, 0, 0, 20, 0, 0, 0)	107	(18, 1, 0, 0, 0, 0, 0, 0, 1, 0)
8	(0, 0, 0, 0, 0, 0, 0, 20, 0, 0)	108	(18, 1, 0, 0, 0, 0, 0, 0, 0, 1)
9	(0, 0, 0, 0, 0, 0, 0, 0, 20, 0)	109	(18, 0, 1, 1, 0, 0, 0, 0, 0, 0)
10	(0, 0, 0, 0, 0, 0, 0, 0, 0, 20)	110	(18, 0, 1, 0, 1, 0, 0, 0, 0, 0)
11	(19, 1, 0, 0, 0, 0, 0, 0, 0, 0)	111	(18, 0, 1, 0, 0, 1, 0, 0, 0, 0)
.	…	.	…
.	…	.	…
100	(18, 2, 0, 0, 0, 0, 0, 0, 0, 0)	10^7	(2, 2, 2, 2, 2, 2, 2, 2, 2, 2)

By increasing the level of subcontracting in more complex production scenarios, number of system states raise dramatically. For instance, there are 68,923,264,410 system states when 20 houses are under construction using 20 specialised trade contractors. Number of system states dramatically decreases to about 10^7 using 10 cross-trained contractors. Previous research has proved that fewer number of system states will result in shortened cycle times as all system states are not likely to happen with the same probability (Hopp & Spearman 2008). It is consistent with results obtained in the revised construction production line of experiment 4. For example, in the event that there are two houses in site preparation or foundation, it is guaranteed that both are being worked on. However, in the original arrangement of 20 subcontractors, two houses could have wound up at either site preparation or foundation processes and one always has to wait.

Overall, our results show that implementing two strategies of even flow production; namely constant level of work-in-process (CONWIP) and integrated work processes, can considerably improve tangible performance measures in production homebuilding.

6. Conclusion

Prior work has documented several problems in production construction and the efforts to model and address those. To mitigate high levels of variability and resultant risks for homebuilders, subcontracting has been widely used in the complex configuration of residential construction. While attempts have been made by construction management professionals to improve the situation within the present system configuration, little attention has been paid to reconfigure it in order to improve production parameters.

This study focused on implementing principles of even flow production in residential construction. Controlling the number of houses under construction, in accordance to system capacity, prevented long queues and work starvations within the network of trade contractors. Also, employing cross-trained contractors was found to significantly improve tangible performance measures by means of reducing the number of system states. This initiative results in better management of hand-offs among fewer trade contractors. This finding extends those of Dalton, Wakefield and Horne (2011), confirming that faster, more predictable systems tend to have more simplified configurations. Implementing such initiatives are more cost effective than adding more resources during the boom periods because efficiency is all about the how of converting WIP inventory to throughput.

Most notably, this is one of the first studies to our knowledge to investigate construction system behaviour under the principles of even flow production over the long term. Our results provide compelling evidence for the need to design simpler construction production systems and suggest that this approach appears to be effective in reducing variability that degrades performance measures. Even flow production causes significant savings in holding cost for capital that is generally borne by homebuyers due to extended house completion times.

In this investigation, the effects of controlling levels of work-in-process inventory and integrating work processes were studied. Future work could focus on other even flow strategies that can add flexibility to construction production systems.

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Should the Disaster Management Strategies in Bangladesh be just about Constructing New Shelters?

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Abstract

With a population of over 143 million people and a population density of more than 1,200 persons per km^2 Bangladesh is a very densely populated country. The country's geographic location in the waters of Bay of Bengal, often the source of tropical cyclones and storm surges, makes Bangladesh one of the most natural disasters prone nations in the world. A severe tropical cyclone hits the country, every 3 years on average. As 16 major cyclones have hit the country since 1960 with the loss of nearly 500,000 lives, multi-purpose cyclone shelters – that can provide refuge to susceptible population in the events of natural hazards and to a certain extent with the utility of community functionalities during normal times – have become a vital component of disaster management strategies. Country has already constructed more than 2,500 such shelters across 16 of the most disaster prone coastal districts. This paper uses content analysis of disaster management policies, and programs in order to comprehend and assess the distributions of shelters with a lens of integrated strategic asset management framework. Analysis of secondary data indicates that existing cyclone shelters are not equitably distributed to cater the needs of the highly vulnerable population. In the backdrop of the recommendation of The World Bank [TWB] that the country needs 5,500 new shelters (TWB, 2010), this paper contends that future construction of cyclone shelters must be need as well as evidence-based in order to ensure that highly vulnerable population benefits from cyclone shelters the most.

Keywords: Cyclone Shelters, Disaster Management, Evidence-based Strategy, Leximancer, and Integrated Strategic Asset Management

1. Introduction

With a population of over 143 million people and a population density of more than 1,200 persons per square kilometre, Bangladesh is a densely populated country in the South Asia Subcontinent (BBS, 2012). Bangladesh is also the world's third most vulnerable country to

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sea-level rise in terms of the number of people, and among the top ten countries in terms of percentage of people living in low-lying coastal zones (Pender, 2008). Sixteen coastal districts along the Bay of Bengal are prone to severe tropical cyclones with sustained winds of 64 knots (74 miles/hour) or more that often generate storm surges and huge waves. These surges can rise as high as seven metres and the flood waves can travel up to 30 miles inland. On average, a severe tropical cyclone hits Bangladesh every 3 years and the country has been hit by 16 major cyclones with a loss of nearly 500,000 lives since the 1960s (Karim and Mimura, 2008). It is apparent that the need to reduce natural disasters casualties, particularly cyclone-related deaths, is nowhere more crucial than in Bangladesh.

The country has built more than 2,500 multipurpose cyclone shelters across 16 of the most cyclone-prone coastal districts (CEGIS, 2009). These shelters – that can provide refuge to susceptible population and to a certain extent with the utility of community functionalities during normal times – have become an integral component of country's disaster management strategy. Since the changing climate and associated sea-level rise is predicted to further increase the frequency and intensity of cyclonic events in the foreseeable future (Karim and Mimura, 2008), The World Bank (2010) estimates that Bangladesh needs more than fifty five hundred new cyclone shelters in order to protect the vulnerable population from natural disasters. While the actual number of the need is contested, the current understandings of the way cyclone shelters are distributed and managed are inadequate. It is in this context, this paper makes explores the utility of an integrated strategic asset management (ISAM) framework (AAMCoG, 2012), developed in conjunction with asset management industry associations in Australia, in order to examine the state of cyclone shelters in Bangladesh.

The paper begins with an introductory overview of ISAM framework and its relation to the construction and management of cyclone shelters as assets. An empirical study examining the state of cyclone shelters in 16 coastal districts of Bangladesh is presented next, including the method as well as the results and discussion. The paper ends with the recommendation that future construction of cyclone shelters must be need as well as evidence based so that it can serve the purpose of benefiting highly vulnerable population.

2. ISAM Framework and MPCS Management

According to the BSI (2008), asset management can be defined as '*systematic and coordinated activities and practices through which an organization optimally and sustainably manages its assets and asset systems, their associated performance, risks and expenditures over their life cycles for the purpose of achieving its organizational strategic plan'* (p. 2). In line with this definition and also to provide a contemporary outline to assist asset service owners, providers and operators, AAMCoG (2011) has developed an ISAM framework (Figure 1). The elements of the ISAM framework are put together in order to guide achieving optimisation of service delivery of engineering and infrastructure assets.

The ISAM framework (AAMCoG, 2011) is based on the following five principles:

i. Assets exist to support service delivery. Therefore non-asset solutions should be considered

ii. Agencies should manage assets consistent with whole-of-government policy frameworks and take into account whole of life costing, future service demands and balance between capital expenditure and maintenance requirements

iii. Asset management should be integrated with agency strategic and corporate planning

iv. Asset management decisions should holistically consider sustainability outcomes: environmental, social, economic and governance

v. Governance arrangements should clearly establish responsibility for functional performance of, and accountability for, the asset and service delivery (pp. 5).

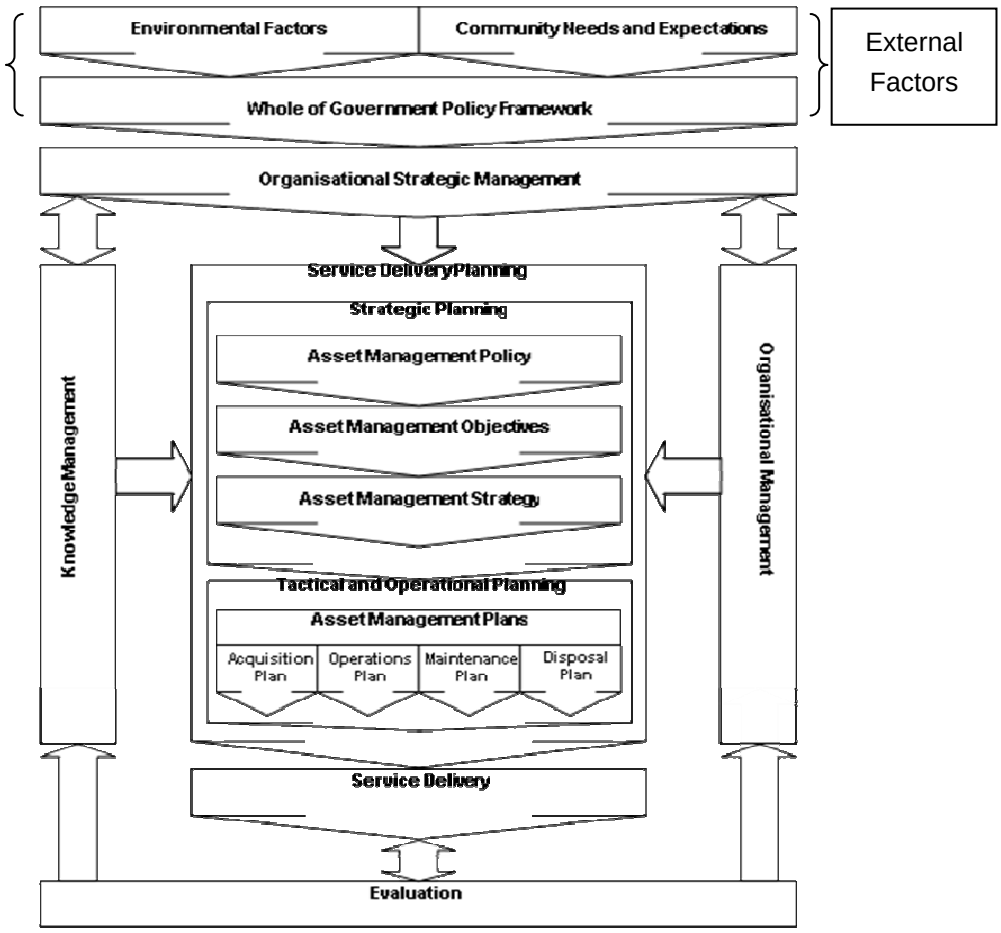

Figure 1: Integrated strategic asset management framework (source: AAMCoG, 2011)

These principles are particularly useful for shaping management of cyclone shelters in order to internalise the needs and expectations of community stakeholders regarding sustainable management. For the purpose of this paper, we focus on the external factors of the framework and utilise it in order to assess the following three factors: a) environmental, b)

community needs and expectations, and c) whole-of-government policy in relation to cyclone shelters distribution and management in Bangladesh. These three factors are elaborated upon next.

2.1 Environmental factors

Recognition of the environmental risks e.g. the changing climate is a valuable first step towards better planning of new infrastructure investments and mitigating potential damage to existing infrastructure (CSIRO, 2006). Like any other major infrastructure assets, cyclone shelters need to operate in dynamic circumstances where they are exposed to short, medium and long-term variability in ambient environmental conditions. The variability includes the estimation of environmental conditions e.g. river erosion, tsunami, earthquake that can be expected over the life of cyclone shelters. These environmental factors can influence the geographical locations of asset construction, their functionalities, and most importantly, their core purpose of delivering services to the vulnerable people. While statistical view of the variability of environmental conditions is understood to have an impact on the construction and management of assets, incorporation of environmental conditions into asset planning and design has been largely overlooked so far (Rayner, 2010). The capacity for identification, assessment and evaluation of risks associated with environmental factors on micro, meso and macro level needs to be substantially increased in managing assets like the cyclone shelters and the information also needs to be systematically integrated in the planning processes of constructing new and existing assets (Smit et al., 2006; Nelson et al., 2007).

2.2 Community needs and expectations

Community needs and expectations need to be managed through the effective institutionalisation of stakeholder engagement. Stakeholder engagement is the process of mapping and interpreting the expectations of external and internal groups and/or individuals, who have stakes in asset management activities or will be effected directly or indirectly by its outputs. According to the Beach and Keast (2010), stakeholder engagement comprises of stakeholder identification, stakeholder classification, strategy development, stakeholder engagement, and of the maintenance of relationships. From the asset management perspective, stakeholder engagement is essential throughout all stages of the asset life cycle. For instance, community is likely to play a major role by sharing local knowledge about environmental factors and actual needs which eventually assist in planning, designing, constructing, operating, maintaining and disposing phases of any infrastructure assets.

2.3 Whole-of-government policy model

Whole-of-government policy model, which is comprised of legislation, policies, plans, service delivery strategies and standards, capital and recurrent budgets, government institutions; and partnerships including with working groups, community based organisations and private providers. In case of public assets, the identification and analysis of the community's need for services is regularly undertaken by different tiers of government agencies and communicated to various departments in a range of ways, including emerging policy,

legislation, priorities and objectives. These are translated by agencies into specific departmental objectives, performance indicators, services and service standards which are addressed in major documents such as strategic plans, budget documentation and annual reports. Bangladesh has a regulative framework for disaster management that provides guidance for relevant policy documents. The contents of three documents related to the regulative framework: a) the *Disaster Management Act*, b) the *National Plan for Disaster Management,* and c) the *Standing Orders on Disaster* (still in a draft stage) are analysed in the context of whole-of-government policy model under the ISAM framework adopted earlier.

3. Methodology

The central research question that this paper addresses is whether or not cyclone shelters in Bangladesh are distributed as per the actual needs. An exploratory case study approach (Blatter, 2008) which examines an operating environment of cyclone shelters using multiple sources of quantitative and qualitative data was selected as the principal research method for this study.

A case study approach is particularly useful in qualitatively understanding a phenomenon because the method is open to the use of theory or conceptual categories that guide data collection and data analysis (Yin, 1984; Meyer, 2001). We relied on various secondary data sources e.g. the Ministry of Food and Disaster Management (MFDM), and the Bangladesh Bureau of Statistics (BBS) in calculating the ratio between population vulnerable to cyclones and cyclone shelters. We also made use of an ISAM framework in order to explore three of the external factors that are important to consider prior to constructing shelters: a) environmental factors e.g. frequency of cyclones, b) community needs and expectations e.g. vulnerability of the people, and c) whole-of-government policy e.g. disaster related policies and their implementation. The utility of exploring these factors is such that it enables us to triangulate our analysis through the content analysis of disaster management policies, programs and literature on disaster management in assessing the distribution of cyclone shelters.

The contents of three policy documents:, i) The *Disaster Management Act*, ii) The *National Plan for Disaster Management*, and iii) *The Standing Orders on Disaster* were analysed using a Leximancer software. Leximancer differs from the standard content analysis, which identifies themes and concepts based on the word frequency and co-occurrence of families of terms (Smith & Humphreys 2006; Smith 2003). Leximancer was particularly useful for examining the interconnectedness of central themes contained within the documents outlined above.

4. Results and Discussions

4.1 Cyclone shelters

In order to reduce the cyclone-related casualties, Bangladesh has already built more than 2,583 cyclone shelters across 16 of the most cyclone-prone coastal districts. The analyses indicate that nearly one tenth (246) shelters are deemed unusable (CEGIS, 2009). As Figure

1 shows, Patuakhali district has the highest percentage of unusable cyclone shelters (30.38%) whereas Satkhira and Shariatpur districts have 100% of cyclone shelters usable. While some of the plausible causes behind the high frequency of shelters being unusable are discussed in the next section, they are worthy of further field investigation.

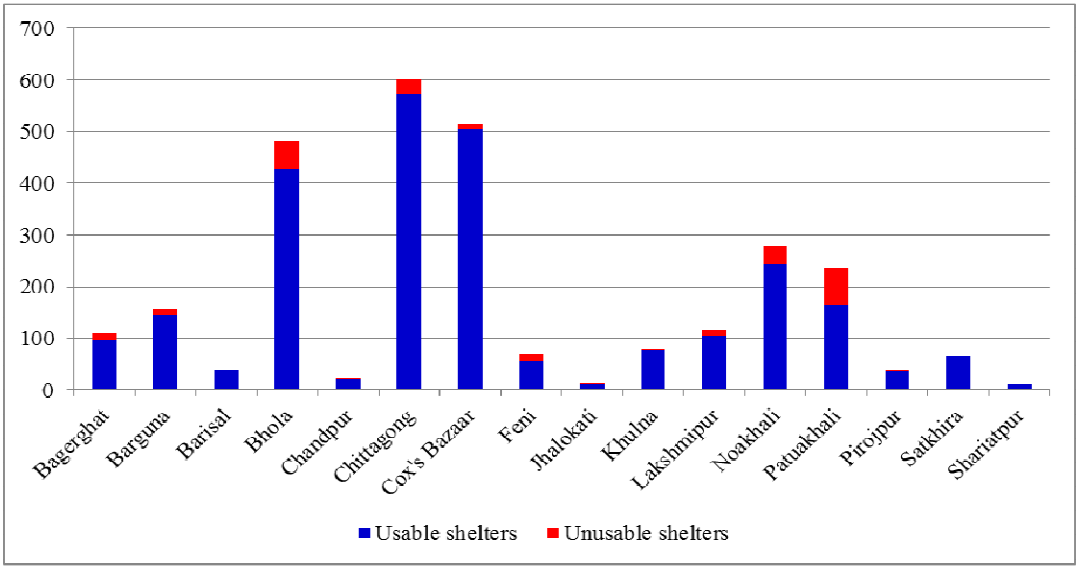

Figure 2: The State of Cyclone Shelters in 16 Coastal Districts of Bangladesh

The analyses also indicate that existing shelters are not equitably distributed to cater the needs of the highly vulnerable population. For instance, Noakhali district with a total of highly vulnerable population of 1,807,000 has an existing shelter capacity for accommodating only 266,000 people. That means at present 85% of the vulnerable population in the district are exposed to high risk. Conversely, Khulna district without any highly vulnerable population has an existing shelter capacity for accommodating 76,000 people. These findings clearly indicate that shelters are constructed on an *ad hoc* basis and hence inequitably distributed.

4.2 Environmental factors

Most of the cyclone shelters that are deemed unusable because of the lack of day-to-day maintenance and external factors such as river bank erosion, poor quality of construction materials, less consideration given to potential high wind speed at construction. It could also the case that, people displaced during the cyclones are hesitant to use these facilities because they are worried about the structural well-being of these shelters due to poor maintenance during normal times. Consequently, cyclone shelters are abandoned and become unusable when needed the most.

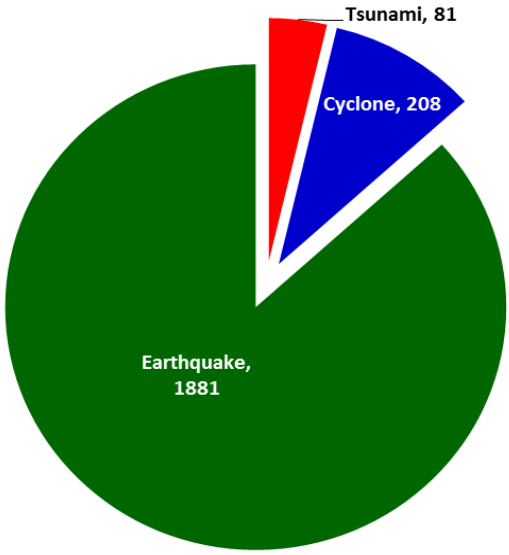

Figure 3: Vulnerability of existing cyclone shelters

For instance, as Figure 3 indicates the structural assessment of 2,583 cyclone shelters conducted by CEGIS (2009) revealed that around 3% of shelters were vulnerable to tsunami, nearly 8% were vulnerable to cyclone and a whopping 73% were vulnerable to earthquake. If these shelters are to be the backbone of the overall disaster management strategy, the construction and management cyclone shelters need to take into hazards other than cyclones in consideration as well. Cyclone shelter construction decisions must rely on evidence-based decision-making and consider environmental factors over the entire life-cycle of proposed shelters and not just the construction phase. Unless these considerations inform the design, specification, construction materials selection and techniques, operating models and disposal procedures of the cyclone shelters, the overall utility of these assets are likely to be reduced in the event of cyclones or other natural disasters for that matter.

4.3 Community needs and expectation

Although there is no unanimous agreement over what constitutes a genuine community stakeholder, an individual or an organisation with a stake or an interest in various stages of cyclone shelters can be considered one. The needs and expectations of these community stakeholders are more or less represented through management committees that are often democratically governed by the local people at the grassroots. However, only 19% of shelters have community participation mechanism in place during the operation phase (CEGIS, 2009).

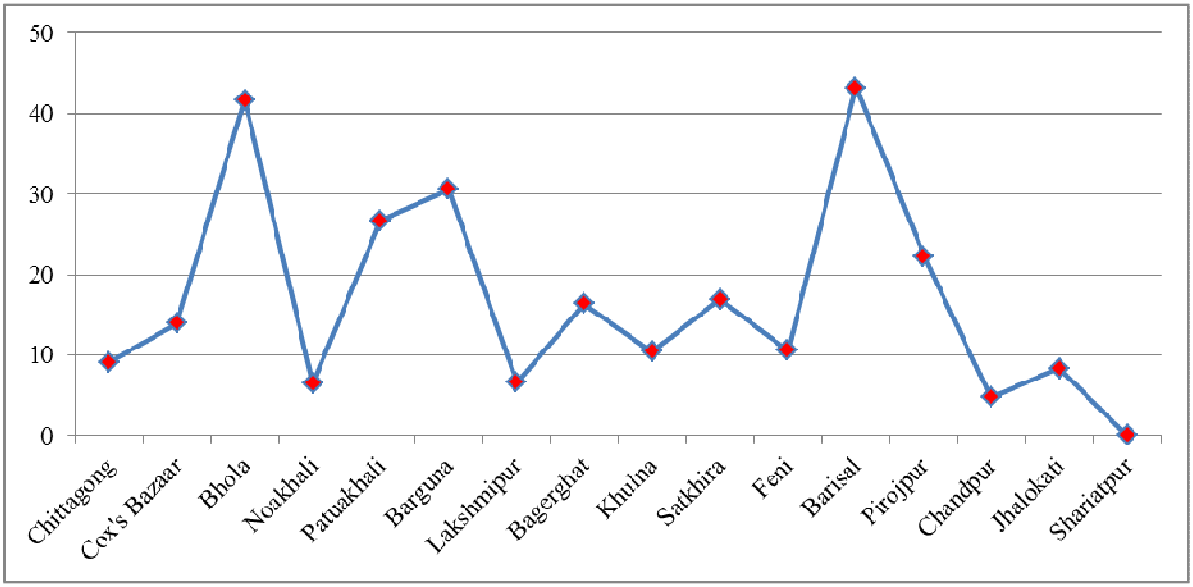

Figure 4: Community participation in the governance of cyclone shelters (%)

These findings suggest that disaster management strategy is more or less concentrated on constructing the shelters for the sake of it instead of long-term utility of the shelters. As Figure 4 suggests, the majority of cyclone shelters do not have community based participatory governance mechanism in place. In particular, Shariatpur district performs very poorly in this regard with none of the shelters having participatory governance mechanisms.

4.4 Whole-of-government framework

Of the three policy documents identified earlier, The *Disaster Management Act* forms the legal basis (i) for the protection of life and property (ii) to manage long term risks from the effects of natural as well as technological and human induced hazards, and (iii) to respond to and recover from a disaster. The *National Plan for Disaster Management* provides the overall guideline for the relevant sectors and the disaster management committees at all levels to prepare and implement specific plans for their respective areas. The plan also identifies the key sectoral policy agenda for disaster management. *The Standing Orders on Disaster* provide a detailed institutional framework for disaster risk reduction and emergency management. These *orders* are expected to outline detailed roles and responsibilities of Ministries, divisions, departments, various committees at different levels, and other organizations involved in disaster risk reduction and emergency management.

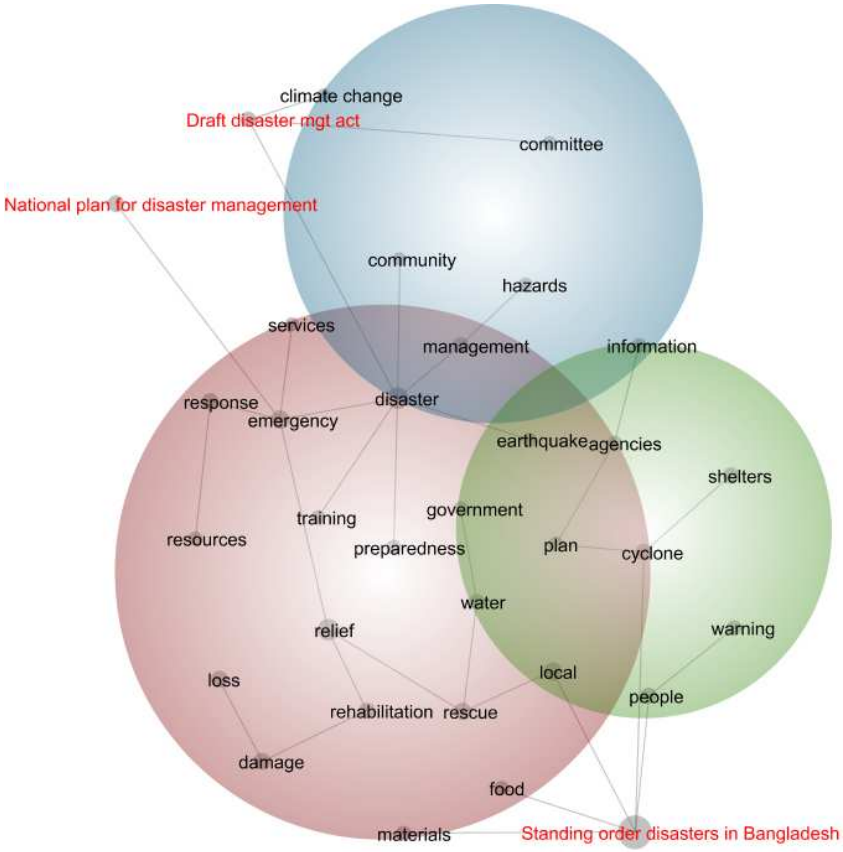

Figure 5: Leximancer generated content analysis map of three policy documents

As Figure 5 shows, the *draft Disaster Management Act* and the *National plan for Disaster Management* are relatively close together when compared to the *Standing Order on Disasters in Bangladesh*, indicating more overlap in terms of the contents analyses. Based on the Leximancer analyses, five of the most prominent concepts in the three documents are concisely included in Table 1 below. The table clearly shows that the concept of community shows high connectivity between the *Act* and the *Plan.* However, the notion of community is disconnected from where it is needed the most, from the *Standing Order.*

Table 1: Five prominent concepts identified by Leximancer

Policy Document	Prominent Concepts
Disaster Management Act	Committee, services, hazards, community and climate change
National Plan for Disaster Management	Climate change, hazards, community, emergency and information
Standing Order Disasters in Bangladesh	Materials, local, rescue, rehabilitation and food

In order to comprehend community needs and expectations in the construction of cyclone shelters, it is important to involve local people including vulnerable groups for improved management of the shelters. However, the Standing Order as it is seems to have failed in serving as guidance to community based cyclone shelters management.

5. Conclusion

This paper began with an introductory overview of ISAM framework and utilised this framework in order to explore the construction and distribution of cyclone shelters in Bangladesh. The results indicated three main findings. First, there was a lopsided focus on constructing the shelters for the sake of it, rather than ensuring ways to manage these assets by engaging communities. For instance, nearly 9% of the existing shelters were deemed unusable in the event of natural disasters. In some cases e.g. Patuakhali upto one-third of the cyclone shelters were unusable. Second, the current distribution of cyclone shelters was disconnected from the on-ground needs. The cyclone shelters were not equitably distributed to cater the needs of the highly vulnerable population e.g. 85% of the vulnerable people in Noakhali district are at risk in the event of future natural disasters. Third, while the actual construction of the shelters was the responsibility of several layers of government agencies, these agencies did not have clear guidelines for the management of the cyclone shelters. The fact that less than one-fifth of the shelters have community participation mechanism in place during the operation phase means that the existing planning mechanism is myopic and has failed to take into account the operation phase and beyond.

Based on these findings, the paper sees some value in the ISAM framework as an integrated guidance for need-based construction and evidence-based management of cyclone shelters. In order to achieve this, hazard and risk maps and related information need to be not only updated regularly but also used in planning processes at all levels for cyclone shelter construction and management. There is no doubt that existing and new shelters are vital for mitigating or minimising the casualties of vulnerable populations in the event of natural disasters. If cyclone shelters are to be the backbone of disaster management strategies in Bangladesh, these facilities cannot be disconnected from the very local communities that they service. This paper recommends that policy level direction on the distribution and management of cyclone shelters might be more effective when: a) it promotes democratic election the management committee at the bottom-up level rather top-down level, and b) incorporating community needs and requirements in designing the facilities and finalisation of proposed shelter locations.

Acknowledgement

This paper was developed within the CRC for Infrastructure and Engineering Asset Management (CIEAM), established and supported under the Australian Government's Cooperative Research Centres Programme, in collaboration with the Collaborative Research Network (CRN) program within Southern Cross University.

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Defining employers-of-choice in the construction industry from a graduate perspective

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Abstract

Employer-of-choice status is emerging as a critical reputational asset in attracting developing and retaining scare human resources in an increasingly competitive labour market. Through a major survey, we explore the preferred workplace characteristics of university students in construction and built environment faculties around the world. This research provides valuable insights for all businesses operating in the construction industry into the relationships between management practices and human resource management strategies. We conclude with a series of recommendations to bring these into alignment.

Keywords: Employer of choice, human resource management, graduates, labour market

1. Introduction

While highly cyclical, construction industry employment is also growing in many countries. For example, in Australia employment grew by 57% in the ten years to February 2011, making it the second largest growth industry over this period (DEEWR, 2011). Despite this growth, DEEWR (2011) found that 56% of employers reported recruitment difficulties and 18% reported that staff retention was a significant challenge. Graduate employment presents a special challenge with 89% of employers saying competition for graduates from other industries is a major issue (AAGE, 2011). In particular, demand for 'top' graduates is exceeding the available supply, thus creating a potential secondary labour shortage in the future. The above challenges are not Australian-specific. There is evidence that attracting and retaining the right graduates has consistently been a top business concern for the last six years around the world (Capelli, 2008; AAGE 2011). Firms in the construction industry therefore need to develop innovative strategies to compete in this global inter-sector market. This is required to ensure that they have the best pool of qualified graduates to select from, that they are attractive to them and that once recruited they will be retained and contribute to the company's objectives for a reasonable period of time (Richardson, 2003).

A recent graduate survey of 2,815 new and future graduate employees across 138 organisations in Australia (AAGE 2011), found that the graduate's first year at university is a particularly formative time in forming perceptions and expectations about prospective employees. In understanding what these may be, Arnold and McKenzie's (1994) cross-

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sector study of 1,000 graduates is useful. In particular, they found that above all, long-term career prospects were the most important factor in graduates' employment decisions. The AAGE (2011) survey findings support this conclusion, reaffirming that graduates are thinking "long-term" when they are making career decisions. Indeed, graduates appear to be looking for a clear career path for at least five years ahead with their first employer.

It is interesting to note that there were no construction organizations among AAEG's top 20 employers in 2011 and that the top five criteria in selection an employer were (in ranked order): training and development opportunities; career prospects; overall reputation; work content and; security of employment. Many other less important factors were also ranked including: work-life balance; ethical record; opportunities for professional accreditation; mentoring and flexible working etc. Like most surveys' salary package features low in the priority of most graduates. Very little research has been conducted into the specific perceptions of graduates entering the construction industry. One exception is Burt's (2003) research into the factors that influence construction graduates' decision about a future employer. Burt found that the most important factors were (in order of priority): company culture; advancement opportunities, type of work; location; training opportunities; company size; salary; entry position and; signing bonus. More recent research in the Australian construction industry, especially with regard to minority groups such as women, indicates that the perceived attractiveness and unattractiveness of certain workplaces and job characteristics is also critical to a potential candidate's decision to apply for a position, and their ongoing engagement with it (Gilbert & Walker, 2001). In this context, the purpose of this paper is to add to our limited understanding of what factors graduates use to characterize an employer-of-choice. This will help businesses operating in the industry to reflect on the impact of their business practices and corporate image on their recruitment programs.

2. What is an employer of choice?

An employer-of-choice (EOC) is an employer that is recognized for their leadership, culture, and best employment practices. This means that workers, employees and subcontractors choose to work for that employer when presented with other choices of employment (Herman and Gioia 2001). Historically, the main motivation for being an EOC relates to a firm's enhanced ability to attract increasingly scarce human resources in an ever more competitive labour market. There are also numerous reputational advantages which some argue can lead to competitive advantage. For example, Lenaghan et al (2006) argues that EOCs tend to be more successful because they attract higher quality human resources and because employees in such organizations tend to show higher levels of engagement, satisfaction and loyalty, as well as improved well-being. Beyond these immediate advantages, the popularity of EOC has emerged from a number of other contemporary business pressures and trends in the areas of corporate social responsibility (CSR), equal opportunities and diversity, corporate governance, responsible investment and the growing lists of ratings and surveys on EOC which has created competition among companies to be "indexed" as one (Wilson, 2004, Gill 2008). A review of the various indexes and EOC research indicates that they generally include various combinations of the following criteria: personnel policies, pay, conditions, benefits, employee engagement, leadership quality,

safety and well-being, quality of workplace relationships, workplace culture and climate (stimulating, innovative, creative, passionate and fun), equal opportunities, staff development and career paths and opportunities, flexible family-friendly work practices, work-life balance, worker empowerment, receiving and giving feedback on work performance clear company strategy and values, healthy and stimulating physical work environment, community involvement and sustainable practice (PriceWaterhouseCoopers, 2002, Gill, 2007; Kuhnel et al., 2009; Dream Employer, 2011; Universum, 2011). However, the EOC concept is also an evolving one, changing in response to workplace demographics . For example, as the workforce ages into the future, Maurer's (2001) research suggest that it is likely that opportunities for confidence building learning activities will become more valued as an attribute of an EOC than they are now.

While there are numerous advantages associated with being an EOC, the jury is still out on whether this translates into a more productive, profitable and competitive business (Herman and Gioia 2001; Leary-Joyce 2004). For example, Fogarty and Dirsmith (2001) argue, that some employees take EOC benefits for granted after a period of time and if implemented without thought can result in reduced labour competitiveness. There is also some evidence to suggest that this affect varies considerably across different groups of employees and it is clear that EOC programs are not all equally effective. The value of EOC as a concept is also contested. For example, some studies have highlighted excellent workplaces which do not necessarily have an EOC strategy, while others have identified very poor workplaces that do have one (Hull and Read 2003). Critics of EOC also point out that there appear to be no agreed criteria or method for measuring EOC which means it essentially remains a self-proclaimed achievement (Gill, 2009a, 2009b). Indeed, a survey of 2,186 job candidates found that 52% of candidates reported they are rarely or never attracted to a company by their claims of being an EOC (Chandler Macleod, 2007). Finally, there is also evidence to show that the motives of many employers in seeking EOC status are not driven by a concern for their employees but by a cynical attempt to comply with an increasing number of externally derived business indices or mimic the initiatives of their competitors – particularly in the area of corporate social responsibility (CSR). In their analysis of CSR strategy in the construction sector, Loosemore and Phua (2011) found that while the best firms are driven by a genuine desire to balance their economic, social and environmental responsibilities, the majority, despite the rhetoric, are still primarily driven by the bottom-line. So while some firms might appear to be an EOC, life for employees in reality may present a very different picture. In these firms, the competitive value of EOC status is significantly reduced as employees quickly realize that the informal underlying culture they experience during their day-to-day lives undermines the formal statements which purportedly represent business policy.

3. Method

To explore graduate employer preferences and the relationship between factors affecting them an electronic survey was conducted across a total of 26 Universities in the UK and Australia. Surveys were distributed to over 400 students and a total of 160 responses (40%) were received which is consistent with similar larger scale studies of graduates by the

government and commercial organisations (OCPE, 2006; AAGE, 2011). The sample structure is shown in Table 1.

Table 1 Sample structure

Respondent characteristic	**Number of respondents**
Male	102
Female	58
Work experience (no)	61
Work experience (yes)	99
Undergraduate	134
Postgraduate	26

Electronic questionnaires were utilised for a number of reasons: first, because of the wide geographical dispersion of respondents; second because of their fast delivery and return; third because of the ease of sending of reminders and; finally because of cost effectiveness over a large sample compared to postal questionnaires. To maximize our response rate we used closed questions and maintained brevity by keeping the survey to two pages. We also offered a financial incentive of an iPad 2 selected randomly from a prize draw of respondents at the end of the data collection process. Finally, we guaranteed anonymity and assured that our respondents that could make a difference to construction employee practices by responding to the survey.

The structured survey required respondents to rate twenty six EOC criteria on a seven-point ordinal Likert scale derived from relevant literature on EOC. A seven-point ordinal Likert scale was used in the survey to enable us produce hierarchies of preferences which were then compared across groups of respondents. This prevents respondents being forced to adopt a positive or negative position they do not hold (Garland 2001). To avoid respondent bias from misinterpretation, each variable was defined and in accordance with good survey practice, a pilot test was conducted with a small sample of students intending to working in the construction industry. The survey also included one open question which asked respondents to rank (if applicable) “other” workplace characteristics which they thought were important to construction industry EOC that were not cited in the closed survey questions.

4. Discussion of results

The preferred workplace characteristics of respondents are listed below in rank order.

- Good quality working relationships
- Being able to learn on the job

- A workplace that is passionate about work
- A relaxed, fun and social workplace
- Seeing and understanding the purpose of tasks
- Recognition and encouragement of my contribution
- A workplace with training programs
- Training in how to use new technologies
- Working with people who have the same values and approach to work
- Flexible hours
- A safe workplace
- Receiving and giving feedback on work performance
- A workplace with a strong work ethic and high commitment to work
- A line manager with leadership and energy
- A good reputation
- Emotional stability and feeling protected by the organisation
- High income
- Having a say in decisions that affect day-to-day activities
- A line manager that is well organised
- Being involved with the local community
- A high quality workplace
- Travel opportunities
- Paid a salary rather than causally
- Opportunities to work extra hours
- Paid by the hour
- Union membership

Female respondents (33% of our sample) consistently rated the following characteristics as more ‘important’ than their male counterparts suggesting that recruitment strategies for male and female graduates should be different.

- Emotional stability and feeling protected by the organisation
- A workplace with training programs
- Working with people who have the same values and approach towards work
- Being involved in the local community
- Being able to learn on the job
- A manager that focuses on leadership and energy
- Training on how to use new technology

Our results also showed that as students progress through university the relative importance of this pay-related variable change. Respondents from later stages of university consistently indicated higher pay as more important than students from first and second years. This suggests that recruitment strategies targeted at students in later years of a program should place more emphasis on pay than those targeted at students in earlier years.

Our results also show that students with work experience value the above variables as significantly more important in judging future employers, than those without work experience.

- Union membership
- A high standard of accommodation and fit-out of the workplace
- A manager that focuses on leadership and energy
- High level of personal physical safety

It is interesting to note that it is the more intrinsic aspects of the employment relationship that seem to become more important as work experience accumulates. Our results do indicate that recruitment and retention strategies do need to be dynamic and responsive to different workforce segments.

It is also interesting that our results did now show any significance between preferences between different professions in our sample. These included:

- Small builder – 16%
- Planner – 16%
- Large builder – 11%
- Architect - 10%
- Project manager – 8%
- Consultant - 6%
- Subcontractor – 6%
- Developer - 3%
- Quantity Surveyor – 3%
- Supplier 1%
- Engineer – 1%
- Other – 19%

This result was surprising given the wide variety of occupational cultures within the industry and our sample.

Finally, our results also showed that as the size of the potential workplace increases so does the importance of being fully employed (rather than casually). We also found that the importance of union membership decreases as the size of the workplace increases. This was an interesting finding since union membership in the Australian construction industry is primarily focused in the large developers. Despite this, our findings suggest that respondents from smaller companies are more concerned with their work conditions, benefits and remuneration being protected by unions than respondents in larger companies. Our data also showed that casual time-related employment (rather than full-time employment) is significantly more acceptable to those who work in the smallest of businesses compared to those who work in larger organizations who prefer to be paid a salary. This may reflect differences in normalised modes of employment in these groups or perhaps differing entrepreneurial values.

5. Conclusion

The aim of this paper was to explore the factors that are important to graduates in the construction sector in selecting their preferred employees. Accepting that this is always

changing as generational workforce shifts, our results indicate that the top three most important characteristics for university students with construction industry related work experience are respectively: good quality of work relationships; being able to learn on the job and; a workplace that is passionate about work. The implications for firms competing for scare graduate labour in the construction industry is that initiatives such as mentoring and coaching, continued development opportunities and strong corporate culture should be the focus of management and marketing efforts. Although male and female respondents generally agreed on these important characteristics, it was found that good workplace leadership, safety and emotional stability, learning and development opportunities and being involved with the local community were more preferred by women than men. These findings are of importance to an industry that has the highest proportion of male employment of all 19 broad industry groups (DEEWR, 2011).

Our findings relating to ranked EOC characteristics in the construction sector are aligned with the wider literature in this area. This indicates that graduates considering entering the construction industry have largely similar EOC expectations as graduates in other fields. Given that much recent research (for example see Dainty and Loosemore 2012) suggests that employment conditions in the construction industry are inferior to many others, particularly in areas like safety, diversity, equal opportunities, work-life balance and gender equity, our results would suggest that many firms in the construction industry would have difficulty in competing for human resources against other “more attractive” industries. Opportunities for diversifying the workforce may therefore be limited. While our research indicates that there is nothing particularly unique about the preferences of graduates in the construction sector, it does suggest that placing more emphasis on specific workplace characteristics for different groups may be effective in accessing an important and untapped source of new talent for the construction industry.

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Analysis of delay, disruption and global claims in the context of statutory adjudication in Australia

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Abstract

There has been a fusion of delay, disruption and global claims in the context of statutory adjudication in Australia. These claims arise within a contractual setting or from principles of common law. The one thing that these claims have in common is that they arise due to an act, default, or omission by the principal, or where those matters are caused by a third person who is the responsibility of the principal. The courts have recognised that delay, disruption, and global claims are claimable and can be determined by an adjudicator under statutory adjudication. The purpose of this paper analyse delay, disruption and global claims in the context of statutory adjudication in Australia. A comparative 'black-letter' approach is adopted to analyse case law in various international jurisdiction dealing with delay, disruption and global claims in construction. The paper shows that delay, disruption, and global claims are frequently unappreciated within the framework of statutory adjudication. There are varying degrees of consideration to be taken into account where there can be compensable, non-compensable, and modified or apportioned claims. There is also causation, criticality, and concurrency to be considered. These are generally complicated factors that adjudicators are requested to consider in statutory adjudication. Those matters often lead to the unfortunate results that one of the parties on opposite sides' ends up aggrieved. The research may be of interest in international jurisdictions where statutory adjudication for the construction industry has been introduced or is being contemplated.

Keywords: Adjudication, Australia, delay claim, disruption claim, global claim

1. Introduction

This paper deals with the fusion of delay, disruption and global claims in the context of statutory adjudication in Australia.[1] A detailed overview of the problem giving rise to the need for statutory adjudication in the Australian building and construction industry as well as contemporary discussions on the topic is provided in Brand & Davenport (2012), Brand & Davenport (2011), Brand & Uher (2010) and Commonwealth of Australia (2002).

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[1] Statutory adjudication is adjudication which takes place under legislation. All Australian States and Territories have comparable legislation for the building and construction industry: see *Building and Construction Industry Security of Payment Act 1999* (NSW); *Building and Construction Industry Security of Payment Act 2002* (Vic); *Building and Construction Industry Payments Act 2004* (QLD); *Construction Contracts Act 2004* (WA); *Construction Contracts (Security of Payments) Act 2004* (NT); *Building and Construction Industry Security of Payment Act 2009* (Tas); *Building and Construction Industry (Security of Payment) Act 2009* (ACT); and *Building and Construction Industry Security of Payment Act 2009* (SA).

Delay, disruption and global claims often arise within a contractual setting or from principles of common law. The one thing that these claims have in common is that they arise due to an act, default, or omission by the principal, or a third person who is the responsibility of the principal.

The courts have recognised that delay, disruption, and global claims are claimable and can be determined by an adjudicator under statutory adjudication. The common law principles of those types of claims have been adopted by the courts, but the application of such claims remain inconsistent within the area of statutory adjudication. This is particularly where the accepted doctrines of such claims have not been fully appreciated by the courts and where there can be a regular theme that delay, disruption and global claims are categorised as claims in damages arising from a breach of contract.

This paper shows that delay, disruption, and global claims are frequently unappreciated within the framework of statutory adjudication. There are varying degrees of consideration to be taken into account where there can be compensable, non-compensable, and modified or apportioned claims. There is also causation, criticality, and concurrency to be considered. These are generally complicated factors that adjudicators are requested to consider in statutory adjudication. Those matters often lead to the unfortunate results that one of the parties on opposite sides' ends up aggrieved.

2. Delay and Disruption

It has been argued in the past that the recovery of costs on account of delay and disruption through statutory adjudication are excluded by the operation of the *Building and Construction Industry Security of Payment Act 1999* (NSW) ('the NSW Act')[2] and the *Building and Construction Industry Payments Act 2004* (Qld) ('the Queensland Act').[3] The *Building and Construction Industry Security of Payment Act 2002* (Vic) ('the Victorian Act')[4] expressly prohibits the recovery of any time related costs[5] that would conceivably extend to claims for delay and disruption costs.

Whilst the Victorian Act expressly bars the recovery of any time related costs, the same cannot be said for its New South Wales and Queensland counterparts. It has been claimed that delay and disruption costs amount to a claim in damages that is not claimable under the NSW and Queensland Acts. This is because damages are not referable to the performance of construction work and damages arise from a breach of contract. The exclusion of damages from the NSW Act was confirmed in *Quasar Construction v Demtech* [2004] NSWSC 116, wherein Barrett J said (at [34]):

> The clear message throughout the Act is, in my opinion, that any "progress payment", including one within paragraph (a), (b) or (c) of the definition of "progress payment", can only have that

[2] New South Wales (abbreviated as 'NSW') is one of six states of the Commonwealth of Australia.
[3] Queensland (abbreviated as 'Qld') is one of six states of the Commonwealth of Australia.
[4] Victoria (abbreviated as 'Vic') is one of six states of the Commonwealth of Australia.
[5] *Building and Construction Industry Security of Payment Act 2002* (Vic), s.10B(2)(b)(ii).

> character if it is "for" work done or, where some element of advance payment has been agreed, "for" work undertaken to be done. The relevant concepts do not extend to damages for breach of contract, including damages for the loss of an opportunity to receive in full a contracted lump sum price. Compensation of that kind does not bear to actual work the relationship upon which the "progress payment" concept is founded.

The proposition was put that delay costs were claimable under the NSW Act where the contract sets out a mechanism for such amounts to be claimed in progress claims. In *Kembla Coal & Coke v Select Civil* [2004] NSWSC 628 ('the *Kembla Coal* case'), McDougall J decided where the contract provides a mechanism for quantification of a progress payment, it is the mechanism that is to be adopted and where the contract provides for assessment of a progress payment, the effect of s 9(a) of the NSW Act is to be given.

Deciding whether an amount is actually damages for breach of contract or part of the consideration payable under the contract for the work, goods or services is not always easy to ascertain. Hodgson JA in *Coordinated Construction Co v JM Hargreaves* [2005] NSWCA 228 ('the *Hargreaves* case') (at [41]) says that any amount that a construction contract requires to be paid as part of the total contract price of construction work is generally an amount due for that construction work, even if the contract labels it as damages or interest.

Those matters were indeed taken further by the New South Wales Court of Appeal in the *Hargreaves* case (at [41]) and in *Coordinated Construction Co Pty Ltd v Climatech (Canberra) Pty. Ltd. & Ors* [2005] NSWCA 229 ('the *Climatech* case') (at [40]). Those decisions stood for the proposition that where a contract provides that progress payments include certain amounts; section 9(a) of the NSW Act strongly suggests that such amounts are to be included in a progress payment under the NSW Act.

In the *Climatech* case, Hodgson JA discussed the circumstances in which 'damages' may validly fall within the jurisdiction of the NSW Act. This is where the contract contains mechanisms for such amounts to be claimed, such that the requirement in section 9(a) of the NSW Act is engaged. His Honour said:[6]

> In my opinion, the circumstance that a particular amount may be characterised by a contract as 'damages' or 'interest' cannot be conclusive as to whether or not such an amount is for construction work carried out or for related goods and services supplied. Rather, any amount that a construction contract requires to be paid as part of the total price of construction work is generally, in my opinion, an amount due for that construction work, even if the contract labels it as 'damages' or 'interest'; while on the other hand, any amount which is truly payable as damages for breach of contract is generally not an amount due for that construction work.
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> Under the contract in this case, delay damages are payable only if an EOT is for a compensable cause, that is, in general some act or omission of the head contractor or the superintendent or the sub-contract superintendent; but nevertheless, they are not of their nature damages for

[6] *Coordinated Construction Co Pty Ltd v Climatech (Canberra) Pty. Ltd. & Ors* [2005] NSWCA 229 at [41] and [42].

> breach but rather are additional amounts which may become due and payable under the contract...and which are then to be included in progress payments...They are therefore prima facie within section 9(a) of the Act.

It is now generally accepted that amounts on account of delay and disruption costs are claimable under the NSW Act providing there is a contractual right for the claimant[7] to pursue such claim for costs of delay or disruption. However, intertwined with that entitlement to delay and disruption costs generally stems from an extension of time entitlement under the contract.

The above authority indicates that an entitlement to a delay cost claim only arises where there has been a positive determination under the contract for an extension of time claim. This is assuming the contract makes such a positive determination, which in most instances will be the case. Therefore, this creates the concept of an extension of time acting as a condition precedent to an entitlement to a delay cost claim under the NSW Act and this is not easily reconcilable with the claimant's entitlement to a delay cost claim in circumstances where an extension of time was not granted by a superintendent under a contract. Whilst this may be accepted, the Adjudicator is left with having to decide whether the claimant was entitled to an extension of time with respect to any delay or disruption.

In *Hervey Bay (JV) Pty Ltd v Civil Mining and Construction Pty Ltd and Ors* [2008] QSC 58, McMurdo J considered that it was open to the Adjudicator to decide what the superintendent should have done in response to the claims made and to conclude that the superintendent, acting fairly, would have granted the extensions which the Adjudicator found were justified. The decisions in the *Hargreaves* and *Climatech* cases demonstrate that a claimant does not have a right to include in a payment claim under the NSW Act a claim for costs of delay or disruption as part of the value of construction work carried out under the contract, in the absence of a contractual right for the claimant to pursue such claim for costs of delay or disruption.

The above authority with respect to delay and disruption claims made under the NSW Act commonly suggests that if the contract permits a claim for delay and disruption costs arising from an extension of time under the contract, the claimant will be entitled to such claims providing an extension of time has been granted, or the Adjudicator decides that an extension should have been granted in the circumstances of the claimant's claim for delay or disruption costs.

The position, however, is different if the contract does not deal with delay or disruption claims. This is particularly where a person, who the claimant is not responsible for, causes the claimant to incur additional cost from delay or disruption. On one view this could be a breach of contract or tort by the person that caused delay or disruption and the claimant's only remedy is in damages. On another view, this could not be a claim for damages of any kind, but rather, a claim for additional costs that the claimant incurred for, among other

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[7] The "claimant" is the person *by whom* a payment claim is served (e.g., see: *Building and Construction Industry Security of Payment Act 1999* (NSW) ss. 4, 13).

things, the provision of labour to carry out construction work, based on certain disruption. This proposition can lend support from the High Court decision in *Carr v JA Berriman Pty Ltd* (1953) 89 CLR 327, followed by *Council of the City of Sydney v Goldspar Australia Pty Limited* [2006] FCA 472 (3 May 2006), which highlights the meaning of damages as being distinct from cost of works. Either way, there is difficulty in reconciling the concepts, particularly where a claim for any delay or disruption by the claimant may be in connection with the work under the contract and for construction work done or related goods and services supplied under the NSW Act or the Queensland Act.

3. Global Claims

A global claim is where a claimant does not seek to attribute any specific delay, cost or loss to a specific breach of contract, variation or direction, but alleges a composite loss as a result of all the breaches, variations or directions where it is impractical to disentangle part of the loss which is attributable to each head of claim, and none of the delay, cost or loss has not been brought about by delay or other conduct of the claimant.[8]

The concept of global claims has previously been considered by the Supreme Court of New South Wales in the context of the NSW Act. For the purpose of this paper, it is apt to refer to global claims interchangeably with total cost claims.

In *Shell Refining (Australia) Pty Limited v A J Mayr Engineering Pty Limited* [2006] NSWSC 94 ('the *Shell Refining* case'), Bergin J accepted that a global claim for disruption and delay can be made in a payment claim, valued and determined under the NSW Act. In the *Shell Refining* case, the claim was a global claim stemming from disruption, with quantification based on a modified total cost method. Bergin J upheld the Adjudicator's determination in the *Shell Refining* case regarding the validity of a claim under the total cost method, where her Honour said:[9]

> The defendant submitted that the type of claim put forward by it in its application is not a novel one. It was submitted that it was an extremely common, simple way of putting forward a claim for loss and expense in circumstances where it is difficult to link each item to a particular breach. It was submitted that what the defendant did was to add up all the hours it had spent on the job; compare that total with the hours allowed in the tender; deduct the latter from the former to represent the unrecovered number of hours and multiply that figure by the contract rate to obtain the unrecovered cost. In this regard the defendant submitted that the Contract envisaged that in respect of such costs, what was required to be done was the making of an "estimate" (see cl 2.3(2)(e) of the General Conditions). It does not seem to me that such description can assist the defendant. That was an estimate to be provided in the Notice to the Company of a claim for an "eligible delay". What was claimed was not merely an estimate, but a figure that had been calculated pursuant to a specific methodology. In the claim made by the defendant the method used to calculate the amount or, perhaps put more accurately, to make a judgment of its worth, was clearly set out.

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[8] *John Holland Construction & Engineering Pty Ltd v Kvaerner RJ Brown Pty Ltd* (1996) 13 BCL 262 at [267].
[9] *Shell Refining (Australia) Pty Limited v A J Mayr Engineering Pty Ltd* [2006] NSWSC 94 at [28].

In *Siemens v Tolco; Tolco v Siemens* [2007] NSWSC 257, Macready J, considered a claim based on a total global costs method made under the NSW Act, based on the allegation that Siemens had breached the contract, which caused Tolco loss.[10] His Honour had occasion to consider Siemens' proposition that Tolco's claims were claims for damages which are not permitted under the NSW Act.[11] The Court did not ultimately decide the question in the context of the NSW Act on the validity of the total global costs method, nor whether such a claim amounted to damages.

In *Laing O'Rourke Australia Construction v H&M Engineering & Construction* [2010] NSWSC 818 ('the *Laing O'Rourke* case'), McDougall J considered in the context of the NSW Act claims for disruption that were characterised as global claims or total cost claims by Laing O'Rourke. H&M Engineering advanced in the adjudication as part of its overall claim that it had not sought to particularise the nexus between the individual alleged disruptive matters and the alleged consequences in terms of time and cost.[12]

H&M Engineering referred to the decision of Byrne J in *John Holland Construction Engineering Pty Ltd v Kvaerner RJ Brown Pty Ltd* (1996) 13 BCL 262 and to what his Honour, writing extra-curially, had said in *Total Costs and Global Claims* (1995) 11 BCL 397 , together with other decisions and writings dealing with global claims or total cost claims. McDougall J outlined the premises of H&M Engineering's claims by saying:[13]

> H&M denied, in its adjudication application, that claim 110 was a "global claim" (and, presumably, took the same position in relation to claims 115 and 122). It said that it had "provided more than sufficient evidence to demonstrate that as a result the [sic] vast number of breaches of the contract and acts of prevention caused solely by LORAC, H&M has incurred substantial additional work-related costs for which LORAC must reimburse H&M.
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> However, although H&M identified many of what it said were acts of disruption, delay or prevention, it did not seek to describe a connection between any individual act (or related groups of acts) and any particular loss of time. H&M's case was that, taken together, it was all those acts of LORAC that had caused H&M to incur the number of man hours of labour over and above those, in effect, budgeted. (Indeed, as I have noted, H&M appeared to recognise this in its adjudication application.) It is clear that H&M asserted, at least implicitly, that there were no other causes. That is because, as I have said, it claimed for each and every one of the hours in question.

McDougall J considered that it was unnecessary to exhaustively review all of the cases that dealt with global claims, or total cost claims, but considered that it was necessary to refer briefly to the decision of Byrne J in *John Holland Construction Engineering Pty Ltd v Kvaerner RJ Brown Pty Ltd* (1996) 13 BCL 262 and to Byrne J's paper *Total Costs and Global Claims* (1995) 11 BCL 397.[14] This was because those materials were relied on by

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[10] *Siemens v Tolco; Tolco v Siemens* [2007] NSWSC 257 at [28].
[11] *Kembla Coal & Coke v Select Civil & Ors* [2004] NSWSC 628; *Quasar Construction v Demtech Pty Ltd* [2004] NSWSC 116).
[12] *Laing O'Rourke Australia Construction v H&M Engineering & Construction* [2010] NSWSC 818 at [42].
[13] *Laing O'Rourke Australia Construction v H&M Engineering & Construction* [2010] NSWSC 818 at [44] and [45].
[14] *Laing O'Rourke Australia Construction v H&M Engineering & Construction* [2010] NSWSC 818 at [74].

both parties in relation to the aspect of their debate in the *Laing O'Rourke* case. In that case, McDougall J did not ultimately consider the permissibility of a global or total cost claim in the context of the NSW Act, nor did his Honour consider that such claims amounted to damages.

The important theme in all of the above decisions[15] is that the Supreme Court of New South Wales did not find that global or total cost claims were incapable of being claims made and determined under the NSW Act. It is more probable than not to conclude on the basis of those decisions that global or total cost claims are allowable under the NSW Act.

This paper advocates for the proposition that global or total cost claims are available remedies under the NSW Act and Queensland Act. This is especially where a contract between a claimant and respondent[16] does not expressly recompense the claimant for delay or disruption caused by the respondent or by a person who is the reasonability of the respondent. This paper also puts forward the proposition that if a global or total cost claim is not an available remedy to a claimant due to principal factors, the notion of a modified total cost claim is open to a claimant and is an available remedy that can be pursued and determined under the NSW Act and Queensland Act.

The principles that underpin an entitlement to a global or total cost claim are supported by a number of authorities and have been derived for the purposes of this paper from English and Australian case law. It can be deduced from Smith J's decision in *Nauru Phosphate Royalties Trust v Matthew Hall Mechanical & Electrical Engineers Pty Ltd* [1994] 2 VR 386 ('the *Nauru* case') that there are four conditions that must be satisfied in order to maintain the validity of a total cost claim. These can be summarised as the following:

1. it is impossible or highly impracticable to determine the losses with any reasonable degree of accuracy;

2. the claimant's contract price must be shown to have been realistic;

3. the actual cost incurred must be reasonable; and

4. the claimant must be shown not to have contributed in any marked degree to added expense, or added to any other events for which the respondent is not responsible, subject to any of the qualifications outlined in *John Doyle Construction Ltd v Laing Management (Scotland) Ltd* [2002] Scot CS 110.

Smith J expressed the view that it may be permissible to maintain a composite delay/disruption claim (a 'global claim') where it was impossible and impractical to identify a specific nexus between each of the alleged events and the particular delay/disruption

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[15] *Shell Refining (Australia) Pty Limited v A J Mayr Engineering Pty Limited* [2006] NSWSC 94; *Siemens v Tolco; Tolco v Siemens* [2007] NSWSC 257; *Laing O'Rourke Australia Construction v H&M Engineering & Construction* [2010] NSWSC 818.

[16] The "respondent" is the person on whom a payment claim is served (e.g., see: *Building and Construction Industry Security of Payment Act 1999* (NSW) ss. 4, 13).

caused. In considering the matter in the *Nauru* case, Smith J distinguished *Wharf Properties Ltd v Eric Cumine Associates No* 2 (1991) 52 BLR 1, but followed *J Crosby & Sons Ltd v Portland Urban District Council* (1967) 5 BLR 121 ('the *Crosby* case')[17], *London Borough of Merton v Stanley Hugh Leach Ltd* (1985) 32 BLR 51, and *Mid Glamorgan County Council v J Devemald Williams & Partner* (unreported, Queens Bench Division decision of Official Recorder, Mr Tackaberry QC, 17 September 1991).

Smith J demonstrated in the *Nauru* case that it is permissible for a disruption claim to be framed globally where the claimant can demonstrate that it is not possible to identify the nexus between the interaction of events and their relationship to the quantum claimed.

In *John Holland Construction & Engineering Pty Ltd v Kvaerner RJ Brown Pty Ltd* (1996) 8 VR 681 ('the *Kvaerner* case'), Byrne J said (at [11] and [12]):

> Further, this global claim is in fact a total cost claim. In its simplest manifestation a contractor, as the maker of such claim, alleges against a proprietor a number of breaches of contract and quantifies its global loss as the actual cost of the work less the expected cost. The logic of such a claim is this: (a) the contractor might reasonably have expected to perform the work for a particular sum, usually the contract price; (b) the proprietor committed breaches of contract; (c) the actual reasonable cost of the work was a sum greater than the expected cost.
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> The logical consequence implicit in this is that the proprietor's breaches caused that extra cost or cost overrun. This implication is valid only so long as, and to the extent that, the three propositions are proved and a further unstated one is accepted: the proprietor's breaches represent the only causally significant factor responsible for the difference between the expected cost and the actual cost. In such a case the causal nexus is inferred rather than demonstrated. For present purposes, I ignore any adjustment that may have to be made for variations and extras. The unstated assumption underlying the inference may be further analysed. What is involved here is two things: first, the breaches of contract caused some extra cost; second, the proprietor's cost overrun is this extra cost. The first aspect will often cause little difficulty but it should not, for this reason, be ignored. The likelihood and nature of some extra cost flowing from the breaches of contract may be readily apparent from the nature of each of the breaches and a general understanding of its impact on the building project. It may also be apparent in what precise way this breach led to the extra cost. In most, if not all, cases, however, there is an intervening step relating the extra cost to the breach. For example, it may be that a breach means that work has to be redone, or that work takes longer to perform, or that its labour or material cost increases, or perhaps that there was extra cost due to disruption or loss of productivity. Again, in the given case this may be readily apparent but difficulties will arise for the parties and the tribunal of fact where the global nature of the claim involves the interaction of two or more of these intervening steps, particularly where they and their role are not, in terms, identified and explained. It is the second aspect of the unstated assumption, however, which is likely to cause the more obvious problem because it involves an allegation

[17] In the *Crosby Case*, reliance on that method is justified in cases where the claim depends on an extremely complex interaction of events and where it may well be difficult or even impossible to make an accurate apportionment of the total extra cost between several causative events.

> that the breaches of contract were the material cause of all of the contractor's cost overrun. This involves an assertion that, given that the breaches of contract caused some extra cost, they must have caused the whole of the extra cost because no other relevant cause was responsible for any part of it.

Based on the above extract, it can be seen that Byrne J set out four elements that are required in order to succeed in a global claim, which are not dissimilar to the four set out in the *Nauru* case. The four elements can be identified as the following:

1. the claimant might reasonably have expected to perform the work for a particular sum, usually the contract price;

2. the respondent committed breaches of contract;

3. the actual reasonable cost of the work was a sum greater than the expected cost; and

4. the respondent's breaches represent the only causally significant factor responsible for the difference between the expected cost and the actual cost.

The concepts of the total cost method have been well illustrated by the extra judicial writings of Byrne J in two articles named *Total Cost & Global Claims* (1995) 11 BCL 397 and *Global Claims: Maze or Way Forward* (1996) 15 ACLR 113.

Byrne J's decision in the *Kvaerner* case indicates that a global claim may be relied upon where it is impractical to disentangle part of the loss which is attributable to each head of claim, and this situation has not been brought about by delay or other conduct of the claimant, and the proprietor's breaches represent the only causally significant factor responsible for the difference between the expected cost and the actual cost. In fact, Byrne J was of the view that where it is found to be impossible or impractical to identify each aspect of the nexus, a demonstration of its probable existence is sufficient.

It can be accepted that the total cost method can be used in claims relating to disruption where the claimant has had difficulty in assessing the impact of individual acts or omissions in financial terms. Where a respondent caused disruption and loss of productivity, it was found: (a) that it was permissible to establish the threshold nexus between the alleged breach and the alleged disruption by establishing that there is no other explanation for the disruption[18]; and (b) that the capacity of the events that caused disruption may be inferred.[19]

Furthermore, where a respondent has been responsible for interruptions beyond the control of a claimant and for acts or omissions by the respondent's agents, this may support a global claim.

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[18] *Nauru Phosphate Royalties Trust v Matthew Hall Mechanical & Electrical Engineers Pty Ltd* (1992) 10 BCL 179 at [192]; *Ralph M Lee Pty Ltd v Gardner & Naylor Industries Pty Ltd* SC Qld, Moynihan J, 1753/1991, 11 February 1993, unreported, BC9302590 at [5].

[19] *Nauru Phosphate Royalties Trust v Matthew Hall Mechanical & Electrical Engineers Pty Ltd* (1992) 10 BCL 179 at [192].

Those propositions were demonstrated in the *Crosby* case, whereby Wilcox J said:[20]

> …In the manner of pointing a blunderbuss at a target it is maintained that there were many RFI's, and there was considerable delay. The delay in part can be explained by other causes but a balance is left which must be caused by the volume of RFI's. In addition, by reason of the volume of them negligence must be concluded. It is termed a global claim. It can properly be described as a global claim in the sense that it is the antithesis of a claim where the causal nexus between the alleged wrongful act or omission of the defendant and the loss of the plaintiff has already been clearly spelt out…

In other words, a total cost claim is a claim in which the nexuses between cause and effect in individual cases is *'globally'* and not on an item-by-item basis. It is not necessary to prove that all the matters, which formed part of the total cost claim, were the responsibility of the respondent. However, it is necessary for the claimant to demonstrate that any liability for disruption, which falls on the claimant, has no material effect. This was considered in *John Doyle Construction Ltd v Laing Management (Scotland) Ltd* [2002] Scot CS 110, where Lord McFadyen said (at [37]):

> …Failure to prove that a particular event for which the defender was liable played a part in causing the global loss will not have any adverse effect on the claim, provided the remaining events for which the defender was liable are proved to have caused the global loss…

The claimant is not required to demonstrate causation, the nexus of the facts with causation and the adequacy of the information relied upon as the basis for the total cost claim. This was addressed in *John Holland Pty Ltd v Hunter Valley Earthmoving Co Pty Limited* [2002] NSWSC 131, whereby McClellan J said:[21]

> The description of a claim as a "global claim" is familiar to those involved in the construction industry. Generally, it is used as a "short-hand" method of describing a claim, which does not readily permit of the individual identification of each of its component parts.

The consequence from the above is that the burden of proof effectively passes to the respondent to produce evidence of non-compensatory events, which caused or contributed to the overrun.[22] This places a considerable tactical burden on the Respondent.[23]

In the event that the respondent can demonstrate that the claimant caused or contributed to the overrun of the costs claimed on a global basis, the question arises whether the claimant's whole global claim should fail. The answer must be no because the figures forming part of the global claim can be adjusted under the principle of a 'modified total cost claim' in order to provide a just measure of extra cost. This proposition would arise if an allocation of responsibility were attributable to the claimant, whereby the Adjudicator should

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[20] *London Underground Ltd. v Kenchington Ford plc and others* (1999) CILL 1452.
[21] *John Holland Pty Ltd v Hunter Valley Earthmoving Co Pty Limited* [2002] NSWSC 131 at [12].
[22] See *Nauru Phosphate Royalties Trust v Matthew Hall Mechanical & Electrical Engineers Pty Ltd* (1992) 10 BCL 179 and Byrne J, *Total Costs and Global Claims* (1995) 11 BCL 397.
[23] *Saccharin Corp Ltd v Wild* [1903] 1 Ch 410.

apply a 'modified total cost' approach to the task of assessment. Such an approach was accepted in the *Crosby* case, where Donaldson J said:[24]

> I can see no reason why (the arbitrator) should not recognise the realities of the situation and make individual awards in respect of those parts of individual items of the claim which can be dealt with in isolation and a supplementary award in respect of the remainder of these claims as a composite whole.

The concept in the *Crosby* case was somewhat expanded in *John Doyle Construction v Laing Management (Scotland) Ltd* [2004] Scots CS 141 (11 June 2004), whereby Lord Drummond Young LJ said (at [16]):

> ...if it cannot be said that events for which the employer is responsible are the dominant cause of the loss, it may be possible to apportion the loss between the causes for which the employer is responsible and other causes. ...Where the consequence is delay as against disruption, that can be done fairly readily on the basis of the time during which each of the causes was operative. During [that period] each should normally be treated as contributing to the loss, with the result that the employer is responsible for only part of the delay during that period. Unless there are special reasons to the contrary, responsibility during that period should probably be divided on an equal basis...
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> Where disruption to the contractor's work is involved, matters become more complex. Nevertheless, we are of opinion that apportionment will frequently be possible in such cases, according to the relative importance of the various causative events in producing the loss. ... It may be said that such an approach produces a somewhat rough and ready result. This procedure does not, however, seem to us to be fundamentally different in nature from that used in relation to contributory negligence or contribution among joint wrongdoers.

The concept of apportionment in *John Doyle Construction v Laing Management (Scotland)* [2004] Scots CS 141 has not been entirely appreciated within the context of the NSW Act and Queensland Act. The present authority in Australia within the confines of statutory adjudication has only gone so far as supporting global or total cost claims on the dictum in *John Holland Construction Engineering Pty Ltd v Kvaerner RJ Brown Pty Ltd* (1996) 13 BCL 262.

4. Conclusion

It is implicit that delay, disruption and global claims can be permissibly made by a claimant and determined by an Adjudicator under the NSW Act. The Supreme Court of New South Wales considered such claims within the context of the NSW Act and generally supported their application. Whilst the authority in New South Wales is not binding on the Supreme Court of Queensland it is submitted that the available remedy for delay, disruption and global

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[24] *J Crosby & Sons Ltd v Portland Urban District Council* (1967) 5 BLR 121 at 136.

claims within the context of the Queensland Act is persuasively supported by the dicta of New South Wales.

The contract is the genesis to support the right for a claim on account of delay or disruption costs arising from an extension of time granted under the contract, or where an Adjudicator decides that an extension of time ought to have been granted under the contract. The remedy of global or total cost claim concepts under the NSW Act and the Queensland Act are not curtailed in the absence of a contractual right to claim for delay or disruption costs. This is especially where it is not possible to identify the nexus between the interaction of events and their relationship to the quantum claimed. This is however subject to common law precedent that encapsulates the elements that are required to be made out to support global or total cost claims and the concept of apportionment.

Acknowledgements

The authors wish to acknowledge the support provided by the NSW Department of Finance & Services for the *Adjudication Research + Reporting Unit (ARRU)*. The authors wish to thank the anonymous reviewers for their constructive comments on the manuscript.

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Residential real estate education and globalisation in Australian real estate markets and practices

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Abstract

The purpose of this scoping paper is to offer an overview of the literature to determine the development to date in the area of residential real estate agency academic and career education in respect to Foreign Direct Investment (FDI) transactions and implications in Australia. This paper will review studies on the issue of foreign real estate ownership and FDI in Australian real estate markets to develop an understanding of the current state of knowledge on residential real estate agency practice, career education and real estate licensing requirements in Australia. The distinction between the real estate profession education, compared to other professions such as accounting, legal and finance is based on the intensity of the professional career training prior or post formal academic training. Real estate education could be carried out with relatively higher standards in terms of licensing requirement, career and academic education. As FDI in the Australian real estate market is a complex globalisation and economic phenomenon, a simple content of residential real estate training and education may not promote proper management or capacity in dealing with relevant foreign residential property market transaction.

The preliminary summarising from the literature of residential real estate agency education, with its current relevant or emerging licensing requirement are focused on its role and effectiveness and impact in residential real estate market. Particular focus will be directed to the FDI relevant residential real estate agency transactions and practices, which have been strongly influenced by the current residential real estate market and agency practices.

Taken together, there are many opportunities for future research to extend our understanding and improving the residential real estate agency education and training of Foreign Direct Investment in the Australian residential real estate sector.

Keywords: Foreign Direct Investment (FDI), Real Estate Education, Australia, Globalisation, Ownership

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1. Introduction

The residential real estate sector is one of the critical economic indicators for a country, contributing significantly to GDP, and having extensive connection with other industries, such as construction, investment banking, insurance and many more. Since adopting the Australian Economic Policy in the 1980s, Australia has increased its trade intensity from 28% to 40% and household estimated income of $3900 per annum (Department of Foreign Affairs and Trade 2011). Since the Annual Demographic International Housing Affordability Survey, increasing Foreign Direct Investment (FDI) inflows for the acquisition of residential real estate identified the ownership affordability crisis in Australian metropolitan residential real estate as amongst the most severe in English-speaking nations. To its extent, conflict has gradually arisen between domestic and foreign ownership in the Australian residential real estate market (Kotkin 2011; Bruegmann 2012).

More international residential real estate has begun transacting since the early 1980s keeping pace with the globalisation phenomenon. Nevertheless, Australians enjoys the economic growth from the benefit of globalisation. At the same time, there is noticeable concern of speculation activities in the Australian residential real estate markets, where extra capital has not been structurally distributed and is instead being misallocated with unproductive activities. For example, Australian residential real estate education does not sufficiently train the real estate profession to act as the frontline gate keeper from the reverse effect from globalisation for the Australian residential real estate markets instead contributing some or in part to the speculation activities. Furthermore, real estate agents require minimum formal academic or professional qualifications which has caused some concern and consequence in regards to the injustice and asymmetry real estate market condition (Bishop 1993; Small 2001).

Increasing percentage of domestic and international home investment and purchase are demanded in the Australian residential real estate markets. There were 7,265 real estate agencies during 1992 to 1993. At the end of June 2003, the real estate industry contributed around $6.818 million to GDP, although more than 2763 people joined and worked in the real estate services industry. There is a trend of an increasing number of real estate businesses, especially small companies, joining the real estate market. The Real estate industry recorded the largest absolute increase in operating profit before tax in 2010 ($11.1b). Over the five years through to 2011, revenue within the real estate industry is expected to grow at an average annual rate of 1.5% (Australian Bureau of Statistics 2011). Given the significance of residential real estate education, markets in respect to foreign and domestic ownership of Australian residential real estate market, it is worthwhile to conduct further research on the relevant issues.

2. Literature Review

2.1 Education and Standard Operation Procedure in Australia

Unlike other business sectors with higher industry standards, such as accounting, banking and finance, influenced by the widespread phenomenon of de-regulation in the 1990s, the

real estate sector minimised its self-regulating Standard Operation Procedure (SOP). One of the important traditional resources integrated in the franchise system in some cases is to reinforce the re-training on SOP or certain standard of practices conduct in order to lessen the agency's costs and problems within a real estate organisation (Flint-Hartle and De Bruin 2011).

A real estate agent is required a minimal education in dealing with such important capital assets or heavy mortgage burden for average householders. However, each of the states in Australia has a different standard of real estate education, including registration and licensing training course. Moreover, Small (2001) concurs that there is relatively little practice training and SOP available for agents. On the other hand, the Australian residential real estate markets attract a large number of foreign direct investments which will be a far more difficult and complex issue. Authors such as Storms (2000) argued that some real estate investment transactions are highly complex. He further pointed out that the current estate financial planner has low educational requirements. Foreign real estate transactions involve more complex financial planning analysis for each individual investment. Real estate agents with absolutely no relevant financial planning training have played a blurred role of estate financial planner confined in the past legislative regime (Storms 2000)

Research carried out at the tertiary level has a little sound understanding of the Western or other institutionally based contemporary real estate theory and relevant agency practice (Small, 2001). Some high-context Asian cultures practice systems of land real estate that are quite evidently feudal and different to Western systems (Small, 2001). Percudani (2010) also stated that the current law imposed on the licensed principal agent, including new consumer protection law could improve agency practice as it will be the responsibility of principals to ensure they have employed, and then appropriately trained and equipped sales people, including consumer protection obligations. Potential concerns are raised in dealing with investors from foreign cultures with differing value systems. It is important to investigate the effect of relevant issues (Sharma and Bandara 2010).

The lesson should be learnt from the United States secondary loans in the housing market in 2008. However, misbehaviour is difficult to identify with current real estate legislation or state consumer protection. It has indeed relied on the general guidelines of Commonwealth consumer protection of misleading and misrepresentation (Parliament of Australia 2011). Furthermore, despite academics promoting the benefits and significance of jurisdiction and dual agency significantly reducing sales prices, there still appears to be a much smaller influence to date after the legislation (Kupke 2004; Gardiner et al. 2007). The desire is to build real estate education extending beyond the traditional valuation and analysis fields (Hefferan and Ross 2010). It is for this reason that ideas are developed politically and educationally, as suggested by Crews (1998) in which real estate agents have to pay attention in developing strategies to ensure the needs of society. With the current advanced technology used such as the World Wide Web, Information system database, 3D photography (real estate dot com). The service offered by real estate agents in the past is no longer genuine but possible for substitution in the foreseeable future.

This paper with the relevant literature argues that real estate education has to improve the quality or standards in order to meet more contemporary complex Globalisation issues currently facing the real estate industry (Newell and Acheampong 2002; Schulte et al. 2005). For example, the buyer has the potential to be ill-represented in the overwhelmingly dual agency environment in real estate markets and practices in Australia (Blumenthal 1995; Zeitz and Newsom 2002). Foreign direct investors are likely to suffer in a higher degree of information asymmetry, wrong perceptions and ethical issues in the transaction. The new Occupational Licensing National Law Act 2010 will list real estate licensing in the first wave of the standardisation process which may begin in July 2012 (National Occupational Licensing Authority 2010). It has long been a concern for public policy makers of misconduct and mismanaged agency behaviour. It is deemed the first step to improve the real estate agency practices in Australia. (Clauretie and Daneshvary 2008; Dickie 2011). It will summarise ownership in the Australian residential real estate markets in the next section. It will clearly discuss the relationship between real estate education and ownership.

2.2 Ownership

Australian residential real estate ownership changes from time to time and from domestic to international externality effects, including the international financial market, exchange rate, interest rate and FDI or global economy movement. The issue of foreign residential property ownership and its impacts, availability, affordability has been a concern for Australian regulatory bodies since 1960. In line with one key issue in residential real estate education, it is critical to deal with residential real estate foreign ownership by employing this specialised real estate education in the relevant field of study (Schulte 2003). Indeed, foreign direct investment (FDI) in globalisation practice is made more complex by dated real estate career and training requirement in Australia.

Seabrooke et al., (2008) concluded that the economic transaction in international real estate including FDI, marks the point at which ownership rights are assigned or exchanged. On the other hand, several authors indicated that residential real estate ownership is commonly associated with obligation to the state and a mean of social right instead of wealth (Mortensen and Seabrooke 2008; Small 2004). Indeed, it is a challenge for policy makers to balance the policy regards residential homeownership between social right and solely economic transaction. However, Australia now has a certain degree of limitation on FDI which has been imposed by the Foreign Investment Review Board (FIRB), an advisory government agency in dealing with FDI in the Australian residential real estate market. However, some research indicates the FIRB guidelines of FDI in the residential real estate sector have a potential nature of foreclosed ownership. For instance, the FIRB guidelines potentially mean the foreign entity have limited rights in full possession of the ownership (Commonwealth of Australia 2011).

The globalisation of economic activity stimulated a large number of international real estate transactions which has also brought benefits to the economy and residential real estate industry with opportunity costs in Australia. There are also some opportunity costs from globalisation in the residential real estate markets, agency practices and education. These opportunity costs are the issue of affordability, likely reduction of Australian domestic

residential ownership, government restriction imposed to FDI and confrontation between domestic and international residential ownership and quality improvement on real estate education. Furthermore, it potentially facilitates domestic real estate speculation with current real estate practice which can result in a bubble Australian residential real estate markets. In recent years, Australia has become one of the nations encountering the most unaffordable properties amongst the English speaking nations. Additionally, there are numerous problems of affordability and availability that have resulted from the restriction on land development on marginal urban areas (Gao 2005; Bruegmann 2012; Kotkin 2011). According to FIRB data released in August 2009, these direct impacts of foreign investment of the Australian real estate market represent an increase of 30%. FIRB believes that FDI has resulted in increasing residential real estate prices and increasing borrowings (Mortensen and Seabrooke 2008; Bentick and Lewis 2003). Those concerns have gradually become a deliberation for all Australians for the best solution that either blocks all FDI or welcomes it, with well-trained real estate professionals to handle the extra capital and minimise the adverse effects. The media and scholars have reported on real estate agency practice speculation activities such as real estate investment seminars, two-tier marketing, and the bubble effect of price estimation. Hence, this paper argues that there could be a better management put in place either from the government or industry self-regulating professional standard.

The effect of FDI has rapidly increased in Australian ownership since opening up economy and globalisation. It is instructive to consider FDI undertaken through chains of ownership by FDI. Hence, the next section will review the literature of FDI in Australian real estate markets to develop an understanding of the current state of knowledge on the requirements of the education systems in Australia.

2.3 Foreign Direct Investment

The Australian residential real estate markets rapidly increased demand by domestic or foreign purchasers since the opening up economy and globalisation Policy by the Hawke Government in 1983 (Department of Foreign Affairs and Trade 2011). The FIRB introduced policy and a new screening program in “sensitive” residential real estate markets between 2008 and 2011. In general, FDI in residential real estate markets has dramatically decreased an average 20% annually since 2008 (Blonigen 2005). It could increase the regulatory cost for investors. Furthermore, domestic and international investors in residential real estate markets will act closely with the government and Central Bank policy making process and outcomes. The issues of exchange rate, competitive advantage, and interest rate surrounding FDI in globalisation practice will be taken into consideration by policy makers of the appropriateness of tightening policy at the time of global financial chaos from year 2008 to the present. FDI thus become one of the most modern forms of international real estate phenomenon (transaction) as FDI is getting more prudent and well-educated on the knowledge of prime international real estate investment (Seabrooke et al., 2008).

In the past, urban development in residential real estate was focused on state regional or even in the local council areas. In early 1980 and 1990, private foreign investment was mainly underlying to share-holding or portfolio types of real estate investment (Seabrooke et

al., 2008). In addition, the OECD has investigated that FDI in Australia is restricted in the real estate sector, where FDI in the real estate index ranked 0.3 compared to an average of OECD countries 0.283 and average of all countries 0.281 respectively (restrictiveness = 1, open = 0). The real estate Index used weights largely based on the sector share in global real estate FDI flows. Overall speaking, Australia is a country with restrictive policy toward to FDI which is ranked relatively higher by the OECD amongst the OECD member countries and average of all countries, where FDI Index Scores by Country score Australia 0.138, all countries 0.117 and OECD average 0.095 (restrictiveness = 1, open = 0). Hence, the recommendation of the OECD is that Australian foreign investment rules could be more relaxed (Jinjarak 2007).

In the international FDI framework, foreign investors informally represent their home countries; protectionist trade policy could lead to retaliatory consequences of deteriorating diplomatic relations between host and home countries and face various expropriation risks. Protectionist policy in residential real estate markets is twofold, whereas it could result in harmful perception to international investors, loss of credible commitment, fewer economic ties with others and careless externality pressure. It could potentially mean loss of jobs, more external debts, affordability crises in residential real estate markets and even domestic financial crises.

The tightening policy was initiated in 2008 by the Australian Labour Party. It means that there is no sign nor, yet any effective measurement in improving the speculative activities. At present, there are no guaranteed property rights, free transfer of property by either voluntary contractual agreement or keeping promise made in relation to social transactions. It has become an institutions risk for FDI in engaging in international real estate transactions with Australian residential real estate markets. In line with the argument of Karl-Werner Schulte (2005) “real estate education needs to convey the knowledge required for property involvements in the global context”. Indeed, it is the most urgent and important aspect of structural reforms in the Australian residential real estate industry. The structural reforms that have recently begun are the first step on the unification of federal licensing requirement. The ongoing first step measure of the reform appears as a glimpse into further promoting the current minimal real estate education requirement which is the most essential core value of training real estate professions in dealing with the complexity of FDI or international real estate as a globalisation phenomenon.

3. Research Methodology

This scoping paper is based on the real estate educational system that will be summarised from the dominant residential real estate professional bodies in the following institutions: Real Estate Institute of Queensland (REIQ), Real Estate Institute of New South Wales (REINSW), Real Estate Institute of Victoria (REIV), Real Estate Institute of Northern Territory (REINT), Real Estate Institute of Western Australia (REIWA) and Real Estate Institute of Southern Australia (REISA).

Data from the websites of these six institutions were conducted over a 2 month period from October to November, 2012. Furthermore, all the data from all the profession institutions

have been the most up to date version on 13th November 2012. To determine a more accurate level of information, all data are updated information for research method in this research which making replicable and valid inferences to provide a representation of facts and a practical guide to action. It was found that the educational system and Standard Operation Procedure in each of the states have a different standard to follow (Table 1).

Table 1: A summary of licensing requirement of professional bodies in Australia

Residential Salesperson	QLD	NSW/ACT	VIC	WA	SA	NT
Shortest Time in completion of registration	10 days	4/5 days	5 days	8 days	6 wks	52wks
Units in completion of registration requirement	7 units	4 units	3 Units	7 units	17 units	24 units
Interim Registration	No	No	No	No	No	Yes
Salesperson Registration with Certificate III Units	No	No	No	No	Yes	Yes
Employment requirement	No	No	No	No	No	Yes
Licensing Course						
Shortest Time and units completion of Licensing	12.5/5 days, full/fast track	25days	2months*	6 months	6 wks + 8 units	52 wks + External
Units in completion of Licensing requirement	19	21+3 registration	24	26	25-27	26
Diploma otherwise Certificate III	No	No	No	Yes	Yes	Yes
Employment Requirement/*salesperson registration	No	Yes*	Yes	Yes	No	Yes
Compulsory Continuing Career Development (CAD), *=available	No*	Yes	No*	Yes	No*	No*
Developer	Yes	No	No	No	Yes	No
Buyers agent	Yes	Yes	Yes	No	No	No
Education with Finance Stream	Yes	Yes	Yes	Yes	Yes	Yes
Economy, Investment, &Foreign Investor Stream, Taxation and Accounting, Ability of future excellence of research and development	No	No	No	No	No	No

In the preliminary analytic process, this paper strives to make sense of the data and present the real estate educational system in Australia. All the available residential real estate registration and licensing courses are currently synchronised with Australian National Recognised Training. Firstly, they provide the variety of the delivery modes in order to provide flexibility. For example, the days of shortest time in completion of registration in Northern Territory is 1 year followed by South Australia (6 weeks), Queensland (10 days), Western Australia (8 days), Victoria (5 days) and New South Wales (4 days). Also, similar professional training could be undertaken in the other occupational institutions such as TAFE or other recognised private occupational training providers. Notably, the Real Estate Institution of Northern Territory describing the agents Representative Introduction course contains a non-in-depth knowledge of the real estate industry, but only introduction to the

basic legislative requirements and type of work in the real estate industry. According to the table, a registered residential salesperson in Queensland, New South Wales and Victoria is considered an industry profession without an in-depth knowledge of the real estate industry.

According to Table 1, Northern Territory (REINT) has the best carrier training standard in residential real estate salesperson registration than in Queensland, New South Wales and Victoria. Moreover, Northern Territory is the only state to offer the Interim sales representative registration with the supervision of a licensed agent in the progression of introduction to real estate sale representative course. For instance, it is very similar to the mentorship of the accounting profession. In Northern Territory, to be a registered sales representative one has to firstly complete the introduction and concurrently enrol into the Certificate IV in Property Service. The Licensing Course at the diploma level is comprised of 25-28 Units which are only available in Western Australia, South Australia and Northern Territory. The Certificate III Licensing Course is offered by Queensland, NSW (ACT) and Victoria. As mentioned previously, under the new unification of Occupational Licensing National Law Act 2010, all the training is now synchronised in the similar bases. The content units in Table 1 offered by REINT covers most of the units availability in other states with minor differences in the legal framework in each states.

Table 2: A methodology summary of previous research

Year	Surname	Keyword	Method	Summary Finding
2011	Flint-Hartle and de Bruin	franchising, New Zealand, real estate brokerage, system success	Quantitative: Second Hand and Qualitative: interview	The franchise system in some cases is to reinforce the SOP or certain standard of practices conduct in order to lessen the agency's costs and problems within a real estate organisation
2010	Sharma and Bandara	Foreign Direct Investment, Australia, Regional integration	Second hand data, Examine Hypotheses Quantitative, multiple regression	Australia could deal effectively with inward and outward foreign direct investors with similar cultural or language background. Hence, in certain degree loss of international linkage which is not addressed in real estate education
2010	Hefferan and Ross	Universities, Higher education, Professional services, Property, Australia	Qualitative: Interview, content analysis	There is a strong demand for tertiary/property real estate education as it is the critical economic sector in Australia.
2007	Small and Karantonis	Property education, academics, teaching	Qualitative: Survey	There are absences of terminal degrees, compensated for by strong industry experience. It appears to be an over-emphasis on Lecturer level academics. The challenge of limited upper level academic. It is a challenge to the quality of university education. This has potentially identified the problem that it is questionable that real estate career training is conducted by an instructor of strong industry experience without formal trained academics.
2005	Schulte, Schulte-Daxbok, Holzmann and	International Real Estate Education	Qualitative: university real estate	1. Increase the proportion of departments and faculties that cover foreign countries from a real estate perspective. 2.International real estate

	Wiffler		programme web scanning, Quantitative: survey	education curricula could be enhanced by accredited internationally recognised bodies to gain reputation and international cooperation
2003	Schulte	Real estate, investment, finance, education	Quantitative	At present, real estate investment and finance play an important role in real estate discipline. However, FDI being the critical form of real estate investment is indeed being overlooked in the development of relevant fields of study in real estate discipline either in University or industry level throughout the world.
2002	Newell and Acheampong	Property education, GCCA surveys, benchmarking, teaching quality, student satisfaction.	Quantitative: Survey	A broader property education strategy is clearly needed. The strategy is likely to draw on teaching approaches from other disciplines, integrating national and international best practice, as well as expanding the benefits of the property industry assisting more effectively in property education.
1998	Crews	Real estate agency, real estate agency practice,	Qualitative: Law review, Case Study	Real estate agent has to be careful in developing the strategy to ensure the needs of society. The importance of training and education is one of the major strategies.

To date, real estate studies have been focused with the foreign direct investor dominating the real estate studies undertaken. Australia should deal effectively with inward and outward Foreign direct investors with a similar cultural or language background (Sharma and Bandara 2010). This has caused the costs and problems of the certain standard of practices within a real estate Industry (Flint-Hartle and De Bruin 2011). This paper has identified the problem for further research that it suspects that real estate training and/or licensing courses are conducted by instructors with industry experience, but without formal training (Small and Karantonis 2007). Finally, there has been little examination of the impact of educational importance in recent real estate studies despite our knowledge that real estate education exists. Clearly, there is a need for greater effort to investigate global real estate education especially in the area of Foreign Direct Investment. The preliminary findings above provide a useful reference and guide by a summary of key characteristics. Still, there is a room to extend and enrich real estate education with border strategy. The strategy is to draw on teaching approaches from other disciplines integrating national and international best practice (Newell and Acheampong 2002; Schulte et al. 2005).

This paper also recommends future research with similar approaches as shown in the table above. It should examine real estate education across states to further enhance the standard of Australian real estate education and career training. In addition, single methods have dominated real estate studies over the past ten years with considerably fewer studies utilising multiple methodologies. Therefore, future research studies should utilise mixed methods when examining this important matter.

4. Conclusion

This paper uses the preliminary information of the current education systems from all states and real estate literature to investigate and again an understanding of the current education systems in the Australian real estate industry. As the national licensing requirement has been unified in recent years, gaining a real estate license is to take the diploma of agency management in South Australia, Western Australia and Northern Territory. In all other states, the requirement of the real estate licensing course is still not as sufficient as diploma level. Unlike the professional bodies in other industries, it is designed for specified industry standard of procedure, research issues, attestation in the previous academic qualifications or avoiding misbehaviour. This research confirmed with Schulte's (2005) study that Australian real estate agency education is encountering an urgent structural reform in the nature of regional and national focus.

The different standards of education systems will in turn be vigilant for the Australian real estate sector which should generate the structures and standards of education systems across Australia. However, with the issues of agency relationship, social responsibility, and real estate bubble incurred by agency practice, ethics, training and misconduct have long been overlooked by real estate professions which reduce customer and client satisfaction (Zietz and Sirmans 2011). It is critical to address the globalisation of real estate education for the industry. A more global standard to real estate education can provide a more professional real estate service for the Australian real estate markets, as well as improving agents to locate FDI that actually meets all the investment from local and foreign investors. Future research in this area is therefore necessary to identify the education and globalisation in the Australian real estate markets.

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Establishing the 'DEA Energy Management System' for Individual Departments within Universities - An Exploratory Study

Kung-Jen Tu[1]

Abstract

The energy management of existing buildings has become a critical research topic worldwide. The mixed use of a single university facility by different departments is prevalent in Taiwan and has complicated the energy management task. Individual departments need a tool capable of assessing their energy efficiencies from 'management' perspective. This study explores the 'space type' and 'internal benchmark' research concepts as well as the 'data envelopment analysis' method to establish the 'DEA Energy Management System (DEMS)' to assist individual departments within universities in assessing the energy efficiencies of their facilities from 'management' perspective. The DEMS proposed considers each 'space' in a given 'time' (such as a month) as a DMU. Then, regression analysis is performed on data of the independent variables related to the 'existing environment' and 'occupancy' factors, and data of the dependent variable (actual energy consumption EUI) of all DMUs. The regression equation derived is then used to calculate the 'predicted EUI' for all DMUs. The 'actual EUI' is considered as the input data, and the 'predicted EUI' as the output data of the DEMS, on which data envelopment analysis is conducted to produce three types of energy efficiency scores (overall efficiency, scale efficiency, and pure technical efficiency) to indicate the energy efficiencies of all DMUs. The 'pure technical efficiency' scores reveal the 'energy management effectiveness' of all DMUs. Those DMUs on the efficiency frontier are the most energy efficient ones and are given with the highest pure technical efficiency score of 100%; and those DMUs that are away from the frontier are less efficient ones and are given with efficiency scores less than 100%. Energy efficiency assessments can also be performed to compare the energy management effectiveness among different space types as well as those of individual space types over time. The DEMS will be implemented in the Department of Architecture of NTUST in Taiwan to illustrate how it can be used to assist individual departments within universities in assessing the energy management effectiveness of their spaces and in improving the energy efficiencies of their facilities. The implementation research tasks to be conducted are planned and outlined.

Keywords: space type, internal benchmark, existing environment factors, occupant and management factors, energy management effectiveness

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1. Introduction

1.1 Background

‘Energy management’ has become an important facility management issue for universities in Taiwan. Individual departments within universities are usually held responsible for managing the energy efficiency of their facilities. This becomes an even more challenging task when several departments occupy the same facility and that individual departments lack reasonable energy consumption benchmarks or indices. Although Taiwan government has issued average EUI indicators for different categories of universities as energy benchmarks, nonetheless, these single indicators are unable to assist facility managers in further assessing the energy efficiencies of their facilities, spotting the over-consumed areas and causes, and identifying the subject and directions of energy management (Tu and Lin, 2012). As a result, the average EUI indicators are not as practical and effective for 'energy management' purpose.

Similarly, several energy efficiency scales, such as the average energy use intensity (EUI) of various types of building, have been established to indicate the energy efficiency of existing buildings, or regarded as the external benchmarks or energy saving targets for existing buildings in different countries (US Green Building Council, 2009; Lee et al., 2007; Poel et al., 2007; Bohdanowicz and Martinac, 2007; Chung et al., 2006; Haji-Sapar and Lee, 2005). These energy efficiency scales might be able to indicate the energy performance at the ‘building’ level; yet they fail to inform a ‘department’ or 'institution', who occupies only certain floors of a building, much about the energy efficiency of its facility at the 'floor' level.

To be effective in building energy management, it's essential to first realize there are three groups of factors that may affect the energy consumptions of individual departments. The first group of factors are 'existing environment' factors, including existing climate factors (such as temperature and relative humidity) and existing building infrastructure factors (such as building enclosure, opening, types and performance of lighting, HVAC and various equipment). Since the 'existing environment' conditions of a facility most likely remain unchanged over the course of its building life cycle, their effects on annual energy consumptions can be considered stable and predictable. 'Occupancy' factors, such as use patterns, work and equipment needs, and environmental quality requirement, are the second group of factors and are the deciding factors that differentiate energy consumptions among various space types (different functional use), given the fixed 'existing environment' conditions. For each type of space, the effects of 'occupancy' factors on energy consumptions can also be regarded as predictable as well, since its occupancy use patterns are more or less stable over time. Finally, 'management' factors, such as department's operation strategy and occupant's energy consciousness, are the third group of factors that have critical and variable effects on building energy consumption. Individual departments with active energy management strategies are likely to further reduce their building energy consumptions, and vice versa.

Within the same building (same 'existing environment' conditions), two departments with different 'occupancy' needs are likely to consume different amount of energy, and it will be

unreasonable to say that the department consuming less energy is more energy efficient than the other. This study thus argues that it is critical to take into account the 'management' factors while assessing the energy efficiencies of individual departments within universities. For effective energy management, individual departments are in great need of a tool capable of first assessing their energy efficiencies from 'management' perspective to identify problem areas and improvement plans exhibiting immediate energy saving effects, before any other expensive energy saving measures such as building renovations are taken.

1.2 Research objectives

To assist individual departments in their complex energy management tasks, this study adopts the research concepts of 'space type' and 'internal benchmark' proposed by Tu and Lin (2012). The concept of 'space type' allows us to explicitly observe and distinguish the effects of 'occupancy use patterns' on energy consumptions among different space types. When a standard energy consumption can be identified for each space type, then the standards energy consumptions of all space types can be aggregated as the 'internal benchmark', which becomes a reasonable energy references for individual departments.

The data envelopment analysis (DEA) has been generally used in the performance assessment of resource usage. In the field of building energy management, it has been adopted to assess the energy efficiencies of several building types, such as hotels (Önüt and Soner, 2006), commercial buildings (Chung et al., 2006) and school buildings (Filippin, 2000). This study believes that it is potentially applicable to energy efficiency assessment of various 'space types' within individual departments.

The objectives of this study are to adopt the ‘space type’ and ‘internal benchmark’ research concepts, and to explore the idea of applying the ‘Data Envelopment Analysis’ method in establishing the ‘DEA Energy Management System (DEMS)’ to assist individual departments within universities in assessing the energy efficiencies of their facilities from the 'management' perspective. The underlying DEA theory as well as the methods of the DEMS in assessing the 'energy management effectiveness' of individual departments are described. The DEMS is to be implemented in the Department of Architecture of a national university (NTUST) in Taiwan. The future implementation research tasks are outlined in this study and assessment results will be reported later.

2. Theory of data envelopment analysis (DEA)

Data envelopment analysis (DEA) is a method developed to empirically measure the relative productive efficiencies of multiple 'decision making units' (DMU), such as organizations, firms or institutions, when the production process presents a structure of multiple inputs and outputs (Charnes et al., 1978). DEA measures the efficiency of a DMU by evaluating its input level relative to its output level, and comparing them against those of other DMUs. Conceptually, a DMU is considered as 'efficient' if it can produce more outputs with less inputs. A numerical efficiency score is given to each DMU, defining its relative efficiency. DEA identifies the most efficient DMUs as the benchmarks which form a 'frontier' (line ABC in Figure 1) against which the relative performance of all other DMUs can be compared.

Those DMUs on the frontier are the most efficient ones and thus are given with the highest efficiency scores 100%, and all other DMUs are considered less efficient (such as D in Figure 1) and are given with efficiency scores less than 100% . A DMU can be made efficient either by reducing the input levels and getting the same output (input orientation) or by increasing the output level with the same input level (output orientation). In addition to providing efficiency scores, DEA can inform the less efficient DMUs of their potential benchmarks and efficiency improvement targets. For example, it is suggested that D in Figure 1 consider S as its benchmark and improve its efficiency by reducing its input level from L4 to L3 while remaining at the same output level Q.

DEA has been applied to assessing the performance of organizations such as banks, hospitals and corporations. Besides, some researches have used DEA for 'project selection' purpose (Sohn & Moon，2004；Cook & Green, 2000；Sowlati et al., 2005). The main advantage to this method is its ability to accommodate a multiplicity of inputs and outputs. It is also useful because it takes into consideration returns to scale in calculating efficiency, allowing for the concept of increasing or decreasing efficiency based on size and output levels. A drawback of this technique is that model specification and inclusion/ exclusion of variables can affect the results (Berg 2010). This study argues that DEA can be potentially applied to assessing the energy management effectiveness of various space types within individual departments.

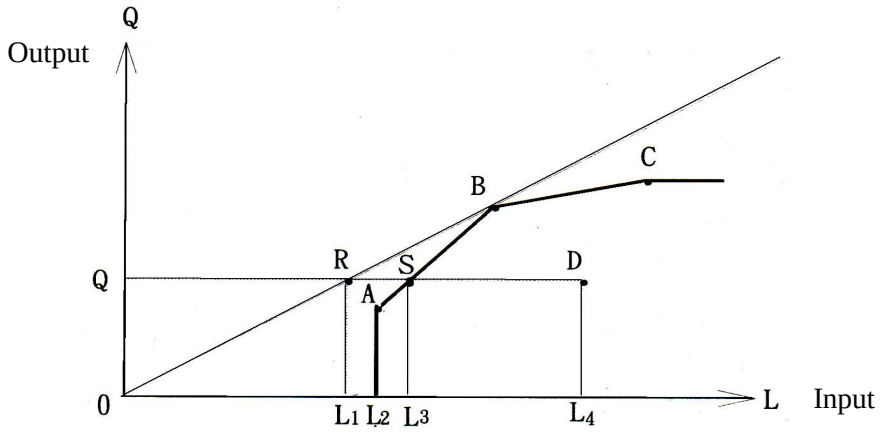

Figure 1: DEA identifies A, B, C as the most efficient DMUs which form the 'frontier', and suggests that DMU D move towards S by reducing its input level from L4 to L3.

3. Establishing the DEA Energy Management System (DEMS)

3.1 Approaches of DEA application in energy efficiency assessment

3.1.1 The 'space-time' DMU definition

This study considers each 'space' in a given period of 'time' (a given month, week, or day) as a DMU and assess the 'energy management effectiveness' of all DMUs (Figure 2). To be more specific, a DMU is defined as 'a space in a month' in this study. In other words, the monthly input and output of a space (type) will be used to assess its energy management

effectiveness; and each space in different months are considered as different DMUs. The 'space-time' DMU definition allows us to assess and compare the energy management effectiveness among different space types or that of a particular space over time. In other words, this approach allows us to identify 'the best practice or worst case' among different space (types) or those of a particular space (type) over time.

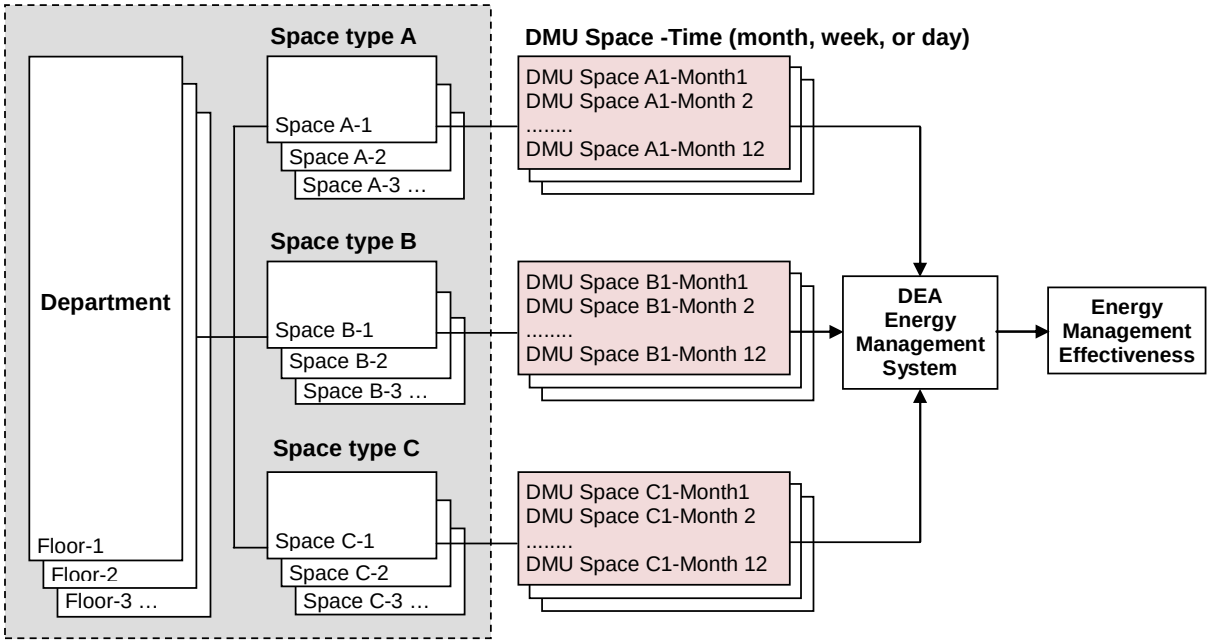

Figure 2: Each 'space' in a given period of 'time' is regarded as a DMU whose energy management effectiveness is further assessed by the DEMS.

3.1.2 Multiple regression analysis

As mentioned earlier, the actual energy consumption of each space is an interacting result of three groups of factors, i.e., the 'existing environment' factors, the 'occupancy' factors and the 'management' factors. For each space (type), since its 'existing environment' conditions most likely remain unchanged over time, and its unique 'occupancy' use patterns are rather stable over time, their effects on energy consumptions can be considered predictable. If the data of the 'existing environment' and 'occupancy' factors (independent variables) of all DMUs in a department can be collected and multiple regression analysis performed on their actual energy consumptions (dependent variable), a regression model can be identified and used to predict the energy consumption of each DMU. For each DMU, the difference between its 'actual energy consumption' and 'predicted energy consumption' can be interpreted as the effect of those 'management' factors. If the 'actual energy consumption' of a DMU is larger than its corresponding 'predicted energy consumption', it could be due to poor 'energy management effectiveness or conduct'; and vice versa. The 'energy management effectiveness' of all DMUs can then be further assessed by the data envelopment analysis.

In this study, 'monthly actual EUI' (Wh/m^2-month) is defined as the dependent variable of the regression model to be analyzed. On the other hand, the independent variables include ten 'existing environment' factors such as monthly highest temperature (°C), monthly highest

relative humidity (%), space/room orientation (0~360°), room area (m^2), envelop surface area (m^2), envelope U-value (W/m^2K), fenestration percentage (%), light fixture density (w/m^2), equipment density (w/m^2), and HVAC density (w/m^2); as well as two 'occupancy' factors such as occupant density (person/100m^2) and space utilization hours (hr/month).

3.2 The DEMS procedure

The DEMS assesses the energy management effectiveness of all DMUs by analyzing their input levels relative to their output levels. The data envelopment analysis will be conducted to produce the overall efficiency, scale efficiency, and pure technical efficiency scores for all DMUs to indicate their energy efficiencies from different perspectives.

3.2.1 Data envelopment analysis

This study designates the 'predicted EUI' as the 'output', and the 'actual EUI' as the 'input' of the DEMS. Figure 3 shows a scatter plot of the input (actual EUI) and output (predicted EUI) data of certain hypothetical DMUs (space-time). The solid line in Figure 3-a is the regression line derived from the multiple regression analysis. The DMUs above the regression line are considered as 'energy efficient' DMUs. For instance, X in Figure 3, given the same level of output (predicted EUI), has a lower energy input level (actual EUI = x) than its expected input level (actual EUI = y) and is therefore regarded as an efficient DMU. It's logical to reason that the reduction in X's actual EUI could be due to certain positive 'management' factors such as higher level of energy manager's involvement. On the other hand, Z in Figure 3 has a higher energy input level (actual EUI = z) than its expected input level (actual EUI = y) and is therefore regarded as an inefficient DMU, possibly due to certain negative 'management' factors such as lower level of occupant energy consciousness.

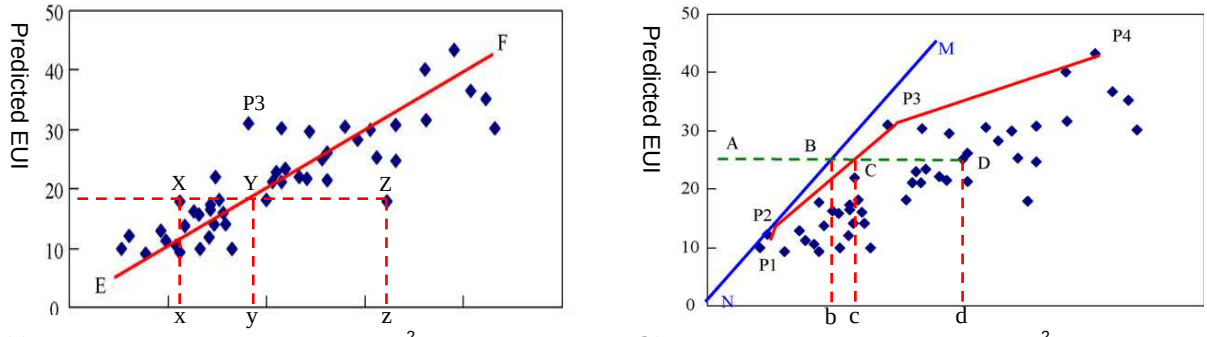

Figure 3: (a) Scatter plot of actual EUI and predicted EUI of a group of DMUs and the regression line derived; (b) the efficiency frontier of the same group of DMUs.

In Figure 3-b, the line connecting the forefront points of all DMUs, i.e., P1, P2, P3, and P4, forms their 'efficiency frontier'. All the points on the efficiency frontier are regarded as the most energy efficient DMUs (spaces at certain time) and are given the highest efficiency score of 100%. They are the benchmarks for those DMUs away from the frontier which are not as efficient and are given with efficiency scores less than 100% (the lower the scores, the less energy efficient they are).

3.2.2 Energy management effectiveness scores

According to the DEA methodology (Charnes et al., 1978; Chauhan et al., 2006), the following three types of efficiency scores can be produced for all DMUs to indicate their energy efficiencies. Point D in Figure 3-b is used to illustrate their meanings:

1. Overall efficiency: The line MN in Figure 3-b represents the envelope of the data set with constant returns to scale (CRS). It is a straight line that connects the origin and the most forefront data point on the frontier (P2). Those points on line MN are considered as efficient and has the highest 'overall efficiency' score of 100%. Those points that are not on line MN are given with 'overall efficiency' scores less than 100%. The 'overall efficiency' score of DMU D is defined as AB/AD (Figure 3-b). One can interpret that AB is the 'ideal input' required to produce the output B on MN (actual EUI = b), if constant returns to scale were to prevail. In the DEMS case, the 'overall efficiency' score of DMU D indicates its overall energy management effectiveness relative to other DMUs. The 'overall efficiency' scores reflect the effects of three groups of factors, i.e., the 'existing environment', 'occupancy' and 'management' factors.
2. Scale efficiency: The line connecting the most efficient DMUs P1, P2, P3 and P4 in Figure 3-b represents the envelope of the data set with variable returns to scale (VRS), which represents a more realistic phenomenon in reality. 'Scale efficiency' is therefore defined to quantify the effect of the presence of VRS in the DMUs. The 'scale efficiency' of D is defined as AB/AC (Figure 3-b), representing the ratio of its 'ideal minimum EUI' (AB) to the 'minimum EUI' (AC). In the DEMS case, the 'scale efficiency' scores reflect the influences of the 'existing environment' and 'occupancy' factors on energy efficiency (since the 'predicted EUI' is calculated by the regression model with the both groups of factors).
3. Pure technical efficiency: The 'pure technical efficiency' is the 'overall efficiency' that has the effect of 'scale efficiency' removed. Those points on the frontier are given with the highest 'pure technical efficiency' score 100%. The 'pure technical efficiency' of D is defined as AC/AD (Figure 3-b) and is calculated by dividing its 'real minimum EUI' (AC) by its 'actual EUI' (AD). In the DEMS case, 'pure technical efficiency' scores indicate the energy management effectiveness of all DMUs and reflect the effects of the 'management' factors on energy efficiency.

With the above three types of efficiency scores, the DEMS allows individual departments to know the energy efficiencies of all spaces within their facilities from different perspectives, and further identify appropriate energy saving targets. For example, DMU D will be given an 'overall efficiency' score of AC/AD; and be advised to move towards point C (pure technical efficiency score of 100%) and try to reduce its actual EUI from d to c (Figure 3-b).

In addition, the DEMS will assist individual departments in analyzing and comparing the energy management effectiveness among different 'space types' to understand the differences and the effects of various ' management' factors on energy efficiencies among different space types. Finally, the DEMS is able to analyze and compare the energy management effectiveness of a certain type of space over time to understand the pattern or

trend of its energy efficiency over time and to identify critical 'management' factors that have great effects on its energy efficiencies over time.

3.3 The DEMS implementation: future research tasks

This study intends to further implement the DEMS in the Department of Architecture (DA) of a national university (NTUST) in Taiwan, and use it as a case to demonstrate how the DEMS can assist individual departments within universities in assessing the energy management effectiveness of their spaces and in improving the energy efficiencies of their facilities. The implementation research tasks to be conducted are planned and outlined.

3.3.1 The DEMS implementation subject

There are about 350 occupants in the Department of Architecture of NTUST (17 full time faculty members, 10 research assistants, three full time administrative staff, 200 under-graduate students, and 120 graduate students). The department occupies the 7th, 8th and 9th floor of the *Research Building* on campus. There are a total of 66 spaces in the DA of NTUST, taking up a total of 3,386 m^2 of floor area. These spaces can be classified into five major types according to their 'functional uses': administrative office, faculty office, research lab (for graduate students), design studio (for undergraduate students), classroom (excluding spaces such as workshop, lobby, corridor, elevator, toilet and staircase). Each space type is characterised by its unique occupancy patterns (Table 1).

NTUST is located in Taipei City with a humid subtropical climate. The average temperature in summer is 29.4 ˚C and in winter 11 ˚C. Summers are hot (133 days in a year with maximum temperature exceeding 30 ˚C) and humid (mean relative humidity 74.0~81.1%), and accompanied by occasional rainstorms and typhoons. Winters are short and mild. Taipei's average annual sunshine is 1,408 hours (67% of the time is cloudy), and average annual precipitation is 2,325 mm (46% of the days rain).

Table 1: The five space types and their occupancy patterns in the DA, NTUST.

Space type	**User type** **Density**	**Equipment type** **Density**	**Occupancy time (wk, day)** **Length of daily use**
Classroom	Students Medium density	Office equip. Low density	Variable (wk), intermittent (day) Short-to-long hours
Admin. office	Admin. personnel Low density	Office + special equip. Medium density	Constant (wk), continuous (day) Medium hours
Faculty office	Faculty Low density	Office + special equip. High density	Variable (wk), continuous (day) Short-to-medium hours
Research lab	Graduate students Medium density	Office + special equip. Medium density	Variable (wk), intermittent (day) Medium-to-long hours
Design studio	Undergrad. students High density	Office equip. Medium density	Variable (wk), intermittent (day) Short-to-long hours

3.3.2 Intelligent energy monitoring system installed

An intelligent energy monitoring system was installed in the DA in August 2011. The system was set up to record the electricity consumption data of lighting, equipment, and HVAC on each of the three floors. In addition, the system also records the electricity consumptions in five typical spaces, each representing one of the five major space types: RB-809 classroom, RB-810 administrative office, RB-905 faculty office, RB-906 research lab, and RB-909 design studio. The logged data can be tabulated into hourly, daily, or monthly data tables for reference. As shown in Table 2, the monthly actual EUIs of the five spaces and those of department average are summarized (data from January to December 2012).

Table 2: The monthly actual EUIs (kWh/m^2) of the five space types and the department average in the DA (data from January to December 2012).

	2012 Jan	2012 Feb	2012 Mar	2012 Apr	2012 May	2012 Jun	2012 Jul	2012 Aug	2011 Sept	2012 Oct	2012 Nov	2012 Dec	Total kWh/m^2
RB-809 Classroom	4.8	4.0	6.5	6.7	13.4	9.3	6.9	5.5	11.3	9.3	8.6	5.2	**91.5**
RB-810 Admin. office	4.2	4.2	5.6	5.5	7.3	7.5	9.6	7.4	8.4	6.6	6.8	5.3	**78.3**
RB-905 Faculty office	2.8	3.6	4.0	4.4	5.3	6.9	8.3	5.9	6.5	4.3	3.8	3.9	**59.5**
RB-906 Research lab	4.2	4.2	4.7	6.2	8.4	10.1	14.6	9.7	10.7	12.4	13.1	7.4	**105.6**
RB-909 Design studio	2.3	2.2	4.0	5.3	7.4	9.6	10.9	2.5	5.4	10.0	7.8	5.9	**73.4**
Department average	**4.2**	**3.6**	**6.2**	**8.1**	**10.4**	**10.2**	**11.2**	**7.7**	**8.1**	**9.1**	**8.5**	**6.3**	**93.7**

3.3.3 Future research tasks planned

The monthly electricity consumption data of the DA in 2012 is ready for comprehensive data analysis. This study plans to perform the following research tasks of the DEMS implementation, and present the actual implementation and analytical results thereafter:

1. DMU definition: For a full year, there will be a total of 60 DMUs (= 5*12) in this study.
2. Regression analysis: Multiple regression analysis will be performed on the ten 'existing environment' and two 'occupancy' independent variables ('management' factors NOT included) and one dependent variable 'month actual EUI'.
3. Calculate the 'monthly predicted EUI' of five types of spaces: The derived regression equation will be used to calculate the 'monthly predicted EUI' (Wh/m^2-month) of the 60 DMUs by feeding the values of independent variables of all DMUs into the equation.
4. Data envelopment analysis: The DEA-Solver-Pro software will be used to conduct data envelopment analysis on the input (monthly actual EUIs) and output (month predicted EUIs) of all DMUs.
5. Energy efficiency assessment of all DMUs: The overall efficiency, scale efficiency and pure technical efficiency scores of all DMUs will be inspected. Pure technical efficiency

scores will be used to identify benchmark DMUs (on the frontier) as well as those that are least energy efficient. For the least efficient DMUs, the causes and problems will be speculated (low pure technical efficiency scores mean less effective in 'energy management', and the related 'management' factors will be examined) and their energy saving targets will be identified.

6. Energy efficiency assessment among different space types: The energy efficiency scores of five space types will be analyzed and compared to realize the most and least effective space types (in terms of 'energy management'), as well as to understand the differences among different space types and the 'management' factors that may have caused them.
7. Energy efficiency assessment of each space type over time: The energy efficiency scores of each space type over 12 months will be analyzed in order to understand the its energy management effectiveness over time and identify the 'management' factors that may have caused them.

After implementing the DEMS and obtaining the analytical assessment results, this study will further discuss the potential and the limitations of the DEMS. It's expected that certain problems may arise during the DEMS implementation process. For example, how should the energy efficiencies between spaces with different envelope construction be compared? Such issues will be addressed and future research tasks to improve the DEMS will be outlined.

4. Conclusions

This research explores the ‘space type’ and ‘internal benchmark’ research concepts, and the ‘data envelopment analysis’ method to establish the ‘DEA Energy Management System (DEMS)’ to assist individual departments within universities in assessing the energy efficiencies of their facilities from the ‘management’ perspective. DEA is a method that assesses the efficiencies of a number of decision making units (DMU) by analyzing and comparing their input levels relative to output levels.

The DEMS proposed considers each ‘space’ in a given ‘time’ (such as a month) as a DMU. Then, regression analysis is performed on data of the independent variables related to the ‘existing environment’ factors (such as highest temperature, highest relative humidity, space orientation, room area, envelop surface area, envelope U-value, fenestration percentage, lighting fixture density, equipment density, and HVAC density) and 'occupancy' factors (such as occupant density and space utilization hours), and of the dependent variable (actual energy consumption EUI) of all DMUs. The regression equation derived is then used to calculate the ‘predicted EUI’ for all DMUs. The ‘actual EUI’ is considered as the input data, and the ‘predicted EUI’ as the output data of the DEMS. Finally, data envelopment analysis is conducted on the input and output data to produce three types of energy efficiency scores (overall efficiency, scale efficiency, and pure technical efficiency) to indicate the energy efficiencies of all DMUs. The ‘pure technical efficiency’ scores reveal the 'energy management effectiveness' of all DMUs. Those DMUs on the efficiency frontier are the most energy efficient ones and are given with the highest pure technical efficiency score of 100%; and those DMUs that are away from the frontier are less efficient ones and are given with efficiency scores less than 100%. Energy efficiency assessments can also be performed to

compare the energy management effectiveness among different space types as well as those of individual space types over time.

The DEMS will be implemented in the Department of Architecture of NTUST in Taiwan to illustrate how it can be used to assist individual departments within universities in assessing the energy management effectiveness of their spaces and in improving the energy efficiencies of their facilities. The implementation research tasks to be conducted are planned and outlined, and the actual implementation and analytical results will be presented thereafter.

Acknowledgement

The author thanks the National Science Council of the Executive Yuan of Taiwan for sponsoring this research work (Project No. NSC 101-2221-E-011-149).

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The development of integrated solutions in construction: towards better value for the clients?

Frédéric Bougrain[1], Kim Haugbølle, Marianne Forman and Stefan Gottlieb[2]

Abstract Title

In construction project firms are moving into new kinds of value-added activities. This move is explained by the place of the housing stock and the growing demand for packaged product and service delivery. Integrated solutions are not dominant in construction which is characterised by the separation between design, construction and operation activities. The aim of this paper is twofold: 1/ to explore how relations are conducted between the integrated solution providers and the client during the construction and the operation of the building. 2/ to identify whether the development of integrated solutions in construction improves the quality of the process and stimulates innovation.

To deal with these issues, the paper will present two projects in Denmark and France. Both projects will be considered as complex and unique. Before developing the case studies, the paper will define the conceptual framework and the notion of complex products and systems (CoPS). Delivering CoPS projects requires the combination of project management capabilities and systems integration capabilities.

Keywords: Complex products and systems, integrated solutions, contracts, complex performance, construction system.

1. Introduction

Construction is actually facing several challenges:

- Construction is moving from the building activity to the service provided by the built environment (Carassus, 2002). As in other sectors construction firms are modifying their business model. They are moving into new kinds of value-added activities (AEGIS, 1999) and are becoming providers of integrated solutions. "*Integrated solutions involve the bringing together of products and services in order to address a customer's particular business or operational requirements*" (Brady and al., 2005, p.172). This move is explained by the place of the housing stock which is growing in importance in comparison with new construction. Moreover public authorities are

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more and more demanding for packaged product and service delivery. Finally, whereas margins are shrinking in construction, the provision of services offers continuous revenue stream.

- Construction is also shifting toward a performance based model. This is mainly due to a change of procurement. Traditional design and build contracts based on input specifications are more and more replaced by service-led contracts where the output to be delivered is specified (Hoezen and al., 2010). It also means that the scope of the contract goes further than design and build and encompasses operation and maintenance. Under this scheme a comprehensive performance measurement system containing key performance indicators often becomes the backbone of operational management.

Integrated solutions are not dominant in construction which is frequently characterised by the separation between design, construction and operation activities. However the development of new procurement process such as Public Private Partnerships (PPP) has contributed to the development of such solutions. Under this scheme, design, build, finance and operation are transferred to private sector partners. It is a way to deliver integrated solutions to public authorities. Fees are paid by the public authority to cover finance, construction and operating costs. Payments are made according to the quality of the service delivery which is judged on performance indicators. For public clients, the rationale of these projects is to deliver a enhanced service to its customers.

The aim is to explore whether this move towards integrated solution provision based on performance measurement system, provide better value for the clients.

To answer to this question the paper aims to scrutinize two different configurations, PPP and conventional procurement based on performance criteria. The projects will be located in different countries: Denmark and France. One will be in operation while the other is still at the construction stage. Both projects will be considered as complex and unique. The relationships between the integrated solution providers and the client during the construction and the operation of the building will be analysed.

Before developing the case studies, the paper will highlight how integrated solutions can be delivered in the Danish and the French construction systems. Then it will define the conceptual framework and the notions of complexity and complex products and systems (CoPS). Governance issues for the delivery of CoPS will also be examined.

2. The delivery of integrated solutions in construction: regulatory aspects

2.1 The French construction system

France has a long experience in private finance procurement. It concerns mainly infrastructure projects such as a road. In this system public authorities grant specific rights to a private partner to construct, maintain and operate the infrastructure for a given period. The

private partner operates the service at its own risk and is remunerated in the form of a price paid by the users of the service. Thanks to this experience French companies working on this market have developed strong capabilities to design and construct roads but mainly to operate, maintain and finance the infrastructure during its life cycle.

Only a limited number of assets such as buildings (hospitals, schools, prisons, stadiums…) were delivered under this form of procurement. Indeed according the law n°85.704 laid down the 12th of July 1985, the public client generally establishes two different contracts with the architect and the contractor. Design, build and operate (DBO) is possible but the client has to demonstrate that it is less expensive or technically necessary. However finance cannot be transferred to the private partner like for concession.[3]

The law passed in June 2004, proposed a complementary framework. It introduced the partnership contract ("Contrat de partenariat"). Under this new scheme, design, build, finance and operation are transferred to private sector partners. The partnership contract became the most used PPP contract. At the end of February 2013, 171 contracts were signed. About 33% of them deal with public lighting.

2.2 The Danish construction system

The construction market for refurbishment in Denmark is by and large of the same size as the market for new buildings. The main actors of the building process are the construction client, consultants, contractors and suppliers (Levring & Bonke, 1996). The Danish building process shares many of the same characteristics as the professional system in UK dominated by the consultants, which is quite different from the French industrialised system where the contractors are more dominant (Winch & Campagnac, 1995; Winch, 2000).

The typical procurement protocols are traditional (or trade) contracting, main (or general) contracting and design-build contracting. In recent years, integrated delivery mechanisms have come to the fore. This has led to a hybrid practice of design-build contracting – by some practitioners termed "controlled design-build contracting" – in which the client exercises a larger influence on the design than typical for the usual design-build contract. The client makes the initial contact to a design team for a conceptual design, which is then followed by a slightly adapted design-build contract where the client retains some degree of control of the design (Söderberg et al. 2004; Levring & Bonke, 1996).

The development of integrated delivery mechanisms has been supported by a number of subsequent development programs: Project New Ways of Collaboration, The Client Creates Value (in Danish, Bygherren skaber Værdi), and the PLUS network (Partnering, Learning, Development, Collaboration). The diffusion of integrated delivery mechanisms has been championed by the public authorities and certain key actors in the building process like the contractor NCC. Today, partnering has become a fairly widely used delivery mechanism,

[3] Since August 2011, DBO is also possible when it favours energy efficiency in buildings.

while energy-service companies (ESCO) are in its infancy and mechanisms like public-private partnerships and integrated procurement are seldom used (Larsen et al., 2010).

3. The theoretical framework

3.1 Complexity in service-led projects and managerial consequences

Baccarini (1996) considered that construction projects become progressively more complex. As construction is moving away from its production-based focus by developing new service activities (financing projects, operating and maintaining systems…), project complexity is even stronger since interfaces between stakeholders, organisations and project phases are multiplied.

Project complexity is characterised by two dimensions: structural complexity and uncertainty (Williams, 1999). Structural complexity (Baccarini, 1996) refers to the number of subsystems of a product / the number of specialties and their inter-relationships. Interdependencies intensify complexity since a change in one element will have an impact on the subsystem. Uncertainty can also be classified according two dimensions: the uncertainty in goals is linked to the difficulty of the users / clients to specify their requirements. This increases the risks of changes (i.e re-work). The uncertainty in methods is more due to a lack of experience on a similar project which requires modifying and refining the methods during the course of the project.

Hobday (1998, p.693) introduced the notion of complex products and systems (CoPS). "*CoPS projects normally involve a series of phases including pre-production bidding, conceptual and detailed design, fabrication, delivery and installation, post-production innovation, maintenance, servicing and sometimes, de-commissioning.*" Hobday identifies several indicators to characterise product complexity: the degree of technological novelty, extent of embedded software in product, quantity of sub-systems and components, feedback loop from later to earlier stages, uncertainty/change in user requirements…

The project based organisation is apparently ideal to manage the uncertainties ("*unforeseen and unforeseeable features which occur during design, system integration and production*") that characterised CoPS projects (Hobday, 2000, p.891). However it is not adapted to project learning. Delivering CoPS projects requires the combination of project management capabilities (managing uncertainty and changes in user specifications) and systems integration capabilities. Thus coordination mechanisms between the stakeholders of the construction value added-chain are critical factors for the success of service delivery.

3.2 Governance for integrated solutions provision

Relationships between buyer and supplier are usually based on formal contracts. When all contingencies that might affect the relationship are foreseen by the agents, the contract appears adapted. Buyer and supplier are able to write a clear and enforceable contract. The uncertainty is limited and it is easy to implement and monitor tasks. However according to the framework defined by Williamson (1991), uncertainty, frequency of exchange and asset

specificity render most contracts incomplete. Therefore it is only possible to define procedures for resolving unforeseeable outcomes.

The delivery of CoPS modifies the traditional relationship between buyer and supplier. Indeed the coordinator of the project has to manage networks including suppliers, designers, contractors, facility managers, financial institutions and government authorities. In PPP projects, the coordinator is the Special Purpose Vehicle (SPV) which organises the division of tasks (design, construction, operation and finance) among the partners of the SPV (Brady et al., 2005). The management of these complex interfaces is the key issue to deliver integrated solutions to clients and to create value for the end users.

Within these projects a comprehensive and complex performance measurement system containing key performance indicators often becomes the backbone of operational management. These indicators are established according to the expectations of the public authorities. In case of poor performance or buildings unavailability the payments to the private partners can be reduced. To be efficient, measurement procedures have to go along with the quality of the service. However these long term contracts are by nature complex and incomplete since all contingencies cannot be anticipated (Caldwell et al., 2009). Moreover ex-post contract monitoring costs can be very high with CoPS (Lewis and Roehrich, 2009).

In such situation relational governance is considered as a complement to contracts. One of the key elements of relational governance is trust (Roehrich and Lewis, 2010). When trust replaces uncertainty and opportunism, informal obligations may constitute a more stable framework for interaction (Lundvall, 1988). However for large and complex projects informal control mechanisms are difficult to implement.

4. Case studies

4.1 INSEP

INSEP (National Institute of Sport and Physical Education) brings together a large number of top-level athletes specialising in a wide range of sports. The Institute located in the Bois de Vincennes forest west of Paris, is the training centre for the French sports elite. About half of the medals gained by the French athletes at the Olympic Games (16 out of 33 in 2004, 21 out of 40 in 2008 and 19 out of 34 in 2012) were won by athletes trained at INSEP.

4.1.1 The renovation project:

The renovation project of INSEP was decided in 2005 by the Ministry of Sport. Two different public procurement schemes were used:

1. The renovation of the Southern section was carried out under a public management contract. The Ministry of Sport was the client since it was the best actor to support the risks associated with the management of the sport facilities.

2. A public private partnership tender proposal was retained for the renovation, the maintenance and operation of the Northern section. Since the delivery deadline set to enable the preparation of athletes for the 2008 – 2012 Olympiad was crucial and the complexity of the renovation was high, a partnership contract was considered as the most adapted solution.

The partnership contract was awarded in December 2006 to a consortium gathering three large companies. It concerned the renovation, the maintenance and operation of the buildings for the thirty years of the contract and the delivery of services (hotels, catering, cleaning…). The renovation costs reached 102 million Euros and the annual unitary payment is 12 million Euros. The renovation works started in June 2007 and ended in January 2010.

4.1.2 The governance mechanism within the project

The governance mechanism within the consortium and between the consortium and the public user are different. Within the consortium the company in charge of hospitality issues, coordinates the helpdesk but it does not have any power on the other members of the consortium. The public users criticize in several occasions the role of the coordinator since he was not always able to provide direct answers to day-to-day problems. As a coordinator he transferred the questions to the appointed companies. Thus this organisation hindered communication and created a supplementary administrative layer between INSEP and the companies working on the site. However according to the coordinator, it could have been possible to have a company in charge of managing the other members of the consortium. However it would have resulted in supplementary cost at the level of the final bid.

To monitor the consortium output specifications were integrated to the contract. However some monitoring procedures were not adapted. At the beginning, it took more than half a day to monitor the quality of the cleaning. Therefore both parties agreed to modify their approach. The number of key performance indicators (KPI) was reduced from 276 to 153 in order to improve the efficiency of the monitoring procedure and to enforce the contract.

Despite the formal contract signed between the partners, several changes occurred during the renovation and operation of the buildings. The public authority tended to adopt the behaviour of traditional public owners: INSEP asked for new services once the partnership contract was awarded (e.g. a balneotherapy complex was created and the architecture of the R&D lab was modified after the enrolment of a new manager).

Once the renovation was completed, some contractual services appeared to be not adapted to the day-to-day life of the residents. Consequently services were modified but the financial perimeter of the contract was kept unchanged. There was no financial consequences but according to the private consortium, most changes were time consuming.

4.1.3 The service quality

The construction was not done on time because INSEP asked for several changes during the renovation. Moreover asbestos was found in one building. Under traditional public

procurement the works would have stopped and the client would have modified the initial contract with the contractor. This modification of the initial contract is usually very time consuming and the contractor always tries to benefit from the bilateral negociation. In this project, the contractor who was member of the consortium decided to take the risk (while nothing about this risk was mentioned in the initial contract) and to pursue the renovation works. At the end, the delay was one month. Despite a delay of one month, INSEP was very satisfied since the budget was not modified. Moreover, it was aware that such a result would never have been attained under traditional public procurement procedures.

All actors also indicated that the service quality is better than before. For example the mail desk is open from 8 am to 10 pm instead of 7 am to noon and 2 pm to 5 pm. The reception desk also lengthened its opening hours. New services were created for people who come to INSEP for short training period (such as a luggage room).

Despite these positive feedbacks some elements of dissatisfaction remain. The contract is interpreted differently by the stakeholders. Firstly this is due to a change of employees within INSEP. People who took part to the competitive dialogue and to the signature of the contract are not anymore here. Secondly the output specification was not always well specified.

Budgets for maintenance and operation are also limited because the public authority (INSEP) had no experience in this field and had in the past a very limited budget dedicated to these tasks. Finally it also appears that the interface between the contractor and the system operators (two different companies belonging to the same large French contractor) was not very efficient. Due to a lack of experience in similar projects and to the penalties associated with construction delays the contractor strongly focused on the delivery of the buildings. Moreover the system operator did not have any incentive to adopt a whole life cycle cost approach. This was due to a strong lack of data for technical equipment and to the separation between construction and operation within the consortium.

Maintenance is also lacking since the company in charge of maintenance and operation did not realise that it would have to operate the building 24h/24h. Moreover some renovation activities are still ongoing in the Southern section of the INSEP campus. Thus the private company in charge of cleaning the buildings has to work more than expected because most people living and working on the site tend to bring dust and mud inside the buildings.

Changes during the construction phase have also an impact on the performance of the contract. For example the private consortium had incentives to operate buildings and manage systems in order to reduce energy consumptions. But INSEP asked for new services (e.g. balneotherapy and TV in the rooms of the athletes). Thus the reference base has to be redefined before developing any energy performance mechanisms. This example illustrates the structural complexity of the project as defined by Becattini (1996).

4.2 UN City, Copenhagen

The capitol area of Copenhagen is growing rapidly. As heavy industry is disappearing from the harbour of Copenhagen, new space for urban development becomes available. One of

the most prominent areas is the Northern Harbour of Copenhagen (Nordhavnen). One of the first developments to take place here is the establishment of the UN City.

4.2.1 The project

The intention of the UN City is to establish a joint headquarters for some 1,100-1,200 employees from the seven United Nations agencies presently dispersed around the city of Copenhagen. The UN City consists of two campuses at the Northern Harbour of Copenhagen. Campus 1 encompasses the new administration building for UN and is situated on the Marble Pier (Marmormolen) in the port of Copenhagen. The building will be constructed as a star-shaped building with eight points. The new domicile will be constructed in two phases to be concluded in the beginning of 2013 respectively the beginning of 2014 with around 45,000 m^2 gross floor area and 8,000 m^2 basement.

Campus 2 includes a warehouse, which will handle goods for UNICEF for development and emergency projects around the world. The warehouse was built in the Free Port at the outer part of the Northern Harbour of Copenhagen and was ready for moving in at the beginning of 2012. The warehouse holds a capacity of close to 40,000 cubic meters in a fully automated high bay warehouse.

4.2.2 The governance mechanism within the project

The two most prominent governance processes at play in this particular case are policy processes and business processes. The policy processes are predominantly taking place between the regulatory and institutional framework on one hand and businesses on the other hand. These policy processes between the project and its environment is characterised by: 1) privatisation of public policy through the creation of the developing organisation, and 2) provision of a legal framework for developing the site.

First, the development of Nordhavnen is carried out by the developer CPH City Port and Development I/S. The developing organisation was established in 2007 and is owned 55 % by the Municipality of Copenhagen and 45 % by the Danish government. Being the largest land owner and developer in Copenhagen, the developing organisation plays an important role in the development of Copenhagen. Although the developer is publicly owned and has to comply with a range of public regulations (e.g. on public tendering procedures), the company is effectively operating as a private company. The company is required by law to carry out its activities on ordinary commercial bases, for example through the sale of building rights to the majority of the most attractive sites in Copenhagen. As such the developer is operating without the usual direct democratic control of public organisations and with a more narrow economic scope. Although board members of CPH City Port and Development are appointed politically, the developer is operating at arm's length from the political system. As such CPH City Port and Development is the epitome of what Pedersen et al. (1992) has coined the privatisation of public politics.

The second policy process is related to the provision of a legally binding framework for the development of the actual site. This process is highly institutionalised through the provisions

of the Planning Act. Given the significance of the development of the Northern Harbour, the policy process of providing a legal framework for developing the site took a different route than usual. In December 2005, the City of Copenhagen and the Danish government agreed on the principles that should govern the development of the Northern Harbour. This agreement was turned into a parliament act in May 2007. Based on the winning proposal of an international competition, the Municipality of Copenhagen developed a municipal plan supplement for the entire Northern Harbour and two local plans for the Marble Pier and the nearby Århusgade Quarter in order to set the legally binding framework for the first stage development of the inner part of the Northern Harbour (BY & HAVN, 2009).

Turning from the policy processes towards the business processes, the business processes along the property market and the construction market are characterised by a 1) high degree of complexity on the demand side relations, and 2) reproduction of typical governance mechanisms between the actors in the building process. First, as pointed out by Haugbølle et al. (2012) this case study has illustrated the complex and emergent character of the demand side with multiple user organisations (in this case seven UN organisations), extensive role separation (as owner of building rights, developer, construction client, building owner, financier, user, tenant, leaseholder and letting office), overlapping roles between the regulatory system and the business (the double role of the municipality as both authority and part owner of the developing company), and repeatedly changes in the ownership structure over time.

Second, this case study has illuminated the reproduction of typical business relations between the actors in the building process. Despite the complexity on the demand side and the extraordinary security and confidentiality issues of building for United Nations, the procurement procedures have been fairly conventional in its application of a design contract with the design team. The design-build contractor was selected after an open pre-qualification round, where six tenderers where selected to bid in a limited tender based on economically most advantageous tender following the European regulation on public tendering (Public Sector Procurement Directive, Council Directive 2004/18/EC). Part of the tendering requirement included the obligation of the winning contractor to incorporate the design team in what may be labelled a “controlled design-build” contract.

4.2.3 The service quality

As the building project is still underway, observations on the realised service quality is not yet available. The intention is to design the UN City as a sustainable building. It has a strong emphasis on energy consumption in order to comply with three different set of requirements: The Danish Building Regulations on low-energy class 1 buildings with a projected energy consumption below 50 kWh/m^2/year, the American LEED certification scheme with the goal of achieving a minimum score of LEED Gold, and the developer organisation becoming a Green Building Partner as one of the first Danish organisations (European Commission – Joint Research Centre – Institute for Energy and Transport, 2006). In addition to the energy focus, the building will be using recycled rainwater for toilet flush, cooling will take place with sea water, all lighting will be automatically controlled, and photo-voltaic cells will be installed on the roof of the building.

A second core design principle is to support networking and health by the design of a spectacular staircase in the middle of the large atrium connecting the eight arms of the star. Contrary to the focus on elevators in the 1990s among designers, the architects are now placing much more emphasis on the staircase as a central guiding design in atriums. Elevators are secluded from the atrium in order to encourage users to take the stairs rather than the elevators to promote exercise to improve health and to facilitate networking between the building users.

A third core design principle is related to the strict security concerns applied by UN as an international organisation. Thus the building features a range of security measures to avoid terrorist attacks on UN. For confidentiality reasons most of these security features cannot be described in detail. Some are however evident from the design in itself like. For example the building is being constructed at an isolated island. The only access point will be a bridge accessible only on foot, by bike and with small vehicles.

5. Conclusion

Both cases INSEP and UN City illustrate how construction projects become more and more complex and that complete contracts cannot be written. This is due to:

- The number of interdependencies among the stakeholders of the projects (users and companies in charge of construction and facility management);

- The multiplicity of users with different requirements and the overlapping roles between the regulatory and the business systems (UN City);

- The necessity to define ex-ante services and to propose key performance indicators which will be easy measured (INSEP).

- The uncertainties surrounding these projects which are unique. In the INSEP case, the uncertainties require flexibility in order to deal with all contingencies that were not anticipated at the bid stage. Moreover staff turnover from the public side prevent the development of trust which would have been necessary for the operation of the buildings. It also appears that the user tends to have a strict interpretation of the output specification. The relationships are more based on contractual than on relational governance.

One of the aim of the paper was also to explore whether the move towards integrated solution provision provide better value for the clients. The answer is not straightforward.

In the case of INSEP, the service quality is higher than in the past. Conversely the link between the project execution and the service delivery was not a smooth path. It also appears that the level of requirements of the public user has increased (it did not have the same level of expectation when the service was done by internal staff),

Most studies related to construction focus on the design and construction stages while from a user perspective the operational phase is the key issue. Moreover design and construction last usually around two years whereas operation concerns a minimum of twenty years. Thus more research is necessary in this field to understand how public and private stakeholders can learn to deliver integrated solutions combining building and operation.

6. Acknowledgements

We wish to thank PUCA (Plan Urbain Construction Architecture), the French funding agency that sponsored part of the research and the Danish Energy Agency. We would like also to express our deep gratitude to those involved in the case studies who were interviewed and provided valuable information. However, the views expressed are those of the authors alone and should not be attributed to those interviewed or their institutions.

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ADR Practice in the construction industry: a futuristic perspective

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Abstract

Research suggests that the practice of Alternate Dispute Resolution (ADR) is successfully implemented in the South African Construction Industry however; research also indicates that parties seldom negotiate their own settlement and that decisions are made for them. This study records the current situation relating to ADR practice in the South African construction industry and projects possible future trends based on the evolution of the ADR process in the industry. A literature review was conducted on standard ADR practice (as practised internationally) after which an empirical study employed both questionnaires and interviews to determine the current situation in the industry. A comparative analysis was conducted in order to determine the relationship between standard and current practice in the industry. The comparative analysis also serves to identify ADR trends in the industry which may serve as predictors and provide a futuristic perspective to the development of ADR in the South African construction industry. Dispute resolution is an important element in the management of projects which in turn is dependent on the effective application of ADR.

Keywords: Alternate Dispute Resolution, ADR, construction industry, current practice, future trends.

1. Introduction

Arbitration has been used as a means of Alternate Dispute Resolution (ADR) since the days of Jan van Riebeek and was based on Roman-Dutch law. The present South African Arbitration Act 42 of 1965 and contract documentation are based on English Law. Mediation and conciliation in South Africa and the UK are in some respects applied in a different manner to international standard practice. In standard mediation practice, the mediator is not required to recommend a solution to the dispute, but in the construction industry it is required of him. The application of conciliation is also reversed (Butler & Finsen, 1993: p10-11).

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Dispute resolution in the construction industry is different due to the use of unique adjudicative methods whereby judgments can be made with non-binding decisions which are characterised with consensual and control features (Finsen, 2005: pp222-223). It is important to note that the consensual nature of arbitration places it in the ADR context (Pretorius, 1993: p176; JBCC PBA, 2007: pp30-31).

Mediation was introduced to the South African construction industry in 1976 as an alternative method of dispute resolution to the cost and time consuming method of arbitration. The Joint Study Committee issued a practice note with the intention of saving costs and time in the resolution of disputes. However, it was submitted that should parties be dissatisfied with the outcomes, they were still entitled to submit to arbitration (Quail, 1978: p165). Adjudication was introduced to the South African construction industry as an ADR method which requires expert determination and was therefore included in the Joint Building Contracts Committee Principal Building Agreement (JBCC PBA) Series 2000 4th Edition (2004: p30). This approach took effect after the change to adjudication, adopted from the Latham Report in the United Kingdom (Scott & Markram, 2004: p1). Adjudication is applied as a dispute resolution method when the parties require a decision to be made for them and this decision is provisionally binding unless it is overturned in a subsequent arbitration (Finsen, 2005: pp222-223).

Agent resolution was included in the PBA of 1991 Dispute Clause 37 which was recommended by the JBCC (1991: pp21). Agent resolution as a method of dispute resolution was identified in the Association of South African Quantity Surveyors (ASAQS) 1981 Practice Manual under the Agreement and Schedule of Conditions of Building Contracts (1981: p17). However, due to its popularity in practice (ASAQS, 1981:p17; Verster & van Zyl, 2009: p7; JBCC PBA, 1991: p21) agent resolution was included in this study. Although conciliation is not included as a method of dispute resolution in the JBCC Contract documentation, it may suffice as a method of informal dispute resolution as required in Clause 40.2 in the JBCC PBA (2007: pp30-31).

The similarities that exist between arbitration, the oldest method of ADR, and mediation, may be appreciated because new methods were developed for the purpose of speeding up the arbitration procedure so as to provide a more informal and cost-effective way of resolving disputes most suited to the industry (Butler & Finsen, 1993: p8).

Having adopted a process which is exclusive to ADR practice in the South African construction industry, the context in which the methods are applied (which originally stem from arbitration and have overlapping similarities) may vary, and the application may prove to be somewhat confusing when compared to standard practice as practiced internationally.

2. Current ADR practice in the South African construction industry

The ADR process is intended to give parties control and responsibility for the outcome (Bevan, 1992:p18) which ultimately produces advantages and is referred to as the Four C's. These advantages which constitute the features of the ADR context apply to the non-adjudicative methods of ADR and are as follows:

- Consensus
- Continuity
- Control
- Confidentiality. These features produce effective outcomes (Loots, 1991: pp8-13; Verster, 2006: p13).

Adjudication now takes precedence to arbitration in the dispute clauses of the following contracts: General Conditions of Contract for Works of Civil Engineering Construction (GCC) (2010:pp68-71), the New Engineering and Construction 3 (NEC3) (2005: pp28-33) and the International Federation for Consulting Engineers (FIDIC) (1999: pp66-70). Adjudication in the engineering discipline follows a different process in the form of Dispute Adjudication Boards (DAB) (Lalla & Ehrlich, 2012: online) which is supported by the FIDIC (1999), GCC (2010) and the NEC, (2005) contracts, whereas in the building industry, adjudication is supported by the JBCC PBA (2007: pp30-31). The South African Institute of Architects (SAIA) generally practise adjudication according to the JBCC PBA Dispute Clause 40 (The Cape Institute for Architecture, 2010: online). The DABs follow much the same process however; the establishment of the board differs where three adjudicators are appointed to resolve the dispute. The process relies on the expertise of engineers (Owen, 2003: p25).

Researched authors are of the opinion that there is a growing preference for adjudication in the construction industry and courses have been developed in order to promote the practice of adjudication (Alusani, 2012: online). Maritz (2009: online) is of the opinion that adjudication will be underutilised without statutory intervention however; the (Construction Industry Development Board (cidb) promotes adjudication as a rapid and cost effective method (cidb, 2012: online).

Similar to this process is the method of expert determination. With adjudication, a dispute is referred to an expert rather than to litigation, where a judge may base his decision on law, rather than technical issues. Expert determination is also based on rules (What is ADR, 2010: online). This suggests that adjudication in the JBCC PBA (2004) was based on the principles of expert determination. In view of the above, DABs are based on the same principles and may involve more experts which according to Swart, (2012: personal communication), tends to generate expenses and may be suited to larger projects. Mediation has been identified as a preferred method of ADR however; the application of mediation in the South African construction industry has been questioned. Professionals are appointed as mediators due to their expert knowledge and the mediation process is often expedited to suit the hurried nature of the construction industry. As such, mediators are relying on inherent ADR communication skills and making decisions for the parties (Povey, 2005: pp6).

Conciliation is the psychological component of mediation where the neutral third party will attempt to create an atmosphere of trust and co-operation which is conducive to constructive negotiation. The aim of conciliation is to correct perceptions, reduce fears and improve communication in order to relax parties and guide them into conflict-free negotiations and

bargaining. Conciliation also offers parties the opportunity to determine their own end results. Being a primary element of mediation, conciliation is applied with the intention of preparing the parties psychologically to enter into the extended process of mediation (Moore, 1986: pp4-6). As such conciliation may serve as a preventative measure against disputes developing on site.

The relief of court congestion has been addressed by the Department of Justice and Constitutional Development in the Civil Justice Reform Programme (CJRP) (2012: pp14-20) by simplifying lengthy and complex court processes and implementing ADR in the form of mandatory mediation in order to settle out of court. The intention is to implement these court based mediation rules gradually commencing in 2012. However, Joubert and Jacobs (2012) are of the opinion that for this process to be successful, the voluntary process of mediation would be considered an obstacle (online).

3. The standard ADR process compared to current practice

Table 1 compares the standard practice of mediation to current practice as adopted in the South African construction industry. The table is divided into two columns; the left column is an illustration by Moore (1986) of the standard mediation process in a detailed description which works through set stages. It is important to note that the process may be somewhat tapered to suit the hybrid type of ADR practiced in the South African construction industry, which is based on the conclusions of Povey's (2005:p6) research. The reader may find that the stages relating to current practice have been adjusted or eliminated to more accurately reflect the situation in the industry. Due to the possibility of the lengthy stages being questioned in regard to the construction industry, the process was adjusted to accommodate the trend to expedite the mediation process.

Table 1: The process of standard practice of mediation compared to current mediation practice

Standard practice of the mediation process	**Current mediation practice**
Stage 1: Initial contacts with the parties • Making initial contacts with the parties • Building credibility • Educating the parties about the process and selecting approaches	Stage 1: The dispute is reported according to JBCC PBA, 2007 Dispute Clause 40

Stage 3: Collecting and analysing background information • Collecting and analysing relevant data, dynamics, and substance of a conflict	Stage 3: The principal agent has all the information at hand
Stage 6: Beginning the mediation session • Opening negotiation between the parties • Establishing an open and positive tone • Assisting the parties in venting emotions • Assisting the parties in exploring commitments, salience and influence	Stage 6: Beginning the mediation session • Opening negotiation between the parties • Establishing the problem • Facilitator offers an opinion for a settlement
Stage 9 Generating options for settlement • Generating options using either positional or interest-based bargaining	
Stage 10: Assessing options for settlement • Reviewing the interests of the parties • Assessing how interests can be met by available options • Assessing the costs and benefits of selecting options	
Stage 11: Final bargaining • Reaching agreement through either incremental convergence of positions, final leaps to package settlements, development of a consensual formula, or establishment of a procedural means to reach a substantive agreement	
Stage 12: Achieving formal settlement • Identifying procedural steps to operationalise the agreement • Establishing an evaluation and monitoring procedure • Formalising the settlement and creating an enforcement and commitment mechanism	Stage 12: Achieving formal settlement

Source: (Adapted from Moore, 1986: p32; Povey, 2005: pp2-7).

Stages 2, 4 and 8 regarding the strategy, design and hidden interests were eliminated due to the existing involvement of the professional fulfilling the role of principal agent or project manager. In standard practice, mediation may be conducted by a natural person however; in the construction, industry mediation is invariably conducted by an expert.The hybrid form of mediation practice to suit the needs of the fast track nature of the industry is illustrated.

4. Research methodology

A literature review was conducted to identify the current trends of ADR practice in the South African construction industry in order to compare these with international standard practice. The research followed a mixed methods approach gathering qualitative and quantitative data. A questionnaire survey was conducted to determine the preference for the methods of ADR and how important the respondents consider these methods to be, to what extent conciliation will prevent differences developing into disputes and the application of ADR. In addition to this, the respondents were requested to give their opinion of current practice in the industry. One hundred questionnaires were distributed with a 45% response. Interviews were also conducted to determine the current situation in the industry. The results of the data analysis are addressed in the findings.

5. Findings

The evaluative process of mediation is implemented successfully in so far as disputes are being settled however; the qualitative data analysis suggests that the facilitative process is lacking. The quantitative data suggests that professionals in the construction industry are in favour of applying ADR which produces the advantages relating to the Four C's. Although respondents rated themselves as knowledgeable of the process, the qualitative data indicates that the psychological component is being disregarded by professionals. The qualitative data contradicts the quantitative data in so far as professionals have indicated that they do not have "the time to waste" on the psychological needs of the parties because they have "a business to run". A statement by a respondent such as "I make the decision for the parties and tell them that this is how the dispute will be resolved" suggests that an autocratic approach tends to be used in the resolution of disputes. This suggests that professionals are aware of the requirements for effective facilitation and have limited time available for implementation.

Figure 1 illustrates the quantitative data relating to the effectiveness and the satisfactory end results experienced by the respondents. This supports the notion that the basic fundamentals are in place.

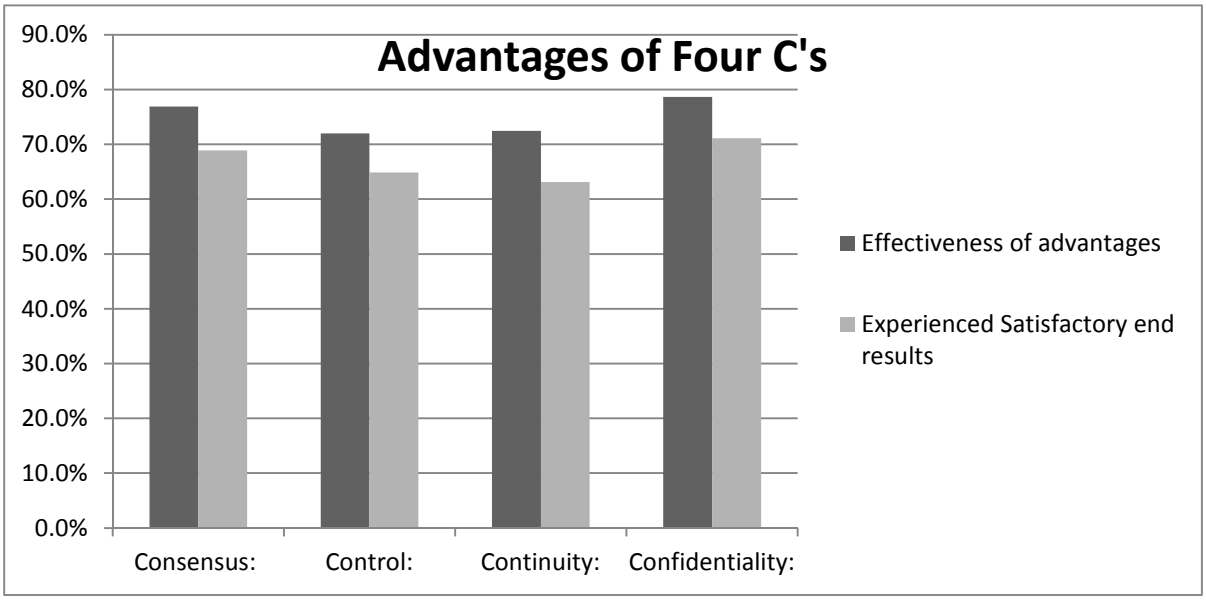
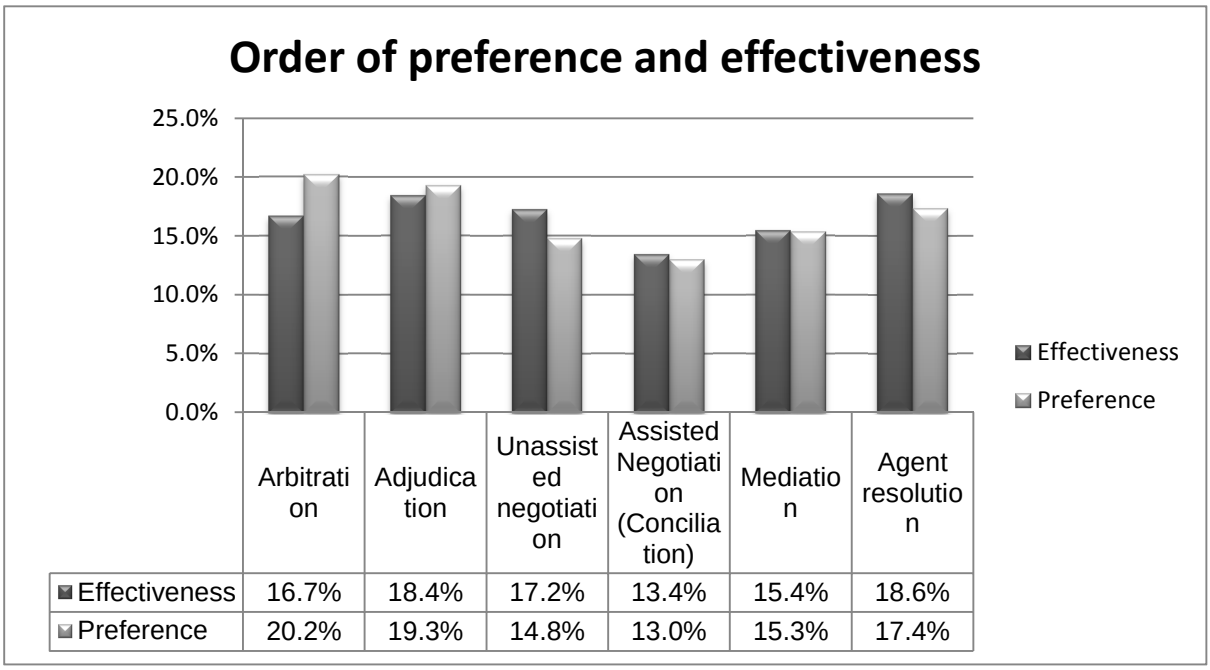


Figure 1: Advantages of the Four C's

Secondary data indicates that there is a preference for mediation however; according to the data analysis, the trend is changing towards adjudication. This is also supported by the literature review. Arbitration was also identified as a preferred method, which suggests that it holds its stance as the support system to ADR. Although DAB's are considered to be effective, the cost implications on smaller projects limit the use of this method.

Figure 2 depicts the order of preference for the various ADR methods and the respondents' opinion on their effectiveness. Respondents prefer arbitration closely followed by adjudication. Agent resolution is considered the most effective method with a rating of 18.6% and conciliation the least with 13.4%.



	Arbitration	Adjudication	Unassisted negotiation	Assisted Negotiation (Conciliation)	Mediation	Agent resolution
Effectiveness	16.7%	18.4%	17.2%	13.4%	15.4%	18.6%
Preference	20.2%	19.3%	14.8%	13.0%	15.3%	17.4%

Figure 2: Order of preference and effectiveness

Contrary to the findings of the order of effectiveness and preferences as depicted in Figure 2, Figure 3 indicates that respondents are of the opinion that conciliation will prevent differences developing on site to the extent of 68%.The respondents were divided into age groups to determine at which point the application of conciliation is considered important in preventing differences occurring on site. The advantages of conciliation are realised with experience. Although agent resolution is not included in the JBCC PBA (2007) Dispute Clause 40, it may be related to conciliation in so far as these skills are used to apply the method (pp30-31). As such, this highlights the importance of conciliation on site.

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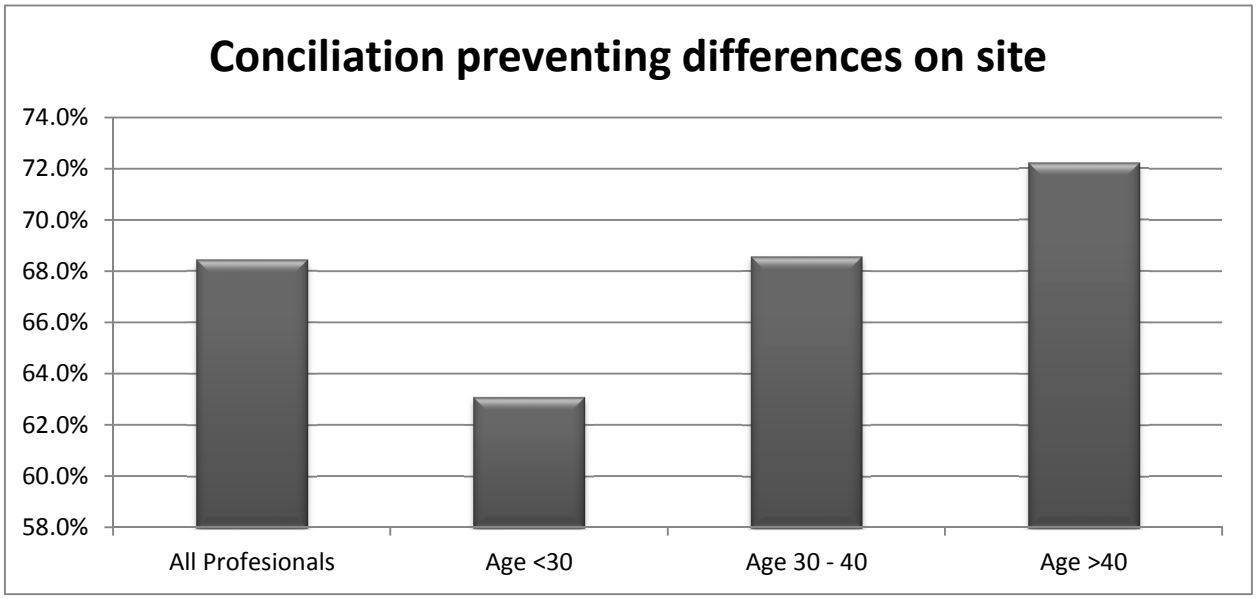

Figure 3: Conciliation preventing differences on site

6. Discussion

ADR practice has evolved to suit the needs of the industry and this has led to a form of practice which differs from standard mediation practice as identified in the literature review. Having identified the current situation in the industry the question is, what future events are likely to influence current trends?

Professionals in the construction industry have practiced ADR to suit the needs of the industry since the original introduction to mediation. As depicted in the comparison of standard with current mediation practice, the hasty nature of the construction industry lends itself to expediting the resolution of disputes rather than applying ADR according to the identified requirements. Measures may need to be taken to encourage professionals to apply the mediation rules in regard to the application of conciliation as an element of mediation.

Mandatory mediation and adjudication may have a negative impact on time and cost goals as opposed to the use of the expertise of the professional on site. The Department of Justice is currently systematically introducing mandatory mediation and the changing trend toward adjudication suggests that the intention is to follow suit. Although the current voluntary process is considered a hindrance, the construction industry has a history of applying ADR to suit the needs of the industry. This suggests that the construction industry will in all probability continue practice to suit their needs. The opinion of professionals in regard to the focus of adjudication (with possible statutory intervention) may require further research. However, mandatory mediation may present a challenge in a fast track industry.

7. Conclusion

From the introduction of mediation dating back to 1976, the applications of the ADR methods have been adapted to suit the needs of the industry. As such, it is concluded that although ADR practice may be facing challenges in the future and the evolutionary trends remain

constant, the hybrid form of ADR practice may in all probability continue unless the change is forced on professionals in the form of regulations. The consensual basis of ADR in the dispute clauses of the various contracts is supported by the industry and professionals are aware of the advantages. However; the application of conciliation and the realisation of the importance of settling differences on site before a dispute develops are lacking.

The consensual approach to ADR in the South African construction industry is effective without statutory intervention in so far as it gives contracting parties the opportunity to use the method of dispute resolution best suited to their needs.

8. Recommendations

Despite the implementation of mandatory mediation and the probability of statutory involvement in adjudication, it is recommended that more emphasis be placed on the advantages of and subsequent implementation of effective conciliation for the successful completion of projects

It is further recommended that institutions may consider providing opportunities for professionals in the industry to update their knowledge of ADR in the form of Continuous Professional Development and that emphasis should be placed on conciliation and the changing trends which are taking place.

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Applications of Linear Scheduling Method for Nuclear Power Plant Construction

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ABSTRACT

According to a forecast, global energy demand is expected to increase by 44% from 2006 to 2030 (IEO 2009). The nuclear power plant construction market is also growing with sharper competition. In nuclear power plant construction, scheduling is one of the most important functions due to its mega size and heavy complexity. Therefore, it is crucial to incorporate the 'distinct characteristics of construction commodities' and the 'complex characteristics of scheduling techniques' when selecting appropriate schedule control methods for nuclear power plant construction. However, among various types of construction scheduling techniques, the traditional critical path method (CPM) has been used most often in real-world practice. In this context, the purpose of this paper is to examine the viability and effectiveness of linear scheduling method (LSM) applications for selective areas in nuclear power plant construction. First, in order to identify criteria for scheduling method selection, the characteristics of CPM and LSM were compared and analyzed through a literature review. Distinct characteristics of nuclear power plant construction were then explored through the use of a case project. Finally, promising areas for actual LSM application are suggested based on the proposed evaluation criteria and the case project. The findings and practical implications are discussed for further implementation.

Keywords: Nuclear Power Plant Construction, Scheduling, Linear Scheduling Method (LSM), Critical Path Method (CPM)

Global energy demand is expected to increase by 44% from 2006 to 2030 (IEO 2009). In developing countries, especially China and India, energy demand is expected to significantly increase. Due to the 2009 U.S. financial crisis, international crude oil prices surged to a slight slowdown. Another fact is the decreasing use of fossil fuels for energy due to environmental concerns. As a result, using oil for energy is expected to decrease to 32% by 2030. By contrast, the world's nuclear power generation was 2.7 trillion kWh in 2006 and is expected to increase to 3.0 trillion kWh by 2015 and 3.8 trillion kwh by 2030. Therefore, the nuclear power plant construction market is also growing with sharper competition. Under this intense competition, companies in the nuclear industry strive to enhance the quality, costs, and time for nuclear construction.

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In nuclear power plant construction, scheduling is one of the most important functions due to its mega size and heavy complexity. Therefore, it is crucial to incorporate the 'distinct characteristics of construction commodities' and the 'complex characteristics of scheduling techniques' when selecting appropriate schedule control methods for nuclear power plant construction. However, among the various types of construction scheduling techniques, the traditional critical path method (CPM) has been used most often in real-world practice. Using only one type of method may not be an effective way for these types of construction projects.

In this context, the purpose of this paper is to examine the viability and effectiveness of linear scheduling method (LSM) applications for selective areas in nuclear power plant construction. First, in order to identify criteria for scheduling method selection, the characteristics of CPM and LSM were compared and analyzed through a literature review. Distinct characteristics of nuclear power plant construction were then explored through the use of a case project. Finally, promising areas for LSM application are suggested based on the proposed evaluation criteria and the case project. The findings and practical implications are discussed for further implementation.

1. Breakdown structure for Nuclear power plant

Nuclear Plant Deployment Program Model (NPDPM 2008) provides a guideline for the entire process of nuclear power plant construction, including licensing procedures for construction companies in the U.S.A. The NPDPM defines hierarchical levels that can be used as construction activities. Depending on the complexity of management requirements, the level of work breakdown structure (WBS) is required to be determined. The WBS of NPDPM is analyzed in this study in order to develop evaluation criteria for the utilization of LSM in nuclear power plant construction.

Table 1. NPDPM Classifications (EPRI 2008)

NPDPM Level	Level I	Level II	Level III	Level IV
Classification Facet	Life Cycle (Phase)	Physical Break-down Structure (PBS)	Physical Break-down Structure (PBS)	Functional Breakdown Structure, or Commodity (FBS)

NPDPM (2008) Level I in Table 1 is a classification based on facility life cycle. This stage consists of seven phases that include "planning, design, procurement, construction, start-up, maintenance, and reload". For the purpose of analyzing LSM application, the phase is limited within 'construction phase' in this paper. Level II conforms with the general form of physical breakdown structure (PBS) systems. Level II has "improvements, off-site improvement, nuclear island, auxiliary building, turbine island, rad waste building, control building". Level III is a sub-level PBS, for example, consisting of "structural modules (below grade), structural modules (above grade), system modules, nuclear island construction testing" following each single facilities in Level II. In this study, the activities for LSM evaluation were selected based on Level III.

2. LSM adaptability for construction projects

LSM technique is effective for repeated and successive construction activities. (Yamin and Harmelink 2001; Soini et al. 2004, Kallantzis et al. 2007; Lucko 2008; Hegazy and Kamarah 2008) By contrast, critical path method (CPM) is apt to analyze a variety of complex occurrences of construction activities. As such, including scheduling methods, management techniques for each business functions each have their own distinct characteristics. Based on extensive research literature, this study identified 'process characteristics', 'spatial characteristics' and 'resource allocation' as three LSM assessment variables and detailed requirements were defined as six items. (Table 2)

Table 2 Assessment Measures for LSM Application

Variable	Measure	Definition
Process characteristic	Repetition of the same work types	Suitable if same processes is repeating
	Occurrence of concurrent works	Advantage by interference check for concurrent works
Spatial characteristic	Vertically or Horizontally continuous operation	Effectiveness by visualizing spatially continuous operations
	Density of work space	Suitable if workspace is not dense
Resource allocation	Equal distribution of resources	Suitable if productivity is stable
	Continuity of resources	Suitable if resources are required constantly

'Process characteristic' has two measures; 'repetition of same work types' and 'occurrence of concurrent works'. Clearly, LSM is effective for repetition of the same types of works (Yamin and Harmelink 2001). A good example is the construction of a skyscraper where same works are repeated vertically. The 'Occurrence of concurrent works' is an important feature for interference check process, and LSM is utilized more effectively for this feature. 'Space characteristic' is another effective perspective for LSM application as LSM itself clearly shows an inter-relationship between space and time. Using LSM for 'resource allocation' brings about the effects of shortening the construction period by maintaining the same productivity with an even distribution of labor, materials, and equipment. (Hsie et al. 2009)

3. LSM Assessment for nuclear power plant construction

A two-step assessment methodology for identifying appropriate activities for LSM application is developed in this study. The proposed methodology uses the two dimensions previously discussed in this paper. One dimension is the WBS of nuclear power plant construction in Table 1, the other dimension is LSM assessment measure as shown in Table 2. In order to effectively identify promising LSM areas, the first step examines an appropriate facility (e.g. reactor container building). The second step evaluates LSM suitable work sections (e.g. concrete work) by scheduling activity level.

3.1 Step 1: Appropriate facilities for LSM application in nuclear power plant

Nuclear power plant facilities are composed of “site improvements (SITE), nuclear island (RCB), auxiliary building (AUX), turbine island (TUB), rad waste building (RWB), control building (COB), yard structure (YARD)”. Work-sections were defined into six categories including ‘common temporary work, civil, architectural, mechanical, electrical, and piping’. Based on these six work sections, a total of 26 detailed commodities were defined, and these commodities were reviewed and confirmed by experts in this area.

Table 3. Assessment of Facility for LSM Application

Work-section	Commodity	Facility						
		SITE	RCB	AUX	TUB	RWB	COB	YARD
Common Temporary work	Crane installation	0	0	0	0	0	0	
	Foundation excavation	0	0	0	0	0	0	
Civil	Concrete foundation	0	0	0	0	0	0	
	Outdoor utilities							0
Architectural	Structural steel plate		@					
	Structural steel (Tendon)		@					
	Steel frame		@	0	0	0	0	
	Metals		@	0	0	0	0	
	Concrete pouring		@	0	0	0	0	
	Case work		@	0	0	0	0	
	Painting/Coating		@	0	0	0	0	
	Finishing		0	0	0	0	0	
Mechanical	General equipment		0	0	0	0	0	
	Steam condenser				0			
	Turbine generator				0			
	HAVC		0	0	0	0	0	
	NSSS		0					
	Tank							0
	Fuel rail		0	0		0		
Electrical	Electrical instrument		0	0	0	0	0	
	Electrical wire		0	0	0	0	0	
	Outdoor switching station							
	Security/communication							
	Instrumentation/Equipments							
Piping	Piping		@	0	0	0	0	
	Insulation		0	0	0	0	0	
Total		3	19	16	17	16	15	2

LEGEND: O: Commodities included in each facility.
@: Highly repetitive commodities in schedule.

A matrix for assessing facilities was developed as shown in Table 3 by using the 'facility' (e.g. SITE, RCB in Table 3) and 'commodity' (e.g. concrete pouring) dimensions. An initial trial evaluation was performed to see whether each facility has the same redundant activities based on 'process characteristics' in Table 2. Namely, a facility was reviewed for its number of subordinate commodities and the frequency of repeat activities for each commodity. For example, a nuclear island (RCB) as in Table 3 has 19 commodities as schedule activities. Among these 19 activities, eight activities marked with an @ have highly repetitive work processes. It should be noted that a nuclear power plant expert performed this evaluation.

Another issue is that the construction period of a RCB on the critical path has significant impact on the entire nuclear power plant construction schedule. Moreover, a RCB is the most important building for safety constructed under intensive management throughout the project. Therefore, a shortened construction period of a RCB can contribute positive results for the entire schedule. RCB was selected as the most promising LSM application area in this study.

Table 4 Assessment of Commodity for LSM Application

	Process characteristic		Spatial characteristic		Resource allocation	
Measure	Repetition of the same work types	Occurrence of concurrent works	Vertically/ horizontally continuous operation	Density of work space	Equal distribution of resources	Continuity of resources
Method	Times of repetition	Y/N	Y/N	Relative volume	Same labor	Buffering time
Score	None : 0 Under 10 times : 5 Over 10 times : 10	No : 0 Yes : 5	No : 0 Yes : 5	High : 0 Middle : 5 Low : 10	No : 0 Yes : 5	No : 0 Yes : 5

3.2 Step 2: Appropriate worksections for LSM application in Nuclear Power Plant

In the first step, a RCB was chosen as being the first priority. In the second step, for RCB, a subordinate 19 commodities were evaluated by using six measures as defined in Table 2. For each measure, measurement methods and units are defined as shown in Table 4. For the process characteristic variable, a measure of 'repetition of the same work types' was scored by the 'times of repetition' of each commodity in a facility. Scores for no repeat, under 10 times, over 10 times are 0, 5, and 10 respectively.

In 'spatial characteristic', 'vertically or horizontally continuous operation' is judged by yes or no. Comparing to the CPM technique, activities that have characteristics of continuous operation is more efficient by adopting LSM control. 'Density of work space' approaches the

topic in terms of space management. In a congested space, many activities being performed at the same time may cause interference or decreased productivity. It is also an important issue to consider for the buffering of time and delays together. The measurement method for 'density of work space' is to evaluate the relative scope of work to the volume of workspace.

'Equal distribution of resources' are well addressed in relevant research titled "choosing a proper combination of production rates can effectively shorten the project duration" by Hsie et al. (2009). This paper focuses on the utilization of the same labor group as suggested by Hsie et al. (2009). 'Continuity of resources' evaluates the availability of buffering time. Due to the complexity of nuclear power plant construction, numerous stakeholders generate much construction and interference. Therefore, wait time process that occurs during construction should be managed within the planned construction period.

Table 5 LSM Assessment for RCB Scheduling Activities

Work-section	Commodity	Scores
Common temporary work	Crane installation	5
Civil	Foundation excavation	5
	Concrete foundation	15
	Outdoor utilities	10
Architectural	Structural steel plate	40
	Structural steel (Tendon)	40
	Steel frame	35
	Metals	35
	Concrete pouring	40
	Case work	40
	Painting/coating	25
	Finishing	0
Mechanical	General equipment	0
	Steam condenser	0
	Turbine generator	0
	HAVC	0
	NSSS	0
	Tank	0
	Fuel rail	0
Electrical/ Instrumentation	Electrical instrument	0
	Electrical wire	0
	Outdoor switching station	0
	Security/Communication	0
	Instrumentation/Equipment	0
Piping	Piping	25
	Heat insulation work	5

In a case-study with expert participation, nineteen commodities categorized into six work-sections for RCB were evaluated by using the assessment method shown in Table 4. Final scores for these commodities are summarized and listed in Table 5. For the measure of 'repetition of same work types', structural steel plate, structural steel (tendon), steel frame, metals, concrete pouring, case work, painting/coating, and piping were evaluated as high scores. In 'occurrences concurrent work type', six commodities obtained a high score including structural steel plate, structural steel (tendon), steel frame, concrete pouring, case work, and painting/coating. The result of 'vertically or horizontally continuous operation' is the same as the results for 'repetition of same work types'. As for 'density of work space', the commodity of concrete (civil, architectural) were also evaluated with high scores. This means that a large volume required a relatively small working space during concrete works. 'Equal distribution of resources' appeared to be confined within the 'architectural' work-section. For the 'continuity of resources' measure, almost all commodities except for mechanical and electrical / instrumentation scored similarly. It is found that there is much interference between such activities.

4. Conclusion

The distinct characteristics of each project and its commodities should be thoroughly considered when selecting the most appropriate and effective management techniques. The unique characteristics of a nuclear power plant construction project include its mega size and heavy complexity. In this context, the purpose of this paper is to develop a methodology for selecting appropriate areas to apply LSM techniques in nuclear power plant construction

The proposed methodology has two major dimensions for assessment; one is the WBS of a nuclear power plant, and the other is LSM assessment measure identified in this study. Based on these two dimensions, detailed assessment methods and scales are developed. A two-step evaluation of LSM applicability for nuclear power plant construction was conducted as a case-study. Eight commodities in a nuclear island (RCB) that included structural steel plate, structural steel (tendon), steel frame, metals, concrete pouring, case work, painting/coating, and piping were selected as promising areas for LSM application.

This study is currently on-going, and further case studies will compare the CPM and LSM schedules for the chosen eight commodities. This would validate the proposed methodology. It is expected that the methodology and measures developed in this study can facilitate to increase efficiency and to reduce the project schedule for nuclear power plant construction projects.

5. ACKNOWLEDGEMENTS

This study was supported by the Korean Ministry of Land, Transport and Maritime Affairs(MLTM) of the Korean Government under Grant No. 10 R&D B01 (Modernized Korean Housing Development Program by KICTEP), and the Korean Ministry of Knowledge Economy under Grant No. 2011T100200143. The supports are gratefully acknowledged.

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Impact of construction firms' competitiveness on corporate performance: An exploratory study

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Abstract

This paper investigates the competitiveness and corporate performance of construction companies in South Africa. It examines whether there are key indicators of construction firms' competitiveness that enhances their corporate performance. The rational for the study is based on the fact that the factors, which give construction companies their competitive advantage in South Africa is unknown. A descriptive survey approach and a combination of convenience and snowball sampling techniques were used in identifying 35 building and civil engineering construction companies based in three provinces of South Africa and registered in grades 2-6 of the Construction Industry Development Board (cidb) contractor grading register. The data used in the study was collected from this cohort of respondents through the use of structured interviews incorporating closed and open-ended questions. The findings of this exploratory study indicate that there is a negative significant relationship between staff size a key indicator of competitiveness and their overall corporate performance Return on Total Assets (ROTA) and also the technical ability and company industry affiliation are positively and highly correlated with their overall corporate performance. Based on these significant findings, it can be concluded that it is not the size of staff that determines competitiveness but their productivity. Effective and efficient staff, good technical ability and the level and strength of industry affiliation will make the construction company more competitive and influence its corporate performance. The findings of this research provide construction companies with new knowledge, enabling contractors to understand their competitive advantage and weaknesses in order to formulate effective competitive strategies that will enhance their corporate performance.

Keywords: Competitiveness, corporate performance, marketing strategy, net asset, and, profitability.

1. Introduction

Competitiveness as described by Man, Lau and Chan (2002), is the ability of a firm to increase market share, profit and growth in order to be competitive for a long time and to improve the firms' capability as well as the firms' financial strength. According to Corbett and Wassenhove (1993), a firm's competitiveness has price, place and product dimensions. Implying that competitiveness is a multidimensional phenomenon. The increasing global nature of markets and economic activities has resulted in the increasing complexities of competition among

construction companies (Ibrahim, Ibrahim and Kabir, 2009; Korkmaz, and Messner, 2008), which has made construction companies to be continuously challenged to meet the needs of society and clients (Sexton and Barrett, 2003).

Assertions made by Man et al. (2002), are that firms' competitiveness and corporate performance is characterized by its managerial skill and technical capability or acquisition of strategic assets. Competitiveness however is being regarded as a means to an end which is a firms' performance. Tan, Shen, Yam and Lo (2007), noted that competitiveness is generally used to grade contractors according to their capacity and capability. Conversely, organizational performance is described by DeHaan, Voordijk, and Joosten (2002) as a function of a firms' competitiveness and capability. This paper examines the competitiveness of construction companies that impact their corporate performance, making use of construction company capacity and marketing strategy as competitive variables for the study. To do this, the paper first of all reviews pertinent literature on what constitutes competitiveness of construction firms. Secondly, the research methods used in the study are presented. Thirdly, the data collected in the study is presented and analysed. Finally, the paper discusses the research findings and its implications for construction company performance and growth, which will be the subject of further research.

2. Overview of construction firms' competitiveness

Assertions made by Price and Newson (2003), are that companies competitiveness is evident when it has an edge over its counterparts in attracting customers and protecting its share of the market against other competing forces. In addition, since the market undergoes continuous changes, it implies that competitive advantage cannot be maintained for a very long time without changes in strategies (Korkmaz, and Messner, 2008) and firms therefore rely on the acquisition of new forms of competitiveness in order to be at an advantage and hence maintain their lead (Thompson and Strickland 1999). According to Porter (1990), firms can only be competitive in the market within the boundaries of their competitive advantage. Korkmaz and Messner (2008), Man et al. (2002) established that company competitiveness is a function of a firm's managerial capability, market share, profit and growth.

2.1 Capacity of construction firms

Capacity is described as the possession of adequate human resource team (Russell, 1991), level of managerial skill (Green, Larsen and Kao, 2007), ability to recognise the value of technological innovation and apply it (Zahra, and George, 2002), having financial capital (Bakar, Razak, Yusof and Karim, 2011), as a measure of the development and growth of firms (Bakar, Razak, Yusof, and Karim, 2011), as technical ability in terms of land, buildings, plant and equipment (Tan, Shen, Yam and Lo, 2007). Construction company capacity can therefore be said to include, assets, technical & managerial skills, human resource, turnover, finance, and ability to innovate.

Asset refers to land, buildings, plant and equipment. Penman (2001) describe assets as resources possessed by firms for use in the business operations for an economic benefit as a result of some current or past transaction. Since construction business is a high-risk venture, financial institutions tend to be more difficult in approving loan applications for contractors (Adams, 1997). Lack of collateral security in the form of land, buildings poses a setback for loan acquisition by contractors. It has been validated by previous research that possession of assets by firms enhances their overall performance (Adams, 1997).

2.2 Overview of Marketing Strategies used by Construction Companies

Business networking/relationship can be described as a collaboration of a firm with a strategic actor to form strong and extensive service that enhances the firm's performance (Chell and Baines, 2000). Korkmaz, and Messner (2008), identified marketing strategy as a key business performance factor. This study argues that construction firms that are performing and expanding in operations must have acquired specific advantages and resources through market strategies and the level of their affiliation with construction industry stakeholders like clients, which enables them to be more competitive and perform at higher levels when compared to their counterparts in the construction industry who have not acquired these (Day, 2000).

2.3 Factors influencing corporate performance

Organisational performance is acknowledged as a function of a firms's competitiveness and capability (De Haan, Voordijk and Joosten, 2002); financial, operational and organizational effectiveness (Man et al., 2002); technical capacity (Man et al., 2002); profitability or financial gain (Beatham, Anumba, Thorpe and Hedges, 2004; and Norris, 1990); a basic goal for running a business (Tam, 2002; Naoum, 2003) and a function of timely delivery (Soetanto, Proverbs and Holt, 2001). Bakar et al. (2011) opine that growth and performance can be measured by the dependent variables of turnover and number of permanent employees of the firm.

Although previous research has validated several factors that influence the corporate performance of firms, however, (Man et al., 2002) opined that managerial skills and technical ability are influential factors of performance. Man et al. (2002) further argued that competitiveness of firms has a strong relationship with competitive scope, organizational capabilities, entrepreneurial competences and performance. This implies that competitiveness has a very strong link with performance of the firm. Figure 1 shows a conceptual framework of the relationship between competitive advantage and corporate performance adapted from previous studies by DeHaan et al. (2002), Man et al. (2002), Beatham et al. (2004), Norris (1990), Ofori and Chan (2000), Tam (2002), Naoum (2003), Soetanto et al. (2001) and Bakar et al. (2011).

From the arguments of DeHaan et al. (2002), Man et al. (2002), Beatham et al. (2004), Norris (1990), Ofori and Chan (2000), Tam (2002), Naoum (2003), Soetanto et al. (2001) and Bakar et

al. (2011), the relationship between competitive advantage and performance can be modeled mathematically as:

Corporate Performance {ROTA; ROCE; PM, PBIT, Turnover} = Competitiveness [TA+NA + TECHAB + STSZ + AGE + CAPSTR + INDAFF] (See Figure 1)

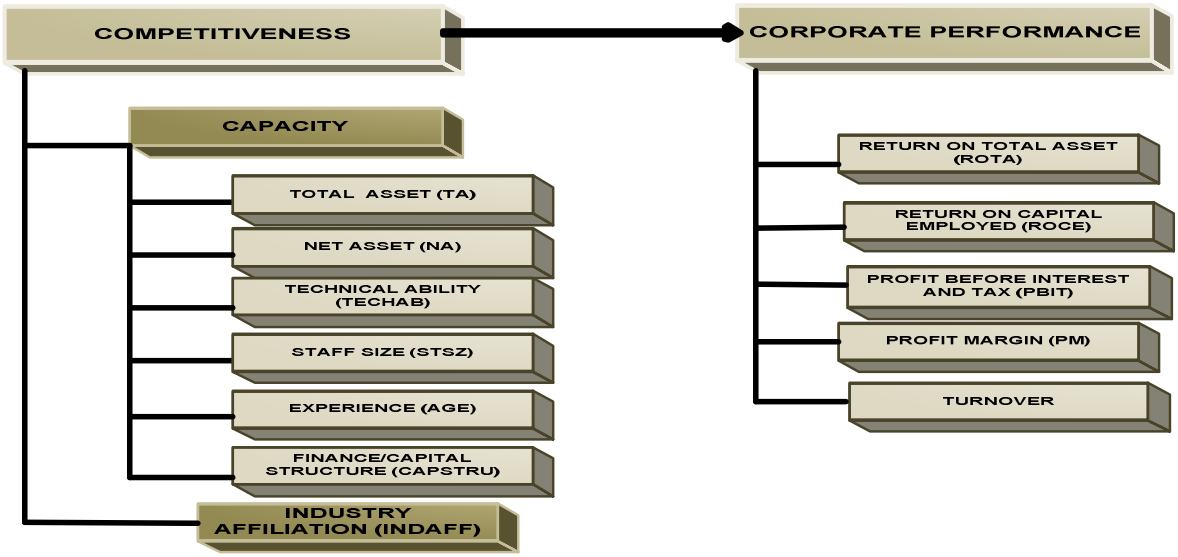

Figure 1: Conceptual frame work of the competitive indicators and performance outcome

Adapted from: DeHaan et al. (2002); Man et al. (2002); Beatham et al. (2004); Norris (1990); Ofori and Chan (2000); Tam (2002); Naoum (2003); Soetanto et al. (2001); and Bakar et al. (2011)

2.4 Research Hypothesis

In addition, the study will be employed in testing the following hypothesis:

H_A: *There are significant competitiveness factors related to the corporate performance of construction companies in South Africa.*

H_O: *There are no significant competitiveness factors related to corporate performance of construction companies in South Africa*

3. Methodology

This research is an area extensively documented in construction management studies (Adams, 1997; Bakar et al. 2011; De Haan et al. (2002); Man et al., 2002; Korkmaz and Messner, 2008; Ofori and Chan, 2000; Russell, 1991; Soetanto et al. 2001; and Tan et al., 2007). A purposive but convenient snowball sampling technique was used in selecting the cohort of construction

companies used in the study from a population of grade two to six building and civil engineering contractors registered on the cidb contractor register. Sampling in this research effort describes a specimen or part of a whole of the population under survey which would reflect the characteristic of the remaining population (Naoum, 2007). Grade two to six building and civil engineering contractors were used in the study because these grades of contractors are often used in contractor training and development programmes on government housing projects in South Africa and also form the major contributors to infrastructure delivery. All potential participants were invited telephonically to take part in the study after which the survey questionnaire was emailed to one hundred (100) participants who agreed to participate in the study. The study was undertaken between July and September 2012 (a ten week period) at the end of which 35 valid responses were collected, representing an overall response rate of 35%. Idrus and Newman (2002), consider any response rate in the range of 20% to 30% to be adequate and valid for research in the construction industry Participants who did not complete the survey via email were reminded intermittently via phone calls. A descriptive and multi-attribute methods and rank correlation was used in analysing the data collected (Chang and Ive, 2002). This is deemed by Mbachu and Nkado (2007) as being appropriate for quantitative and qualitative research data and questions.

3.1 Rating of construction firms' strategic competitiveness and industry affiliation

In order to rate the the indicators of construction firms' strategic competitiveness and industry affiliation, a relative importance index was computed with a minimum value of 0, and a maximum value of 4 from data obtained from a Likert scale used in obtaining information on respondents perception of factors enhancing construction company's competitiveness and industry affiliation (Table 3, figure 2). The relative importance index was calculated using the formula:

Relative Importance Index (RII) $= \frac{4n1+3n2+2n3+1n4+0n5}{(n1+n2+n3+n4+n5)}$

Where: n1, n2, n3, n4 and n5 = Excellent, Good, Average, Poor and Very Poor respectively.

3.2 Corporate Performance Measurement

This study employs the following variables as measures of corporate performance:

- **Return on Total Assets** (ROTA, %) - This is measured in terms of profit before tax which is expressed as a percentage of the total asset. It is an indicator of both profitability and growth. Calculated as: (Pre Tax Profit/Total asset)*100. (Armstrong, 2006; and Ibrahim et al., 2005).

- **Return on Capital Employed** (ROCE, %) - This is a measure of the profitability and growth of the firm as it measures the effectiveness of the management of the firm. It is defined as

the ratio of profit before interest and tax to the total assets less current liabilities. It is calculated as: Profit before Interest (PBIT) and Tax/(Shareholders Funds + Long Term Loans + Other Long Term Liabilities)*100% or PBIT/TA-CL (Armstrong, 2006).

- **Profit before interest and tax (**PBIT): This is described as the profit inclusive of interest and tax. It is calculated as [(Return on Capital Employed, ROCE)* (Shareholders Funds + Long Term Loans + Other Long Term Liabilities)]/100 or (Profit Margin, PM * Turnover)/100 (Armstrong, 2006).

- **Profit Margin** (PM, %) - According to Ibrahim et.al. (2005), profit margin is referred to as net profit on sales and reflects the degree of competitiveness in the market, the ability to differentiate products, the economic situation and ability to control expenses. It is calculated as: (Profit before interest and Tax/Turnover)*100%.

- **Turnover**: This is the volume of contract performed by construction companies, usually rated per year of its operation. (Armstrong, 2006). It is calculated as (Profit before interest (PBIT) and Tax/Profit Margin, PM)*100%

3.3 Measurement of Capacity

- **Total Asset** (TA): This is the fixed Asset plus the Current Asset.

- **Net Asset** (NA): This is the asset excluding liabilities. It is calculated as the Fixed Asset – the Current Asset.

- **Staff Size**: This refers to the permanent employees of the firm within a certain period of time. It is measured by the number of employee on its payroll.

- **Age of the firm:** This is the number of years the company has operated since its inception in the construction industry.

- **Technical ability** (TECHAB): is described as the ability to recognise the value of technological innovation and apply it (Zahra, and George, 2002).

- **Capital Structure**(CAPSTRU): refers to the combination of funds, in the form of debt and equity, a firm uses to finance its asset investments of the firm (Muzir, 2011: pg. 87). This is usually controlled by cash position which simply means the amount in cash held by company in its bank account to finance projects. In other words, it's the company standing capital

- **Industry Affiliation (INDAFF)**: This refers to as marketing strategy in terms of networking which is defined as a cunning inception, sustainability of interpersonal connections for the purpose of commercial gain or an activity in which owners of construction firms build and manage personal relationships with particular individuals in their environment to gain market share (O'Donnell, 2004). It is measured in this study by respondents' perceived strength of relationship with key construction industry stakeholders – client, consultants, suppliers and sub-contractors/other contractors.

3.4 Method of Data Analysis

The Pearson product moment correlation (r) was used to test the proposed research hypothesis in section 2.4. According to Naoum, (2007) and Oyewobi,et al. (2011), the relationship can be either positive or negative and the strength of it is measured on a scale that varies from +1 through 0 to -1. If the critical value obtained is equal or more than the critical value tabulated, then the null hypothesis proposed will be rejected and vice versa (Naoum, 2007)

4. Findings and discussion of results

The data collected in the study are presented in the following sub-sections:

4.1 Background of the Respondents

The study sought to find out the background of the respondents used in the study and data collected in this respect is presented in Tables 1.

Table 1: Work Category of Respondents' Company

Work Category	No. of Respondents	Percentage (%)
Civil Engineering Contractors	22	62.86
Civil Engineering and General Building Contractors	7	20.00
General Building Contractors	4	11.43
Civil, Building and M&E contractors	2	5.71

Table 1 reveals that a significant number of the respondents are made up of civil engineering contractors. It emerged that the respondents are highly placed in the organisations in which they work. The respondents comprised of 57.14% owners, 22.86% Directors, 14.29% Management staff and 5.71% Technical staff. This implies that the information provided by this cohort of respondents is reliable and valid.

4.2 Perception of respondents regarding the factors enhancing construction company competitiveness

This study aims at understanding the perception of contractors regarding the factors which enhances their competitiveness. Data collected in this regard is presented in Table 3 and Figure 2.

Table 2: Perception of respondents regarding the factors enhancing competitiveness

Factors	Rating of Respondents' Perception - Frequency					RII	Rank
	Very poor……Excellent						
Contractor Affiliation with Clients	0	0	0	21	14	3.40	1
Asset	1	1	5	18	11	3.11	2
Contractor Affiliation with Consultant	0	0	10	20	5	2.86	3
Technical and Management Skills	0	4	0	29	2	2.83	4
Contractor Affiliation with Suppliers	0	0	12	17	6	2.83	4
Experience	1	1	9	17	7	2.80	5
Turnover	3	3	5	19	5	2.57	6
Staff of the organization	2	5	6	21	2	2.51	7
Finance	2	1	10	22	0	2.49	8
Contractors Tender Value	4	6	3	18	3	2.23	9
Contractor affiliation with other contractors	0	12	16	7	0	1.86	10

Table 2 and Figure 2 indicates that from a ranking perspective and the radar diagram, construction firms have very strong affiliations with their clients which were ranked first with an RII of 3.40, followed by possession of asset ranked 2nd with RII of 3.11. It reveals that contruction firms rely more heavily on clients' affiliation as a marketing strategy and possession of assets for job procurement and competitiveness.

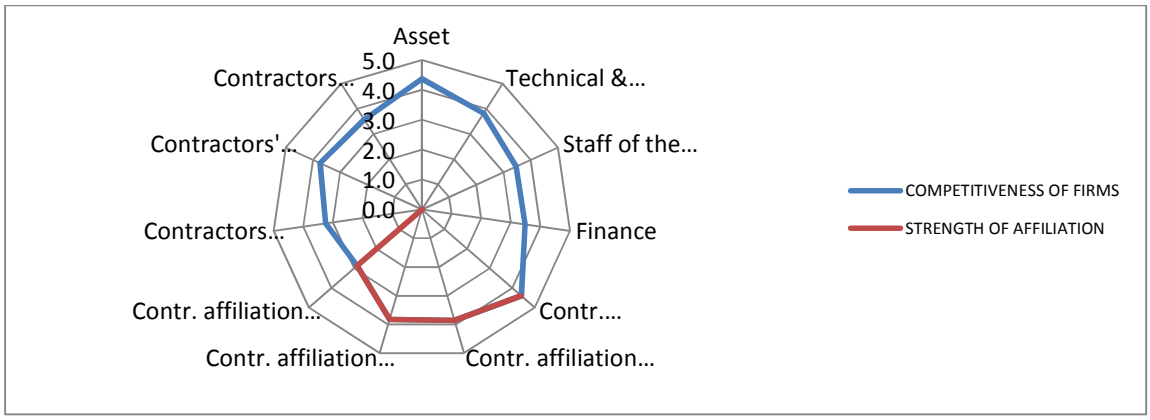

Figure 2 Perceptions of factors contributing to competitiveness & contract procurement.

4.3 Relationship between competitiveness and corporate performance

Figure 3 shows the crossesction of quantitative measures of competitiveness and corporate performance of the construction companies used in the study respectively. Figure 3 reveals that Firm 19 had the highest ROTA of 1400%; Firm 15 had the highest profit of 1100%; and Firm 22 had a ROCE of 550%.

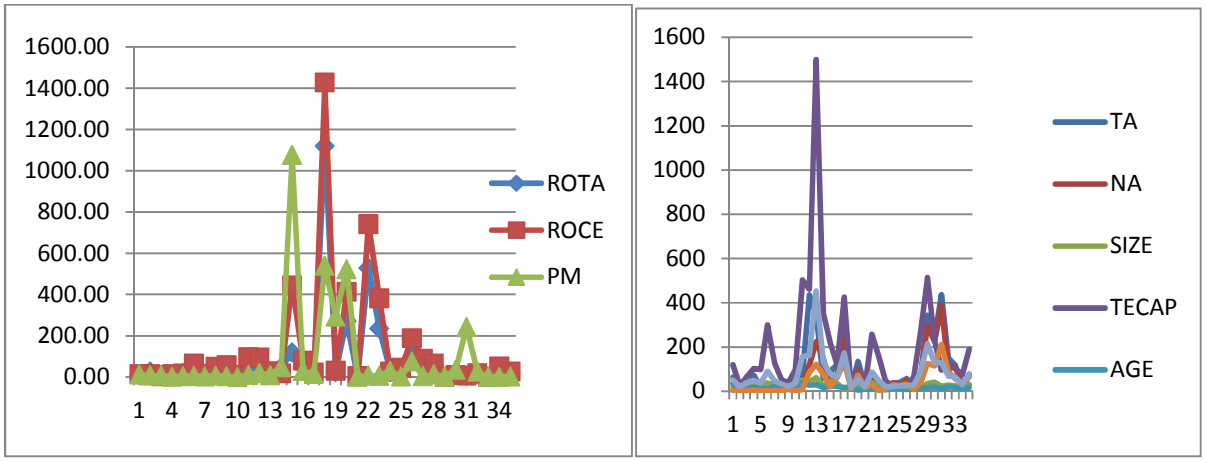

Figure 3: Indicators of Performance and Competitiveness of Firms

Results of the Pearson Correlation Analysis computed between the indicators of competivieness and corporate performance of the responding companies are presented in Table 3.

Table 3: Correlates between company competitiveness and corporate performance

Competitiveness indicators / *Corporate Performance*	*TA*	*NA*	*STAFF SIZE*	*TECHCAP*	*AGE*	*CAP STR*	*IND AFF*
PBIT	.264	.062	.031	.188	.625	.145	0.734**
TURNOVER	*.239*	*.081*	*.132*	*.451***	*-.022*	*.134*	*-0.083*
ROTA	*-0.235*	*-0.235*	*-.291**	*-0.168*	*-0.049*	*-0.217*	*0.929***
ROCE	*-0.227*	*-0.263*	*-0.218*	*-0.158*	*-0.031*	*-0.240*	*0.967***
PM	*-0.009*	*-0.041*	*0.93*	*-0.111*	*-0.29*	*-0.001*	*o.734***

*** Correlation is Significant at the 0.01 level (1-tailed)*

**Correlation is Significant at the 0.05 level (1-tailed)*

Pearson Product Moment Correlation analysis was used to test the hypothesis that there are significant competitiveness factors related to the corporate performance of construction companies in South Africa. It emerged from the analyses presented in Table 3 that there is a significant negative relationship between the staff size, size of the construction companies and corporate performance (ROTA), with a critical value -0.291* and a significant positive relationship between turnover and technical ability, with a critical value of 0.451** and also a significant positive relationship between contractor's strength of construction industry affiliation with corporate performance - profit before interest and tax (PBIT), Return on Total Asset (ROTA), and Return on Capital Employed (ROCE), and Profit Margin (PM) with critical values of 0.734**, 0.921**, 0.921** and 0.734** respectively, whilst there is no significant relationship between other indicators of competitiveness such as Age, TA, NA, Capital Structure (CAPSTRU) and corporate performance. This implies that the null hypothesis is rejected

5. Conclusion and Further Research

This exploratory study provides insights into the competitiveness of South African construction companies in terms of capacities, capabilities and company industry affiliation.The findings suggest that the staff size of the construction companies is negatively correlated with corporate performance (ROTA). In addition, the technical ability and company industry affiliation are positively and highly correlated with their corporate performance whilst no significant relationship was seen between other competiveness factors and corporate performance, It can be concluded therefore that there are significant competitiveness factors related to the corporate performance of small and medium sized construction companies which lie in well managed, efficient and effective staff, good technical ability, and the level and strength of the company industry affiliation. It follows that the smaller the company staff size, good technical ability and strong industry affiliation with client the more will be its corporate performance

This research effort reports the pilot study of an on-going research into the impact of capacity networking strategy of small and medium sized contractors on their corporate performance. Further research to validate the results obtained in this study using a larger sample size across more provinces of South Africa, will form the basis of future studies.

6. Limitation of the research

The finding of this research was focussed only on building and civil engineering contractors listed in Grade 2 to 6 on the cidb Contractor Register. The findings of the research will therefore not be generalizable to the total population of small and medium sized contracting companies in South Africa due to the smallness of the sample size and the limited number of provinces surveyed. The findings and conclusions are also limited to the quality of the responses on the salient information relating to the research questions given by the respondents in the study.

Acknowledgement

The authors are grateful and thankful to the firms that participated in the study.

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Environmental Performance of External Roller Blinds Retrofit for Offices in the United Kingdom

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Abstract

Fixed external shading devices, such as louvers, are widely used to combat solar gains that can lead to excessive overheating. External roller blinds, although commonly used in mainland Europe, are rarities in the UK.

External roller blinds are retractable shading devices formed of horizontal slats that roll up into a casing above a window opening. They are a well-developed technology with distinct advantages over fixed external shading devices. When fully extended the blinds block solar radiation externally reducing heat gain in summer, in the winter they add thermal resistance and reduce heat loss through windows. Appropriate design and applications of external roller blinds have the potential to improve the sustainability of buildings.

This paper reports on an on-going applied research project that investigates the effect of external roller blinds on the internal thermal environment and potential advantages to the sustainability of retrofitting office buildings in the UK. The first part of the paper describes a proof of concept study in which an in-situ external roller blind was installed in a 'test' room and its summertime thermal performance was compared with that of a 'control' room under the same external climatic conditions.

Dynamic thermal analysis was carried out to establish the annual thermal performance of the blind, including impact on cooling and heating energy requirements. Associated annual carbon dioxide emissions were established and the blind was discovered to reduce the greenhouse gas emissions (CO_{2e}) by 15% annually, majority of which is reduction in requirement for heating.

The life cycle impact of the blind was investigated. Individual process contributing to the production, manufacture, decommissioning and transport of the blind were assessed in terms of their greenhouse gas emissions. Under the conditions of the concept study scenario and taking into account the recycle of the components, the external roller blind in operation is estimated to take approximately six months to save enough to compensate the embodied greenhouse gas emissions mainly due to the manufacturing process. The results

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have demonstrated there is significant potential of using external roller blinds to reduce the operational and life cycle greenhouse gas emissions of buildings in the United Kingdom.

Keywords: External roller blinds, shading devices, solar control, environmental impact, heat loss reduction.

1. Introduction

There is a growing demand for strategies to combat excessive solar gains in buildings. Inclusion of effective shading has the potential to improve the indoor thermal environment: it can reduce summertime overheating, regulate swings in temperature and reduce cooling load. Windows are usually the weakest thermal element in the building envelope, and one of the most common causes of overheating is excessive solar gain through windows. Therefore reducing solar gain though windows is a key consideration in maintaining comfortable indoor temperature and implementing low energy building design. In comparison to mechanical cooling, shading is a more energy efficient and cost effective way to control overheating (CIBSE, 2006; Littlefair, 2002; 2006). Effective shading as an integral part of a building should be considered from early design stages of new buildings and for retrofit of existing buildings.

To evaluate the true environmental benefits, the greenhouse gas emissions throughout the life cycle of the shading device including its production, installation, operation, maintenance, decommissioning, recycling and transportation should be taken into account. A methodology commonly used, and adopted in this study, is the Life Cycle Assessment (LCA), which identifies and quantifies the inputs and outputs for a whole life cycle or individual life cycle stages of a product. Review indicated that previous study to establish the life cycle impact of external roller blinds has not been carried out. One relevant study carried out by Huang et al (2012) demonstrated that retrofitting a fixed overhang for shading had a negative environmental impact over its lifetime due to the geographical and meteorological factors.

This paper reports on an on-going applied research on the feasibility of integrating external roller blinds as a sustainable technology for retrofitting office buildings in the UK. It summaries the initial findings and conclusions of the first three stages of the research programme: an in-situ experimental concept study, computer modelling and simulation of the annual operation and performance, and the life cycle assessment of its environmental impact.

1.1 Background

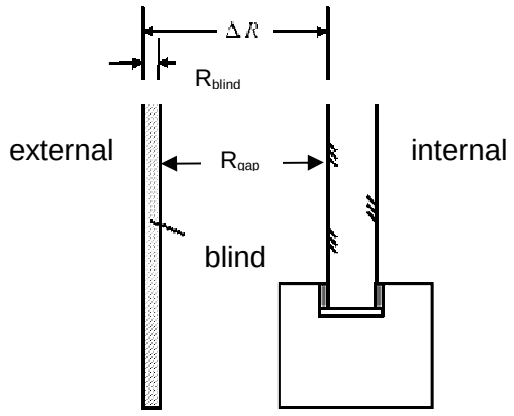
The solar radiation transmitted by and absorbed within the glazing system establishes the level of solar gain in a space (CIBSE, 2006). External shading is more effective than internal shading in reducing overheating, as most of the heat in solar radiation is prevented form reaching a building surface. According to Wulfinghoff (1999) external shading can reduce solar heat input by 80% to 90%. Detailed design, in particular of fixed systems, is required to ensure heating and lighting demand is not increased as incoming daylight is blocked and

useful winter solar gain can be reduced (Littlefair 2002; 2006). The need for shading is not the same throughout the year; variation comes from seasonal requirements, daily weather and occupant requirements. Therefore, moveable devices that can respond to the climate and user needs are preferred.

1.2 Quantifying shading

On a clear summer day, an unshaded window in the UK can admit 3 kWh/m^2/day (Littlefair, 1999). To reduce overheating, a shading device should have a low total *solar transmittance,* or *g-value* - the fraction of incoming solar radiation that passes through a window and shading system. It includes radiation that is transmitted directly through the window and radiation that is absorbed; and the re-radiated, convected or conducted heat into the room. If possible, the g-value should be low in the summer to reduce solar heat gain and high in the winter to take advantage of passive heat gain. The *effective solar transmittance*, or effective g-value g_{eff}, allows for the effects of radiation coming in from different angles, throughout a sunny day, accounting the extra radiation blocked by a shading device (CIBSE, 2006). Current definition of g-value for static shading devices is not applicable to moveable roller blinds. Dynamic g-values governed by the blind's shading position and external climatic condition at a particular time and day of the year are needed to be developed to represent the dynamic shading performance.

External blinds provide additional insulation due to the air enclosed between the window and the blind. The degree of insulation depends on the level of enclosure, the effective entrapment by top and bottom seals and side channels (CIBSE, 2006). EN ISO 10077-1:2006 gives the thermal transmittance of a window with closed external blind, U_{WS}, as:



$$U_{WS} = \frac{1}{1/U_W + \Delta R}$$

U_W thermal transmittance of window;

ΔR additional thermal resistance due to the air layer (R_{gap}) enclosed between the blind and the window, and the closed blind (R_{blind}) itself.

Figure 1: Thermal transmittance of a window with closed external blind (BSI, 2006)

1.3 Quantifying greenhouse gas emissions

Greenhouse gases emissions can be calculated by measuring the energy consumption of the processes and applying published conversion factors. Conversion factors used are based on Defra (2011) guidelines as indicated in Table 1.

Table 1: Carbon emissions conversion factors (Defra 2011)

Spain electricity	UK electricity	Natural gas	Transport road	Transport shipping
0.32588 kg CO_2e / kWh	0.48462 kg CO_2e / kWh	0.224 kg CO_2e / kWh	0.25897 kg CO_2e / tonne.km	0.00411 kg CO_2e / tonne.km

2. Performance and functionality of external roller blinds

External roller blinds are retractable shading devices that are widely used in continental Europe. They provide solar control and reduce heat gains by blocking solar radiation externally. In a down position the blind increases thermal resistance, resulting from both the blind itself and the additional air layer enclosed between the window and the blind. External roller blinds have a range of different insulating properties; thermal and acoustic insulation and resistance to wind and water. In wintertime, due to the supplementary thermal resistance in a closed position they can reduce heat loss through windows at night. When fully extended the access to natural light and ventilation can be restricted. The blinds are commonly used with windows that open inwards or that have a sliding opening mechanism.

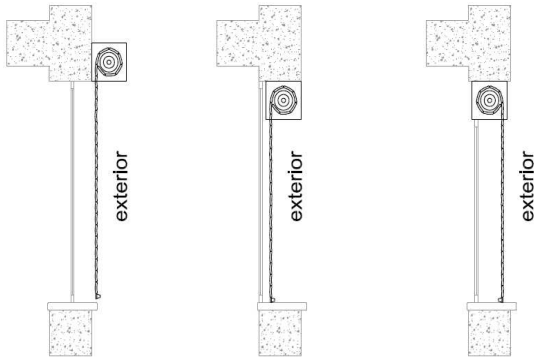
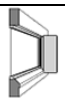


Figure 2. External roller blind systems

Table 2: Functionality of generic shading devices (Littlefair 2006, Stack et al 2000)

Shading device	Description	Performance g_{eff} *	Recommended orientation (UK)	Illustration
Fins	Vertical projections fixed at the sides of window openings	0.35	North	
Louvres vertical	Framed assemblies of vertical slats, fixed or adjustable angle	0.31	Northeast, northwest	
Overhangs	Horizontal devices fixed above window openings	0.27	South, southeast southwest	
Reveals	The sides to window openings, window heads and sills	0.35 (0.2 x width) 0.16 (0.5 x width)	South, north	
Louvres horizontal	Framed assemblies of horizontal slats, fixed or adjustable angle	0.21 (no tilt) 0.15 (45° tilt)	South, southeast, southwest	
Awnings	Retractable fabric-on-frame projections above window openings	0.13	Any	

*South facing low emissivity double-glazed window with *g* value of 0.68

The thermal impact of various fixed external shading devices has been studied (Littlefair 2006, Stack et al 2000); focus often being on reducing summer overheating without blocking out useful daylight. Performance indicators are established for generic shading devices as shown in Table 2. However, these performance indicators, in terms of *effective solar transmittances* (g_{eff}), are not appropriate for external roller blinds. Dynamics shading coefficients that relate blind position and time of the year are currently being developed. The market place for external roller blinds in the UK is currently mainly for security applications. Anecdotal evidence indicates that the public perception of the system is as a security product and their thermal impact is not realised. The importance of establishing the thermal performance of the system is a key consideration for wider applications in the UK.

There are two main types of roller blind systems: retrofit and compact, as shown in Figure 2. The retrofit system has the blind mechanism fixed to the exterior of the building with access to all components externally. The compact system has the blind as part of the window system, housed in a lintel box, with internal access to all components. Operating system is either manual belt driven or motorised. Motorised blinds can be automated via a building management system, or by local control using wireless handheld device or wall mounted switch. The slats that form the shutter are aluminium with polyurethane insulation. The thermal capacity of the blind is determined by the thickness of the slat and density of the polyurethane foam.

3. Demonstration of concept study

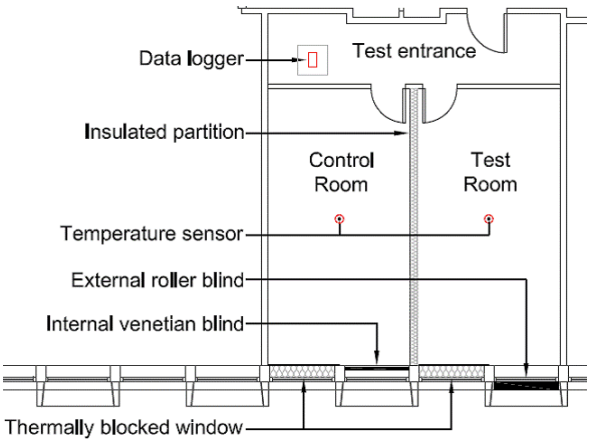


Figure 3. Floor plan of the concept study

A study was conducted with the aim to determine the shading effect of an external roller blind. The concept study was carried out in August 2011 at the University of Brighton, England. A southwest facing room was partitioned into three compartments: entrance area, control room and test room, as shown in Figure 3. Control room and test room had the total floor area of 16.5 m^2 each, 3.5 m high. Each room had two windows with boxed type projection fins, one of which was blocked and thermally insulated. The remaining window was installed with either an internal venetian blind or an external roller blind. Blind positions were set manually at midday to an internal daylight level of 300 lux in order to achieve visual comfort in offices (CIBSE, 2006). This set the external roller blind 650 mm open from the base. Rooms were unoccupied, windows remained closed, the lights were switched off and no equipment was present. The mean radiant temperature was recorded at five-minute intervals. Local meteorological data (Weather Underground, 2011) of external air temperature was collated.

3.1 Concept study results

Temperature data was simplified to hourly mean values and organised to daytime; 8 am to 6 pm, and night time 6 pm to 8 am, representing office occupation hours. The results (Ylitalo et al 2012) summarised in Table 3, show that the mean daytime temperature difference between the rooms was 1.8°C, maximum difference 3.5°C and minimum difference 0.4 °C. The analysis of temperature frequency in rooms revealed that the temperature range in test room is more uniform and levels out at a lower temperature with peaks closer to the trend indicating that the external roller blind is regulating the level of solar gain.

Table 3: A summary of the experimental study daytime temperature data

	Mean radiant temperature °C			External air °C
	Test room	Control room	Difference	
Mean	20.4	22.2	1.8	17.3
Max	22.5	24.7	3.5	23.0
Min	18.6	20.0	0.4	12.0

4. Computer thermal modelling and simulation

Dynamic thermal simulation was carried out using IES Virtual Environment software to predict the impact of an external roller blind on cooling and heating loads. The simulation parameters are based on the concept study setup as summarised in Table 4.

Table 4: Simulation parameters

Item	**Parameter**
External wall	300mm concrete, cavity, concrete block, U-value 1.06W/m^{2}K
Internal partitions	120mm plasterboard, glass fibre quilt, plasterboard, U-value 0.34W/m^{2}K
Internal ceiling/ floor	Carpet, screed, concrete, cavity, ceiling tiles, U-value 1.0687W/m^{2}K
Glazing	1.3m x 2.3m, 6mm single glazing, metal frame, U-value 5.56W/m^{2}K
External shading device	Left and right fin projection 500mm, offset 0mm
External roller blind	Summer profile: extended at 300W/m^2 incident radiation, retracted at 100W/m^2, extended when building unoccupied, U-value 2.5 W/m^{2}K Winter profile: extended at night and when building unoccupied, U-value 2.5 W/m^{2}K
Internal venetian blind	Shading coefficient 0.61, short-wave radiant fraction 0.4
Weather data	Heathrow
Heating	1st Oct – 31st May, temperature set at 21°C, follows occupancy profile
Cooling	1st Jun – 31st Aug, temperature set at 23°C, follows occupancy profile
Occupancy profile	8am – 6pm, Mon to Fri, unoccupied at weekends and holidays

4.1 Simulation results

The results in Table 4 show different temperature profiles for test room and control room,. Majority of annual energy consumption is for heating energy, the room with external roller blind has 13% lower requirement. The summertime results show a lower requirement for cooling energy in the test room with the external roller blind. Test room cooling requirement is not significant enough to justify the installation of an active cooling system. The simulation results show that with the use of external roller blinds annual emissions can be reduced by 68 $kgCO_{2e}$, or 15%.

Table 4: A summary of the simulation annual energy consumption results

	Heating energy		Cooling energy		Annual total	
	(kWh)	($kgCO_2e$)	(kWh)	($kgCO_2e$)	(kWh)	($kgCO_2e$)
Control room	2018	452.32	23	11.15	2041	463.47
Test room	1761	394.46	1.5	0.72	1762.5	395.18
Difference	257 (13%)	57.86 (13%)	21.5 (94%)	10.43 (94%)	278.5 (16%)	68.29 (15%)

5. Environmental impact of external roller blind

The environmental impact of the external roller blind is established by life cycle assessment (LCA), consisting of four phases; goal and scope defining; life cycle inventory; life cycle impact assessment and interpretation (ISO 2012).

5.1 Goal and scope definition

The goal of the LCA is to establish the life cycle greenhouse gas emissions of one functional unit of an external roller blind. The scope includes establishing a functional unit of the same dimensions and specifications as used in the concept study. The production of aluminium is included but a benchmark figure is used for embodied energy content. The assessment includes the mechanical processes of aluminium roll forming, coating, blind manufacturing and associated transport, including transport to site and end of life recycling of steel and aluminium. The end of life management process beyond recycling is excluded.

5.2 Inventory of processes and emissions

5.2.1 Inventory of processes

i. **Aluminium production –** The main material of external roller blinds is aluminium. Aluminium is widely used in the construction industry; it is lightweight, strong and long lasting. Aluminium can be recycled without loss of quality; the re-melting of aluminium requires 5% of energy in comparison to production of primary aluminium. The production process starts by surface mining of Bauxite, an ore containing alumina, or aluminium oxide. In 2011, the largest producers were China, Russia and Canada (USGS 2012). The alumina refinery process involves four steps; digestion; clarification; precipitation and calcination. To burn bauxite into alumina, the ore is

ground and mixed with lime and caustic soda, the mix is pumped into high-pressure containers and heated. The alumina is dissolved by caustic soda and precipitated out of the solution. It is then washed and heated to drive off water. What is left is the alumina, a white granular material that becomes aluminium metal in the smelting process. The smelting takes place in the electrolytic cell, where current passes through molten aluminium oxide dissolved in a 920 - 980°C cryolite bath. The process separates aluminium metal for casting as primary aluminium. Primary aluminium is transported around the world to further processing (IAI 2012).

ii. **Coil manufacturing -** In the coil manufacturing process the primary aluminium ingot is combined with recycled aluminium and manganese to form an alloy. External roller blinds in the concept study are made of aluminium alloy. The aluminium alloy is processed by continuous casting to form 19 mm thick strip. The strip is reduced by hot rolling mill to 2mm strip, cold mill process further reduces the thickness to as thin as 0.25 mm. Tension levelling line is used to improve the precision flatness of the aluminium strip. The slitting line cuts the master coil down to required width. The end plates for the roller casing box are die cast. The extruded aluminium side guides are formed from sheets. Raw aluminium components are transported to coating factory.

iii. **Coil coating -** For the coating process the raw aluminium coils are linked to form a continuous band to allow coating. To clean and surface treat the aluminium, in order to improve adhesion and resistance to corrosion, a pre-treatment layer is applied. Prime coating is then brushed over as a first step of the lacquering process. Following this, the upper face receives a primer or paint coat, depending on the product, and the back face receives a protective layer, which is then dried and cured in a furnace. Final coating is applied, then dried and cured. End plates and side guides are coated. Coated aluminium is transported to blind manufacturer.

iv. **Roller blind production -** The coated coil is roll formed by sheet roll forming machine that produces the slat. Polyurethane foam insulation is injected during the forming process. Slats are cut to size at the end of the line. The casing is roll formed in sections. Other components are sourced, including the manual operating mechanism, seals and brackets. The blind is assembled and the final product is packaged ready to be transported to site. The blind used in this study is transported from Valencia in Spain to Brighton in England.

v. **Installation, operation and maintenance -** The blind is manually operated with no associated operational energy. Annual cleaning and maintenance is required. Replacement of some components is required, namely the belt. The blind has 25-year lifespan.

vi. **End of life management -** End of life management is taken to include recycling of majority of the components. Of the aluminium content 95% is recycled, 80% of steel is recycled (Hammond and Jones 2011). Remaining components will go to landfill.

5.2.2 Inventory of emissions

This assessment includes the manufacturing of the blind from aluminium ingot, with assumed recycled content of 33% (Hammond and Jones 2011), the transport of ingot to manufacturer is not included in the assessment. One functional unit is taken as external roller blind sized to fit experimental study window, sized 1.3m wide and 2.3m high (surface 2.99m^2). Total weight of aluminium is 21.8 kg. Assessment is based on *Aluplex A-40 Curved* high performance insulated slat (Aluplex 2012). Any part of the blind that contributes less than 2% to the total quantity of the blind, such as coatings and operating mechanism components, are not included in this assessment. Blind lifespan is 25 years. The transport energy is based on weight of one functional unit and packaging, taken as 30kg. Return journeys and maintenance of vehicles are not considered. Table 6 details the greenhouse gas emissions contribution in the life cycle of the external roller blind.

5.3 Impact assessment

Annual saving of 68.29 kgCO_{2e} can be expected from the results of the computer simulation in the concept study and the life cycle impact of the blind from the LCA is 37.54 kgCO_{2e}. Therefore, within the boundary of the assumptions and limitations, the saving of greenhouse gases while the blind is in operation will compensate its life cycle emissions in less than six months, which are mainly due to production of aluminium and transport. If end of life management is not taken into consideration and the blind is not recycled, the life cycle emission becomes 215.19 kgCO_{2e}, approximately three years operational saving would be required to cover the life cycle emissions.

6. Analysis of results and discussion

This study consists of three parts. Firstly, the proof of concept in-situ experimental investigation, secondly the assessment of annual energy consumption and associated carbon emissions analysis and thirdly the life cycle assessment.

The concept study set out to demonstrate the thermal impact of external roller blinds. Results of temperature profiles show improvement of thermal comfort in the test room when compared with the control room. Daytime data analysis shows that maximum temperature difference between the rooms was 3.5ºC; mean temperature was reduced by 1.7ºC and temperature swing reduced by 3.2ºC. Therefore, it can be concluded that under the concept study conditions external roller blind has demonstrated potential to improve thermal comfort and reduce overheating.

The dynamic thermal analysis of annual energy consumption is a comprehensive study of both summer and winter performances taking into account the daily operation profiles of occupants and the operations of the roller blind. The results indicated a 15% carbon reduction could be achieved. Proportion of heating energy was significantly higher than cooling energy and the results suggested the possibility of avoiding the requirement of comfort cooling with the use of external roller blind.

Table 6: Life Cycle Assessment summary

Process	Input	Item	Quantity	Data source	Output ($kgCO_2e$)
Aluminium production	N/A	Bauxite mining Alumina refinery Aluminium smelting Recycled secondary aluminium (33%) Ingot casting	22 kg x 155MJ = **181.28 $kgCO_2e$**	Hammond & Jones (2011)	181.28
Transport energy		Transport to factory	Excluded		
Coil manufacturing	Natural gas	Aluminium strip continuous casting	5.86 kWh = **1.31 $kgCO_2e$**	Process energy estimated	3.967
	Electricity	Strip milling Tension levelling Coil slitting	1 kWh = **0.32588 $kgCO_2e$**		
Transport energy		Transport between factories	300km by road = **2.33073 $kgCO_2e$**	Defra (2012)	
Coil coating	Coatings Electricity	Prime coating Paint coating Curing	0.5kWh = **0.16294 $kgCO_2e$**	Process energy estimated	2.555
Transport energy		Transport between factories	250 km by road **= 1.942275 $kgCO_2e$**	Defra (2012)	
External roller blind production	Polyurethane Electricity Natural gas	Polyurethane insulation injection	1.8 kg **= 6.264 $kgCO_2e$**	Hammond & Jones (2011) Process energy estimated	13.06
		Slat roll forming Casing roll forming	1kWh = **0.32588 $kgCO_2e$**		
		End plate die casting Side guide extrusion	1.95kWh **= 0.4375 $kgCO_2e$**		
	Steel	Steel axle	4.5 kg **= 6.03 $kgCO_2e$**	Hammond & Jones (2011)	
	Metals Plastics	Other minor components	Out of scope	Hammond & Jones (2011)	
	Electricity Packaging	Product assembly Packaging	Out of scope	Hammond & Jones (2011)	
Transport energy		Transport to site	1900km by road **= 14.76129 $kgCO_2e$** 120km by ferry **= 0.014796 $kgCO_2e$**	Defra (2012)	14.77
Site	Out of scope	Installation Maintenance	n/a	Hammond & Jones (2011)	
End of life management		Aluminium recycled Steel recycled Others landfill	95% -ve 172.22 80% -ve 5.43	Hammond & Jones (2011)	-ve 177.65
				Net	**37.54**

The life cycle analysis cannot be considered as comprehensive, but adequate to establish preliminary results in terms of the carbon payback. Minor items excluded in the study are likely to cause a slight increase in the embodied carbon, nevertheless within its 25 year lifespan the external roller blind will clearly result in significant greenhouse gas savings.

7. Limitations and future work

The concept study was limited in time and provided a snapshot of the blind operation only. Further monitoring of blind installation to collect real time summer and winter operation data is planned. The simulation is based on fixed operation profile for the roller blind, the integration of dynamic shading coefficients being developed will enable closer to real-life simulation of the shading performance of the roller blind in response to the external climate. The LCA study is hampered by the lack of existing manufacturing data. The assumptions made have to be validated in the future studies when the data become available.

8. Conclusion

External roller blinds are movable external shading devices with potential to improve the thermal performance and sustainability of buildings in the UK climate. An experimental trial concluded that summertime internal temperatures, temperature peaks and temperature swing could be reduced with use of external roller blind. Computer simulation predictions corroborate the results of the experiment that external roller blind can be used to reduce, or in some cases, avoid the requirement for active cooling.

Life cycle analysis of greenhouse gas emissions of a functional unit representing the roller blind used in the concept study, taking into account the key materials and processes throughout its life cycle, show that a six months payback time for the life cycle greenhouse gas emissions or three years if the metallic components were not recycled. The findings so far indicated there is significant potential of using external roller blinds to reduce the operational and life cycle carbon emissions of buildings in the United Kingdom. The on-going research continues to develop the dynamic performance of the roller blinds that can work in conjunction with interior lighting and thermal systems of the building as well as responding to the external climatic conditions and other functional requirements of the building facade.

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Does green building affect decision in apartment purchase? The case of Sweden

Agnieszka Zalejska - Jonsson[1]

Abstract Title

The latest research indicates that green apartments and green commercial spaces yield higher prices; however it is not really certain whether the environmental factors contribute to the profit. This paper examines the importance of environmental factors on the residential market and investigates whether Swedish home-owners are prepared to pay more for green apartments. The paper presents results from a quasi-experimental study and a survey addressed to 600 apartment owners of both green and conventional residential buildings in Sweden. Survey results suggest that people are prepared to pay approximately five per cent more for low-energy buildings; however they are not equally willing to pay for a building with an environmental certificate.

Keywords: residential buildings, green buildings, willingness to pay

1. Introduction

Financial barriers have often been considered the greatest hindrance to green construction development. Developers have been concerned about high initial costs and uncertainty about return on investment (Issa et al., 2010). Considering, then, that a profit-maximizing company in the event of increased cost is seeking to increase its prices, the rational question is how much more the customer is prepared to pay for green building.

Research has put forward evidence that even though green buildings require higher initial cost (Zalejska-Jonsson et al, 2012), the labeled buildings can generate a price premium on the commercial (Miller et al., 2009, Eichholtz et al 2010, Fuerst and McAllister 2011) and the residential market (Ott et al 2006, Bloom et al, 2011; Brounen and Kok, 2011). The results from pricing models indicate that green properties can transact 3-12% higher prices than conventional buildings.

Furthermore, the latest research indicates that customers value sustainable features and are willing to pay the premium. For example, a positive willingness to pay for environmental attributes was found among households that purchased single-family houses in the Stockholm area of Sweden in 2000 (Mandel and Wilhelmsson, 2011). The analysis indicated that environmental awareness affects willingness to pay and the calculated non-marginal WTP for environmentally aware households was about 2-4% higher for energy efficient systems and 5-8% for water reducing technologies.

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However, it is still unclear whether the potential buyer is being informed about green aspects of building and whether information about energy performance and building environmental impact is important to the customer. Brounen and Kok (2011) concluded that home buyers took into consideration information extracted from building energy certificates. However, a study conducted in Australia (Bryant and Eves, 2012) demonstrated that information about sustainable features of buildings was often not disclosed by home sellers and seldom proactively requested by home buyers. Moreover, previous studies suggest that occupants may be confused about the meaning of building certification (Addae-Dapaah and Su Jen Chieh 2011) and sometimes not even be aware that they are living in a green building (Chau and Chung 2010).

This paper investigates whether customers consider energy and environmental factors when making the decision to purchase an apartment and whether customers are willing to pay a premium for green dwellings. The analysis is based on 289 survey responses collected during a quasi-experimental study among occupants of cooperative green and conventional multi-family buildings in Sweden.

The paper contributes to the discussion on factors impacting a home-purchasing decision and on the extent to which environmental aspects are present to the prospective buyer (Reed and Mills, 2007; Carswell 2009; Eves and Kippes, 2010; Goodwin 2011;). The paper also relates to the literature on valuing sustainability aspects on the property market (Lorenz et al., 2006; Lorenz and Lutzkendorf, 2008, Runde and Thoyre, 2010), debating the importance and value of energy and building certification from the perspective of an apartment buyer.

2. Method and data collection

2.1 Study design

The study is based on a quasi-experimental method (Bohm and Lind, 1993), which was used to examine whether there is a significant difference between the decision to purchase green or conventional apartments. Moreover, the investigation aimed at capturing differences in overall satisfaction, indoor comfort and behavioral change. The research was designed as a multi-case study, in which green and conventional residential buildings were carefully selected and paired in such a way that building characteristics were comparable and only differed in energy and environmental performance. Only buildings with very low energy requirement (close to passive house standard) and buildings registered or certificated according to a building environmental scheme were considered as green. It was imperative that the controlled building i.e. conventional building was constructed according to current Swedish Building Regulations.

2.2 Data collection and questionnaire

The analysis and the results presented in this paper are based on a survey conducted in 2012 among co-operative condominiums in Sweden. Data collection was conducted in two periods: May-June and September-October.

The survey questionnaire was divided into four sections. The first part investigated which factors impacted customer purchasing decision, the second part focused on occupants' overall satisfaction with their apartment and perception of indoor environment quality. The third part aimed at obtaining information about respondents' perception of building environmental certification and willingness to pay for buildings with an environmental profile. The final section asked a few background questions.

The examples of questions regarding factors impacting housing purchase decision and customers' willingness to pay for green buildings are presented in table 1. The questionnaire included closed questions but also offered respondents the possibility of commenting.

Table 1: Questions Example

question	possible answers
Which of the following factors contributed to your decision to purchase the apartment? Indicate the importance og the following on your decision: location, price, apartment size, apartment design, calculated low energy consumption, environmental factors (other than energy), accessibility to collective transport, limited choice of available apartments	decisive (4) important but not decisive (3) not very important (2) not important at all (1)
Are you willing to pay a higher purchasing price for a building with an environmental certificate? Are you willing to pay a higher purchasing price for a building with significantly lower energy consumption?	yes, approximately 10% (3) yes, approximately 5% (2) no (1)

The survey was sent by regular mail to all occupants of the selected buildings, who at the time of the survey were at least 21 years old. The envelope was addressed to individuals and included cover letter, survey questionnaire and return envelope. The particulars (name and address) were obtained from a publicly accessed online database. Persons invited to participate in the survey could submit their answers in paper form using the return envelope or answer online using the link indicated in the cover letter. All participants were offered a gratuity in the form of a scratchcard worth 25-30 Swedish krona (SEK). Only respondents who submitted their contact details received a letter of appreciation with the gratuity enclosed. All participants were ensured that responses would be treated as anonymous. In order to fulfill this promise, all responses were coded.

The participants were asked to answer the survey within 10 days. A reminder was sent to non-respondents two weeks after the first invitation letter. Answers received in paper form were manually added to the database.

The survey was addressed to 603 persons and 289 responses were received, which gave a total response rate of 48%. Detailed information about the response rate for each case is presented in table 2.

Table 2: Response rate

green/conventional	case pair number	questionnaire sent	response	response rate
green	1	35	18	51%
conventional	1	91	38	42%
green	2	21	14	67%
conventional	2	47	28	60%
green	3	55	24	44%
conventional	3	63	38	60%
green	4	58	31	53%
conventional	4	85	33	39%
green	5	63	35	56%
conventional	5	85	30	35%
Total green		232	122	53%
Total conventional		371	167	45%
Sum		603	289	48%

2.3 Statistical analysis

In the first stage of the analysis, descriptive statistics were used. The statistical difference in responses from occupants of green and conventional buildings was tested by the Mann-Whitney test. The correlation between willingness to pay (WTP) and perception of environmental factors and building certification was conducted with a non-parametric Spearman rank correlation test.

3. Results

3.1 Description of respondents

There are certain differences in age distribution between respondents living in green and conventional buildings. The majority of the respondents in green apartments were between 31 and 40 years old (37%), whereas in conventional buildings, this group of occupants accounted for only 18%. The relative majority of respondents in conventional buildings were 61 years old and older. Approximately 55% of the respondents were females. The majority of the respondents in green buildings live in 3- or 4-room apartments, and in conventional buildings in 2- or 3-room apartments.

3.2 Factors impacting apartment purchasing decision

The analysis indicates that the most important factors considered in the respondents' purchase of an apartment were the apartment size, location, access to collective transport, and price. Considering that the search for a new apartment is often prompted by life style changes such as starting a family, divorce or changes in health, it is understandable that apartment size would have the highest importance: 40% of green building respondents and 47% of the occupants of conventional buildings indicated that dwelling size was the decisive factor in their apartment purchase decision.

The next most decisive factors were access to public transport (approx. 40% for both green and conventional buildings) and building location (approx. 40% for conventional buildings and 34% for green buildings). The location of the buildings relates not only to geographical location but also to the sense of familiarity, and social and family life.

Table 3: Factors impacting on apartment purchase decision, 1=unimportant, 2=very little importance, 3=important but not decisive, 4=decisive

factors	mean value standard div
apartment size	3.37 (.62)
location	3.34 (.56)
apartment design	3.21 (.65)
access to public transport	3.26 (.69)
price	3.27 (.58)
estimated energy consumption	2.76 (.82)
distance to work	2.46 (.99)
environmental factors (other than energy)	2.54 (.82)
limited choice of available apartments	2.22 (.97)
distance to school	1.97 (1.10)

Generally, energy and environment were ranked rather lower in importance than other factors (table 3). Interestingly, energy factors were indicated by 24% of green building respondents as decisive, whereas only 8% of the occupants of conventional buildings indicated the same. Other environmental factors than energy were ranked low: only 13% of green building occupants and only 6% of those in conventional buildings ranked environment as decisive to their apartment purchasing decision.

The difference in responses from occupants of green and conventional buildings was tested with a Mann-Whitney test. The results show that on a statistically significant level of $p \leq 0.05$, occupants' responses only differ with regard to the impact of three factors: distance to school, energy and environment (see table 4).

It is interesting that aspects related to building energy and environmental performance had greater importance for people living in green buildings. This may be related to the fact that people who choose to live in green residences are more environmentally concerned and indicated more interest in those factors. Indeed, when respondents were asked to state their opinion on the importance of environmental certification for buildings, more than half of the respondents in green buildings stated that environmental certification is important and that it may have a positive impact on building value. This opinion was shared by approximately one third of the respondents living in conventional buildings. Only 10% of the occupants of green buildings indicated that "environmental certificate for buildings is unimportant", compared to 26% of the respondents in conventional buildings.

The findings demonstrate that environmental education may be correlated with extent to which customers value energy and environmental factors when purchasing an apartment. The Spearman correlation test shows that perception of environmental certificate for buildings is significantly correlated with perceived importance of energy and environmental factors (table 5).

The results also demonstrate that the quality of information provided to occupants about building performance may affect the importance of factors impacting purchase decision (table 5). It was clear from our study that ample information about building performance and environmental impact was presented to the prospective buyers. On the other hand, the same information was less likely to be given to customers of conventional buildings unless explicitly requested. Approximately two thirds of the respondents living in conventional buildings indicated that they "do not know", "do not remember" or "did not receive" any information about building energy or environmental performance. However, about 90% of the respondents living in a green building remember being given information about expected energy consumption or building environmental impact.

3.3 Willingness to pay

In general, respondents are willing to pay more for low-energy buildings (mean 1.84) than for buildings with an environmental certificate (mean 1.52). This is an interesting result, suggesting that customers are willing to pay more for features they can understand. Customers can translate low-energy building features into a lower requirement for energy

and therefore lower operating cost. It is not as easy to find direct benefits from owning an apartment in a building with an environmental certificate.

The Spearman correlation test shows a statistically significant (0.21) correlation between information about energy and environmental performance and willingness to pay, indicating that a customer who receives energy and environmental information about the building is willing to pay more for these features. On the other hand, the Spearman correlation test indicates a statistically significant and relatively high correlation between personal opinion on the importance of building environmental certification and willingness to pay (0.44 for WTP for low-energy buildings and 0.67 for WTP for buildings with environmental certification). This suggests that a customer who perceives value in building certification is willing to pay a premium for a green building.

The majority of respondents living in conventional buildings are not prepared to pay more for a building with an environmental certificate, whereas green-building residents are willing to pay 5% extra. Respondents are willing to pay a 5% premium for low-energy buildings, regardless of which building they live in.

Table 4: Mann-Whitley test

Mann-Whitney test for difference in responses between green and conventional buildings [p, probability]	
FACTORS	
building location	0.63
apartment price	0.48
apartment size	0.46
apartment design	0.52
estimated energy consumption / cost	0.00*
environmental factors	0.00*
access to public transport	0.64
distance to work	0.44
distance to school	0.02**
limited choice of available apartments	0.85
CERTIFICATION	
importance of environmental certification for buildings	0.00*
AVOWED WILLINGNESS TO PAY	
WTP for low-energy buildings	0.00*
WTP for environmental certified buildings	0.07***

statistically significant *p≤0.01; **p≤0.05, ***p≤0.1

Table 5: Spearman correlation test

	information regarding building performance [coefficient (probability)]	perceived importance of building certificate [coefficient (probability)]
importance of energy factor	.23 (.0003)	.19 (.002)
importance of environmental factor (other than energy)	.24 (.0002)	.28 (.000)
avowed willingness to pay for low-energy building	.25 (.0001)	.44 (.000)
avowed willingness to pay for environmentally certified building	.19 (.001)	.68 (.000)

4. Conclusions

A quasi-experimental approach was chosen to study the impact of energy and environment factors on customer decisions to purchase an apartment and to investigate customers' willingness to pay for green buildings. The analysis is based on data collected by a survey questionnaire addressed to owners of green and conventional buildings in Sweden.

The results indicate that energy and environmental factors have a rather low impact on the apartment purchasing decision. The results lend support to studies conducted in Germany, New Zealand and Australia (Eves and Kippes, 2010; Amecke, 2012; Bryant and Eves, 2012). The energy and environmental factors influencing the decision to purchase a dwelling were found to be correlated to respondents' perception of the value of building environmental certification and the quality of information provided about building performance. An issue worthy of discussion is information asymmetry, as developers are more likely to inform prospective buyers about building environmental performance when the energy or environmental impact gives a positive signal and may increase selling value. The information asymmetry has its consequences. Firstly, potential buyers are informed about how exceptional green buildings are, yet they do not know what they can expect from conventional buildings. Secondly, the generously given information creates specific expectations, which may have an impact on occupants' overall satisfaction.

It was shown that occupants in green buildings are generally more willing to pay extra for such buildings; however, respondents stated different willingness to pay for low-energy buildings and building with an environmental certificate. One explanation for this lower willingness to pay might be that occupants are not convinced that environmental certification translates into higher value. Customers are willing to pay a premium for features they understand and of which they can see potential benefits, such as low-energy consumption.

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Developing managers in the construction industry for the Asian Century

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Abstract

The inexorable shift in economic power from west to east presents managers in the construction sector with unprecedented opportunities and challenges which are not well understood. In particular, there is little understanding of the new knowledge, skills and competencies which construction project managers need to work effectively in overseas locations. International management capabilities will move to the forefront of business concerns as firms seek to expand into overseas markets. Through case studies of Australian construction multinationals who are experienced in working overseas, the practices of developing global managers in the construction sector are explored. It is concluded that although most multinational construction companies do have procedures in place to manage overseas assignments, global leadership development programs do not reflect research and are not yet fully developed.

Keywords: globalisation, human resource development, leadership, education, training.

1. Introduction

The 2012, the annual meetings of the International Monetary Fund (IMF) and the World Bank provided insights into a profound change taking place in global politics and economics. This change is the political and economic power-shift from a world dominated by Western Europe and the United States to an Asian Century and a world with many regional powers and no obvious global leadership. Hawksworth and Cookson (2008) project that over the next twenty years the emerging E7 countries (China, India, Brazil, Russia, Mexico, Indonesia and Turkey) will grow by 50% more than the current G7 countries (US, Japan, German, UK, France, Italy and Canada). By 2050 the Brazilian economy will be larger than Japan, the Russian, Mexican and Indonesian economies will be bigger than Germany, France and the UK and the Turkish economy will be larger than Italy's. Other countries with high growth potential include South Africa, Nigeria, Philippines, Bangladesh, Saudi Arabia, Malaysia, Thailand, Pakistan and Iran (assuming political problems do not pose a barrier to growth in the future). The growth in these developing countries is reflected in the rapid increase in international jet travel which Boeing forecasts to grow from 4,621 billion Kilometres in 2008 to 12,090 Kl in 2028. The sectors with the greatest annual grow rates are Africa to South East Asia (9.2%), within China (8.6%), within South West Asia (8,7%) and within South East

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Asia (8.1%). This will fuel the process of globalisation and lead to a more interconnected world with greater flows of people, ideas and cultures.

The scale and pace of Asia's transformation has prompted the Australian Government to commission a White Paper on Australia in the Asian Century to consider the likely economic and strategic changes in the region and what more can be done to position Australia for the Asian Century (COA 2012). Dr. Ken Henry AC, a prominent Australian economist, public servant and special Advisor to the Prime Minister, who chaired the working group who produced this paper argues that Australian business must get over their suspicion of Asia and must see themselves as regional rather than nationalistic and see Asia as a source of productivity growth rather than threat. It is clear that to capitalise on the economic shift of power we are seeing companies will need to be more adaptable, flexible, resilient and creative in their thinking.

While the potential returns from working overseas in new emerging markets like Asia are enormous, so are the risks. Many of these risks are well known and documented and include: political sovereign risks associated with unstable governments; economic risks associated with fluctuating exchange rates, poorly managed economies and asset repatriations; legal risks associated with inadequacies in international law; security risks associated with unstable governments; logistical risks associated with sourcing and moving raw materials and; cultural risks associated with doing business in different value-systems etc. However, one category of risk which has received less attention and is not well understood is the risk of managing human resources in an international context. As Pinnington (2011) points out, many firms underestimate the complexities of managing human resources across borders and there is a serious shortage of international management talent for them to draw from. This in turn has highlighted the importance of implementing effective HR practices to properly select, train, manage, compensate, support and develop employees to work in overseas environments. As Farndale et al (2010) argues, many firms adopt an ad-hoc rather than strategic approach to the management of global talent. To address this potential problem, the aim of this paper is to explore the issue of issue of how firms develop their human resources to work effectively in these overseas environments.

2. Developing an international human resource management strategy

From the perspective of international human resource management, Evans et al (2011) argue that there are three basic levels of consistency that should be considered in effectively managing an international operation. The first is *'employee consistency'* which reflects whether employees (individually) perceive HRM processes such as performance appraisal, promotion and compensation as being fare and consistent across regions. The second is "*temporal consistency*" which refers to whether employees in similar roles but of different genders, ethnic origins or backgrounds are treated equally. While some research indicates that consistency is important for effective international operations, other research indicates that there is also a risk of taking consistency too far. For example, according to Rowley et al (2011), practices developed in one context and transplanted to other regions without consideration of regional context will inevitably fail.

In addition to resolving the dilemmas of international control discussed above, issues of recruitment and retention are considered central to an effective international HRM strategy. As Phatak et al (2009) point out, poor selection of human resources for international assignments is a major cause of failure in overseas projects and while there is no established body of theory about the attributes of a successful global manager, many researchers have attempted to identify the distinctive competencies, knowledge and personal behavioural attributes which enable managers to succeed in overseas roles (Evans et al 2011). This research has identified a multitude of competencies and personal traits and values which have been linked to global manager effectiveness. For example, necessary competencies include: relationship building skills across different cultures; cross-cultural communication skills; an ability to emotionally connect with people of different cultures; an ability to motive and inspire people from different cultures; conflict management skills; negotiation expertise; an ability to empower people and manage cross-cultural ethical issues; social Literacy and; cultural Literacy. The personal traits and values which appear to be important in working overseas include: inquisitiveness and curiosity; continual learner; accountability; integrity; courage; commitment; hardiness; maturity; results-orientation; personal literacy; tenacity and; emotional intelligence.

Despite the wide range of competencies and attributes listed above, research indicates that technical competence remains the primary criteria used by firms in selecting employees for overseas assignments (Phatak et al 2011). Research suggests that this achievement-orientated focus on technical and job-related competence has guided selection processes because they are easier to measure. However, as Briscoe et al (2009) point out, while many western multinational business selection processes are “achievement” oriented, in many Asian and Latin cultures an “ascriptive” approach to selection predominates which takes greater account of the culture, age, gender, family background, and social connections of the candidate.

Positions in overseas locations can be filled using a variety of methods. These include: traditional expatriate assignments, overseas recruitment of host or even third-country nationals, short-term international assignments and even virtual team membership. According to Phatak et al (2009) a firm’s corporate cultures tends to influence the focus of its recruitment strategy in the above three categories. For example, a firm with an *ethnocentric* orientation typically staff important positions with parent company nationals, a firm with a *polycentric* orientation will typically select host country nationals, a firm with a *regiocentric* orientations will staff positions with trans-company nationals and, a firm with a *geocentric* orientation will generally favour the selection of the most suitable person for the job. However, research shows that most companies tend to “set-up” initial operations using their own pool of Parent Company Nationals but over time, as business grows, increasingly rely on host and trans-company nationals, supported by in-patriation into parent company cultures.

Having been selected for an overseas assignment, employees must be “prepared” to successfully negotiate the inevitable culture-shock of unfamiliar working and living environments. Culture Shock is defined by Phatak et al (2009) as a state of anxiety and disorientation caused by exposure to a new culture. Culture shock moves through various phases and is best managed by selecting the right people, by effectively managing the complex logistics of international assignments and by instilling the competencies described

above through an international human resource development (IHRD) program. This program should use a range of pedagogical approaches to learning which might include: self-examination and reflection; formal education about the a country's unique cultures, business procedures, local politics, economics, customs and practices; experience through pilot assignments and; mentoring by people who have worked overseas before, during and an international assignment (Kramer 2005).

Once on an overseas assignment the performance of managers needs to be managed and monitored. As Evans et al (2011) shows, developing a global performance management system is challenging not only because of the large size and geographical spread of the workforce but due to differing expectations, standards and practices across different business regions.

The final stage of an overseas assignment is repatriation and on-going development which if managed badly can not only adversely affect staff retention but can also undermine the integrity and attractiveness of future overseas assignments. The aim of repatriation should be: to give time for returning staff to re-adjust to home (often the culture shock of returning home is worse than shock of arriving in a new country); to ensure the home business captures and disseminates the experiences of returning overseas managers; clarify the return-on-investment from the program and; to ensure continued development and career progression of global managers on return.

3. Method

To investigate how each of the key considerations discussed above are managed in the construction sector we undertook semi structured face-to-face interviews with the human resource managers of five multinational firms in the Australian construction sector. All five firms were members of the Australian Contractor's Association, a body which represents the interests of tier-one contractors in the Australian construction and engineering industry. Sample details are provided in Table 1.

Table 1 Sample details

Firm	**Countries/Regions of Operation**	**Annual Revenue in AU$ ('000,000)**	**Employee Workforce**	**Market specialisation**
A	Asia, Australia, New Zealand, Pacific, Middle East	2000	8000	Building, Mining, Oil and Gas, Petro-chem, power, public infrastructure, transport, water
B	Asia, Australia, Pacific, USA	1000	3600	Oil and Gas
C	Asia, Australia, New Zealand, Pacific, Middle	1000	2000	Construction, Mining and Services (energy, water, telecommunications)

D	Asia, Canada, Pacific, Europe and Middle East,	3000	3700	Building, construction, minerals handling, mining, oil and gas, rail and power
E	Asia, Australia, Canada, Europe and Middle East	3000	3500	

We also collected documentary data relating to the company's international human resource management strategies. Our interview questions addressed a range of issues discussed above, including: how the firms staff overseas assignments; how they choose staff; what attributes make a successful global manager; how they sourced potential global management talent; how staff are prepared for an overseas assignment; what competencies employees are expected to acquire whilst on assignment and how is this facilitated; what sort of infrastructure is in place for the expatriate while overseas; expectations when the employee returns from assignment; what on-going development the firm may provide; how to utilize and identify new skills the employee may bring back; how employee performance is assessed and monitored by the company and; how issues of cultural relativity are approached.

4. Discussion of results

Tables 2 compares how our respondent firms source managers for overseas assignments. There appeared to be no one dominant approach within our sample. Our results suggest a highly pragmatic approach which responds to the availability of the best resources at a particular point in time.

Table 2 Sourcing of global managers

Firm A	Recruit internally and regionally. Cross-transfers sometimes happen.
Firm B	Recruit locally by region.
Firm C	Focus on our regional hubs, which like to recruit locally.
Firm D	Selection is based on the talent available.
Firm E	Sourced from wherever the talent is.

Table 3 addresses the issue of Global Training and Development by showing how the firms helped their selected global managers to acquire the necessary competencies and knowledge to do their job effectively. None of the firms interviewed had a formal global competency framework in place to guide their HRD process although one was developing it. Most saw the best way of developing global management competencies and knowledge as

being through overseas work experience itself (throwing managers in at the deep end). Preparation is normally perceived as a logistical rather than a competency challenge. Inductions are normally expected to be carried out at the overseas host location, although this can often not happen due to time pressures. Ethical and cultural differences between working practices in different countries are not specifically addressed as part of the overseas assignment and it is broadly seen as the responsibility of the host country to educate new expatriates about local cultural practices and expectations. Instead, the focus of attention at this stage is very much on employment contract issues, pay and compensation arrangements, tax, pensions, travel arrangements, accommodation, family logistics such as schools and spouse support and, safety and security etc.

Table 3 Preparation

Firm A	We do not have a different training or competency conceptual framework for overseas rotation. Working in a different culture and working with many different nationalities, will develop the employees' technical knowledge, business concepts and personal/interpersonal skills.
Firm B	Preparation depends on the location. We provide access to an online cultural awareness tool. In high-risk locations extra preparation is required. Competencies are linked to the expat's role. Overseas assignments should help develop role based competence regardless of role or level.
Firm C	We don't have a formal program for preparing staff for overseas assignments. New competencies are generally expected around behavioural and personal attributes.
Firm D	We like to use performance profiles for candidates and keep the communication close between the regional-hub. Improvement of technical knowledge is achieved through work experience on site.
Firm E	Selection is based on the talent management software and case notes from their line manager. We are putting in place a global management development program which define these leadership and behavioural competencies.

Tables 4 indicates the attributes our respondents associated with people who tend to perform well overseas. Most of our sample believed that they intuitively knew the attributes of a successful global manager. Only one company had specifically and consciously identified these from research and consultation with its global managers and had begun to use this information to develop a global competency framework to develop these.

Table 4 Attributes of successful global managers

Firm A	Firm B	Firm C	Firm D	Firm E
Technical knowledge	Strong technical skills	Deal with Diverse Cultures	Technical knowledge	Technical knowledge

Leadership	Strong leaders	Manage uncertainty	Business Concepts	Understand different regulations and standards
Behavioural	Client Relations	Personal skills	Health/safety conscious	Business Etiquette
Client Management	Personal Skills	Personal resilience	Personal Skills	Proactive learner
Innovation	Interpersonal Skills	Work as part of team	Management	Tolerance for religion/culture
Networking	Client Management	Leadership	Interpersonal Skills	Leadership
Decisiveness	Independence	Inspiration		Acculturation and Integrity
Intuitiveness	Safety OH&S			Learning Agility and Open-mindedness

Table 5 describes the repatriation expectations of the firms we interviewed and strategies for ongoing development of global managers after return home. None of the firms we interviewed had a formal repatriation strategy in place (although one was in development) and there were no specific strategies to maintain, further develop and capitalize on the skills employees acquired during the overseas assignment experience.

Table 5 Repatriation

Firm A	To transition back into the Company relatively seamlessly. To date they have not had any problems with staff returning and repatriating to Australia.
Firm B	Individual returns to a role that is either the same as prior to their departure or aligned with any changes to their experience, skill set obtained whilst working overseas.
Firm C	No different to other executives, our organisation expects them to seamlessly integrate back into the local environment.
Firm D	That the returned employees would integrate with little to no fuss
Firm E	There usually is little to no difference in employee performance and behaviour. We know that it is important to do repatriation well and are developing a formal program to ensure sooth transition and

	ongoing development.

5. Conclusion

The aim of this paper was to explore how multinational firms in the construction sector manage their international human resources. This paper is set within the context of profound changes in balances and barriers to international trade. While our sample was admittedly small, there is no reason to believe that the practices of other multinational firms in the Australian construction sector would be different to those we found. Our research indicates that many firms lack the strategic approach to international human resource management as formally described in the human resource management literature. Rather than being strategic, the human resource management function appears to be a highly functional one focused on the contractual logistics of overseas assignments. The majority of the firms we studied adopt a highly pragmatic geocentric approach to recruitment. Most recruit occurs without a formal global manager competency framework although there is quite strong agreement informally on the types of attributes which make an effective global manager. The selection of global managers appears to be mainly on the basis of technical knowledge and the recommendations of line managers regarding skills and personal attributes. None of the firms interviewed had a formal global management training program in place although one was developing a global management competency framework. When acculturation or logistical training was provided to prepare candidates for overseas assignments it was generally outsourced to external consultants and, apart from one firm, there was little sense that human resource management practices were contributing a central set of values being driven through the regional business. In terms of preparing managers for overseas assignments, most of the companies believe financial assistance is the most important factor for success. Only two of the companies offer relocation consultants to help the expats relocate and settle in, and only one offers cultural awareness training. Only two of the companies also supply a mentor either overseas or from the home office. In terms of ensuring the on-going development of global managers when on overseas assignments, regional businesses and indeed projects were highly autonomous and were expected to take responsibility for the development of any overseas managers assigned to them. Overseas managers have to fit into ‘normal’ staff development programs and their competencies and development are assessed by line managers and in some cases mentors in the host country. All our respondents expect employees to readjust with no major problems.

The implication of these findings is that the international projects of many multinational contractors might be exposed to considerable human resource management risks. To minimise these risks companies should reduce their emphasis on technical competencies in the selection of candidates for overseas assignments. In many Asian and Latin cultures, this approach is unlikely to result in the best candidate where culture, age, gender, family

background, and social connections may be better indicators of success. Furthermore, it is important to consider the personal traits and values candidates. Inquisitiveness and curiosity; continual learner; accountability; integrity; courage; commitment; hardiness; maturity; results-orientation; personal literacy; tenacity and; emotional intelligence appear to be particularly important indicators of success. Having been selected, employees must be prepared to negotiate the inevitable culture-shock of working overseas. Training must be provided to build networking skills across different cultures; cross-cultural communication skills; an ability to emotionally connect with people of different cultures; an ability to motive and inspire people from different cultures; conflict management skills; negotiation expertise; an ability to empower people and manage cross-cultural ethical issues; social Literacy and; cultural Literacy. Once on an overseas assignment the performance of managers needs to be managed and monitored. Appropriate support needs to be provided whenever it is needed. Finally, repatriation and on-going development should be provided to help returning staff to re-adjust to home and to ensure the home business captures and disseminates the experiences of returning overseas managers.

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The development of an Asset Management solution for a large infrastructure facility

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Abstract

The management of physical infrastructure asset plays a key role in achieving the business objectives and effective service delivery of organisations that operate assets as part of their core business. Asset Management is a surprisingly modern discipline that concerns the systematic activities and practices through which an organisation optimally manages its assets and their associated performance, risks and expenditures over their lifecycle. This paper provides an introduction to this emerging discipline and presents a case study of an application of Asset Management in a large infrastructure facility. It presents the main elements of Asset Management, the Asset Management process in the facility, and a software system, developed by the authors, which is used on site in supporting the Asset Management operations.

Keywords: Asset management, Physical infrastructure asset, Asset management system

1. Introduction

Owners of large infrastructure portfolios have a responsibility over diversified set of constructed facilities having different complexities and sophistication (Vanier, 2001) and as organizations grow, business owners consider their buildings and installations as factors for production, a foundation for success and future growth (Frolov et al., 2010; Swallow and Chanter, 2007). In order to achieve the required level of success and growth, these factors, otherwise known as assets, must be managed effectively (Frolov et al., 2010), a process of management known as asset management (Amadi-Echendu et al., 2007).

According to Michele and Daniela, (2011) asset management has a big influence on infrastructure development and use. If the process is undertaken and executed without fully recognizing the complexity, diversity, social and technological evolution of the system, the process will almost inevitably have severe economic, environmental, social, and cultural resources consequences (Michele and Daniela, 2011)

Frolov et al., (2010) and Schneider et al., (2006) have described asset management…as a systematic, structured process covering the whole life of physical assets. It involves several

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activities in maintenance, repair and renewal decisions, as well as understanding the long-term economic life (Life Cycle Costing) of an assets' (Amadi-Echendu et al., 2007; Vanier, 2000). Mohseni, (2003) proposed that asset management is…a matter of understanding the risks…,developing and applying the correct business strategy and the right asset model to solve the problem, all supported and delivered by the organization processes and technology. Brint et al., (2009) summarises asset management as the integration of…maintenance and replacement analyses, finance, economics and systems engineering.

Research in asset management as noted by The Institute of Asset Management (2011) is a term derived from the financial industry, where its concepts are applied to financial investment portfolios and risk management (R.E. Brown and Spare, 2004). The Institute of Asset Management (2011) has put forward a definition of asset management, with reference to infrastructure, as *"a process that converts the fundamental aims of the organization into the practical implications for choosing, acquiring, utilizing and maintaining appropriate assets while seeking the best total value approach (the optimal combination of costs, risks, performance and sustainability)".*

In effect, asset management is the holistic practice of investing in an asset to the benefit of the organization taking into cognizance the cost, risk and performance of the investment. It plays a key role in the detection and evaluation of decisions leading to long-term economic success and best possible earnings (R.E. Brown and Spare, 2004; Schneider et al., 2006). Thus it is no longer sufficient to consider asset management as simply the maintenance of an asset but rather as a holistic approach to the management of assets, incorporating elements such as strategy, risk measurement, safety, environment and human factors (Amadi-Echendu et al., 2007; Frolov et al., 2010).

1.1 Importance of Asset Management

As asset management plays an important role in the overall strategy of an organization its practice possesses the potential to enhance the value base of organizations and institutions if implemented appropriately. This has been identified in the reports of organizations that has adopted a form of asset management strategy (Amadi-Echendu et al., 2007; Dixon, 2007; Holland et al., 2005; D. Leung and Q. Leung, 2011; Vanier, 2001).

The large amounts of expenditure needed to renew, renovate and enhance asset value represents a major, and rapidly growing, cost in developed countries (Brint et al., 2009; Vanier, 2001). For instance, Brint et al., (2009) noted that the replacement value of the English and Welsh water companies' assets has been estimated at £200 billion by the regulator. Likewise Vanier, (2001), in a study of the municipal infrastructure, noted that the potential cost of maintenance and repair expenditures per year in Canada alone is $ 58.8 billion.

In critical operations such as oil and gas drilling, the need for effective asset management cannot be overemphasized. According to Holland et al., (2005) once a site is in operation the strategic focus is on safety, efficiency and productivity through effective asset management

in areas such as maintenance, repair and on-going operations of machinery, equipment and management of staff.

From the literature examined, the importance of asset management has been driven by three factors:

1. The rapid deterioration of infrastructure systems: due to conditions of operations or life span of the asset (Brint et al., 2009; Holland et al., 2005)

2. The advent of new technology: provides a comprehensive asset data systems enabling better analysis and prediction of asset performance provided…that the underpinning data are robust and fit for purpose (Brint et al., 2009; Vanier, 2001)

3. Changing structure of the industries: due to stricter legal regulations (health and safety etc), economic pressures and competition and environmental pressures (Brint et al., 2009; Holland et al., 2005)

As the number of built or acquired asset is set to increases in the United Kingdom in the future (Ravetz, 2008), it will be inevitable that organizations will have a large portfolio of assets to inspect or maintain. This phenomenon may cause the potential future deferred maintenance there by affecting the asset value (Ravetz, 2008; Vanier, 2000). Deferred maintenance as defined by (Vanier, 2000) is the cost of the maintenance…required to bring the asset to its original potential, typically constituting work that has been postponed or phased for future action. To avoid this sort of problem, proper asset management practice needs to be adopted. In order to properly utilize and manage this large portfolio of asset effectively, tools supported with robust methodology must be developed to suit the purpose of the asset management (Amadi-Echendu et al., 2007; Frolov et al., 2010; IAM, 2011; Vanier, 2000).

1.2 Asset Management Approach

The way asset management is performed influences the availability of the service provided, the quality and cost (Tsang, 2002). Doing this present its self with some complexity (Frolov et al., 2010; Vanier, 2000) such as challenges of choice and decisions on what to manage, when to manage and how to manage, however it is non-the-less intractable (Vanier, 2000). This challenges can be attributed to constraints of adequate funding and appropriate support technologies (Michele and Daniela, 2011; Schraven et al., 2011; Vanier, 2000) as a result, certain components of infrastructure can be neglected and receive only remedial treatments.

Attempts proposed to solve this problem require an interdisciplinary approach, in which synergies exist between traditional disciplines such as: accounting, engineering, finance, humanities, logistics, and information systems technologies for its success (Amadi-Echendu et al., 2007; Frolov et al., 2010) all driven by reliable data and information. Despite this interdisciplinary approach as highlighted by authors, a recurrent theme that presents itself as a challenge to effective asset management is the lack of accurate data and information (Amadi-Echendu et al., 2007; Brint et al., 2009; Shien; Lin et al., 2007; Michele and Daniela,

2011; Too, 2008; Vanier, 2000)as many asset intensive organizations generate enormous amounts of data that can only be used in limited arenas (Shien; Lin et al., 2007; Vanier, 2000).

The use of Information management technology can be considered as an enabler to manage this challenge. The implementation of an integrated information technology (IT) system could lead to better deployment of service and maintenance resources…thereby reducing costly maintenance tasks and increases the quality of service (Zhang et al., 2009). According to Vanier, (2000) there are many existing tools and techniques that address part of these challenges, but there is no one solution could readily be adopted or implemented holistically.

Common technologies proposed include; Enterprise Resource Planning (ERP) Systems, Building Information Modelling (BIM) Systems, Geographic Information Systems (GIS), Computer Maintenance Management Systems (CMMS), Integrated Workplace Management Systems (IWMS) (Abudayyeh et al., 2005; Akcamete, 2011; R.E. Brown and Humphrey, 2005; Andy Koronios et al., 2007; Lewis et al., 2010; O'Donoghue and Prendergast, 2004; Shehab et al., 2004; Vanier, 2001; Zhang et al., 2009). Basically these technologies work by linking several enterprise wide applications to a centralized database where the information (in data form) is stored, organized, manipulated, and retrieved. In asset management, this is termed "Enterprise Asset Management".

Several authors and associations have proposed specific methodologies to enhance asset management (Amaratunga et al., 2002; R.E. Brown and Spare, 2004; Ebinger and Madritsch, 2012; IAM, 2011). Most commonly adopted is the Publicly Available Standard 55 (PAS55) (Dixon, 2007; IAM, 2011; Andy Koronios et al., 2007; Woodhouse, 2007). Koronios et al., (2007) summarizes the Publicly Available Specification (PAS 55) as a 21-point requirements specification that aims to be aligned or integrated with other related business system standards.

In the paper, the authors investigated a case study through the development of a site asset management system (AMS). In the case study section, the authors described the physical and management challenges of the site and key components of the AMS.

2. Case study - Asset Management Database for a large infrastructure site

2.1 The Site

The site consists of more than 100 major process plants plus another 1200 significant buildings and items of infrastructure. Overall the site budget of approximately £1250m, annual expenditure on asset care is approximately 25% or just over £300m.

Reliability of operations is an increasing problem as plants are asked to perform well beyond their original design life. Majority of issues centre round asset integrity, condition and performance as a result of plant ageing, wear out and obsolescence.

Review of forward expenditure plans for the site's assets highlighted deficiencies in forecasting future asset care workload/expenditure. Whilst expenditure on maintenance, both current and planned, was reasonably well understood, this was not the case for asset care.

The Site Executive determined that the forecasting of future site asset care workload and associated expenditure required urgent improvement. The site Long Term Asset Care Project initiated in April 2002 with the objective of: "Establishing a Long Term Asset Care Plan for the Sites which identified the lifetime maintenance and asset care requirements of assets, which could be used to create a proactive risk based asset management regime to inform the Site Business Plan". As result of the project, the need of an IT system, Asset Management System was identified to achieve the objective.

2.2 The Asset Management System (AMS)

AMS is a software system developed by the authors to support the asset management process of the site.

It is used to:

- Maintain a register of the assets (items of infrastructure), along with operating timelines and asset hierarchies reflecting Work Breakdown Structures (WBS) and Organisational Breakdown Structures (OBS);
- Maintain KPIs for the assets, such as condition, capability, performance and integrity;
- Record gaps and shortfalls in the assets' condition, capability, etc, that require work beyond routine schedule maintenance;
- Prioritise emergent and repeating asset care work based on risk assessment;
- Compile OBS and WBS asset care work lists and identify future expenditure;
- Monitor project delivery;
- Aggregate and summarise asset management information at various levels of the WBS and OBS hierarchies to assist strategic decision-making.

AMS is a web based system compatible with Microsoft Internet Explorer 7 or above. It utilises a Microsoft 2008 SQL Server at its back end. Its web based user interface has been developed using the Microsoft ASP.NET 3.5 framework.

Figure 1 illustrates all components of AMS system, due to the page limits of the paper, only the main components of the system are introduced.

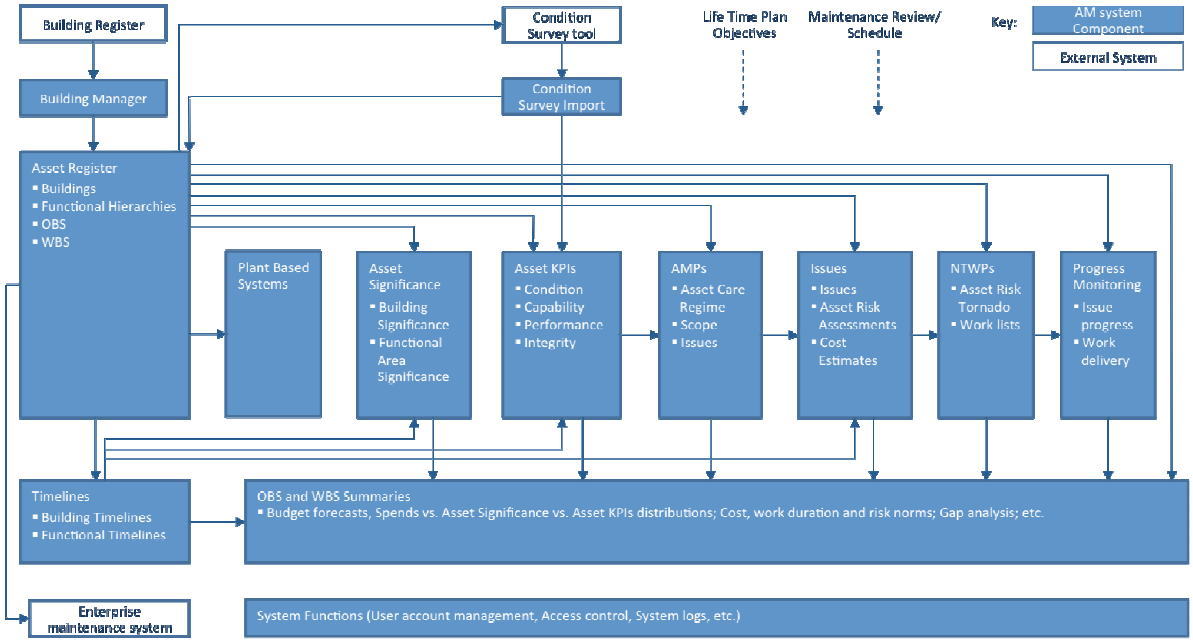

Figure 1 AMS system components

2.3 Key components of AMS

- Asset Register - Central to the operation of AMS is the Asset Register that holds the items of infrastructure comprising the site and its satellite sites. The items of infrastructure, referred to as assets, are defined in a hierarchical fashion. At the highest level of physical assets are Buildings, which are imported from the external Building Register system. Buildings are broken down into Functional Hierarchies comprising of Functional Groups, Plants and Areas. Buildings and their Functional Hierarchies are mapped to work streams and organisational responsibilities, creating two higher level hierarchies for analysis and reporting purposes: the Work Breakdown Structure (WBS) and Organisational Breakdown Structure (OBS).

- Asset KPI Assessment - AMS supports assessing four asset KPIs, namely *Condition*, *Performance*, *Integrity* and *Capability*. The Condition assessments in AMS are predominantly imported from the external condition surveying system, following an approval process. The condition survey system is also used to raise Functional Hierarchy change requests, also following an approval process.

- Asset Management Plans - Asset Management Plans (AMPs) define a proactive asset care regime in relation to Site Lifetime Plan objectives. Each AMP refers to a particular part of the Business Hierarchy. Issues define work aiming to address gaps and shortfalls identified. Each Issue refers to a particular Functional Area and might be assessed for its *Operational* and *Asset Risk*. Alternative options in addressing an Issue might be defined and the proposed solutions is scheduled for delivery and assessed for its cost. An External or Embedded cost estimating template may be used in estimating issue costs.

- Asset Care Work lists - Asset Care work lists define the work to be carried out over a six year horizon. Issues are prioritised based on asset risk. Issues to be executed are declared as funded, the funding source is defined for each funded Issue and the total cost of delivery is calculated for the organisational unit / work stream in question. Asset care work lists go through a periodic approval process. The first approved work list in a Financial Year is considered as the Authorised Baseline for the work to be carried out in the Year. Progress Monitoring functionality allows users to specify the progress of work on approved funded Issues, as well as monitor work delivery performance.

- Asset Care Delivery - A progress-monitoring module is used to monitor the progress of work. Members of the Asset Care Team periodically report the progress of work for each funded issue. The system is able to indicate whether an Asset Care Team, Organisational Unit, etc is behind, on, or ahead of schedule.

- Summaries and Analytics - OBS and WBS Summaries aggregate data at all levels of the OBS and WBS hierarchies for business analysis and reporting purposes. Data are also exported to Business Intelligence tools (e.g. Excel PowerPivot) to identify trends and gain insight into the asset management process. Examples of summaries supported include Asset care work list cost and risk summaries, future asset care expenditure forecasts, Spends vs. Asset Significance vs. Asset Condition distributions, and cost, work duration and risk norms.

In addition to the above core functions supporting the asset care management process, AMS provides auxiliary functionality supporting the system's operation. This includes user account management and access control, system and usage logs, user messaging mechanisms, error reporting, etc. Finally, AMS is considered the reference system for holding the site Business Hierarchy. As a result, the Business Hierarchy is regularly exported to the external site maintenance system.

3. Discussion and Conclusion

The aim of the paper is to introduce the discipline area and the asset management tool developed by the authors. The key conclusion from the development is that an information technology system solely cannot ensure or guarantee that asset management will be effectively carried out, which is echoed by Hipkin's study (2001). It is essential to establish asset management process and develop the IT system to support the process.

The AMS system was set out to address the following challenges facing the site.

- Fragment asset management approach and data.
- Knowledge of gaps and shortfalls in asset condition and performance are still incomplete
- Still too frequently in a 'Find and Fix' mode instead of 'Predict and Prevent'

- Funding constraints force revision of site strategies and changes to lifecycle baseline operating and decommissioning timescales, the need to assess the impact of these changes and understand asset life limiting features becomes more important (and demanding).

It was very soon that the development team realised the site management process and activities had to be identified first (Figure 2). An IT system needed to be developed to support the process.

7 Key activities have been identified during the development process. Although most of the activities have been documented on site with site internal process and procedures, it was the first time that they have been analysed from an IT system point of view. It enabled the site asset team to view those activities in a more logical and holistic way. Each activity is discussed as following together with its approach and lessons learned.

- Activity 1 – Asset Register - A spreadsheets based Asset Register existed on site, but it wasn't never fully updated. Although there is an internal protocol of how the assets should be organised, it wasn't fully complied, Simply because the complexity of the assets, which means the original spreadsheets was never be able to capture all the necessary information. The development of the IT based asset register enabled the site asset team to re-define the required information for each asset, and ensure the internal protocol is fully complied. It also monitors the compliance for any future changes and maps to the organisation structure to establish accountability. Both the development team and site asset team agrees that the establishment of an accurate and consistent asset register is the most important activity of the site asset management process, it should be done with great care as all the additional information will be associated with the register eventually.

- Activity 2 – Maintenance Schedule - There is a maintenance system on site to manage the all the maintenance activities, it provides information at great level of details, however, it wasn't linked to the asset register, therefore, the information was often duplicated or missing. An interface was development to integrate the AWS with the maintenance system to ensure only one reference point is used for data integration, which made the data analysis across two systems possible.

- Activity 3 – Asset Assessment - The site asset management process requires undertaking asset condition assessment at regular basis. Due to the large number of assets, a methodology based on the asset register was developed to ensure all the critical assets were covered in the process. The methodology was integrated into the system to provide more effective reporting and analysis. The similar methodology can also be applied to safety, integrity and performance assessment. It was very effective for site asset team as a consistent methodology and report mechanism were used. It was the first time for the site asset team to have a overall picture of the site in term of the condition, safety, integrity and performance.

- Activity 4 – Maintenance Review - This activity is primarily performed by the site maintenance system, it provides data input for AWS for future planning analysis in

asset management planning activity. AWS also provides asset hierarchy as reference for the site maintenance system.

- Activity 5 – Asset management Planning - Asset management plan (AMP) is the core element of the AWS system. Each AMP covers part of the asset hierarchy and contains all related asset management activities. It also defines the responsibilities and accountabilities at the organisation level. It is essential to include the asset elements from the lowest level of the asset hierarchy in the AMP, all the activities need to be associated at that level, it will ensure all the summaries and analysis could be aggregated to the top. Analysis function also needed to identify any element of the site asset hierarchy missing from the AMPs.

- Activity 6 – Asset care work list - Asset care work list is the report facility to summarise the workload level for the next financial year and future financial years. As it is an official report, an approval process is included to ensure the data integrity of the system.

- Activity 7 – Maintenance and Asset care delivery -This is a project management functionality and track and management current work list. It is a standard project management facility and still under development. The key activities of the asset management process illustrated in Figure 2 have eventually become the core modules of the AMS.

It took the authors almost six years to develop the AMS system. It was interesting journey for both the authors and the site management team. For the authors, it provided a much better understanding of the asset management concepts through a real life practice. For the site asset management team, it provided a holistic view of the site assets and enabled the more effective management through a fit for purpose IT system.

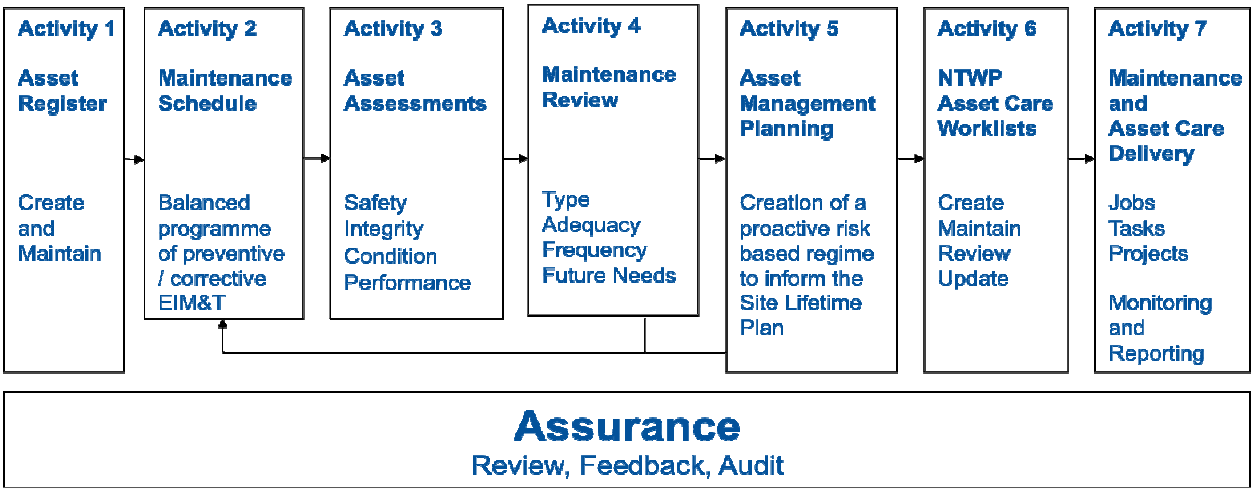

Figure 2 Site asset management process

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Analysis on the governance structure of large-scale AEC project transaction

Guangshe Jia[1], Ting Ye[2], Wenjun Wang[3], Zhijian Xia[4], Yongjun Qin[5]

As there exist numerous problems in institution, mechanism and organization aspects of large-scale AEC projects, this paper, starting from the relationship between transaction classification and contract structure, aims at further discussing on the governance structure of projects transaction by economics paradigm. The cost of project transaction and the accommodation of responsibilities and interests among stakeholders are put in first place. Based on the analysis of driving factors and construction characteristics, a double-level governance structure framework of large-scale AEC projects is initially built, which is composed of unified governance inside government and trilateral governance among legal persons. Then the project governance structure of Shanghai Hongqiao Integrated Transportation Hub (SHITH) is taken as an example for empirical analysis.

Keywords: Transaction Cost, Large-scale AEC Projects, Governance Structure Framework

1. Introduction

The large construction projects have shown numerous characteristics, such as large-scale investment, long-term duration, complicated techniques and uncertain risk with many stakeholders involved. Traditionally, it is common that scholars always pay more attention to management paradigm about AEC project, namely the one that is focused on the quality, duration and cost to improve the life-cycle performance of project organization through the enhancement of project management techniques and optimization of management methodology. However, many phenomena, such as the disorder of monitoring and multiple institution setting in government organization, as well as the unclear obligation of legal persons and uncertain regulation in contracts, have gradually been aware of during the implementation of construction practice. All of those lead to non-rational allocation of power, responsibility and interest among stakeholders, followed by participant corruption, environmental damage and social conflicts, finally the negative externality of the whole project gradually come into being. Therefore, it has gradually been a mainstream to take the

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project as a temporary organization from the perspective of economics paradigm, which, concentrating on the transaction cost as well as the disposal of responsibility and right in joint organization, makes a firm combination between contract classification and governance structure according to different transaction.

2. Governance Review

The concept of 'governance' not only contains the control of national macroeconomic policies and regulations, but also includes the collaboration and continuous improvement in project organization at the micro realm. Therefore different social stratum has different views of governance. The Commission on Global Governance (1995) made a standard definition of global governance starting that 'Governance is the sum of many ways individuals and institutions, public and private, manage their common affairs. It is a continuing process through which conflicting or diverse interests may be accommodated and co-operative action taken', which includes formal and informal institutions and regimes. R.A.W. Rhodes (1996) integrated all the meanings and then summarized six separate definitions of governance, those are: as the minimal state to reduce the expenditure and cost in managerial activities; as corporate governance to guide, control and supervise the operation of organization; as the new public management to introduce incentive structures into public provision and private sector management methods; as a socio-cybernetic system to cooperate and interact between governmental and non-governmental organization, between public and private sectors; as the good governance emphasizing on efficiency, legislation and responsibility of public service system; as the self-organizing networks on the basis of mutual trust and benefit. Rhodes initially summarized all the realm of governance, starting to refine the connotation and its denotation systematically.

Recently, it can be illustrated that the governance basically exists in the form of a temporary organization in company. The traditional project theory emphasizes the project management techniques to improve the workflows, while modern project theory goes to the other perspective which regard the project as a contract organization. Turner (2003) clearly defined the project as a temporary organization to which resources are assigned to undertake a unique, novel and transient endeavour managing the inherent uncertainty and need for integration in order to deliver beneficial objectives of change.

It could be understood that the definition vary as different views of research perspectives and theoretical principle. Up to now, researching on the project governance developed into the following two levels: corporate governance and project governance. Association for Project Management (APM)(2004,2007), Klakegg et al(2008) paid attention to corporate governance, describing the governance of project management should be attributed to the board of directors rather than the project management activities in temporary contract organization. Government and company should define the right project, program and portfolio, supporting the means by which the board and other major project stakeholders are provided with timely, relevant, and reliable information to achieve strategic goal. When it comes to multi-owners, the mechanism of decision-making and reporting arrangements should be established and each owner can be assured that its reasonable stewardship responsibilities will be met. Many scholars and institutes like Turner(2006), Project

Management Institute(PMI)(2008) and The Office of Government Commerce (OGC) (2007) focused on the levels of project governance and pointed out that project governance involves a set of relationships between the project's management, its sponsor(or executive board),its owner, and other stakeholders according to the view of temporary organization. It provides the structure through which the objectives of project are set, and the means of attaining those objectives and monitoring performance are determined. Finally it ensures a project is completed as plan and that its ultimate objectives or benefits are delivered.

Additionally, Winch(1989) introduced the transaction cost into AEC project and company, stating the construction projects are merely temporary coalitions among different companies with diverse vision resulting to distinct socio-economical benefits. Then a conceptual framework was set up (2001) throughout the project lifecycle for understanding the governance of AEC project process, drawing on transaction cost economics, which is widely studied by a scholar named Williamson. At the same time, Turner(2001) described governance structures adopted by successful project-based organizations, and how they use them to manage the interface between projects and their clients. Two roles were observed at the interface, labelled the broker and steward. The necessities of those two roles were raised, finding that the governance structure should match with the complexity of project transaction, otherwise the transaction cost will inevitably be increased, which demonstrated a stark contrast between the classically managed organization and project-based organization. Lee(2009) showed that transaction cost incurred by general contractors and sub-contractors varied according to the type of relationship established. Then the model of transaction-cost-based profit was used in both competitive and partnership relationships, simulating the parameters affecting the nature of the sub-contracted work. Finally the conditions and relationships under which general contractors' profits were optimized have been determined. Zerjav(2012) applied the concept of asset specificity to process-level design and engineering knowledge and induced a theoretical framework on the basis of local and expertise specificity of assets, explaining the different specificity lead to different modes for intra-firm governance of work packages in design and engineering. Therefore, many scholars have been aware of the importance by studying on the topic of transaction cost in project governance from economic perspective.

The paper comes up with the general concept of project governance on the basis of literature review. Unsurprisingly, it's a continuing improving process in the specific institutional context of a temporary contracting organization, which can be assured that its reasonable organization structure and vertical integration will be matched. Meanwhile, aiming at effectively control of transaction cost, it ensures a project completed in accordance with plan from clear coordination of responsibility and benefits among stakeholders and that its social and economical effectiveness is ultimately delivered. Also, the paper analyzes the relationship between transaction type and contracting classifications from transaction cost theory, and at the same time, a framework of double-level governance structure which is suitable for large-scale AEC project under DBB is initially proposed, that is unified governance inside government and trilateral governance among legal persons. Finally the transaction of ex post control and dispute settlement mechanism of previous structure were explained, which has been widely and practically implemented in project management.

3. Relation among Transaction, Contract and Governance

Commons (1934) put three principals of social relationship about conflict, mutuality and order together, regarding that the transaction is not the production exchange, but the ownership transference among human beings. A transaction from the idea of Williamson (1985) occurs when a good or service is transferred across a technologically separable interface. One stage of activity terminates and another begins. The theory of transaction cost do its efforts on the market, hierarchy, and hybrids to be well adapted to the cost and benefit in different institutional contexts, giving a static framework to economical organization, which is the prerequisite for a company in decision-making about whether to implement the vertical integration or not.

3.1 Factors of Transaction Cost

The economics of production focuses on the driving factors of transaction cost. More specifically, it contains three elements, which are contingency factors, behavioural factors and context. Contingency factors are the features of transaction composed of uncertainty, frequency and asset specificity. Behavioural factors are the ways in which managers typically respond to previous features, namely bounded rationality, learning and opportunism, respectively. The last is the institutional context within which the transaction is embedded, which in turn is situated within the broader national socio-cultural context. The framework is presented in Figure 1.

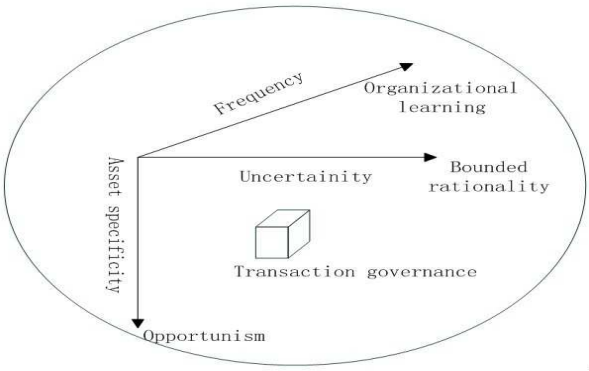

Figure 1: The transaction governance framework（Winch，2001）

3.2 Matching Transaction, Contract Classification and Governance Structure

A two-by-three matrix was proposed by Williamson(1985), which described six classifications of transaction to which governance structures must be matched. The relationship between asset specificity and frequency on the premise that uncertainty is well known is summarized and is presented in sufficient degree to pose an adaptive, sequential decision requirement.

Three contract classifications including classical contracting, neoclassical contracting and relational contracting were put forward. The rights and responsibilities of classical contract are accurately measured, with both emphasizing on the punishment and claim of contract breach instead of long-term maintenance of contract. Without third-party intervening, the

emphasis of classical contracting is therefore on legal rules, formal documents, and self-liquidating transactions, which is suitable for standard transaction. Neoclassical contracting shows preference to long-term contract relation, emphasizing on the establishment of regulation with third-party and developing a more flexible contract mechanism. It is suitable for occasional transaction of mixed and idiosyncratic investment. Rational contracting may or may not include an 'original agreement', it only gives a brief introduction of contract framework. Rational contracting has no details about the contract arrangement, it only contains overall goals, adaptive principle, contingency handler and dispute mechanism, which is suitable for mixed, idiosyncratic recurrent transaction.

Compared with transaction governance based on contract theory, transaction cost theory deals with issues from the perspective of organization theory. The different classifications of transaction are selected by specific governance structure, with the preference on ex post governance, certain relationship gradually occurs. The classical contracting is similar to market governance, while neoclassical contracting is relate to trilateral governance and rational contracting will be organized in bilateral or unified governance. The inter-relationship is illustrated in Table 1.

Table 1: Match of Governance Structures with Transaction and Contract Classifications（Williamson，1985）

<table>
<tr><td></td><td></td><td colspan="3">Investment Characteristics</td></tr>
<tr><td></td><td></td><td>nonspecific</td><td>mixed</td><td>idiosyncratic</td></tr>
<tr><td rowspan="2">Frequency</td><td>occasional</td><td rowspan="2">Market Governance

(classical contracting)</td><td colspan="2">trilateral governance
（neoclassical contracting）</td></tr>
<tr><td>recurrent</td><td>Bilateral
Governance</td><td>Unified
Governance</td></tr>
<tr><td colspan="4">（Rational contracting）</td></tr>
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3.2.1 Market Governance

As for recurrent non-specific transactions, whether to maintain original relationships or start with new partners, who are easy to find at lower transaction cost, could be decided by their previous experience. But when it comes to occasional non-specific transaction, although the opportunism could not be avoided from their experience, it is worth learning from the other buyers in purchasing similar products, as those products have higher standardization.

3.2.2 Trilateral Governance

Mixed and idiosyncratic of occasional transactions, to a certain extent, are related to trilateral governance. Because those transactions refer to specific investment, so they are hard to transfer into other applications or the transaction cost is a little bit higher, meanwhile, it is difficult to solve under market governance. Whereas, the establishment of special governance structure as for lower frequency is so hard to get compensation that an intermediate institutional situation is needed under trilateral governance, which is similar to neoclassical contracting and should rely on the third party to cope with certain affairs.

3.2.3 Special Governance

Special governance structure is raised in the mixed and idiosyncratic of recurrent transactions. The demonstration of ‘fundamental transformation’ is more prominent owing to the characteristics of nonstandard. It contains bilateral governance and unified governance.

The characteristics of bilateral governance are to keep the rights of self-determination. Not all the assets have superior specificity to mixed and recurrent transaction, so it is conducive to achieve scale economy when purchased outside the organization. Compared with vertical integration, outside purchasing could get away from bureaucracy among organization and keep stronger motivation among stakeholders. Absolutely, Market purchase will face with the problem of adaptability and the signing of contract fee. When the adaptability is proposed, the clause of mutual trust should be made to ensure the contract revised to a certain degree.

Unified governance is operated inside a company without market intervention. The higher asset specificity is, the more specialization and individualization of human and materials value will be. The selection of organization mode has different adaptive influence over asset specificity in order to achieve scale economy. Vertical integration could unite the whole proprietary rights from price mechanism in market rather than using administrative method to operate, which could ultimately avoid the existence of temporary agreement to be continuous searched, designed and revised. Compared with bilateral governance, the vertical integration could thoroughly make the price and quantity transformable, thus achieving the maximization of overall transaction benefits. Additionally, the unified governance has certain advantages on supervision and inspection. However, with the emergence of complexity, the ‘Management of diminishing benefit’ resulted from information distortion is inevitable on arrival and the ‘firm boundary’ is particular outstanding at the same time. Lazy behaviour will gradually accrue without effective supervision.

4. Transaction Governance in Large-scale AEC Project

4.1 Governance structure under DBB project management mode

Nowadays, the transaction in construction project has comparatively higher asset specificity and lower frequency, so it refers to neoclassical contracting, which is adapted to trilateral governance. As more innovation and practice are involved in rapid development of real project, trilateral governance has different demonstration under different project management styles. A typical project management mode named DBB is introduced, followed with the analysis of ex post control of contract and dispute solution mechanism.

Consulting or designing company are always entrusted by owner responsible for pre-phase work and assist them in construction bidding under DBB. Contractors provide design and construction proposals to owner and, at the same time, choose the appropriate sub-contractors and suppliers. During the whole process, the owner representative, general construction contractor and construction engineer (supervision group in China) are all responsible for quality, duration and cost. The status of engineer is prominent, who is the construction supervisor and contract manager with many rights to regulate owner and

contractor, such as contract explanation, variation request, construction claim dealing and contract price revision. From the perspective of transaction governance structure, the intervention of engineer has three functions. First is to diminish passive influence of bounded rationality over the transaction as the role of owner representative. Those owners sometimes are short of industrial knowledge and technical skills, therefore they hardly have the ability to reasonably and efficiently coordinate the relationship among variety of contractors. Second is to cope with variety of activities between owner and contractor to effectively solve conflicts and contradiction during the construction process, ensuring thorough benefits will be got by both parties as the contractual manager and pre-arbitrator. Third is to act on behave of owner to monitor and manage contractors as the construction supervisor, making sure that all the goals are accomplished and the opportunism of contractors will be restrained to a large extent.

The information asymmetry obviously exists between owner and contractor during transaction, which poses a great challenge to ex post control including payment, risk control, and construction supervision. The contract relation between owner and contractor is on an equal basis under DBB with the engineer mainly delegated to supervise the process. Additionally, the well-directed clauses of FEDIC, such as the regulation of performance security, guarantee and retention money could efficiently get away from the contractor's opportunism. If any party is dissatisfied with solution, the issue would be resorted to Dispute Adjudication Board (DAB), who will handle it with the help of engineer. If the proposer still not be satisfied with the solution, the arbitration will get involved until it is ultimately solved.

4.2 Principal-agent in AEC: Demonstration of Transaction under DBB

The demonstration of transaction under DBB between owner and contractor varied on the basis of economical reform and unique construction management. From self-construction mode under planned economy, state-owned company mode and construction headquarters mode, gradually to widely spreading mode of principal-agent system nowadays, which has achieved remarkable effectiveness in practice. The specialized project management units are always chosen by authority through public bidding, and they are responsible for construction implementation from the control of investment, quality and duration, then delivering the production at the end of construction. During that time, the agent units fulfil the function of owner according to contract, while their rights and status depend on the degree of owner' authorization.

Large-scale AEC projects generally set up a project company or entrust government-owned investment company as the representative of governmental owner, who is responsible for managing the whole process of investment, loan repayment and facility operation. The project management company is always responsible for specialized work in construction management, thus forming the following management model, which is 'government-the government-owned investment company-construction management company'. The principal-agent relationship, at the same time, has changed from 'owner-contractor' to 'owner-owner representative -contractor' (Figure 2). It is found that there exist two levels of transaction, which are the one between owner and representative, and the other between representative and contractor. It not only has the characteristics of normal project governance about higher

asset specificity and greater uncertainty, but also makes them much more salient owing to complicated techniques, plenty of participators and highlighted schedule mission.

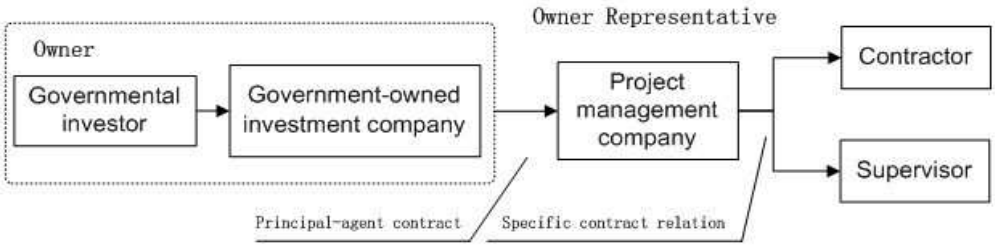

Figure 2: Form of principal-agent

4.2.1 Asset specificity

Asset specificity is a level that one asset could be allocated to the other alternatives on the premise that other production value is not underestimated. It could not only induce complex ex ante motivation, but also arise ex post governance structure reaction. As for contractor, the fixity of a project in site selection results to site specificity of transaction, a variety of temporary facilities and machinery will gradually create production-site specificity owing to higher relocation costs after start-up. During the implementation of a project, physical asset specificity exists because of heavy demand of structural members, building materials, etc. Meanwhile, design concept and unique construction techniques varied according to different characteristics, leading to human asset specificity. As for owner, the most important factor is the duration of a project, because the financial evaluation, investment decision and force majeure etc. all have great influence over it.

Government often set up project legal person to meet the requirement of regulation in construction project. Therefore, compared with specialized company owner, such as real estate companies, the human material and financial resource are much simpler, which will lead to huge transfer cost. Additionally, many factors in large-scale project often have unique techniques and environmental requirements, leading to the asset specificity outstanding.

4.2.2 Uncertainty

Uncertainty includes initial and secondary uncertainty. When it comes to AEC project transaction, certain consequences such as the critical information hidden by owner, the regulation broken by contractor, the coalition between contractors, equipment suppliers and other stakeholders are demonstrated obviously. Large-scale project has strong soci-economic influence, therefore project transaction suffers from higher initial uncertainty in the beginning. Meanwhile, stakeholders with different benefit requirements have communication disorders, which will enhance the secondary uncertainty and behaviour uncertainty.

4.2.3 Frequency

Compared with continual industrial project, large-scale AEC project is government-oriented infrastructure with one-time characteristics. Owner is only responsible for construction and

operation, thus having lower frequency with contractor. Moreover, the implementation of vertical integration in order to reduce transaction cost seldom exists in the company.

4.2.4 Fundamental transformation

The contractor who is selected from previous bidding will establish dependent relationship with owner because of the continuous increasing asset specificity. The transformation of contractor will affect the process of construction and even result in the termination of transaction. So 'fundamental transformation' of transaction cost is particularly prominent during the project transaction. Selected contractors have advantage over previous competitors and then stand out from the original bidders, gradually transferring into bilateral dependence, which pose higher requirement to the transaction governance.

4.3 Governance Structure Framework of Large-scale AEC Project Transaction

As can be seen from previous statement, there are two levels of governance structure under principal-agent system. The governmental owner is the planning department or users. The owner representative is a special construction management center established by government, who are usually the institutions or government-owned investment company. The contractors are construction units selected from competitive bidding.

4.3.1 Framework of Governance Structure

According to the characteristics of large-scale AEC project transaction and on the basis of relation between transaction and governance structure, a framework is built in Figure 3.

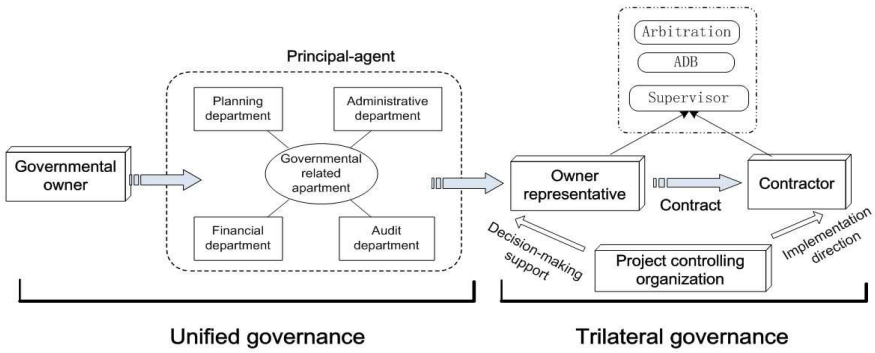

Figure 3: Governance structure framework of large-scale AEC project transaction

(1) Unified governance

Large-scale AEC project transaction has higher asset specificity, while government generally set up special construction management institutions to increase the frequency of transaction. Thus this kind of relation is suitable for unified governance structure.

The relation between representative and government investment institutions is inner principal-agent managed under the administrative regulations. Lower cost of principal-agent and the flexibility of operation is the advantage of intra-cooperation, which could adapt to

continuous transformation and seldom revise temporary agreement. Additionally, unified governance is good at supervising and it could effectively deal with ‘diminishing benefits of management’ resulted from information distortion owing to complicated hierarchical structure inside organization through ex post control mechanism, which also limits opportunism arise.

(2) Trilateral governance

The transaction between owner representative and contractor is suitable for trilateral governance. The contractor generally uses construction management mode of DBB thereafter receiving a project. Trilateral governance is a mixed governance structure, which depends neither on administrative regulation, nor market rules to arbitrate.

Owner and contractor are independent units. Contractor usually gets more benefits through cost reducing by the improvement of construction technology. At the same time, it has special regulation about the rights and responsibilities of both parties by learning from standard contract regulations and project management practices, thus leading to well control and supervision of project in transaction. Besides, in order to maintain the continuity of contract in large-scale AEC project on dispute settlement, trilateral governance would rather formulate certain multi-level mechanism than directly resort to law court.

4.3.2 Ex post control

Ex post control from owner to representative mainly relies on administration, financial approval, audit and inspection. Meanwhile, the control from representative to contractor should be carried out as the contract clause. According to the characteristics of project transaction, it could add ‘milestone issues’ of payment as the supplementation. As for the project with good final evaluation, we could draw up payment schedule, which could effectively avoid recurrent work of construction evaluating and calculating.

According to significant features on the progress of the target in large-scale AEC projects, it is particularly important to introduce project controlling organization, which will use processed information flows to direct or control material flows by collection, analysis and transmission of scheduling information. It will provide owner with integrated information management service to ensure the best decision-making during the whole process. While some practitioners may argue that the added project controlling organization will absolutely increase the supervision cost of transaction to a project, such an assumption is uneconomic and counterproductive. Others argued that the application of such organization in effective planning is always fruitful and that negative project outcomes such as cost and schedule overruns can be mitigated by increased emphasis on front-end controlling. Because the transaction cost induced from information asymmetry and opportunism is higher than the entrance cost of controlling organization from real practice.

4.3.3 Dispute Settlement Mechanism

The dispute mostly arises between owner representative and contractor. Many methods of dispute settlement in trilateral governance structure are developed, including coordination of

supervision, Alternative Dispute Resolution (ADR) and arbitration. ADR has many different forms, such as negotiation, conciliation, mini-trial, dispute review board (DRB) and dispute adjudication board (DAB). According to the different dispute situations among stakeholders, we usually consider solutions in economical viewpoint. Arbitration has dual attributes of contractual and judicial function. Those two sides accept solutions after arbitrating should give up previous lawsuit, any side is opposed to the settlement neither has right to resort to law court, nor could give proposal to other institutions for variation. Compared with ADR, the requirement is much stricter with longer time-consuming and higher cost. Therefore, this kind of dispute settlement mechanism is not highly cost effective.

5. Case study: Shanghai Hongqiao Integrated Transportation Hub

SHITH, one of biggest projects during the period of 'the 11th five-year plan' in Shanghai, is an important multi-functional infrastructure as the conveyance system of Shanghai Expo. It is an integration of different types of transportation, such as aviation, railway, maglev transportation, subway, highway, city bus, taxi, etc. It takes 13km^2 with a complex overall construction layout including eight project programs, twelve investment entities, over twenty operational entities and one hundred construction entities. Meanwhile, it also contains relevant infrastructures of office work and business service.

5.1 Project Governance Structure

SHITH construction headquarters (SHITHCH), the leading organization responsible for the overall planning and mission, is set up by relevant departments of municipal government (State-owned Assets Supervision and Administration Commission of Shanghai Municipal Government (SASACSM)). The related state-owned company or governmental departments are responsible for airport, magnetic levitation train, high-speed rail and subway in the core unit of SHITH, Shanghai Rainbow Investment Corporation (SRTC) is in charge of investment and coordination. Shanghai Airport Construction Headquarters (SACH) and Shanghai Construction Management Company (SCM) are commissioned by SRTC, being a project management company, executing professional construction management during the process. The unique governance structure is illustrated in Figure 4.

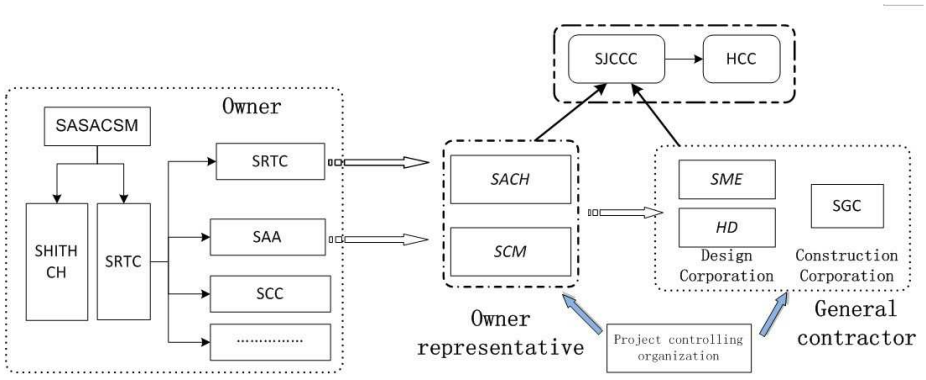

Figure 4: Project governance structure of SHITH

The relation between owner units (SRTC, Shanghai Airport Authority (SAA) and Shanghai Chengtou Corporation (SCC)) and SACH (belonging to SAA)) are inner principal-agent. Although SRTC and SAA are different legal entities, both are subsidiaries directly under Shanghai municipal government. Additionally, SAA is one of the three most important shareholders of SRTC, so the transaction relation is similar to unified governance. The problems come out from implementation were basically all solved from intra-communication and coordination, which decreased the transaction cost to a great extent.

The multi-level trilateral governance structure is established between owner representative (SACH and SCM, etc.) and other contractors. The owner representative contracted with Shanghai Municipal Engineering Design Institute (SME) to undertake the design management of the entire region, while the Hua Dong Design and Research Institute (HD) was responsible for the traffic center. Shanghai Construction Group Company (SGC) was chosen to take charge of the construction management of traffic center. Then owner representative selected Shanghai Jianke Construction Consulting Corporation (SJCCC) as the supervision group, who is responsible for the main project items, such as terminal, traffic center and maglev transportation station. As the supervision group has high quality and rich experience, they effectively reach an agreement between SACH and contractors, which reduce much cost and time. Meanwhile, if the dispute raised from real work could not be well solved by supervision group, High Coordination Committee (HCC) will act as the role of ADB in time to solve the dispute successfully. Owing to the effectively coordination between supervision group and higher committee, there were seldom disputes reaching the arbitration step.

5.2 Transaction Characteristics of Project

As the project has short construction period with complicated techniques in interface, time inevitably becomes the most limited resource after contracting, which reflects the time specificity at lager. The process goals in construction could not allow any discontinuity or termination of transaction, meanwhile, the ex post control of transaction must be assured. At the same time, numerous asset, material and human resource are added during the implementation to face with continuous market change, the conflicts and interface problems from original uncertainty will inevitably occur and should be treated carefully.

SRTC, as a company consisted of governmental department members, invests, operates and manages this large-scale project. In general, the owner has bounded rationality because of the information asymmetry. The technology and management level is not better than specialized project management company in real practice, so project governance structure in the market situation is always chosen to motivate the owner representative through the limitation of contract’s binding clause to maximize the benefits of owner’s rights.

Meanwhile, opportunism behaviour among stakeholders always exists. It demonstrates some strategic opportunistic behaviours such as information hiding, camouflage and distortion. The project controlling office was set up, whose purpose is to search and sort out information to ensure fluent communication. When conflict and contradiction appear, the whole achievement and overall goals are always paid attention to get the Pareto effect.

Generally, contractor will not be changed after pre-bidding, otherwise the transaction cost will increase. ‘Fundamental transformation’ has been prominent, owing to the chosen contractor has advantage over competitors with the acceleration of asset specificity, ranging from the bidding status to bilateral dependency. The trust mechanism between owner representative and constructor is of vital importance to promote the fulfilment of partnership.

5.3 Analysis on the Transaction Cost

The implementation of unified governance and bilateral governance has achieved certain effects from the real project practice. Much transaction cost in construction dispute has been settled down at ex post control through supervision and coordination, stemmed from construction and financial supervision Groups, as well as the fast intermediation from HCC. At the same time, the duration has unprecedentedly cut down compared to similar projects conducted in China, due to the reduction of transaction cost, leading to more efficient and effectiveness of daily work and multi-cooperation.

Absolutely, it is indispensable to supervise the process of construction due to the uncertainty of transaction and the presence of contractor’ opportunism. In order to guarantee the construction mission, owner representative has many monitoring and coordination methods added besides the controlling of construction or financial supervision. The establishment of project controlling organization, who is responsible for the planning formulation and execution, tracking the workflow and realizing the project mission by macro and micro perspective. The schedule it focuses on is not limited to simple planning, it also involves the house demolition and relocation, design preparation and operation management. After accurate searching, processing and transferring information, it could assure in time feedback, thus reducing the transaction cost and risk derivation to a large extent.

6. Conclusion

Through reasonable matching about the transaction characteristics, contract classification and governance structure, this paper has outlined the governance structure framework of large-scale AEC project transaction from the economic paradigm on the basis of transaction cost theory. It pointed out that the universal application of the large-scale AEC projects in China is the mechanism of unified governance inside government and trilateral governance between owners and contractors nowadays. Finally, the actual case of SHITH confirms its specific application process, and provides a unique perspective and method for the study of construction project governance. The implementation of double-level governance structure will more or less spread as AEC projects developed in the future.

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Design for Disassembly

A sustainable option for the construction industry

Márcio Fabrício[1], Letícia Mattaraia[2]

Abstract

This paper is about Design for Disassembly, a concept that has been used in the electronic and automotive industry as a way to ease the disassembly of products and increase the possibilities to reuse and recycle the materials and components. In the construction industry it is important to consider that the residues from construction, maintenance and demolition are responsible for a large part of environmental pollution. To prevent this, it has become such an important issue that a lot of companies, universities and governments are searching for better solutions. At the end of the life of a building, a lot of materials and components that are still in good condition and could be reused or recycled end up as residuals and go to landfills . Most of the time this happens because when the building was designed, the end of its life and its deconstruction wasn't considered , so it is more difficult to separate the materials and components. During the design of a building it's important to think about the lifecycle of the whole building, its components and materials, It´s also very important to consider the different life cycles and the end of its life. Nowadays, in Brasil, demolition is the most common solution at the end of a buildings life. This has serious consequences for the environment, the large amount of waste results in pollution of rivers and other places that are not prepared to receive these materials. This article reports on a common demolition in Brasil, which didn't consider concepts for Design for Disassembly. This helps to understand how it is done, to see what materials and components can be disassembled for future reuse or recycling, also to observe the obstacles that hinder better results. Design for Disassembly can increase the possibility to reuse and recycle the materials and components. It can also contribute to making the process faster and rental more economical. Some design solutions such as the way the components and materials are connected can make the process easier, faster and more attractive.

Keywords: design for disassembly, sustainable architecture, demolition, deconstruction.

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1. Introduction

This article aims to discuss the environmental impact of building demolition in Brazil and argue about the concepts and importance of considering Design for Disassembly (DFD).

Nowadays the most common system of construction here in Brazil is a structure with reinforced concrete, brick walls, timber structure roof and ceramic roofing tiles. At the end of its useful life, usually the building is demolished, some of the materials are separated for future reselling, but most of them are treated as demolition waste and go to landfill or an illegal place.

Demolition has terrible consequences for the environment. Most of the residuals go to landfill or are disposed in illegal places such as rivers or unoccupied lands. The Construction Industry is responsible for a lot of the solid waste in the cities. Demolition causes a lot of material waste, so it's fundamental to look for strategies to minimize it, such as facilitating the reuse and recycling of the materials and components (Heriqson, Rocha and Sattler 2008).

This practice results in a lot of material waste, pollution and environmental damage. It is fundamental to reach for solutions to relieve the situation. The concept of Design for Disassembly can assist in reaching better solutions. By using this tool the disassembly during the design of the building, can contribute to a better deconstruction with more possibilities to reuse and recycle more materials and elements. Therefore contributing to the environment. Nowadays, the way the buildings are designed and constructed results in a large amount of material waste such as the large consumption of primary materials that are extracted with considerable environmental damage (Gorgolewski 2008).

To Design considering the end of life (EOL) of the building also contributes to reducing the consumption of raw materials. The expanding economy and population are increasing the demand for materials, as a consequence this consumes a lot of natural resources (Gorgolewski 2008). It is also very important to consider the lifecycle assessment (LCA) of the building from the design stage, to ease the disassembly and maintenance of different elements and materials during the lifecycle and end of life.

The Design for Disassembly is an important tool to optimize the reuse and recycling of the materials and components from a building that reaches the end of its useful life. It is not usual for the designer to consider the end of life of the building and what to do after that. They are designed to be used for decades, but after that, the most common solution is demolition.

2. Research Method

The paper uses multiple evidence sources: literature review, field research and interviews with some people involved on the case study. It began with a literature review of sustainable development in construction and the environmental impact caused by demolition. The Design for Disassembly concepts are also based on literature review and LCA.

Subsequently, a case study is presented about a common demolition of a one floor commercial building, to analyze what materials could be or not be disassembled and the reasons for that. A thin kind of construction was chosen because it is very usual in Brazil and it would be possible to verify what are the barriers to disassemble the elements to achieve better results.

Finally, this paper talks about the relation of demolition, LCA, DFD and how it can contribute to better results for future reuse or recycling of the materials and the reduction in environmental impact.

3. Demolition and Sustainability

According to Tessaro, Sá and Scremin (2012) the construction industry is a very important sector in society's progress, however, it causes serious environmental impact. Construction and demolition consume large amounts of materials and also generate a lot of waste. Comparing to last century the economy and population have grown a lot, along with them, the consumption and waste of materials.

According to Alves (2010) the population grew 7 times (1 billion to 7 billion) from 1800 to 2010, and the economy has grown about 50 times. That fast growth results in soil, river, lakes and ocean pollution, also deforestation and a large consumption of fossil fuel. This shows how important it is to look for a more sustainable development.

It is important to reach for solutions to sustainable development in the construction sector. The environmental aspects of sustainable development require that we reach for a balance to protect the environment and natural resources and use it in a way to provide a good quality of life (CIB and UNEP-IETC 2002).

In Brazil, during recent years, there has been a fast growth of large and mid-sized cities, so the Construction and Demolition Waste (C&D Waste) has also been growing fast (Nunes, Mahler and Valle 2009). Finding ways to improve the reuse and recycling of materials, subsystems and elements helps to reduce the waste and consumption of raw materials.

Most of the C&D Waste is not recycled in Brasil, but to try and encourage change, the government creates federal regulations to oblige municipalities to implement better solutions to increase recycling. One of the initiatives from the Brazilian government was the creation of the resolution CONOMA 307, which established directives, criterias and procedures for waste management, so municipalities must have a plan to reduce the waste (Nunes, Mahler and Valle 2009). The production of documents that intend to reduce environmental impact is very positive and forces the construction industry to pay more attention to construction and demolition waste (Couto, Couto and Teixeira 2006).

Only 0.2 % of Brazilian municipalities (12 from 5,507) have C&D waste recycling centers installed or under construction (Nunes, Mahler and Valle 2009). For the authors, most municipals are far from reaching the CONAMA resolution.

Nunes, Mahler and Valle (2009) have made some suggestions in arguing for the recycling of C&D Waste:

- The government could be a better example, as it is the biggest consumer of construction materials, by adopting policies that encourage the consumption of recycled materials
- Reduction of taxes and provision of loans with lower interest rates
- The prices of recycled material need to be lower than the conventional materials, especially in Brazil that has a low price of raw construction material
- Motivate construction of private recycling centers

When considering the life cycle of the building, its components and materials need to have better results in future reuse and recycling, this is also one of the concepts that makes up part of DFD. It is essential to look for solutions during the design process with sustainable concepts, besides technical and functional issues, in a way to reduce the environmental impact (Gouvinha and Romeiro Filho, 2010).

4. LCA

The LCA (life cycle assessment) is an important tool to plan and reduce the consequences of our actions (Crowther, 2005). It helps to indentify the output, the inputs and the whole cycle to help the designer take sustainable decisions.

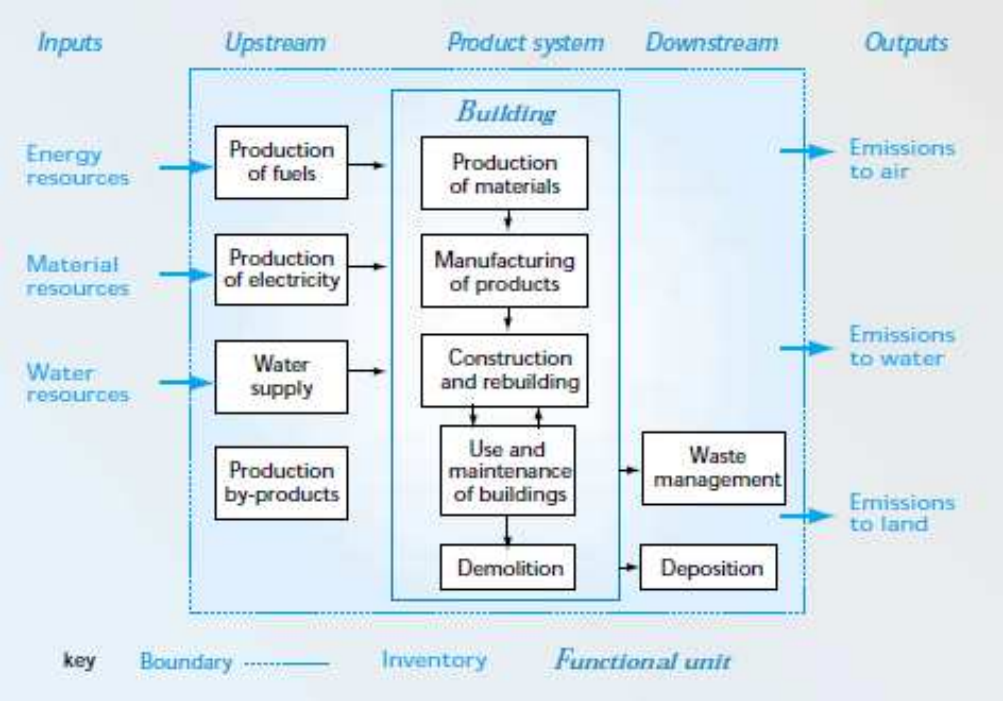

Figure 1: Application of LCA to construction products (Edwards and Bennett 2003)

Finding solutions for material waste is critical in creating a “closed loop” production model for sustainable development (Rocha and Sattler 2009). It is important to consider a cyclic view of the build environmental during the project, so there are more options in its end-of-life (Crowther 2005).

The figure 1 shows the usual procedure of LCA for construction products. It is important to realize what is necessary to produce materials and products for the construction. All phases of the product are important to considerer the environmental impact. From the extraction of raw material to production, use and discard. In this way it makes it possible to realize the critical points and search for solutions. The usual model of industry production is to extract material from the environment, process, manufacture, use and dispose. In the construction industry it also works that way, most of the time (Crowther 2005). This is considered a linear cycle. The concept of DFD collaborates to change that, because it contributes to reuse and recycling.

Some designers have the idea that the building should last as long as it can, so they don't even consider what to do at the end of its useful life. This causes serious consequences to the environment. Sometimes the government needs to intervene with regulations to encourage better solutions.

In Brazil there are regulations that consider the LCA, one of them is the ABNT NBR 15.575, which argues for the consideration of the cycle of the building and the components during the design. The table below shows how long a project should consider the lifetime of the building's components, for residential buildings of up to 5 floors.

Table 1 Life expectation (ABNT NBR 15575, 2008)

System	Years
Structure	>40
Internal Floor	>13
External Vertical Seal	>40
Internal Vertical Seal	>20
Roof	>20
Hydrosanitary	>20

It is possible to note that a lot of new buildings won't last more than 40 years, and if they do, they will need maintenance. This makes clear the importance of finding solutions for the end of their life.

The next table is about the maintenance of the buildings and their life cycle. It is interesting to note that between 30 and 50 years is considered long time usage.

Table 2: Construction processes and the lifetimes (Soares et al, 2000 apud European Commission, 1997)

Life Expectation	Processes of a specific building
1 to 3 years	Design and construction of building / civil engineering work
3 to 5 years	Maintenance time and use
10 to 15 years	Average length of use and partial renewal
30 to 50 years	Long time usage and Renovation

80 to 120 years	Lifetime structural systems of buildings
More than 150 years	Lifetime of monuments

It also shows that most buildings don't last as long as most people think. The designers need to consider this so we can have more options at the end of life and not choose only demolition. Crowther (2005) talks about four end-of-life scenarios:

- · Relocation or reuse of the building
- · Relocation or reuse of the components
- · Reuse of the materials
- · Recycling the materials

Considering this important phase of the building and the life cycle is very important to finding better solutions for reuse and recycling, also in reducing the demotion waste and the environmental impact caused by this industry.

5. Design for Disassembly

The project is the starting point of the building, so a large part of the solution to reduce the environmental damage should come from the designer, who is responsible for this phase (Degani and Cardoso 2002). Design for Disassembly can contribute to finding better solutions at the end of life of a building and facilitate the reuse and recycling of materials.

Nowadays demolition is the most common practice, but it results in a lot of waste and environmental degradation. Disassembly of the buildings to facilitate the reuse of materials and components is not usual in the modern construction industry (Crowther 2005).

The deconstruction valorises the reuse of elements and materials that would be treated as residuals without any value, in addition to contributing to recycling, reuse, innovation of technology, sustainability and the market of used material (Couto, Couto and Teixeira 2006).

Many designers don't pay too much attention to the end of life of construction and don´t consider ways to dismantle the building. However, there are some buildings that were constructed to be disassembled and assembled again, even relocated, such as the portable colonial cottages of nineteenth century Australia and London's crystal palace of 1851 (Crowther 2005). History can supply designers with some successful references.

According to Crowther (2005) there are three broad themes for DFD: consider a model for sustainable design; think about the different layers of the building; and a hierarchy of different types of materials and components that will be recycled.

To understand the building as a composition of components and materials and the relation of different parts, helps to find better solutions for reuse of those parts (Heriqson, Rocha and Sattler 2008). The authors have some definitions of layers:

- Parts: products that compose the building
- Materials: with no specific function (cement, sand, paint, boards, steel profile)
- Components: products with defined functions (windows, locks, handles)
- Elements: materials with components that are a part of the construction (wall, door)
- Subsystem: materials with components and elements that have a function (sanitary modules, facade)
- System: subsystems that have a complete solution for the building (structure, roof)

Thinking about the layer of the building also helps to design for disassembly, so it's possible to consider ways to ease the dismantling without compromising other parts of the building. Usually the buildings are designed as a unit that is conceived, used and disposed. But the building can live longer if it can be changed during time, for example, the structure can be the same and the internal layers changed (Crowther 2005).

With performance building deconstruction, it is possible to have better results for the reuse of bricks, windows and tiles, differently from traditional demolition. The demolition is connected to the process of building. The way that it is constructed, the types of components and materials, the connection and relation between different layers have an influence on the way to disassemble and reuse (Heriqson, Rocha and Sattler 2008).

There are some other points that should be considered when designing for disassembly to gain better results. Based on Heriqson, Rocha and Sattler (2008), who have some suggestions on how to improve the demolition:

- Use resistant and durable materials and components
- Use screws and connections that don´t damage the elements
- Avoid chemical connection
- Independent relation with different layers
- Facilitate access in all parts of the building
- Reuse materials and components to stimulate the practice

It's also important to think about why, what, where, and when to disassemble, and how to design for better results (Crowther 2005). The author mentions some principles for DFD:

Table 3: Based on the Principles of Design for Disassembly (Crowther 2005)

Principles	Description
Use recycled and recyclable materials	To encourage industry and government to develop new technologies
Minimize the number of different types of materials	Simplify the process, reduce transport
Avoid toxic and hazardous materials	Reduce the potential of health risks
Avoid composed materials and make inseparable subassemblies from the same material	Large amount of one material won´t be contaminated by a small amount of a foreign material
Avoid secondary finishes to materials	To not contaminate the base material and difficult recycling
Provide standard and permanent identification of material types	Provide information about material type, place, time, etc

Minimize the number of different types of components	Simplify the process and make the component reuse more attractive
Use mechanical connections rather than chemical ones	Makes the separation easier and reduces damage
Use an open building system where parts of the building are more freely interchangeable and less unique to one application	Allow changes without damage
Use modular design	Makes easier to reuse the materials and components in another system that is compatible
Use construction technologies that are compatible with standard, simple, and 'low-tech' building practice and common tools	Better to disassemble because the user is more used to it
Separate the structure from the cladding, internal walls, and services	To facilitate parallel disassembly
Provide access to all parts of the building and to all components	Makes the disassembly easier when there is access to different parts of the building
Make components and materials of a size that suits the intended means of handling	Better for assembly, disassembly, transport, reprocessing and re-assembly
Provide a means of handling and locating components during the assembly and disassembly procedure	Facilitate the handling of different elements
Provide realistic tolerances to allow for manoeuvring during disassembly	To handle the repeated assembly and disassembly process
Use a minimum number of fasteners or connectors	Easy and quick disassembly
Use a minimum number of different types of fasteners or connectors	More standardized process
Design joints and connectors to withstand repeated use	Minimize irreparable damage or distortion
Allow for parallel disassembly rather than sequential disassembly	Components and materials can be removed without disrupting other components or materials
Provide permanent identification of component type	Work in a co-ordinated way with material information
Use a structural grid	Makes the most efficient use of material type and allow coordinated relocation
Use prefabricated subassemblies and a system of mass production	To reduce site work and allow greater control of quality and conformity
Use lightweight materials and components	Makes handling easier and quicker
Permanently identify points of disassembly	To avoid confusion and make the process faster
Provide spare parts and on-site storage for them	To replace broken or damaged components
Retain all information on the building construction systems and assembly and disassembly procedures	Retain and update the information

The table above shows a lot of concepts inserted in Design for Disassembly, this can work as a guide for designers to improve the solutions for having better results when dismantling the building.

Because it is most used in the automotive and electronic industry, there are a lot of challenges when applying this concept in the construction industry. According to Brewer and Mooney (2008), when applying the DFD principles to the construction industry there are a lot of challenges because of the differences between construction and manufacturing.

- Lack of identification for most of the products to recycle
- Use of generic and composed materials
- Differences in design specifications and the particle build
- Lack of responsibility in coordinating points to facilitate the reuse or recycling
- Some products can become hazardous to health or environment

There are also technical barriers to success in the recuperation of the materials for reuse or recycling. Design for future reuse and recycling has a lot of environmental benefits such as reduction in material waste and energy consumption, but it can also have some consequences that are not so good such as the energy used to recycle and some toxic materials to improve durability (Crowther 2005). It is important to considerer the life cycle of the building and what to do with the material and components at the end of its life from the design stage and also the way it will be reused or recycled.

Design for Disassembly can help to reduce the demolition waste and, as a consequence, reduce the environmental damage caused by the construction industry. However, it is also important to consider the life cycle, how reuse and recycling could be possible, to reach better results.

This study case can assist in understanding how a large part of demolitions in Brazil are being performed. By analyzing, it is possible to note what can be disassembled for future reuse and what cannot, and then explore the reasons for this.

6. Study Case of a Demolition

This demolition was a commercial building of one floor, built with reinforced concrete and bricks, as many constructions are in Brazil. The owners decided to demolish to build another commercial building with an open plan and a different facade.

During a week, four workers disassembled some parts of the building to separate what could be used in another construction for a future resell. The table below shows what they could select for a future reuse:

Table 4: Materials for future sell

	Separated for future sale	Went to landfill
Timber	X	
Glass (common)		x
Glass (tempered)	X	
Electrical System		x
Hydraulic System (PVC Tubes)	X	
Water Tank	X	
Metallic Panel	X	
Ceramic Tiles (Roof)		x
Ceramic Tiles (floor, wall)		x
Structural System (Reinforced Concrete)		x

Plaster (ceiling, wall)		x

After they had separated the materials, in one morning they demolished what was left and took all the waste to the landfill. There was a coordinator, two workers cleaning the ground with hand tools, one man to operate the wheel loader and one man to drive the truck to take the demolition waste.

It was possible to note that the demolition was related to the construction. The workers executed the inverse order of the construction. They first disassembled the roof, then doors and windows. After that, they demolished the wall and structure, as there weren't separate layers. During the demolition or disassembly some parts of the building were also damaged.







Figure 2: Inside of the demolition; Figure 3: Wood being separated; Figure 4: Hydraulic system separated (Mattaraia 2012)





Figure 5 and 6: Mixed materials during demolition (Mattaraia 2012)





Figures 7 and 8: Finishing the demolition and cleaning the ground (Mattaraia 2012)

7. Conclusion

With this case study it was possible to note that with demolition as is practiced today it is possible to separate, for future reuse, only a few materials and elements. Most of them go to landfill and result in pollution and environmental impact.

This shows how necessary it is to reach for solutions at the end of the life of buildings and find ways to improve the disassembly to have better materials for future reuse. One way to do that is to look for better choices during the design phase.

In this study it was possible to see what materials could be removed without seriously compromising their quality, so they can be reused, and which had to be demolished by a machine and eventually removed just as rubbish. As seen in the literature some characteristics such as chemical bonds, designer not thinking about the EOL, mix of materials, related layers and non-resistant materials, can contribute to a poor recovery in materials and elements.

On the other hand, some points from DFD can contribute to better results. For example, the timber used in the roof structure was connected by nails and screws, this facilitates the disassembly and the material was in good condition for future reuse. They are also easy to handle and transport.

Design for Disassembly is an important tool that can be used to reduce the environmental impact caused by the construction industry and contribute to reuse and recycling of materials and elements. By observing and interviewing the people involved it is possible to note that the concepts in DFD would really contribute to better results.

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Acknowledgment

To CNPq who contributed with financial support.

A Study of Building Geometry to Improve Pedestrian Level Wind around High-rise Buildings

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Abstract

There are lots of ways to improve pedestrian level wind of high-rise buildings, and adding building podium is a common way (the so-called "podium design" is fundamental underlying expansion. Hereinafter refer to as podium design). Podium design is common in Taiwan. Therefore, this research focuses on the experiments and verification of improving effectiveness of pedestrian level wind for high-rise buildings with podium design. Improper size of podium could not improve the effectiveness of pedestrian level wind but cause other environmental problems; for example, if the podium is too large, it would become a block of wind field. By blocking the city's aeration, prevailing winds cannot blow into the centre of cities, and there would be less natural aeration. Besides, while podium design is too high or too narrow, both of them cannot ease up the influence of conventional airflow to pedestrian level wind. Therefore, a proper podium design is necessary. This research is mainly discussing how podium design eases up the effectiveness of pedestrian level wind of high-rise buildings by conducting wind tunnel experiments. So, there is a series of wind tunnel experiments designed for measuring ground surface wind speed of different models. While conducting wind tunnel experiments, surface roughness elements of terrain B will be constructed on the basis of proper wind speed profile in Taiwan urban. For the measurement of the variation of wind field characteristics with different profile models and at different angles, the Irwin probes were positioned at the upstream, downstream and single side of the building models. This research discusses wind field characteristics of the building without podium design, and how the size of podium influences the characteristics of pedestrian level wind as well.

Keywords: Podium Design, Pedestrian level wind, Wind Tunnel Experiment.

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1. Foreword

Once high-rise buildings were built, huge structures will become obstacles of wind flow. Due to downburst effect, an opposed airflow emerges near ground surface at windward side under the blockage of buildings. At leeward side, convolution air filed emerges due to the interaction between wind flow and wake flows on both sides; moreover, while wind flow passes both sides of the building, due to the separation of vortex, the wind speed at both corners will be very high. This sudden vortex and strong wind will definitely impact on the surroundings, especially for pedestrians' safety and comfort. To resolve this problem, Environment Protection Administration announced article 22 and 42 of the laws and regulations of "Assessment of Environmental Impacts of Develop Activity" on December 31st, 1997, regulating that there must be assessments of wind flow around the surroundings which might be caused by high-rise buildings, and proper improvement strategies must be proposed. Similar regulations can also be found in article 7 of "Points of Management and Maintenance of Comprehensive Design in Public Area of Taipei City".

There are several ways to improve pedestrian wind flow for high-rise buildings. Adding building podium is a common way. The so-called "podium design" is fundamental underlying expansion. Hereinafter refer to as podium design. Podium design is common in Taiwan. Therefore, this research focuses on the experiments and verification of improving effectiveness of pedestrian wind flow for buildings with podium design. Improper podium design cannot improve pedestrian wind flow but cause other environmental problems; for example, if the podium design is too large, it would become a block of wind flow. By blocking the city's aeration, prevailing winds cannot blow into the centre of city, and there would be less natural aeration. Besides, while the height of podium is too high or the width is too narrow, both of the podiums cannot ease up the serious influence of pedestrian wind flow. Therefore, a proper podium design is essential. This research conducted wind tunnel experiments with models from the perspective of wind engineering. This research discusses wind field characteristics of the building without podium design, and how the size of podium influences the characteristics of pedestrian level wind as well.

2. Research Content

This research is mainly discussing how the dimensions of podiums ease up the effectiveness of pedestrian wind flow of high-rise buildings by conducting wind tunnel experiments. A series of wind tunnel experiments designed for measuring ground surface wind speed of different models were conducted. While conducting wind tunnel experiments, surface roughness elements of suburban terrain were constructed based on the proper wind speed profile in Taiwan urban. For the measurements of the variation of wind flow characteristics for different profile models and at different angles, surface wind speed meters were poisoned at the upstream, downstream and single side of buildings.

To measure the wind flow characteristics nearby, the first step of wind tunnel experiment is to design square tower models without podium for buildings with different heights. The reasonable positions for wind speed measurement were arranged according to the literatures. In order to get a better understanding of how sizes of podium influence the wind

flow characteristics, this research measured wind speed at upstream, downstream, and single side of the models with different height-width ratios.

3. Methodology

3.1 Wind Tunnel Experimental Setup

The key point of this research is mainly about the discussion of wind flow characteristics of high-rise buildings with podiums. The essential point of the discussion is the distribution of ground surface wind speed around buildings. Parameters set for the experiments include the following: with or without podium, the height-width ratio of the podium, and with or without a lower building at windward side.

First, this research discusses differences of wind flow characteristics around the buildings between tower models with and without podium. Then, the proper height-width rations of podiums were analyzed based on the experiments results. There are two parts for the experiments. One is for the experiment for tower model without podium, and the other is for tower with podium. The ratio of experimental model is 1 to 250. The experiment of single tower model without podium is presented in Figure 1. The width of square tower, D is 8 cm. H refers to the height of square tower. The height-width ratios set for the experiments are 1, 3, 5, and 7. The surrounding conditions of the tower models without and with a lower building were assessed. The height of the lower building is 1D and the distance between the lower building and the tower model is 1.5D.

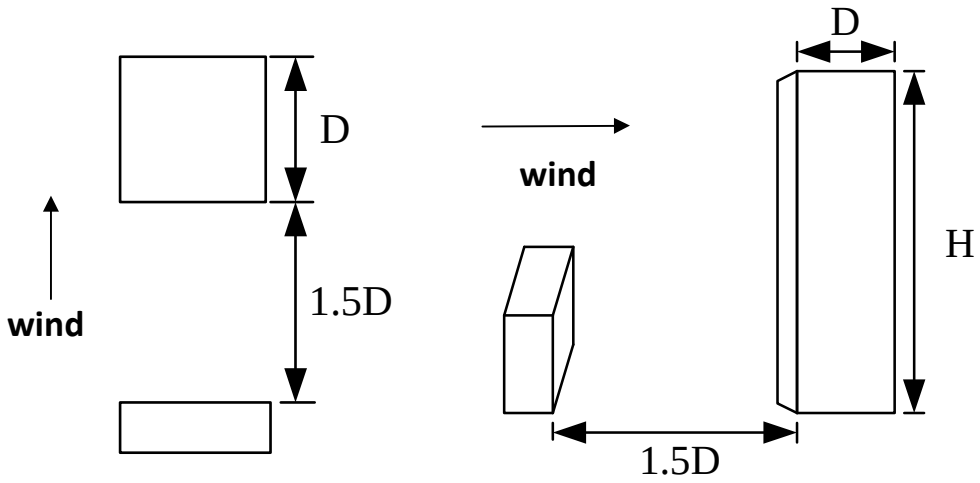

Figure 1 Layout of Single Tower Experiment

The layout of square tower model with podium is presented in Figure 2. Pw refers to the length of projection of the podium, and Ph refers to the height of the podium. For the experiments, projection ratio were set as Pw/D=0.25 and 0.5, and height ratio were Ph/D=0.5, 1, 1.5, and 2.

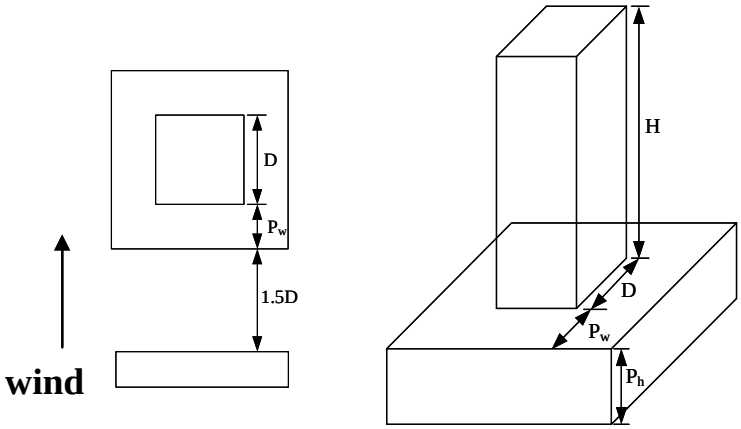

Figure 2 Layout of Square Tower Experiment

The experiments for this research were carried out at the wind tunnel lab. in Architecture and Building Research Institute, Ministry of the Interior. The length of the test section is 36.5 meters, 4 meters wide and 2.6 meters high. The highest wind speed is 30 m/s. Roughness elements of suburban terrain in the test section is arranged, stimulating ground conditions in most cities in Taiwan. For the measurements of the wind flow characteristics for ground surface at upstream, corner sides, and downstream, 60 Irwin probes around the models were arranged. Figure 3 shows the mean Velocity profile and the turbulence intensity characteristics measured at the model location. A power law of exponent α=0.25 gives the fit of the mean speed profile which corresponds to the suburban terrain. The layout of Irwin probes and the model is presented in Figure 4.

(a)Mean Wind Velocity (b)Turbulence Intensity

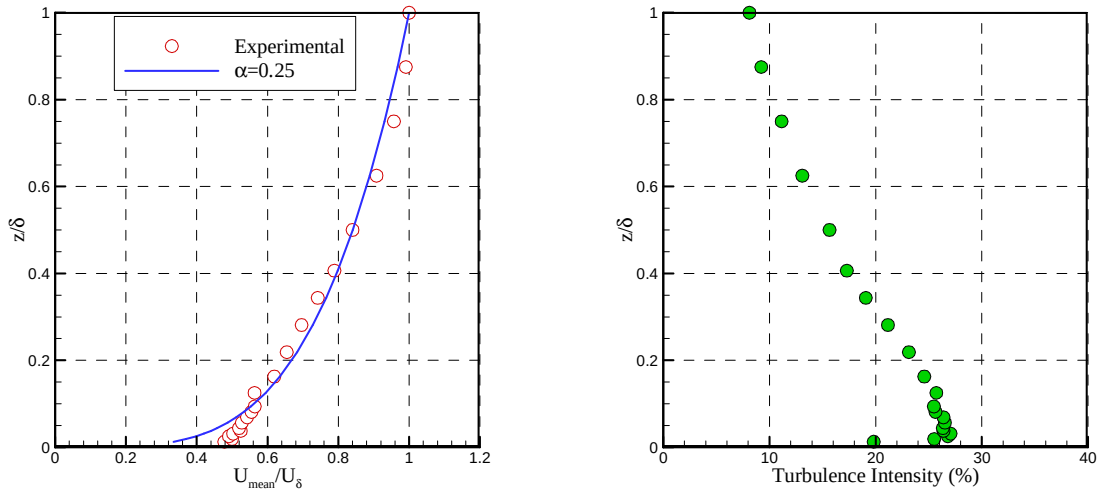

Figure 3 Wind Velocity Profile In the Wind Tunnel Lab.



Figure 4 Layout of the Model and Irwin Probes

3.2 Results and Discussion

3.2.1 With a low building at windward side

For the discuss of wind flow characteristics of single tower at ground surface, the aspect ratio of the single tower model in this research is designed as 1, 3, 5, and 7. Also, a low building was allocated in front of the model. The height of this low building was designed as 1D, and it is 1.5D (1.5D=12cm) far away from the single tower model. The result presented in Figure 5. (a), (b), (c), and (d) are distribution maps of dimensionless average wind speed of ground surface at the model height of 1D, 3D, 5D, and 7D respectively. Based on Figure 5, it is observed that with the increase of the heights of models, the wind speed at the upstream increases accordingly. While the height of building model is 5D, strong wind appears at the upstream corner of building distinctly.

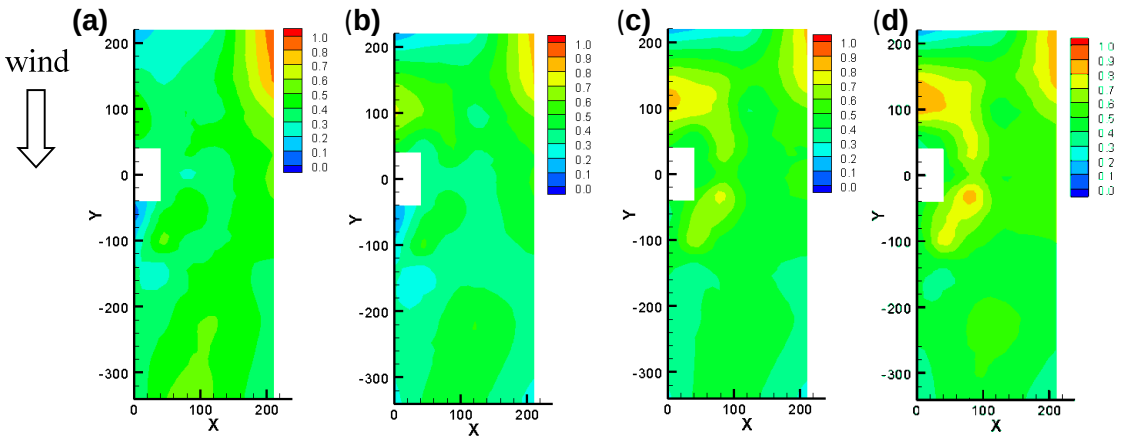

Figure 5 The Distribution of Ground Surface Wind Speed at Different Height Ratio of Single Tower Model with a Low Building at Windward Side (a)H=1D (b) H =3D (c) H =5D (d) H =7D

3.2.2 Without low buildings at windward side

Figure 6 presents the situation of the single tower model without low buildings at windward side. With the increase of the heights of models, the wind speed at the upstream increases accordingly.

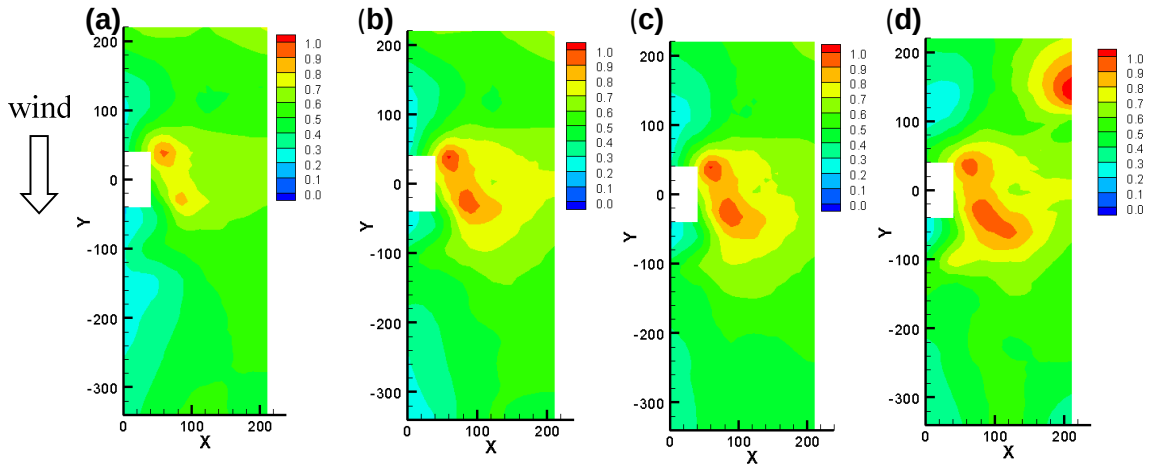

Figure 6 The Distribution of Ground Surface Wind Speed at Different Height Ratio of Single Tower Model without a Low Building at Windward Side (a)H=1D (b) H =3D (c) H =5D (d) H =7D

3.2.3 With low building at windward side, Projection Ratio of Podium: Pw=0.25D

With a low building at windward side, and the projection ratio of podiums set as Pw=0.25D, the results for different podium heights are presented in Figure 7. The low building for the experiment is designed as 8cm high; the distance between the low building and the model with podium is about 12cm. In Figure 7, (a), (b), (c), and (d) are distribution maps of dimensionless average wind speed of the podium height of at 4cm, 8cm, 12cm, and 16cm respectively. At the upstream of the model, when the height of podium is 4cm, no distinct high speed wind is found. However, while the height of podium increasing, the approaching airflow turns into backflow due to the podiums. Therefore, the strength and area of high wind speed expands along with the increase of height of buildings. There is similar situation at both sides of the buildings and corner at downstream. However, low wind speed was found at downstream of the building because of the blockage of the building.

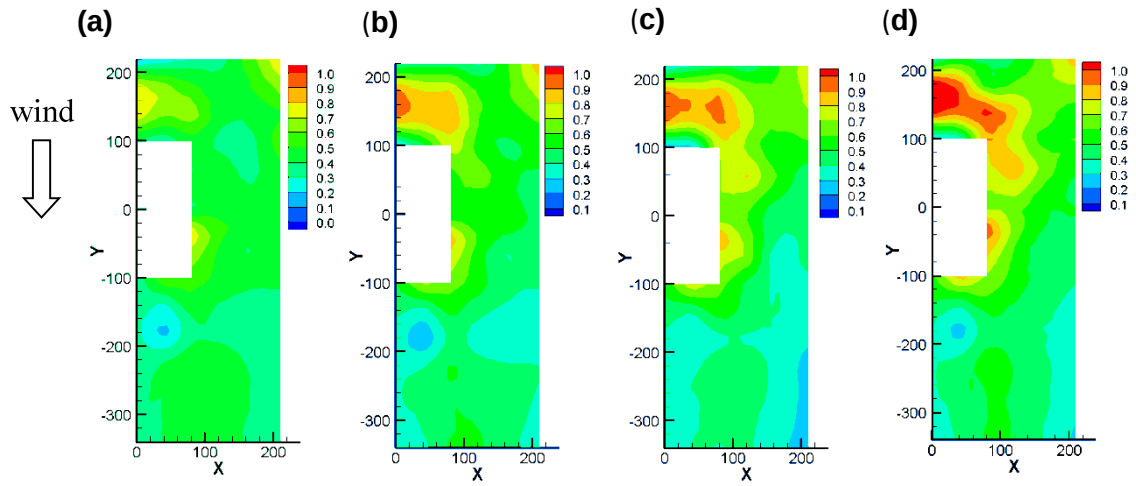

Figure 7 The Distribution of Ground Surface Wind Speed at Pw=0.25D of the Model with a Low Building at Windward Side (a)Ph=0.5D (b)Ph=1D (c)Ph=1.5D (d)Ph=2D

3.2.4 Without low buildings at windward side, projection ratio of podiums: Pw=0.25D

Without a low building at windward side, and the projection ratio set as Pw=0.25D, the results for different heights of podiums are presented in Figure 8. While there is no low building at windward side, lower ground surface wind speed is found. However, high wind speed area shows up at the corner of the buildings. Strong wind at this corner eases up along with the increase of height of podiums. Besides, in comparison with the previous scenario of which with a low building, situation is unclear at downstream area in this case.

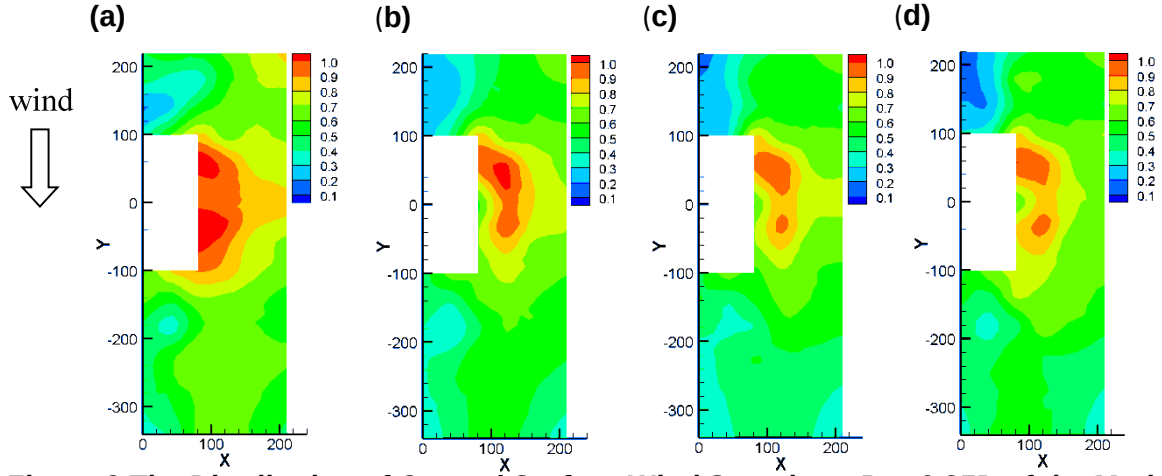

Figure 8 The Distribution of Ground Surface Wind Speed at Pw=0.25D of the Model without a Low Building at Windward Side (a)Ph=0.5D (b)Ph=1D (c)Ph=1.5D (d)Ph=2

3.2.5 Without low buildings at windward side, projection ratio of Podiums: Pw=0. 5D

Without a low building at windward side, and the projection ratio set as Pw=0.5D, the results for different heights of podiums are presented in Figure 9. The experimental results are similar to Figure 7. With the increase of the height of the podiums, the ground surface wind speed getting stronger, and the area expanding as well. However, when the width of podium is wider at the corner of downstream, the strong wind area is smaller. Further researches are needed to prove whether the result is related to the podium width.

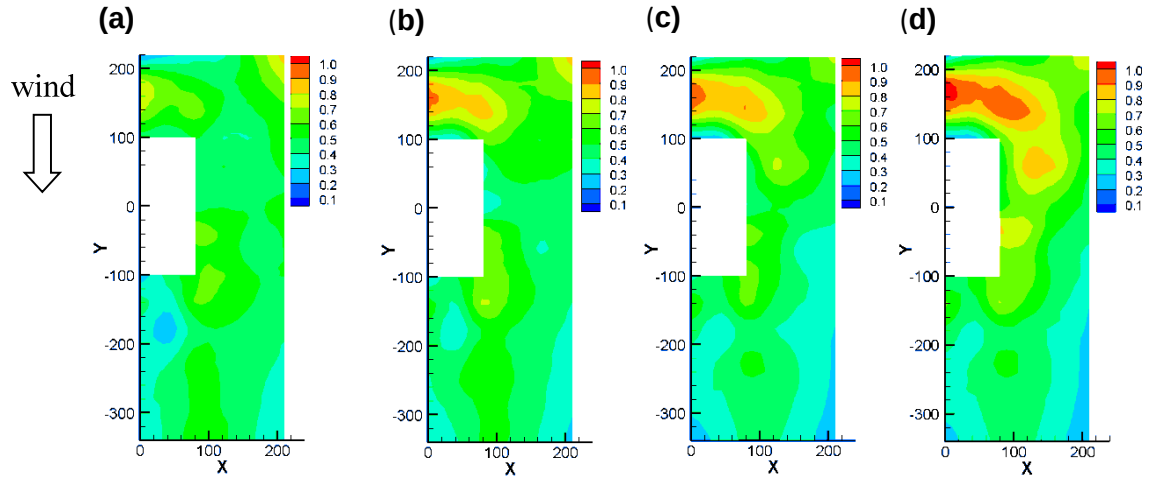

Figure 9 The Distribution of Ground Surface Wind Speed at Pw=0.5D of the Model with a Low Building at Windward Side (a)Ph=0.5D (b)Ph=1D (c)Ph=1.5D (d)Ph=2D

3.2.6 Without low buildings at windward side, projection ratio of podiums: Pw=0. 5D

Without a low building at windward side, and the projection ratio set as Pw=0.5D, the results for different heights of podiums are presented in Figure 10. Situation of wind speed at upstream of the building is similar to Figure 8. Without any blockage, the downward backflow formed by the approaching airflow conflicts with the wind flow in different directions at the back while bumping into the high-rise building of which results in wind speeds eased up. However, the tendency of corner flow is slightly different from Figure 8. The corner flow in Figure 8 is nearer to the building and the strong wind area shrinks along with the increase of podium heights. On the contrary, corner flow in Figure 9 is not close to the building and it gets farer along with the increasing of podium heights. Also, the strong wind area expands along with the increase of podium height. The differences between these two maps could be analyzed and concluded based on further experimental results.

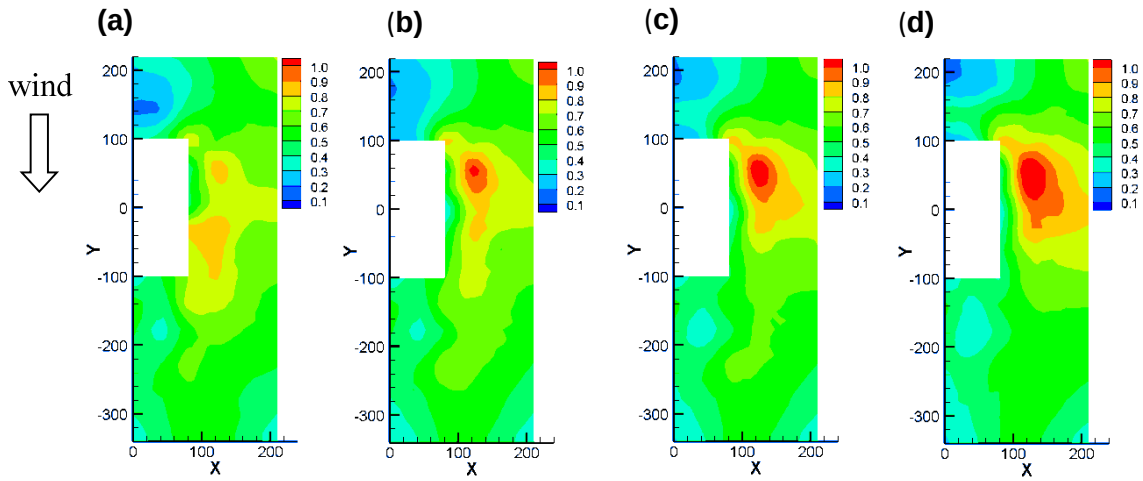

Figure 10 The Distribution of Ground Surface Wind Speed at Pw=0.5D of the Model without a Low Building at Windward Side (a)Ph=0.5D (b)Ph=1D (c)Ph=1.5D (d)Ph=2D

4. Conclusion

Pedestrian level wind environment around a high-rise building with a podium has been experimentally investigated in the wind tunnel using Irwin-probes. Distributions of normalized mean wind speeds around a high-rise building with a podium were found effected by the height of podium. When the height of podium is higher and higher, normalized mean wind speed in the upwind corner is getting larger. Meanwhile, if there is a lower building in front of high-rise building, the normalized mean wind speeds in the upward area were affected by the downwash wind flow to induce a strong wind area. This research is presented that proper height of podium is essential in case high speed of pedestrian level wind was found in the upwind area or corner.

Acknowledgement

This investigation was supported by wind tunnel lab of Architecture and Building Research Institute, Ministry of the Interior, Taiwan(R.O.C)

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An interdisciplinary cooperation network for the optimisation of sustainable life cycle buildings

Julia Selberherr[1], Gerhard Girmscheid[1]

Abstract

Sustainably optimised life cycle buildings as complex systems require, in addition to a good architecture and flexible usability, the integration of several interdependent subsystems. As current design and construction processes are linear and highly fragmented they are inappropriate. Cooperative networks have been identified as appropriate means for the development of optimised systems in various industries. According to a survey conducted at ETH Zurich the project-specific integration of key capabilities for the development of the overall system enables the optimisation of performance and costs which results in a perceivable surplus value for the customer. Therefore a research project has been initiated to investigate the use of cooperative networks for the optimisation of sustainable buildings as complex systems with particular regard to reducing opportunism, keeping competition up within the network to ensure market conformity of offers and generating a perceivable surplus value for the client across the life cycle. This paper focuses on a new cooperative business model, which is theory-led deductively developed. An interdisciplinary cooperation across trades and stages of a building's life cycle masters the temporal and technical interdependencies in a building project through the project-specific integration of the different subsystems. First, the objectives of the participating enterprises are analysed and then the objectives of the cooperative network are consistently derived from them. Then, the network organisation model, consisting of a cooperation network and activated project networks, is presented. Next, the process model is explained, describing the setup of the cooperation network and the operation of the basic service offer as well as possible transformations. In the last section the roles and required capabilities, particularly of the system integrator, are discussed. The new, systematically structured business model enables small and medium-sized companies to pursue a differentiation strategy by jointly creating sustainably optimised life cycle buildings.

Keywords: business model, cooperation, partnering, sustainability

1. Introduction

The building industry bears an enormous potential for sustainability optimisation, which has been recognised but not seized yet. The existing building stock globally causes 30% of total CO_2 emissions and 40% of total energy consumption (United Nations Environment Programme 2009). Furthermore, the building industry consumes with 3000 Mt/a, about 50%

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of the total material consumption, more material than any other economic activity (Pacheco Torgal and Jalali 2011). In addition, design and construction processes are highly fragmented and strongly focused on initial investment cost and are therefore inapplicable for the development of sustainable optimised buildings as complex systems (Girmscheid and Lunze 2009). A survey conducted at ETH Zurich identified cooperative networks as appropriate organizational structure for the development of holistically optimised systems in various industries (Lunze and Girmscheid 2009). Drawing on the experiences of cooperation networks for the optimisation of systems in other industries, a research project was initiated. The project's objective is to seize a cooperation network and project-specifically integrate the key capabilities for the optimisation of a sustainable building as complex system.

2. Research approach

A new cooperative business model is developed to overcome the linear, highly fragmented design and construction processes and to enable construction companies to master the required cross-linking of capabilities and know-how. This paper proposes a systematically structured model for sustainable life cycle service offers in the building industry. The essential innovative elements of the new cooperative business model are: A holistic **sustainable project-specific optimisation of the building as overall system** with regard to life cycle costs supplemented with **guarantees covering the operating phase** through the **creation of synergies** between different interdependent subsystems based on **repeated collaboration between the companies contributing key capabilities**, which drives continuous learning and improvement and can be used as incentive for cooperation compliant behaviour.

3. Research methodology

The development of the business model can be allocated in the third world of Popper (2002) and the hermeneutic science program with the objective of shaping the socio-technical world (Piaget 1973; Von Glasersfeld 1984, Girmscheid 2007). Triangulation (Yin 1984, Girmscheid 2007) through viability, validity and reliability is used to ensure the model's scientific quality. Viability is achieved through theory-led deductive modelling using systems theory (von Bertalanffy 1968) as formal scientific framework. The model's validity is ensured by the internal structuration with structuration theory (Giddens 1984) as meta theory and principal-agent-theory (Jensen and Meckling 1976). The model's reliability is achieved by testing its intended impact (target-mean-relation) using the principle of alternative interpretation.

Structuration theory aims at explaining the recursive relationship between structure and action. Sydow and Staber (2002) identify structuration theory as an appropriate meta theory for the analysis of inter-organisational networks, as the network structures are formed by actors and are continually reproduced and transformed, and thereby they are medium as well as result of social practices at the same time. Principal-agent-theory deals with conflicting interests of a principal and an agent in a contractual relationship. To reduce opportunistic behaviour of the agent principal-agent-theory is used and theory-led deducted recommendations for the design of the model are identified. Table 1 depicts three possible organisation problems, adverse selection, moral hazard and hold-up, and the corresponding

information problems, hidden characteristics, hidden action, hidden information, and hidden intention. Principal-agent-theory develops coping strategies to reduce the resulting negative effects for the principal. From these coping strategies recommendations for modelling the cooperative network are derived (Table 1), which are used as guidelines in order to reduce opportunism.

Table 1: Theory-led deducted recommendations for modelling (Picot et al. 2005)

Problems	**Theory-led deducted coping strategies**	**Theory-led deducted recommen-dations for modelling**
Adverse selection Quality characteristics of the agent are unknown (*hidden characteristics*) before contract formation (CF)	Signalling/ Screening	Standard partner selection process
	Self-selection	Internal competition based on competence
	Harmonisation of interests	Reputation
Moral hazard Actions of the agent cannot be observed (*hidden action*) or evaluated (*hidden information*) after CF	Harmonisation of interests	Fair profit sharing
	Monitoring	Open books, Continuous evaluation of collaboration quality
Hold-up Actions after CF can be observed but not prevented (*hidden intention* may exist before CF)	Harmonisation of interests	Provision of agreed collateral/ financial contribution

4. Modelling

4.1 Motivation and objectives

Mutual objectives are regarded as a constituent feature of cooperative networks in general (Sydow 1992) and also specifically in the building industry (Girmscheid 2010). A thorough analysis of a network's objectives has to take a multi-level approach starting at the objectives of the single enterprise (Mack 2003). On the **level of the single enterprise** the business objectives are made up by intrinsic and economic objectives (Kosiol 1966). The intrinsic objectives are directly connected to the production of goods or the provision of services as they specify the market offer in terms of type and quantity. Superordinate to these are the economic objectives which are concerned with the economic performance of the enterprise (e.g. maximization of shareholder value) and constitute its raison d'être. An enterprise will only participate in a cooperative network if it expects the positive contributions to its individual business objectives to be bigger than the risks involved resulting in a positive net-value.

Therefore any cooperative relationship is a means to contribute to the accomplishment of the objectives of the single enterprise. The **objectives for the cooperative relationship** specify how the cooperative relationship contributes to the objectives of the single enterprise. Different types of objectives can be distinguished (Picot et al. 2005). **Flexibility objectives** comprise efforts to be able to deal in a better way with quantitative fluctuations in demand as well as unexpected changes of a company's external environment. This includes the

objective of overcoming one's own capacity constraints in terms of production as well as financially. **Cost objectives** include reduced transaction costs and cost advantages related to the service provision. Gaining access to external know how through cooperation can also be subsumed under cost objectives. **Risk objectives** include endeavours to reduce the entrepreneurial risk and spread the risks connected to high investments among partners. Access to new markets through cooperation can also reduce risk through diversification. **Synergy objectives** aim at generating advantages in addition to the sum of all the individual contributions. Synergies are more of an instrumental character and may affect flexibility, cost, and risk.

The possibly conflicting objectives for the relationship from all cooperation partners have to be coordinated and eventually modified in order to generate a consistent system of **objectives of the network** (Maier 2002, Girmscheid 2010). This system is made up of reciprocal target-means-relations (Weber 1996). Once a consistent system of objectives for the cooperative relationship has been agreed upon, each single enterprise reviews its business objectives on the level of the single enterprise and adjusts them accordingly. In so far the objectives of the network have a retroactive effect on the individual business objectives. The intrinsic objective of the new cooperative business model is offering sustainably optimised life cycle buildings which constitute a perceivable customer surplus value. The economic objective of the new cooperative business model focuses on productivity, flexibility, and stability, primarily through the creation of synergies by inter-linking and project-specific integration of excellent sub-system capabilities. In addition a sustainability objective is agreed upon which helps to secure the long-term success and stability of the network (Girmscheid and Selberherr 2012). The basic service offer of the new business model pursues the use of sustainable, renewable or renewed building material, the energetic optimisation causing reduced energy consumption and CO_2-emissions as well as increased utilization and generation of regenerative energy sources, and provision of flexible usability.

4.2 Network organisation model

As the next step in the development of the model the organisational structure for the accomplishment of these objectives is specified. The cooperative network is led by the focal enterprise, the system integrator (SI) (Girmscheid 2010). This new business entity can be founded as a strategic business unit in a general contractor or any other company, for example in a heating, ventilation, and air conditioning company (HVAC), or as separate enterprise with the participating enterprises as shareholders. On the strategic level the focal enterprise as system integrator is responsible for the setup and management of the cooperative network as well as for the recruiting of cooperation partners as subsystem suppliers (SUSs). The new service offer is gradually expanded starting with a basic service offer, where investment cost is restricted through a guaranteed maximum price contract and life cycle optimisation is substantiated with predictions of the future energy consumption and model calculations using prior specified objective criteria to demonstrate the amortisation of increased investment cost over the building's life cycle. The essential components for the creation of client-specifically optimised buildings are the key capabilities which are contributed to the network by the subsystem suppliers and project-specifically integrated by

the system integrator. The remaining, complementary services are conventionally passed to subcontractors. For the basic service offer, for example, the subsystem suppliers are heating, ventilation, and air conditioning (HV), building envelope (BE), sanitary (SN), and electrical (EL) contractors. Later also energy contractors (EN), facility management providers (FM), security control technicians (SC), and building automation providers (AT) are included as subsystem contractors. A two-tier network organisation model (Figure 1), consisting of a cooperation network as basis for the setup of an activated project network, is chosen (Weber 1996, Mack 2003, Camarinha-Matos et al. 2005).

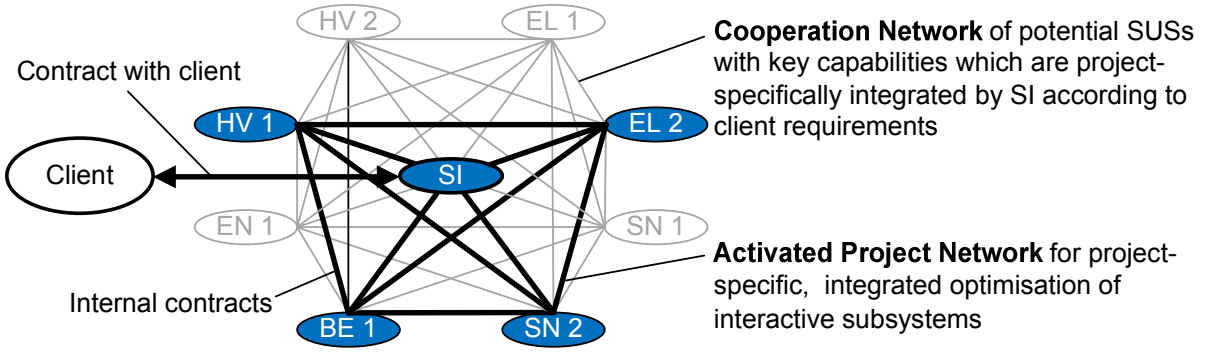

Figure 1: Network organisation model

4.2.1 Cooperation network

The cooperation network (CN) constitutes a pool of potential partners for collaboration in an activated project network. It is founded independent of any particular project and serves a prerequisite for the project-specific activation of a network. The objective, rational characteristics, like resources, competencies, and capacities, which qualify an enterprise as potential partner form the field of potential. The social factors and relational aspects, which make an enterprise a potential partner, constitute the field of social relations. These social and relational aspects can affect the personal level, the level of the enterprise, or the institutional level. The CN can be described as a function of the field of potential and the field of social relations (Mack 2003):

Cooperation network = f (field of potential; field of social relations)

From these fields the selection criteria for cooperation partners can be derived (Table 2). Strategic and organisational fit are vital for companies to belong to the field of potential. Strategic fit (Dyer and Singh 1998) concerns task-related criteria (Geringer 1991) and aims at the complementarity of technological capabilities in order to successfully create synergies. Companies as potential partners have to possess excellent technological capabilities which constitute the core competencies of the individual enterprises. The integration of these competencies is the core competence of the cooperation network. Organizational fit (Dyer and Singh 1998) concerns partner-related criteria (Geringer 1991) and subsumes organisational capabilities as well as the compatibility of situational and structural characteristics of the enterprise. Cooperative arrangements are more successful, if the partners are compatible in terms of characteristics like corporate culture, corporate strategy, process execution, firm size, and nationality (Müller 2005). The field of social relations aims at generating relational fit to build a basis of trust and is therefore connected to relation-related criteria like past experience and relational and reputational capabilities. In the

assessment of a partner's ability to cooperate, strategic fit constitutes a necessary condition, while organizational fit and relational fit are regarded as sufficient conditions (Mack 2003).

Table 2: Requirements for cooperation partners

Type of field (Mack 2003)	Field of potential		Field of social relations
Type of fit (Dyer and Singh 1998)	Strategic fit	Organizational fit	Relational fit
Type of selection criteria (Geringer 1991)	Task-related criteria	Partner-related criteria	Relation-related criteria
Type of capabilities (Hinterhuber and Stahl 1996)/characteristics	Technological (epistemic and heuristic) capabilities	Organisational capabilities and situational/structural characteristics	Relational and reputational capabilities, past experience
Type of connection (Heimeriks 2002)	Complementarity	Compatibility	Communality
Type of competence (Prahalad and Hamel 1990)	Core competence	Complementary competence	Complementary competence
Type of condition (Mack 2003)	Necessary condition for ability to cooperate	Sufficient condition for ability to cooperate	Sufficient condition for ability to cooperate

4.2.2 Activated project network

The CN serves as basis for the project-specific collaboration which is taking place in the activated project network (APN). As soon as a new client is acquired, his requirements are evaluated and an APN is founded. The APN is the level of value creation. Here the subsystem contributions of each partner are integrated to create a holistically optimised sustainable building.

4.3 Process model

The process model describes the operational structure of the new business model. A systematic multi-level approach with increasing level of detail considering main processes, modular processes and elementary processes is chosen (Figure 2).

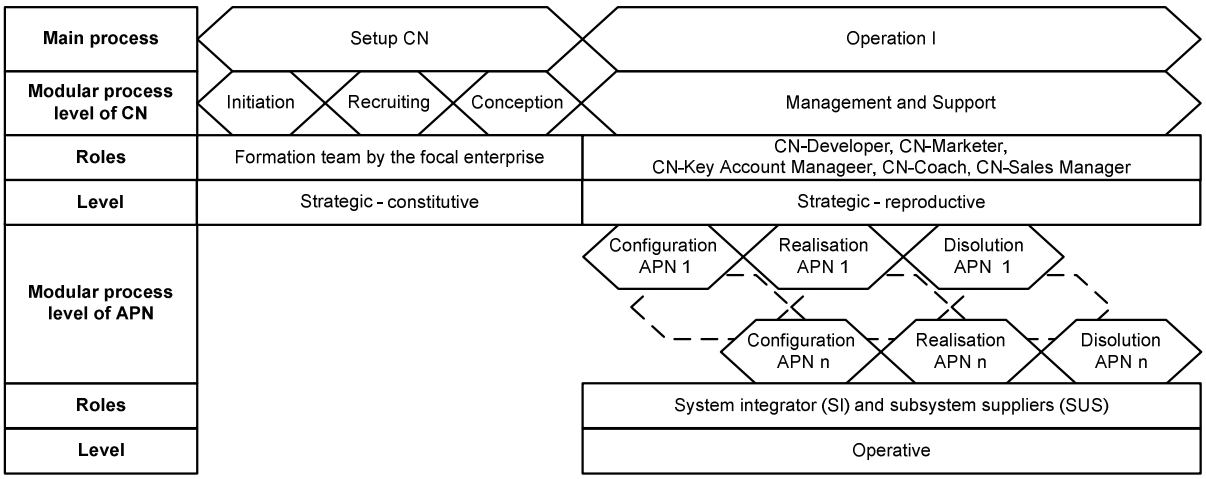

Figure 2: Process model depicting setup of the CN and Operation I

4.3.1 Setup of the CN

The *Setup of the CN* as main process concerns the strategic level of action. It encompasses the modular processes *Initiation*, *Recruiting*, and *Conception*. A formation team from the focal enterprise is responsible for the initiation and recruiting process. The conception process is undertaken together with representatives from the companies selected as partners, the CN members. The modular process *Initiation* prepares the recruiting of partners and conception of the CN. It includes the elementary processes shown in Table 3.

Table 3: Modular process: Initiation

Elementary process	Activities	Role
Formulation of business idea	Clarify client value and competitive strategy	Formation team
Environment and potential analysis	Evaluate market potential and possibly adapt competitive strategy	Formation team
Formulation of mission statement	Derive mission statement from underlying values of the cooperative network	Formation team
Definition of objectives	Define preliminary objectives of the cooperative network (intrinsic, economic, sustainability)	Formation team
Strategy planning	Formulate business strategy specifying service offer and detailed competitive strategy	Formation team

The next modular process, *Recruiting,* deals with the partner strategy. Enterprises with which the focal enterprise already has good experiences from prior business relations are most suitable as partners because they share a basis of trust and mutual understanding which is an important prerequisite for fair and non-opportunistic behaviour in the cooperation network (Girmscheid and Brockmann 2009; Girmscheid and Brockmann 2010). Furthermore, it is essential to discuss and resolve concerns raised by potential partners concerning the cooperation network, for example financial risk or knowledge drain. Table 4 depicts the elementary processes, activities, and roles of this modular process.

Table 4: Modular process: Recruiting

Elementary process	Activities	Role
Evaluation of required capabilities	Evaluate required capabilities, formulate selection criteria, identify and contact potential partners	Formation team
Application for CN membership	Write application specifying motivation for CN membership and select representatives	Potential partners
Selection of partners	Evaluate applications, conduct interviews, and select partners with strategic, organisational and relational fit as CN members	Formation team
Negotiation of code of conduct	Agree on common values, negotiate rules for cooperation based on mutual trust and commitment	Formation team and CN members
Communication of code of conduct	Communicate values and rules to employees to create shared understanding as basis for trust	CN members

The subsequent modular process *Conception* serves the specification of the configuration of the network with the CN and the APNs. It subsumes four elementary processes and ends

with the public announcement of the new service offer (Table 5). After the successful completion of the main process S*etup of the CN* the collaboration in APNs can be taken up.

Table 5: Modular process: Conception

Elementary process	Activities	Role
Revision of objectives and strategy	Evaluate objectives and strategy together with cooperation partners	Formation team and CN members
Definition of CN structure	Define organisational and operational structure of the CN with specification of tasks (management of the CN including admission of new members and support of the APN) and roles (CN-Developer, CN-Marketer, CN-Coach, CN-Sales Manager, CN-Key Account Manager) with attribution to actors	Formation team and CN members
Definition of APN structure	Define standard organisational and operational structure of an APN with specification of tasks and roles and negotiate standard contracts and financial contributions for an APN	Formation team and CN members
Formation	Launch the CN and announce new service offer to public	Formation team and CN members

4.3.2 Operation I: Basic service offer

The main process *Operation I: Basic service offer* encompasses the realisation of several projects. For each project a specific APN is set up, which is responsible for the successful execution. The CN performs a management and support function on the strategic level. On the operative level each project consists of three modular processes, namely *Configuration of the APN*, *Realisation of the APN*, and *Dissolution of the APN.* When a new project is acquired, the modular process *Configuration of the APN*, which concerns the tendering phase and comprises the elementary processes shown in Table 6, is initiated.

Table 6: Modular process: Configuration of the APN (tendering phase)

Elementary process	Activities	Role
Conceptual design	Evaluate client requirements and compile conceptual design	System integrator (SI)
Identification of required key competences	Identify necessary subsystems and prepare catalogue of required key competences	SI
Internal competition on terms of competence	Invite at least two contractors of each key competence from the CN to develop offer for specific contract thereby keeping competition up within the network to ensure continuous improvement and market conformity of offers	SI
Preliminary subsystem design	Develop preliminary subsystem design according to specifications of conceptual design	CN members
Selection of partners	Evaluate subsystem concepts and select best suitable partners as subsystem suppliers (SUS)	SI
Negotiation of internal contracts	Negotiate internal contracts based on standard contracts of the CN, specify organisational structure and attribute roles to cooperation partners	SI and SUSs
Preliminary system design	Integrate preliminary subsystem designs to preliminary system design and determine GMP	SI

If the contract is awarded to the APN, the focal enterprise represented by the system integrator is the contracting party of the client. The internal contracts between the subsystem suppliers create reciprocal guarantee obligations. The collaborative optimisation work in the execution phase starts with the subsequent modular process, *Realisation of the APN,* which consists of the elementary processes depicted in Table 7.

Table 7: Modular process: Realisation of the APN (execution phase)

Elementary process	Activities	Role
Launch of the APN	Arrange kick-off meeting to identify interfaces and analyse synergy potential	SI
Detailed subsystem design	Develop detailed subsystem design considering interfaces to other subsystems	SUSs
Detailed system design	Integrate detailed subsystem designs to optimised detailed design of overall system and identify synergies	SI
Tendering for subcontractor services	Tender for those parts of each subsystem which are passed on to subcontractors	SUSs
Subsystem execution design	Develop execution design of subsystem with regard to the synergies identified by SI	SUSs
System execution design	Create integrated operation scheduling and logistics planning to ensure optimised execution process in addition to optimised design	SI and SUSs
Execution	Execute construction works	SI and SUSs
Commissioning	Commission completed building	SI and SUSs

To ensure that lessons learnt and shared experience from the successfully completed collaborative venture are preserved for a continuous improvement of further projects, the *Dissolution of the APN* is modelled as separate modular process.

4.3.3 Further development: Transformation

The new service offer has to be expanded progressively in order to keep ahead of competitors and to sustain client satisfaction by generating an outstanding client value. The following expansions for the new service offer are suggested (Figure 3):

- *Life cycle offer I* delivers an energetic optimisation with performance guarantees of the entire building with particular regard to the interdependence of the building envelope and the HVAC-system.
- *Life cycle offer II* promotes holistic sustainable optimisation across the building's life cycle with extensive cost- and performance guarantees in the form of a service level agreement.

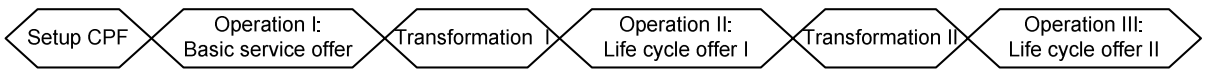

Figure 3: Main processes across the life cycle of the new business model

In order to successfully accomplish the expansion the CN has to actively promote an atmosphere of shared learning. Also new partners with the required capabilities have to be taken up into the CN. Furthermore, the process model for the APN has to be extended to the phases, Operation II and III, and financial arrangements for setting up provisions covering the guarantees for the operating phase have to be negotiated.

4.4 Key roles and capabilities

The key role for the success of the new service offer is that of the system integrator. He is the leading actor in the configuration and realisation of the APN. Whereas the subsystem suppliers contribute the component knowledge and technological capabilities concerning the subsystems, the system integrator is responsible for the integration of the subsystems and optimisation of the building as overall system. It is the system integrator's task to connect the interfaces between the interactive subsystems in order to obtain a client-specific integrative system optimisation. The capabilities required to successfully fulfil the tasks of the **system integrator** include both technical and managerial aspects:

- **System configuration capability** to transform clients' values and requirements into technical solutions consisting of a number of subsystems and to identify the relevant key capabilities corresponding to these subsystems
- **Evaluation capability** to identify the best offer for each subsystem and to ensure market-conformity of prices
- **System integration capability** to match the workflows of the subsystem suppliers and provide scheduling and technical coordination of the subsystems with the objective of optimising the building as overall system
- **Moderation capability** to conduct negotiations between partners and to perceive different points of view and incorporate them best possible in a solution concept

The **subsystem suppliers** are responsible for the life cycle optimisation of the subsystems with regard to interfaces to other subsystems during design and construction, and for the construction of the subsystems in compliance with cost, time and quality objectives. Therefore they need **excellent technological capabilities** particularly with regard to life cycle costs of the subsystems, function-oriented optimisation, and consideration of interfaces in terms of an integrated project delivery. Each subsystem supplier should nominate a **boundary spanner** who is the designated contact person for all activities and inquiries concerning the cooperation network. The subsystem suppliers excel due to the depth of their know-how relating to the subsystems, whereas the system integrator features an enormous width of know-how covering all the aspects which constitute a sustainably optimised building.

Further roles for the management and support processes on the level of the CN are:

- the **CN-Developer** who is responsible for the anticipation of future client requirements (market capability) and identification as well as acquisition of newly required capabilities (absorption capability),

- the **CN-Marketer** who establishes the new service offer on the market through a suitable marketing-mix and is responsible for advertising and sales promotion (marketing capabilities),
- the **CN-Sales Manager** whose task is the acquisition of new contracts (acquisition capability)
- the **CN-Coach** who is responsible for internal mediation, conflict resolution and joint problem solving (mediation capability)
- the **CN-Key Account Manager** who is in charge of client support and customer care (client support capability)

5. Conclusion

The theory-led developed business model takes a systematic approach towards the formation and operation of cooperative networks in the building industry. In this paper the concept of the model is outlined. Strategic, organisational, and relational fit are identified as prerequisites for successful cooperation. The network organisation model and the process model have been developed guided by design recommendations derived from principal-agent-theory. In the further development of the model the incentives for companies as well as individuals to participate in the cooperation network have to be identified and mechanisms to reduce opportunistic behaviour and to keep competition up within the network to ensure market conformity of offers have to be deployed. A balanced mix of trust and selective control mechanisms best ensures a harmonic coexistence of cooperation and competition within a network. Furthermore, it is vital for the success of the new service offer to develop the required capabilities connected to the key roles. This aspect underlines the importance of individuals, not only in the field of social relations but also in the field of potential, for the successful operation of the new business offer. The new business model enables especially small and medium-sized enterprises to pursue a differentiation strategy by contributing their excellent technological capabilities in a cooperative network with the objective of offering sustainably optimised life cycle buildings that are client-specifically created through the integration of interdependent subsystems.

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Cities and Flooding: Lessons in resilience from case studies of integrated urban flood risk management

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Abstract

Flooding can cause disruption and devastation in cities, with massive damage to livelihoods, property and urban infrastructure as recently experienced in New York City, Jakarta, Bangkok, Accra, Mississippi and Queensland. For cities in developing nations, unplanned urban expansion, poor infrastructure and services, inadequate drainage and weak institutional capacity can multiply the negative impact of flooding. In such circumstances, floods often affect informal settlements and bring the additional burden of diverting resources away from poverty alleviation and other development efforts. Preparing for future floods, which may become more frequent in the future, integrated flood risk management recognises that risk reduction which relies solely on engineered defences may be uneconomic, impractical or make flood risk worse under certain circumstances. Therefore authors advocate for a holistic and forward-looking approach to improve resilience of cities in which appropriate engineered measures are combined with non-structural mechanisms, land use planning, emergency preparedness and recovery planning. Decision-makers can use this approach as guidance in implementing balanced and robust solutions in flood risk management.

Funded by the World Bank / Global Facility for Disaster Reduction and Recovery (GFDRR), the flagship report '*Cities and Flooding: A Guide to Integrated Urban Flood Risk Management for the 21st Century*' was designed to provide operational assistance to policy-makers and technical specialists, particularly in the rapidly expanding cities and towns of the developing world, on how best to manage the risk of floods. Comprehensively dealing with available structural and non-structural measures, the handbook provides common guiding principles to building resilience to urban flooding. Over 50 case studies, carefully selected from extensive literature review, workshops and consultations, illustrate current practice, challenges, and lessons learnt from around the world. International and local workshops were held to test and disseminate the key findings and recommendations. A major objective of the research project was to develop a set of policy principles and practical recommendations, based on the case studies, literature and inputs from expert participants at the workshops, to support the implementation of integrated flood risk management through a structured, iterative and participatory process.

Keywords: Resilience, Adaptive Capacity, Urban Flood Management.

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1. Introduction

Flooding poses a serious and frequent risk that challenges the lives of citizens of many major cities around the world (Jha *et al.*, 2011). Direct, rather than indirect, impact from major flood events, as witnessed for example in New York City, Lagos, Pakistan, Mississippi and Australia, are often thought to represent the biggest risk to life and property (Department for International Development, 2005). However, indirect and often long-term effects, such as disease; reduced nutrition; disrupted education; and loss of livelihoods, can have pernicious long-term effects, eroding community resilience and other development goals (UN Habitat, 2010b). In addition to large-scale events, minor and regular flooding can be equally difficult to cope with and detrimental in the long-term. While they are hard to immediately identify and quantify, evidence shows that the poor and disadvantaged suffer the most from long-term effects of flooding (Cannon, 2000, Dodman *et al.*, 2009, World Bank, 2012).

Urban development, rapid growth and increased density of cities are trends implicated in both the increased frequency of flooding and the higher impact associated with urban floods (Jha *et al.*, 2011). The reduced permeability of landscapes associated with urbanisation increases run-off and reduces the capacity of natural floodplains to quickly absorb flows. Higher levels of development expose more people and assets to flood hazard. Rapid urban expansion, which typically takes place without following structured or agreed land use development plans and regulations, makes unsustainable conditions even more problematic. In addition, the urban poor are often excluded from the formal economy, and lack access to adequate basic services. Because of limited resources, and often rights, they tend to be located in densely populated informal settlements (UN Habitat, 2010b).

In response to these challenges, the World Bank handbook for integrated flood risk management was conceived to give guidance in the design and implementation of holistic flood risk management measures that can reduce risk and increase resilience of cities to flood risk challenges in the 21st Century. The handbook incorporated a collection of case studies that informed the development of key principles for integrated flood management. More than 50 examples are used throughout the guide to illustrate particular aspects of integrated flood risk management strategy and systems. While it is impossible to entirely eliminate flooding from cities, the integrated flood risk management approach helps decision-makers and specialists to reduce the vulnerability, manage residual risks, and increase the resilience of the built environment to flood hazard. This paper focuses on the link between integrated flood risk management and improving resilience in cities. The following sections describe the concept of flood resilience within four “capacities”.

2. Concepts of resilience and capacity

Resilience is a contested concept that has gained prominence in the disaster management community over the last decade (Tierney and Bruneau, 2007). The multidisciplinary nature of the disaster management profession ensures that the definitions and concepts of disciplines as wide apart as engineering, finance, ecology and psychology have contributed to the debate around what truly constitutes a resilient environment (Folke *et al.*, 2002, Gallopin, 2006, Institution of Civil Engineers, 2008, Defra/Environment Agency, 2011).

Narrow definitions of resilience, owing their heritage to engineering and from the Latin "resilio", which means to "jump back", usually encompass the ability to return back into shape after being affected by external shock (Plodinec, 2009). The shock absorber or "sponge" concept that is the direct opposite of vulnerability (IPCC, 2001) is the root of the definition of building resilience (wet-proofing) where the acceptance of water into a property is mitigated by the use of techniques and materials that will suffer little damage from contact with flood water or are easily removed, cleaned or replaced (Wingfield *et al.*, 2005). Within this definition of resilience, the construction of flood resistant housing can also be considered a resilience measure, as it reduces damage and allows the city to recover more quickly.

In the context of disaster risk management, the definition of resilience increasingly focuses on community resilience and is shifting towards terminology borrowed from ecology and social sciences. Adger (2000) for example defines social resilience specifically as relating to a community's ability to withstand external social, economic, and political shocks. Bruneau et al (2003) offer the definition that resilience is "the ability of social units (e.g., organizations, communities) to mitigate hazards, contain the effects of disasters when they occur, and carry out recovery activities in ways that minimize social disruption and mitigate the effects of future disasters." Whilst Zhou et al (2010) more narrowly refers to "the capacity of hazard-affected bodies (HABs) to resist loss during disaster and to regenerate and reorganize after disaster in a specific area in a given period". Conversely, Pelling (2003), has a broader definition that "Resiliency is thought of as a characteristic of systems that offers flexibility and scope for adaptation whilst maintaining certain core functions (for example, access to basic needs and social stability)". The definition holds, at its core, the notion that the state of normality post disaster need not be recognisably similar to the pre disaster normality and emphasises the role of adaptation in the complex evolving system of a modern city. Adger et al (2004) posit that a key concept of the resilience of systems is the potential for self-organisation or spontaneous response as opposed to responses imposed by external forces. This implies risk reduction approaches that are people centred and react to local knowledge, and therefore research on resilience needs to understand how communities and individuals survive and cope with disasters.

Increased resilience is also linked to vulnerability reduction although the relationship between vulnerability and resilience is not easy to specify (Adger, 2006). Using the broader definitions of resilience implies that many measures that reduce vulnerability can also be said to increase resilience and this may be reflected in the strengthening of four capacities within the built environment namely: *threshold, coping, recovery and adaptive capacity*. In the context of managing flood risk, *threshold capacity* is the level to which flood hazard must reach before damage and disruption is widespread. *Coping capacity* reflects the ability of cities to continue to function despite the threshold capacity being exceeded. *Recovery capacity* is related to the speed and effectiveness of the return to normal operations of the city after a flood; while *adaptive capacity* denotes an ability to use the recovery period and the time between events to enhance the other three capacities (De Graaf, 2008). Adaptive capacity is central to the broad concept of resilience adopted in this paper. However, while increased resilience results from decreased vulnerability of people and assets it may also result from a general adaptability or coping ability and underlying socio-economic and political factors quite divorced from the flood hazard.

The focus on resilience in flood management shifts the balance of risk reduction within cities from measures perpetrated by authorities to a more collective approach (The World Bank and the United Nations, 2010). As a consequence a coherent, locally-specific and integrated response is needed. The increased resilience of cities therefore requires structural changes to reduce the expected damage from flooding to be balanced with non-structural adaptations directly related to flood management and urban management mechanisms that strengthen the underlying ability of the population and built environment to accept and adapt to change.

Particularly in rapidly developing countries, urban authorities need to address the issues of infrastructure and urban expansion if they want to increase resilience. The broadening of flood risk reduction measures might also affect the clarity in the ownership and perceived responsibility to manage flood risk (De Graaf, 2008), which is why clear institutional arrangements and coordination among the key actors is vital. Flood management can hugely benefit from the involvement of all stakeholders to increase the collective resilience of a city.

3. Strengthening the capacity for resilience: case study examples

As indicated in the section above, resilience of cities can be enhanced by measures that reduced the vulnerability of individuals and communities to flood risk. Selected case studies, included in the World Bank handbook, illustrate how one or more of the four capacities can be strengthened. The case studies were carefully chosen based on a systematic review of relevant literature and examples suggested in consultations and workshops. The selected collection, reaching across Africa (e.g. Ghana, Mali, Mozambique, Senegal, Somalia, Togo, Tunisia, Zambia), East Asia and the Pacific (e.g. Australia, Cambodia, China, Japan, Malaysia, the Mekong region, Micronesia, the Philippines, Samoa, South Korea, Thailand, Vietnam), Southeast Asia (e.g. Afghanistan, Bangladesh, India, Nepal, Pakistan), South America (e.g. Argentina, Brazil, Colombia, Mexico), North America (Canada, the U.S.) and Europe (e.g. France, Germany, Poland, the UK), represents different flood types, geographies, socio-economic variables, city sizes and flood risk measures. A quantitative evaluation of such a diverse body of examples would be limited as the flood circumstances and outcomes were complex and varied, hence a qualitative method was applied.

3.1 Threshold Capacity

Threshold capacity can be increased by many structural alterations to the fabric of a city (Barker, 2011). Some of these measures are the traditional structural changes to the buildings and infrastructure such as raising of buildings (Lamond and Proverbs, 2009) and engineered protection of critical infrastructure (Fankhauser *et al.*, 1999, Kidd, 2011). Increasingly, careful land use planning and regulation, are recognized to be able to reduce the flows associated with a given weather event, while at the same time direct populations out of hazardous areas (APFM, 2007). Furthermore, the implementation of effective and sustainable urban drainage can be employed to absorb flows avoiding damages and losses (Charlesworth and Warwick, 2011).

The following example illustrates plans in New York City to improve the use of urban drainage to control stormwater runoff while decreasing the impact of severe weather by

raising the storm threshold. The New York City Green Infrastructure Program, which forms part of the Green Infrastructure Plan of the Department of Environmental Protection (DEP), introduced new regulations and guidance on the design of stormwater management for new development (NYC Environmental Protection, 2012). The program creates incentives for green infrastructure projects including green-roofing and creating porous paving by property owners, businesses, and community organizations eligible for the funding. The aim was to improve the water quality of the city's waterways while reducing sewer overflows and flooding. Several demonstration projects have been constructed to show the benefits in practice including blue and green roofs at schools and rain gardens in public open spaces (NYC Environmental Protection, 2011). Initial assessments indicate that green infrastructure has the potential to be cost-effective as there are multiple benefits for the infrastructure over and above the reduction in flood risk. The success of the initiative will depend on the sustained support from local communities and businesses. To ensure this, the City has formed a Citizen's Group and steering committee from professional stakeholders and other integral communities. The latest update indicates that approximately US$3.8 million has been awarded to local organizations and private property owners engaged in these resilience activities (NYC Environmental Protection, 2011).

3.2 Coping Capacity

Coping with flood events includes structural and non-structural measures such as: early warning and evacuation (Evans, 2011); emergency planning (Emergency Management Australia, 2000); business continuity plans, and temporary flood barriers and shelters (Jha *et al.*, 2012). Valuable lessons in resilience can be drawn from grassroots experiences of dealing with hazards. Understanding local responses can contribute to the strengthening of planning strategies for adaptation to climate change and variability in cities, and avoid situations when imposed solutions do not fit local conditions and customs.

For example, Dhaka, the capital of Bangladesh with over 10 million inhabitants, is central to Bangladesh's economy. Having experienced nine major floods in the last 55 years and frequent smaller events (Jabeen *et al.*, 2010), the country and city are highly susceptible to flooding. Large areas of the city are only a few metres above the sea level (Dodman *et al.*, 2009). Karail, the largest informal settlement of roughly 100,000 inhabitants, has large areas in the lowest-lying regions and hit by regular inundation. A vulnerability survey carried out by the Development Planning Unit at University College London (UCL) in co-operation with BRAC University in Bangladesh, examined household and collective adaptation strategies to cope with existing environmental hazards (Jabeen *et al.*, 2010). Research indicates that that local coping strategies, that have been adopted either at the household or community level to reduce vulnerability, include physical modifications to the buildings, savings and access to credit, diversified income sources, strong social networks and accumulation of assets. Findings show that the circumstances of living in informal settlements led to the tendency for families to resist evacuation during and after flooding for fear of permanent displacement. Authorities should therefore consider a mix of measures that support the existing local strategy of rebuilding from savings and accumulated assets through risk transfer and micro-finance mechanisms while considering long-term poverty reduction, secure resettlement, and security of tenure to address both flood risk and wider development goals.

3.3 Recovery Capacity

The ability to recover is embedded in all understandings of resilience and encompasses physical, mental and socio-economic aspects. The capacity to reinstate the built environment quickly after flooding minimises the distress and disruption caused by flood events (Samwinga *et al.*, 2004, Active Learning Network for Accountability and Performance in Humanitarian Action (ALNAP), 2008). Rapid damage and loss assessment and effective damage repair arrangements can be highly effective in enhancing community resilience. Similarly, recovery plans, prepared in advance of flooding, increase the likelihood of a swift return to normality, and even lead to an improved and more resilient city (Jha, 2010).

Central to recovery planning is the provision of necessary resources and the ability to direct them effectively to the ones in need while working towards enhancing the future resilience of cities through implementation of resilient building techniques. Financial resources can be provided through many sources including donations, disaster risk financing and insurance products, such as catastrophe funds or public funds, as well as through existing community-driven development program, or social protection and livelihoods support programs, such as cash-for-work transfers. The balance between private financing and communal or charitable disaster pools requires an assessment of the local capacity, risk and designation regimes as well as broader socio-economic and cultural considerations. Nation-wide schemes should fit the needs of local populations and include multi-stakeholder perspectives.

The case of the 2011 floods in Queensland, Australia, illustrates a number of recovery challenges related to post disaster financing and insurance arrangements. In the three consecutive years beginning with 2009, serious flooding and cyclones affected large parts of the state of Queensland, located in the north-east of Australia. The estimated total cost of the recent floods and cyclones during these three years is US$ 10.46 billion (Bloomberg, 2012). However, one month after the severe floods of 2011, only 10 percent of the total of US$2.1 billion worth of private claims had been paid. In January 2011 the Government of Australia ordered a review into all aspects of the response and the aftermath of the 2010 and 2011 flood events (Queensland Flood Commission of Enquiry, 2011, Insurance Australia Group, 2011). The main insurance aspects to be reviewed were: the performance of private insurers in meeting claims for floods and other natural disasters; the potential effect of national government intervention in disaster insurance such as subsidised insurance premiums for individuals and small businesses in high-risk areas; and the need for a national disaster fund to support other financing pools. The Commission collected evidence from individuals and communities that experienced difficulties and delays in recovery due to the denial of their insurance claims and consulted widely after the interim report was issued. The Queensland Floods Commission held a second round of hearings in September and October 2011, and the final 658 page report was published March 2012 (Queensland Flood Commission of Enquiry, 2012). The report proposes changes to the insurers code of conduct in relation to dealing with disputed claims but deferred more fundamental changes until the results of consultations on the wider enquiry into hazard finance by the National Disaster Insurance Review Panel (National Disaster Insurance Review Panel, 2011). The report recognised the importance of the private insurance mechanism to empower communities to help themselves and promoted the provision of improved hazard information and advice on

protection and mitigation for improved resilience (Insurance Council of Australia, 2012). This information is now beginning to be more widely available.

3.4 Adaptive Capacity

The ability of cities to adapt to changes, coping with present hazards without compromising future options is increasingly important in the light of uncertain futures. The drive to enhance adaptive capacity tends to promote flood risk management measures which are incremental in application, reversible and present so called low-regret solutions that bring benefits under a range of future scenarios (Hallegatte, 2009). Adaptive capacity includes dimensions which are generic in nature, focusing on improvements in education, income-levels and health. There are also dimensions specific to a particular hazard such as flooding (IPCC, 2007) or which address a subset of adaptive challenges.

Actions to address environmental issues in the city of Bamako, the capital of Mali, contained examples of both generic and specific adaptive strategies. In 1999, flash floods cased death and destruction throughout Bamako. At the same time, socio-environmental problems plagued the population, including non-existent wastewater collection and treatment, inadequate solid waste management, unhygienic individual behaviour, and poor urban management. Problems were particularly severe in the informal peri-urban settlements inhabited by 45 percent of the inhabitants (Setchell, 2008). A four year programme to improve stormwater management was undertaken in one of the most flood-affected areas of the city including: restoration of channel capacity through the removal of several hundred tons of accumulated refuse and debris, which improved drainage capacity and reduced flood risk; improving water retention capacity by constructing slip trenches (soak pits), reducing runoff volume and impacts; and establishing a refuse collection and disposal service. For the first time in the city, the programme planning involved stakeholder participation in combination with a comprehensive planning framework. The capacity of non-governmental organizations (NGOs), community-based organizations (CBOs) and informal sector groups involved in the process was strengthened so that they would be able to: prepare terms of reference; undertake further studies; and conduct public information campaigns (UN habitat, 2010a, UN Habitat). Implementation of this programme also involved setting up of partnerships between local profit-seeking bodies called Groupement d'Intérêt Economique (GIEs) and the communes of Bamako, which have institutional responsibility for waste collection. Furthermore, links were made with individual households and local farmers who use up to 60% of the collected waste. Local employment opportunities were created related to drainage and retention improvements, refuse collection and disposal, and the initiation of a composting operation (UN habitat, 2010a).

This case study illustrates that tackling flooding and environmental threats while supporting local institutions and stakeholders and promoting good governance, can significantly contribute to an improvement of a city's adaptive capacity, making communities resilient to future challenges in flooding, while addressing urban management needs (UN Habitat).

4. Implementing the principles

Through an iterative comparative approach in preparation of '*Cities and Flooding: A Guide to Integrated Urban Flood Risk Management for the 21st Century*' and during the numerous local and international workshops led to the distillation of twelve key principles for policy and practice in integrated urban flood risk management. These are listed below in table 1.

Table 1: Twelve key principles for integrated urban flood risk management (source (Jha et al., 2012))

1.	There is no flood management blueprint.
2.	Designs for flood management must be able to cope with a changing and uncertain future.
3.	Rapid urbanization requires the integration of flood risk management into regular urban planning and governance.
4.	An integrated strategy requires the use of both structural and non-structural measures and good metrics for "getting the balance right".
5.	Heavily engineered structural measures can transfer risk upstream and downstream.
6.	It is impossible to entirely eliminate the risk from flooding.
7.	Many flood management measures have co-benefits over and above their flood management role.
8.	It is important to consider the wider social and ecological consequences of flood management spending.
9.	Clarity of responsibility for constructing and running flood risk programs is critical.
10.	Implementing flood risk management measures requires multi-stakeholder cooperation.
11.	Continuous communication to raise awareness and reinforce preparedness is necessary.
12.	Plan to recover quickly after flooding and use the recovery to build capacity.

Integrated urban flood risk management is an iterative five step process starting with understanding the hazard, through to identifying measures, planning, implementing and evaluating the results. It is recognized that measures will reduce but never eliminate risk. Similarly, the maximum potential reduction may not be provided in the short-term due to practical and resource considerations. Risk reduction should be a long-term target to be approached through a series of cycles. The principles must be borne in mind at each step in the process and in each iteration. By combining the principles with the planning framework it is possible to derive a checklist for benchmarking the flood risk management process as shown in table 2.

Table 2: Benchmarking the flood planning cycle (after (Jha et al., 2012))

1. Understand	Multiple sources of hazard and risk and extreme events. Potential future changes due to climate change and urbanisation. Diversity of flood management roles and urban form. Capability and limitations of approaches. The wider catchment. Wider urban management and hazard context. Vulnerability and resilience in its broadest sense. Governance structures surrounding communities at risk. The local assessment of need using participatory approaches. How to share information in the most accessible way.

	The residual risk and future need for resources for recovery.
2. Identify	Approaches to tackle each source of flood hazard. Approaches which are robust to future changes. Synergies with existing roles. Structural and non structural measures for full consideration. Whether risk is transferred and to where. What will happen if measures are overtopped or fail? Synergies with other urban management goals. Environmental and social impacts of proposed measures. Capabilities of local networks, experts, businesses, NGOs and other stakeholders. Costs, benefits and consequences. Ways of dealing with residual risk such as financing for speedy recovery.
3. Plan	Re-examine existing structures, measures and plans. Identify under what circumstances plans would need reviewing. Consult widely and engage in cross departmental planning. Plan for the long term including maintenance, forecasting and warning systems. Plan to set up compensation schemes, consult widely. Plan to fail gracefully when design levels are exceeded. Consult widely and engage in joint planning with other stakeholders. Use metrics such as Multi-criteria analysis to make the process inclusive. Engage all stakeholders but clearly define their remits. Put in place agreements for support and mutual cooperation. Share and consult on detailed plans. Plan emergency procedures, put disaster management infrastructure in safe zones.
4. Implement	Tailor implementation to local customs and preference. Build in flexibility. Coordinate the implementation to fit in with other urban cycles. Prioritise the most cost effective measures, often nonstructural. Communicate changes in risk. Set up warning and evacuation systems to offset residual risk. Consider co-financing opportunities and involve all stakeholders. Involve stakeholders in evaluation and put in place grievance procedures. Assign responsibilities using legislation or redefinition of departmental roles if necessary. Involve the maximum number of stakeholders in the implementation. Conduct awareness campaigns around new roles and the limits of implemented measures. Prioritise critical infrastructure and the vulnerable and build back better.
5. Evaluate	Recognise relative risk reduction. Test robustness to future scenarios. Monitor agreed targets. Identify routes to failure. Monitor awareness of changing risk. Measure and report performance against planned protection levels. Identify flood benefits and wider benefits separately if possible. Use participatory approaches to evaluate social and environmental impacts. Get feedback from stakeholders who were involved in the planning stages. Ensure stakeholders goals are addressed in the evaluation. Communicate the results of evaluations including the successful avoidance of damage. Check whether recovery after events has increased the resilience to future events.

Source: After (Jha et al., 2012).

Each step relies on community and stakeholder consultations, and where possible, should adopt local solutions which fit communities' needs. These steps bring the concepts of resilience, consultation and the importance of local needs and capacity assessment to the attention of flood risk management planners. The use of an iterative cycle maximises adaptability to changing circumstances.

5. Summary and Conclusions

Flooding is a serious threat to the safety and economic wellbeing of populations of many cities worldwide. The threat from flooding is growing with increased urbanisation, rapid growth and densification of metropolitan areas in and around our major cities and changing climates also contribute to a future that may see more flooding from multiple sources with greater unpredictability. Action to tackle flood risk is urgently needed and many established measures can effectively reduce risk but action is often delayed or rejected. While it is not possible to completely eliminate flood risk, there is a need to develop approaches that are resilient to continued flood hazard and integrated into wider development plans.

Promoting an integrated flood risk management approach can be challenging as it involves approaches that may run counter to the natural desire to build and rely on structural (engineered) defences. While traditional methods have served reasonably well in the past, saving millions of lives, but they may not be flexible enough to adapt to an uncertain future of climate change and urbanisation trends. Modern flood risk management thinking emphasises the resilience of the built environment through a balanced approach of structural and non-structural measures, based on a wide participation of stakeholders and communities. Non-structural measures are inherently more flexible, and can prove extremely cost-effective. A balanced approach can support the adoption of robust measures with benefits under a wide range of future scenarios.

The application of the five step integrated planning and implementation cycle in the context of the twelve key principles outlined in *Cities and Flooding: A Guide to Integrated Urban Flood Risk Management for the 21st Century* can assist policy makers to design integrated flood risk management programmes for cities that will lead to a more resilient future. They provide a framework for decision making that can lead to systematic implementation of alternative options while encourage participative approaches that will improve the stakeholder buy-in and enhance the sustainability of specific local solutions.

However, the existence of a guiding framework is just one step in building more resilient cities for the 21st century. The impetus to resource and engender change requires that the forward-looking flood risk management and adaptive resilience thinking remains high on the political and policy agenda. The role of risk management, urban development and city planners is critical in facing the flood risks.

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A Knowledge Based Decision Support System (KBDSS) for Indonesian Contractors to implement Business Continuity Management (BCM)

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Abstract

Throughout the business process, crises may give various consequences to an organization, whether financial, legal or operational impacts. Being in an industry that is complex with high uncertainties, contractors are likely to experience costly errors if they are unprepared when a crisis strikes. As firms located over a vast geographical area, Indonesian contractors have also experienced various crises that have significant impacts on their business activities. To become resilient and capable of providing an effective response to such threats, Indonesian contractors need to adopt a systematic management concept in their organizations. Business Continuity Management (BCM) provides this framework, where it is not only focusing on overcoming crises, but also conducting activities that are needed for keeping the business operations running during a period of displacement or interruption. The initial step in developing BCM for Indonesian contractors is to understand the BCM implementation through its principles and non-technical aspects which are the organizational culture and institutional forces. This phase can be conducted in the form of an implementation guideline that starts with assessing the firm's BCM level of preparedness, followed by relevant action plan recommendations. A Knowledge Based Decision Support System (KBDSS) can be used for developing this guideline where it is a computer-based system that supports decision making by aiding knowledge storage, retrieval, transfer and application by supporting knowledge access. This system provides quick access to all relevant information and the problem models that are evaluated in the system can be integrated into a logical framework. The objective of the study is to propose a framework for developing a BCM-KBDSS for Indonesian contractors. The study is based on an extensive literature review and benchmarking to BCM best practices. The result of this

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study is the proposed framework which is the foundation for developing the BCM-KBDSS which forms part of a larger, on-going study.

Keywords: Management, Business Continuity, KBDSS, Contractors, Indonesia

1. Introduction

The business world is currently experiencing an increasing level of uncertainty in its environment, where it can lead to adverse financial implications, damage to corporate reputation, viability and integrity (Marsh, 2007). Events like crises or emergencies can occur unexpectedly during the course of conducting business activities and these cannot be overlooked. A crisis may give various consequences to an organization, whether financial, legal, or operational consequences. It may disrupt the business process from a few minutes up to several months or years in extreme cases. These consequences can impact the business process, and hence may threaten the firm's sustainability.

In order to overcome a crisis and to continue business as usual, an organization or firm must first have systematic ways and approaches in place. Although some organizations survive such events due to perseverance, but continuity of a business is primarily due to planning and preparation. One of the concepts that can be used is Business Continuity Management (BCM), where it is not only focusing on overcoming any crises that occurred, but also considering thoroughly on how to sustain the business in order to obtain its goals and mission. BCM provides a method for managing any disruption to ensure continuity of service when there is a disruption of business. Moreover, business continuity means to conduct activities that are needed for keeping the business operations running during a period of displacement or interruption (Smith, 2003).

In managing a crisis, decision making is considered as an important part of the process. Critical decisions such as task assignment, resource allocation, guidelines to long-term decisions, training and the control capabilities of the organization are necessary for this situation (Yoon et al, 2008). As part of a decision making process in responding to crises or unexpected events, BCM can be designed into an effective model, which is using computer application for providing faster and reliable decision. Based on the development of advanced computer programming technology nowadays, BCM can be automated by using a Decision Support System (DSS) (Eom and Min, 1999). A DSS can also be developed into a system which utilizes knowledge as its based information, where a knowledge base consists of groups of knowledge from experts which provide any information related to the focused problems (Mockler, 1989). The latter description is called Knowledge Based Decision Support System (KBDSS). The broad benefits from this system are that it provides a quick access for the user to all relevant information, the process is direct and personalized and the problem models that are evaluated in the system can be integrated into a logical framework.

One of the industries that should implement BCM is the construction industry, where it has an important role in a country's economic growth and development. Considering its characteristics and complexities, overcoming crises and threats in order to continue business in this industry is necessary. As firms located over a vast geographical area, which

is known as the world's largest archipelago (Raftery, Chiang and Anson, 2004), Indonesian contractors have also experienced various threats or crises that have significant impacts on their business activities. Various crises have recently occurred in Indonesia, such as the financial crises in 1997 and 2008, natural disasters that occurred frequently (earthquakes, floods, tsunamis), the political and financial instability, terrorism issues, and other internal events. The crises stated above had resulted in various levels of impacts, where it can start from disruptions to business activities, loss of potential markets, loss of productivity and profitability, to the extreme case such as bankruptcy of a firm. From these cases, it seems that these firms have not developed their crisis responses into a holistic management approach in the organization, and there is a lack of detailed responses for their business stakeholders. To become resilient and capable of providing an effective response to such threats, Indonesian contractors should start to adopt a systematic management concept in their organizations. BCM provides this framework, where based on its definition, it builds resilience and the capability for an effective response that safeguards the interests of its key stakeholders, reputation, brand and value creating activities (Supriadi and Low, 2012).

Adopting a new concept like BCM is not a straightforward process. There are issues to consider before implementing the concept into the firm. Previous studies had shown that the immediate motivation for a firm in adopting a concept or system comes from institutional forces and organizational culture (Liu et al, 2010). Based on these considerations, before implementing BCM, the Indonesian contractor's organizational culture and institutional forces should be identified in order to determine whether these elements support or do not support BCM implementation.

Based on these problems, the objective of this study is to propose a framework for developing a BCM implementation guideline in the form of a KBDSS for Indonesian contractors. The study is based on an extensive literature review and benchmarking to BCM best practices. In developing the framework, a thorough literature review on BCM principles, organizational culture, institutional forces, Indonesian contractor's business characteristics and KBDSS is conducted. The review also highlighted the relationships between these elements that underpin the basis for the framework.

2. Literature Review

2.1 BCM Overview

The Business Continuity Institute (BCI, 2002) defines Business Continuity Management (BCM) as an act of anticipating incidents that will affect mission-critical functions and processes for the organization, and ensuring that it responds to any incident in a planned and rehearsed manner. Foster and Dye (2005) similarly viewed BCM as the process of developing advance arrangements and procedures that enable an organization to respond to an event in such a manner that critical business functions continue with planned levels of interruption or essential change. In this context, top management must take the lead in driving organizational BCM with a view to garnering the collective efforts of all individuals within the organization for this purpose (Low et al, 2008).

Historically, BCM was developed many years ago, where this concept is an evolution of a disaster recovery approach in a firm. Its roots lie in Information Systems (IS) protection although it is argued that it has grown a long way since then. Elliott et al (2010) developed on these theories in more details explaining that the evolution of BCM has progressed from a focused technical aspect to a broader strategic organizational requirement. BCM is a system that develops a framework of protocols and sets of procedures and instructions which give structure, order and stability to the particular function being managed. It is in line with the definition of a management system, stated by Griffith (2011) that sets out and describes, for a particular management function, the organization's policies, strategies, structures, resources and procedures used, within the firm to manage the processes that delivers its products or services.

The main aspects in BCM principles are described in Table 1 which shows the BCM concepts being grouped into six categories for BCM implementation.

Table 1: Main aspects of BCM principles

No	BCM Principles	Description
1	Risk analysis and review	• Examine internal and external risk events and impacts (qualitative and quantitative) that can affect the critical operation's continuity. • Using Risk Analysis (RA), Business Impact Analysis (BIA), and Cost benefit analysis (justification for initial treatments to prevent or reduce the effects of risks and potential losses).
2	Business Impact Analysis	• Examine the impact to the organization (assesses the potential impact of loss from an internal perspective), qualitatively and quantitatively, due to a disruption of business operations and processes. • BIA must be conducted on a periodic and systematic basis to assess the impact of losses if the corresponding business operations and processes are disrupted in view of proposed changes.
3	Strategy development	Examine the possible strategies for maintaining the operation of Critical Business Functions (CBFs). This should cover pre-incident preparedness, response and recovery.
4	BC Plan development	Examine the BC plan(s) which is an action plan that guides the response and recovery actions of the organization when disaster occurs. It includes an emergency response to stabilize the situation following a disaster, the set up and operation of an Emergency Operations Centre (EOC), and specifies CBFs to be recovered within their established Recovery Time Objectives (RTOs) and Recovery Point Objectives (RPOs) when a disaster occurs. RTO is the period of time in which functions must be recovered after a disruption has occurred, and RPO is the point in time at which systems and data must be recovered after a disruption has occurred.
5	Test and exercises for BC plan	• Ensure that the BC plan drawn up and implemented by the organization is viable and workable. • Tests are intended to verify the capability of the BC plan to attain specified objectives or established criteria. • Exercises are intended to train and condition BC team members to improve their coordination and performance in executing the BC plan. Exercises also serve to highlight any weaknesses in the operation and effectiveness of the BC plan, with establishing generic corrective actions if the result falls below assessment criteria.
6	Program management	• Examine the ongoing efforts and activities of the organization to maintain the effectiveness of its BCM. BCM involves firm commitment of organization's efforts and resources to safeguard the interests of its key stakeholders, reputation, brand and value-creating activities on a continuous basis. Assessment of an organization's BCM efforts should therefore be dynamic. • The BC plan is operated by staff of the organizations. Staff in the organization should be familiar with the plan via appropriate awareness and training programs prior to any test/exercise of the plan. Periodic and systematic training and awareness programs should be conducted to

No	BCM Principles	Description
		familiarize employees to the operation of the BC plan.

Adapted from SPRING (2008)

2.2 Organizational Culture (OC) and Institutional Forces (IF)

Organizational culture had been defined as the way things are done and operated within the internal environment of the workplace. The features in organizational culture are common beliefs; pattern of behavior, norms; values and rules that are exercised among members of the organization. They viewed that the closer the values and beliefs among members of the organization are, the stronger the culture will be (Kotler and Heskett 1992).

The importance of organizational culture towards adopting a concept or system in the organization can be seen from studies which increasingly push organizational culture as the guide for organizational strategies. It is suggested that organizational culture can impact manager's ability to process information, rationalize and exercise discretion in their decision-making processes (Hofstede and Hofstede, 2005). Liu et al (2010) found that identifying organizational culture helps its members to understand organizational functioning. It affects how the firm responds to external events and makes strategic choices. Moreover, organizational culture is a key to many change initiatives, where success in implementing a concept depends on the organizational culture.

Institutions are considered as multifaceted, durable social structures made up of symbolic elements, social activities, and material resources. Institutions are inhabited by people and their interactions. Rules, norms and meanings arise in interaction, and they are preserved and modified by human behavior. The essence of the institutional perspective in general resides in the three pillars – the regulative, normative, and cultural-cognitive – which provide meaning and stability for social behavior. The regulative pillar is distinguished by the prominence given to explicit regulative processes; rule-setting, monitoring and sanctioning activities. In the normative pillar, the emphasis is on values and norms which introduce a prescriptive, evaluative and obligatory dimension into social life. The cultural-cognitive elements include widely held beliefs and taken-for-granted assumptions, the rules that constitute the nature of reality and the frames through which meaning is created (Scott, 2008).

2.3 Indonesian Contractors

In delivering a project, a contractor needs to manage the materials, people, and equipment in a project site and assembling the materials in the proper sequence to construct a project that meets the customer's requirements. In meeting these requirements, the contractor also has to consider their stakeholders, which can vary from the customers, suppliers, creditors, investors, employees, subcontractors, governments and the public, to existing and new competitors. Schaufelberger (2009) also mentioned that each type of construction projects has its unique set of technical challenges, but the following business responsibilities for contractors are similar, which are acquisition of the work, performance of the work, and management of the financial, capital, and human resources of the firm.

The existing conditions of the Indonesian contractors have been analyzed. Suraji (2003) had completed an analysis showing the strengths, weaknesses, opportunities, and threats in general. Based on these findings, the Indonesian contractors have the strengths of delivering more projects due to their many labour resources and the current needs of infrastructures in many cities in Indonesia. There are many opportunities for collaboration with other foreign contractors arising from their recent businesses in Indonesian construction projects. Thus, this can enhance the capability of Indonesian contractors in delivering better projects through technology and knowledge transfer. Some weaknesses identified are the lack of funds and technologies, lack of skilled workers, the high level of competition in the national construction industry, and management inefficiencies. Factors such as the competencies of human resources, research and development, certification and support from other sectors may threaten the firm's growth and sustainability in the future if not considered comprehensively. Moreover, low skill index and experience of construction workers make the business face difficulties in undertaking new concepts and technologies.

2.4 Knowledge Based Decision Support System (KBDSS)

As a computer-based system that supports decision making by aiding knowledge storage, retrieval, transfer and application by supporting knowledge access, KBDSS provides benefits for the management process. Most scholars viewed the major benefit for the management process is improvement in managerial productivity. Managerial productivity is considered as a function of the time spent in retrieving information, generating value added information and finding problems in the intelligence phase, and developing alternative solutions in the design phase of decision making. A good KBDSS may reduce the time required in this process and thereby improves managerial productivity (Raman and Phoon, 1990). Nonetheless, before using KBDSS for the management process, it is necessary to understand that KBDSS is not designed to make decisions for users, but rather it provides relevant information in an efficient and easy-to-access format that allows users to make more informed decisions (Arain and Low, 2006).

In the construction industry, there are several KBDSSs that have been developed for various functions such as for material and procurement planning in construction projects (Mockler, 1989), integration of AUTOCAD and construction scheduling (Wang, 2001), resource allocation, risk management process and project success forecasting (Mohan, 1990). It can be seen that a DSS or KBDSS is quite applicable in the construction industry, and there could be other processes or concepts that can be applied into this tool.

Yoon et al (2008) also found that KBDSS have been developed for emergency response and management. A KBDSS for emergency response was developed to assess the state of preparation of an agency to respond to emergencies, enable the development of new SOPs, and to better train and empower employees in the decision making process. It is utilized to reduce the time to make critical decisions such as task assignment and resource allocation and to guide long-term decisions, training and the control capabilities of the organization. Considering the function and benefit of this tool, developing a KBDSS can be proposed in order to improve the effectiveness and efficiency of the decision making process in BCM.

3. Results

Based on literature reviews, a framework for developing a BCM implementation guideline in the form of a KBDSS for Indonesian contractors is proposed. The framework consists of aspects which are the Organizational culture (OC) dimensions, Institutional forces (IF) attributes, BCM for Indonesian contractors and KBDSS for BCM. Section 3.1, 3.2 and 3.3 describe the aspects that are part of the conceptual framework, followed by section 3.4 which shows the whole framework proposed for the study.

3.1 Determining Drivers and Hindrances of Implementing BCM through OC and IF

Based on the previous discussion, it appears that institutional forces and organizational culture may work together and interact with each other to affect concept or system adoption. Studies also had suggested that the immediate motivation for concept or system adoption comes from institutional forces. Furthermore, organizational culture, as a stable element of the organization, moderates the effects of institutional forces (Liu, et al., 2010). Based on this understanding, IF and OC attributes can be synthesized with BCM principles in developing a framework for determining the drivers and hindrances of implementing BCM by Indonesian contractors. Figure 1 illustrates the framework for this purpose.

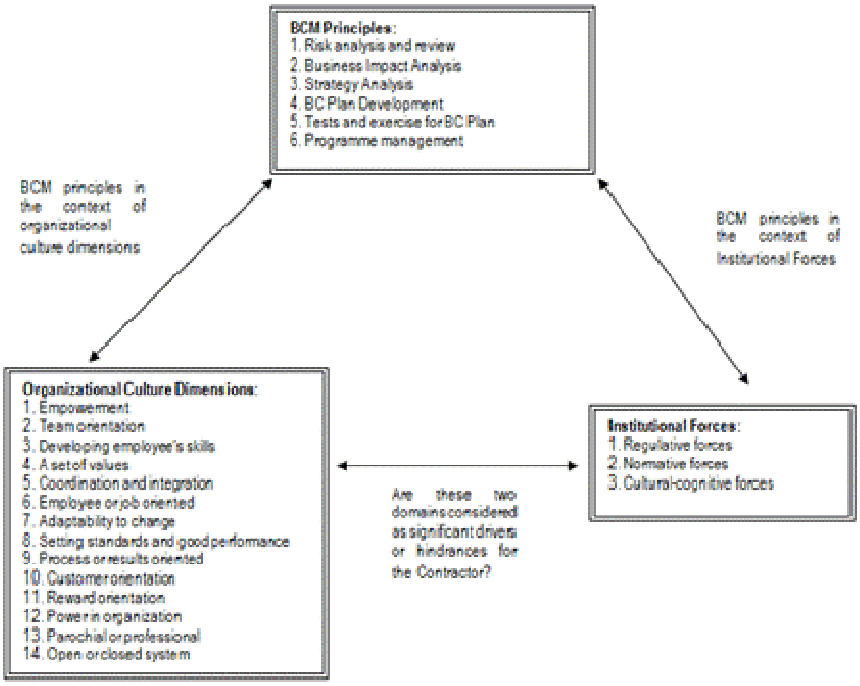

Figure 1: Framework of IF – BCM – OC relationships

There are two relationships that can be described within this framework. Firstly, the relationship between institutional forces and BCM principles is primarily about the contractor's perspective on BCM principles in the context of the institutional framework. It describes whether the contractor views the BCM principles as regulative, normative or cultural-cognitive forces towards implementation. This relationship can be considered as the

first domain. Secondly, the relationship between organizational culture dimensions and BCM principles (the second domain) is generally to determine whether the BCM principles are part of the contractor's organizational culture. In answering this, the 14 OC dimensions are used. The relationship between the two domains is to analyze how the contractor views the BCM principle (in the context of institutional forces and organizational culture dimensions) regarding its level of influence (significant drivers) and level of hindrances for the firm. From this relationship, it can further be determined whether BCM principles are supported or not supported by the contractor.

3.2 Developing BCM for Indonesian contractors

In developing the BCM implementation guideline for Indonesian contractors, the main steps that will be involved are based on BCM's main principles, which are risk analysis, business impact analysis (BIA), strategy development, BC plan development, tests and exercises and programme management. Moreover, BCI (2002) had provided some criteria for understanding the preparedness of the firm towards BCM. These criteria can be used as a benchmark in line with the BCM principles. In this study, some of these criteria will be observed in order to identify the preparedness of Indonesian contractors. Table 2 shows the variables to be used as the benchmark to better understand aspects for BCM preparedness.

Table 2: BCM preparedness criteria

Variables to be used as a benchmark – BCM good practice criteria	
• BCM vision and policy statement	• BCM training budget
• Communicating vision and policy throughout the organization	• Defined BC Plan
• BCM committee from senior management	• Awareness of the significance and importance of legal privilege in all communication and documentation regarding a crisis or BCM event
• Senior and middle management support and strong commitment	• Awareness of the communication and call-out tree
• Monitoring and evaluating BCM implementation and maintenance	• Employing BCM professionals
• Defined BCM roles and responsibilities at all levels within job descriptions	• Attending external BCM seminars and courses
• Integration with organization's reward and recognition system	• Provide formal training and professional development plans for BCM personnel
• Integration with organization's performance management and appraisal system	• Promoting BCM as an issue for continuous professional development for its staffs
• Defined BCM roles and responsibilities at all levels within personal annual performance contracts	• Defined BCM exercising, maintenance and audit programme
• Defined KPI for BCM	• Using BCM standards as a process for embedding a BCM culture
• Integral part of organization's project management process	• BCM awareness and training programme

Source: BCI, 2002

3.3 The Application of KBDSS for BCM

For this study, KBDSS will be proposed as a supporting tool for the management team in developing a BCM. According to Crabb (2011), there are parts in BCM that need consistency

of approach, consistency of information and structure and also consistency of process. This type of phase can be supported by a KBDSS. The content for the proposed KBDSS is to develop a BCM preparedness assessment and recommendation (in the form of action plans). It will provide technical guideline or steps to implement each BCM principle. The non-technical attributes that consist of the organizational culture (OC) and institutional forces (IF) that relate with BCM principles will also be included in the system. The answers from the user (the firm) will be assessed to determine the level of its BCM preparedness, and will be followed by recommendations on that specific level. In the proposed system, the level of BCM preparedness is grouped into four levels, which starts from an undeveloped BCM, beginner level, moderate level and comprehensive level. These levels are adapted from various BCM level of preparedness studies (Smit, 2005). Furthermore, all of the knowledge obtained from the BCM implementation guideline will be placed in the KBDSS for developing the assessment process.

Automating this process will provide the BCM information and knowledge in one place that allows the management to take a more rounded view of issues, resources and situations. This allows organizations to develop a much more strategic-based approach for planning its business resilience. Its content is not in providing the exact solution, but supports the decision maker (the user) with information for obtaining the proper solution in that phase. Knowledge will be provided for the decision maker in assisting him to select the decision for developing BCM through the recommended action plans. Figure 2 illustrates the general process in the proposed KBDSS.

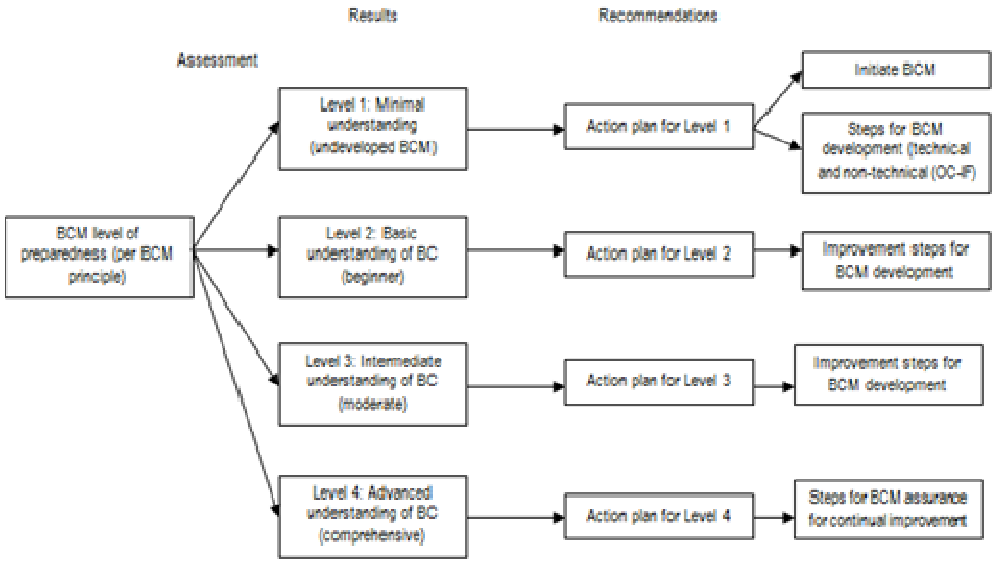

Figure 2: KBDSS process: BCM level of preparedness assessment

In developing the proposed KBDSS, all aspects from the previous phases of the study will be needed, where the data will be compiled and synthesized. Furthermore, the data will be processed as the knowledge base for the system (Mockler, 1989; Turban, 1995). For further illustration, Figure 3 shows the proposed BCM - KBDSS components. KBDSS comprises components such as DSS shell, knowledge base, inference engine, and database. All of the

data from the database will be analyzed to acquire the relevant knowledge needed in the system. Inference engine will be used to develop the knowledge base that will assess inputs from the user and provide the outputs. DSS shell will be the component that structures these processes into a user-friendly interface with the user.

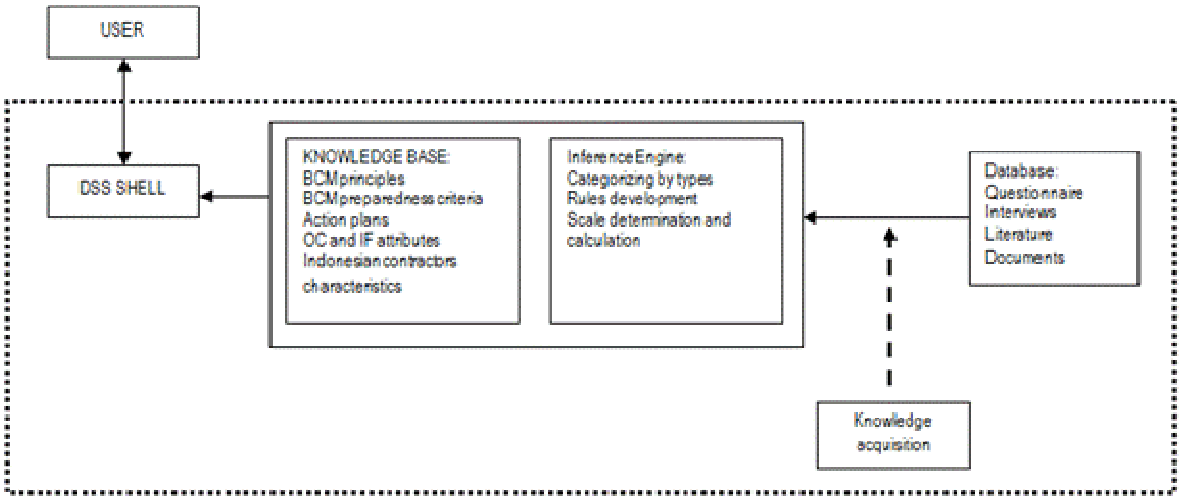

Figure 3: BCM - KBDSS components

3.4 Conceptual Framework

The main conceptual framework for this study is shown in Figure 4. The framework has synthesized the BCM-OC-IF relationships, BCM implementation guideline, and BCM-KBDSS aspects. The constructs needed to understand the Indonesian contractor's knowledge of BCM are developed, followed by defining the relationships between BCM, OC, and IF. These relationships are considered as the outer layer of the framework. Furthermore, in developing BCM for Indonesian contractors, various constructs are identified that will be developed into a guideline for BCM implementation. BCM principles, BCM preparedness criteria and characteristics of Indonesian contractors are the aspects that will be used in this phase. The role of KBDSS as the automated BCM implementation guideline is the inner layer of the framework that consists of the KBDSS process (BCM level of preparedness assessment and action plans) and components.

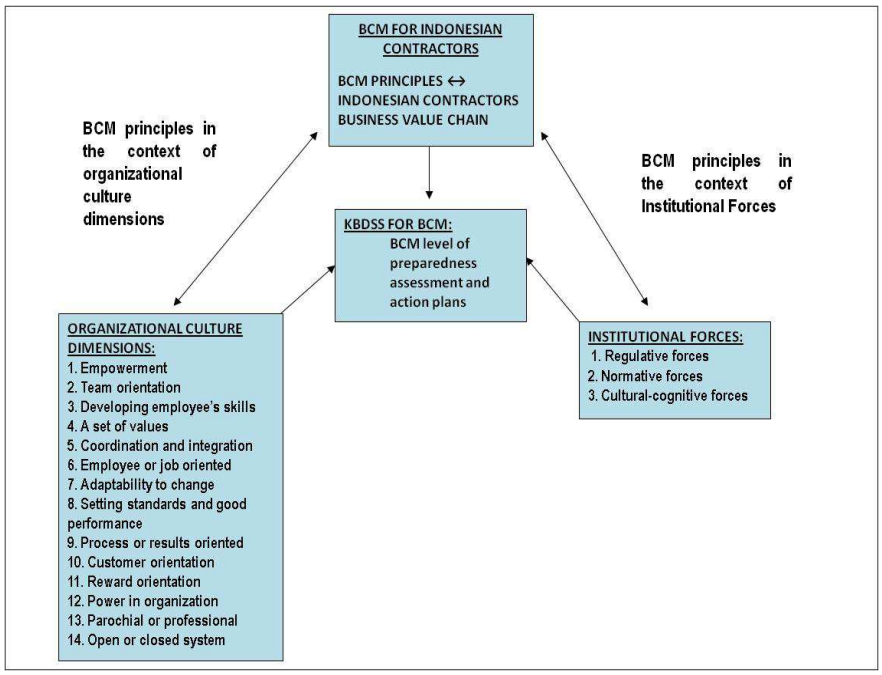

Figure 4: Conceptual Framework

4. Conclusion and Expected Contributions

4.1 Conclusion

Due to its vulnerability to various threats and crises, BCM should be adopted by Indonesian contractors. Furthermore, the roles of organizational culture and institutional forces were found to be important in adopting a concept such as BCM.

This research aims to study BCM implementation by Indonesian contractors, which identifies the significant drivers and hindrances for implementing BCM by Indonesian contractors that are related to their organizational culture and institutional forces. Moreover, in order to reach efficient decisions in the process, BCM will be developed as an implementation guideline model that will be automated into a KBDSS.

The conceptual framework for this study incorporates the constructs relating to the Indonesian contractor's knowledge of BCM; the relationships between BCM, organizational culture (OC) and institutional forces (IF); and aspects that will be used in developing the BCM implementation guideline model such as its principles, its preparedness criteria and the business characteristics of Indonesian contractors.

4.2 Expected Contributions

The BCM implementation guideline model can assist the firms to develop better coordination with their stakeholders that may lead to a competitive advantage and marketing value for the firms. If this model is applied by all the Indonesian contractors for them to become more resilient, the firms may have the ability to absorb, respond and recover from disruptions that will eventually contribute to higher corporate performance. Thus, this may support the role of the Indonesian construction industry in the economic growth plans of the country.

From the academic perspective, along with further understanding about BCM implementation in the construction sector, this study will provide further knowledge on cultural and institutional studies in construction organizations. Last but not least, the development of an automated system (KBDSS) in this study will also contribute to further IT implementation in the construction industry.

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The threat of slow changing disturbances to the resilience of African cities

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Abstract

Within rapidly urbanising South African cities, understanding the dynamics of change and the rate at which change occurs can be used to manage or regenerate parts of the urban system, and may provide effective tools for planning and monitoring 'resilient' development. A 'resilience' understanding may assist local authorities to transition toward cities that are more adaptive toward disasters, hazards and threats within flexible built environments. While most research conducted on the subject of urban resilience tackles issues relating to short-term disasters (pulse disturbances) like flooding, earthquakes, or terrorism, this paper focuses on the relationships between the more persistent issues or slow variables that occur over long periods of time (press disturbances). Examples explored within this paper include natural disasters, rapid urbanisation and urban poverty, environmental degradation, health and safety, crime, informal settlements, and lastly, policy implementation.

While change relating to press disturbances like informality, environmental degradation and urban poverty impacts all countries to some extent, the assumption is that Africa is most at risk since it is experiencing high rates of urbanisation within the context of pervasive poverty and inequality. These city environments may also not have the adaptive capacity to leverage these changes or steer their socio-economic and environmental systems beyond survivalist conditions. This paper tackles these topics from the perspective of an informal settlement called Plastic View in the City of Tshwane, South Africa – a country which has yet to regenerate its cities into integrated environments. It comprises of a desktop study of articles in the press to build an understanding of press disturbances affecting the focal system of Plastic View and their relationships and dynamics. The paper concludes with a motivation toward building a strategy for policy and housing management in the City of Tshwane that incorporates principles of resilience like adaptability, diversity and the acceptance of change as an important component for cities.

Keywords: Ecological resilience, Press disturbances, Slow Change, South Africa, Urban resilience.

1. Introduction

South African cities are characterised by complex and rapidly evolving environments within which the ideological legacy of past Apartheid planning still influences the functioning of the

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city, and where the new political regime has yet to inclusively repair and integrate the gaps left in the city fabric. Within the informality engendered by this transitioning society, niches appear in areas of opportunity and potential where a growing number of urban poor find their sources of livelihood and shelter. In particular, the City of Tshwane has seen the development of fast-growing informal settlements in close proximity to upmarket housing estates where the urban poor generate livelihoods from ad hoc job opportunities servicing the wealthy suburbs. Their presence has been the source of a tense relationship between stakeholders in the area, and efforts to resolve the situation through short-term interventions without a contextual understanding of the long-term pressures on the area, have failed. This poses the question whether broader issues are affecting these environments, and whether there is interplay between them that underlies the manner in which the system responds.

Framed in this background, this paper aims to understand the relationship between the various levels of press disturbances in the city panarchy from the perspective of an informal settlement called Plastic View. This understanding will be built from a desktop study of newspaper articles sourced over the last fifteen years, a time during which informal settlements have persisted in the city despite efforts to remove them. It is also based on observations of the focal area of Plastic View in order to build a deeper awareness of the complexity of the phenomenon.

1.1 A background to the concepts of resilience being discussed

Concepts of urban resilience are based on an understanding that as active components in city systems, human-beings are managers of various systems that are part of living systems comprising of humans and nature together, also referred to as a *social-ecological system* (SES) (Walker & Salt, 2006). The Tshwane SES is no different and as managers thereof, human beings have a responsibility to the city system. Viewing the Tshwane system as a holistic entity that is made up of various hierarchical scales of interaction and interrelation (Holling, Gunderson, & Peterson, 2002) proves useful. The interplay between various press and pulse disturbances therein, requires an understanding of where they sit in the various scales of the SES (the holarchy and panarchy) in which they occur. Looking for links between press and pulse disturbances in informal settlements is enriched by Koestler's holarchic understanding of the relationship between components which themselves are whole, as well as elements in a bigger system within which they operate according to rules and patterns that determine their behaviour (Du Plessis, 2011). System properties emerge from the structural relationships and interactions of the components across different scales. These multi-scaled relationships are part of adaptive cycles that make up Holling's panarchy, the theoretical framework that describes the multi-scaled dynamic relationships within the SES in question (Holling, Gunderson, & Peterson, 2002). Within the panarchy, the lowest scales undergo rapid change, while higher scales occur more slowly.

Resilience perspectives can prove to be useful, as they emerge from the exploration of integrated, post-sustainability outlooks that embrace the dynamics of change as a natural process, within which finite limits to resources can shift current environments into a completely different system state, but not erase it. In order to build resilience, we require an understanding of the forces driving the context, by asking resilience of what to what and

triggered by which disturbances (Resilience Alliance, 2010). In doing so, we may be able to actively build the adaptive capacity of the focal system to innovatively leverage change to release captured energy and resources, to cross a threshold into another more desirable system state, or for a shock to be absorbed without resulting in a system collapse.

If the current focal system is desired to be made more resilient, then attention should be given to increasing the functional diversity, so that it is able to demonstrate a number of different responses to pressure in the system while still maintaining its functionality. Understanding the relationship between multi-scale press disturbances offers an opportunity to open our thinking about city planning in the City of Tshwane into a holistic, long-term and less efficiency driven approach; one that strives for constant evaluation and evolution of the city since “resilience is the great moral quest of our age” (Zolli & Healy, 2012).

2. Contextualising Plastic View

2.1 Informality, the other face of life in the city

Since the establishment of a democratic South Africa in 1994, the country’s major cities have been experiencing an influx of migrants from rural areas and neighbouring African countries, into ‘townships’ and informal settlements on municipal lands (Soggot & Amupadhi, 1997). Within the Apartheid city planning strategy, racial segregation occurred by the deliberate separation of white, coloured and black neighbourhoods usually by natural features, industrial areas, or large distances. The word ‘township’ or ‘locations’ referred to ‘non-white’ neighbourhoods located in the city periphery and continues to be used in reference to these areas. Designed to be easily controlled as self-contained areas, they functioned separately from the ‘white’ city. ‘Townships’ played a crucial role in the formation of the apartheid city and embodied the complex process characterised as functional inclusion, spatial separation and political exclusion (Chipkin, 1998). After the system of control collapsed, South Africans of all races have been drawn to city life, however these urban areas are not always able to meet their needs for housing, employment and health within formal infrastructure frameworks - a trend prevalent the world over (Burdett & Sudjic, 2007). As the number of urban poor increases, so does the gap between the rich and poor in contemporary South African cities. Despite being dominated by strong African and global cosmopolitan influences the Afropolitan (Nuttall & Mbembe, 2008) the nature of our cities has been slow to bridge the social disconnect that continues in a number of forms like informal housing and trade, up-market security estates, car-dominant planning, increased crime and dwindling public amenities. Government investment into the ‘townships’ continues to be sustained with little affordable or alternative subsidised housing being provided in areas of the city where poorer residents want and need to be in order to sustain their livelihoods. In eighteen years of democracy, a high quality integrated housing scheme is yet to be realised in the eastern suburbs of Tshwane.

2.2 The eastern suburbs – home to Plastic View

Over the last fifteen years commercial and residential development and investment in the City of Tshwane has shifted eastward. The gated estate typology has been a dominant

response to the perceived security risk of living in older suburbs as well as a need for affordable medium density housing for middle income markets. A number of golf and equestrian themed estates have also drawn high-income earners to these suburbs that are characterised by large, physically cut-off and privately managed and serviced landholdings, which confine movement around them to car-dominated roads poorly serviced by public transport. They rely on malls, private schools and hospitals with little or no council led investment in amenities, infrastructure or public spaces. This typology results in pockets of left over land consisting of neglected municipal grounds, servitudes and natural areas. Socially and economically, the formation of at least ten fast-growing informal settlements developing in these 'left over spaces', are frustrating local communities (both in informal settlements and outside) who require clarity about the future. Most upmarket estates and households rely on a few low income workers to provide services as security guards, cleaners, domestic workers, gardeners, child minders, retail and construction workers and handymen. However, these estates offer no housing options for these marginal workers to live close to work nor has council provided alternative forms of housing in the area; workers are left to commute long distances to make their livelihoods, at high cost (Turok, Hunter, Robinson, Swilling, & van Ryneveld, 2011).

Development east of a suburb called Moreleta Park, has resulted in the emergence of informal settlements appropriating tracks of unmaintained, un-used, 'out-of-sight', yet well-located land in close proximity to estates. For the past few years tension between the Moreleta Park community and the growing number of vagrants has slowly been building up. The local community link criminal activity to the informal settlement, and cite the over-crowding and unsightly unhealthy living conditions, as reasons for their property investments declining (Roux, 2012). In turn, the vagrants cannot be legally evicted from the land without suitable alternative housing options being provided by council (Department of Housing, 1998).

Plastic View, the focal system of this paper, is an informal settlement located just east of Moreleta Park and is so dubbed because of its appearance when viewed from the major roads on its edges, as it seems to be made largely from salvaged plastic (Venter, 2012). It contains Woodlane Village, a settlement that was 'organised' by some of the informal settlers with the support of a local NGO group in 2008; and which comprises 856 households and roughly 3000 residents. Plastic View's physical characteristics and location inform its emergence and resilience (Figure 1). The municipal land on which it is situated is roughly 9ha in size, of which portions are occupied by informal settlements (Woodlane being the largest) with the rest used for illegal dumping or left unattended. The land is confined by large roads on two of its edges (a regional road leading out of the city, as well as a neighbourhood connector) and various residential security estates along its remaining edges. It contains a perennial stream that connects to a larger open space system that runs through the eastern suburbs and connects to the large Rietvlei nature conservation area.

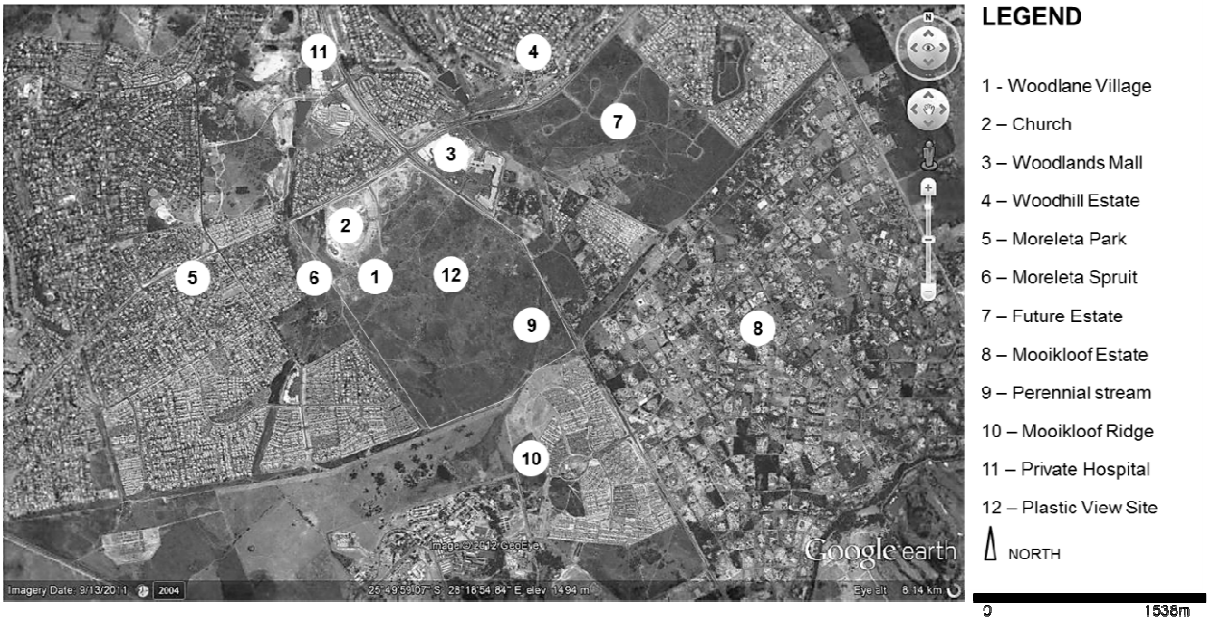

Figure 1: An aerial photo of Plastic View and the surrounding context (Authors, 2012); base image courtesy of Google Earth.

Residents of Plastic View say they have been living there since 2001, indicating that they settled there because of the need to be closer to job opportunities (Hlahla, 2010). It is also conveniently located next to wealthy estates, a large local church, a mall as well as an NGO. In the middle of 2012, the municipal land on which Plastic View is located was allocated for subsidised housing. This court decision resulted from persistent objections by the greater community against the rising number of vagrants in the areas, the effect on their investments (Roux, 2012), their subsequent concerns about the risk of a poor quality RDP housing scheme being built on the land, and human rights organisations protecting the settlers from eviction without suitable relocation as required by law (The Bill of Rights of the Constitution of the Republic of South Africa, 1996) (Department of Housing, 1998).

As Plastic View is poised for transition, the question is posed, how will formalisation affect its internal resilience as well as that of the broader community? The recent court order sets a precedent for the city; its response to informal settlements, alternative subsidised and affordable housing integration, and transformations to housing or planning policy will be interesting to follow. This phase of the Plastic View adaptive cycle offers a window of opportunity, a threshold between an existing system state and, possibly, a new improved one. Ignoring the interplay between deeper issues affecting the focal system in a hasty planning process may destroy the positive qualities of the landscape and place. Instead, alternative ways of proactively managing, coping and adapting to unpredictable change without having to reactively crisis manage, are required.

2.3 The Tshwane Panarchy, from the perspective of Plastic View

Gaining insight into the patterns of change and adaptation in Plastic View and the panarchy in which it sits, provides a platform to recognise where the linkages between press and pulse disturbances exist and their forms of interaction. Increasing this knowledge shapes awareness that settlements like Plastic View are not isolated from bigger forces, but are connected to both large scale issues pressuring the city, as well as small scale needs of its

citizens. To achieve this understanding, the panarchy of the City of Tshwane is divided into three scales; the Plastic View focal scale, the intermediate scale consisting of surrounding suburbs like Woodhill, Mooikloof and Moreleta Park, and lastly the highest scale consists of the Tshwane City Region and beyond. Within each of these scales, a chosen focal area may both respond to a disturbance and exert pressure on the system. In the case of Plastic View, it has emerged out of press disturbances from the City region scale, but also has pressured the intermediate scale of the surrounding neighbourhoods, as illustrated below:

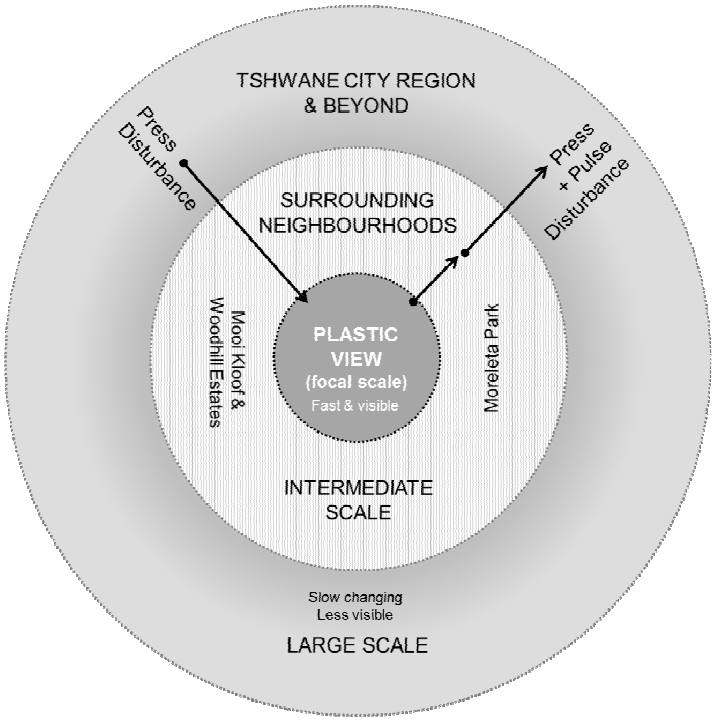

Figure 2: A diagrammatic representation of the Tshwane Panarchy, with Plastic View as the focal scale (Authors, 2012)

3. Understanding multi-scale disturbances in the Panarchy

The Plastic View case study provides a useful way to appreciate the interaction and relationship between drivers and their influence on events across the panarchy of the city. This interlinked web shows strong connections between seemingly unrelated components, such as the emergence of informal settlements next to middle to high income suburbs in Tshwane. A deeper awareness of these intertwined issues may help in changing the perceptions of the community as a whole regarding their responsibility to each other and nurturing a respect for nature as an ecosystem of which they are a connected and integral part. This will be built out of the press disturbances impacting upon Plastic View over the three scales of the panarchy shown in Figure 2; the focal scale, the intermediate scale, and the large scale. A few of the most prominent disturbances will then be looked at to understand their system dynamics and multi-scale dynamics (Resilience Alliance, 2010).

3.1 Large-scale press disturbances that created Plastic View

To build an understanding of the multi-scale dynamics of the city panarchy, the first step begins with the forces driving the city- and national system and have led to the gaps formed in the city, which are points of vulnerability and opportunity. In Plastic View there are many press disturbances that have created its emergence; however a review of newspaper articles has narrowed the list down to three main issues.

The first relates to the Apartheid City plan and its structural legacy affecting the contemporary functioning of Tshwane (Herve, 2009). Its major effects are visible in the extensive distance between affordable housing located in former 'townships' and work opportunities within the wealthy suburbs. Tshwane is the metropolitan region with the longest commuting time (Turok, et al., 2011). The second is linked to the first, and deals with the lack of alternative affordable housing options for unskilled and semi-skilled workers in newer suburbs. Perhaps as a result of security estates not providing onsite staff accommodation (previously most homes in South Africa had staff quarters on the property). There is also the lack of council investment in integrated housing outside of the peripheral 'townships' (Herve, 2009). Thirdly, there is policy, which in practice has been slow to encourage the implementation of integrated human settlements close to job opportunities. The conditions related to the allocation of housing subsidies and legislation that prohibits the removal of settlers without providing alternative accommodation offers an opportunity for informal settlers to 'jump the queue' and get RDP housing after invading municipal land from which they cannot be evicted without receiving alternative housing (Department of Housing, 1994).

3.2 Press disturbances that Plastic View places on the larger system

The second step in understanding the panarchical relationships begins with an analysis of the pressures exerted by the focal system on the intermediate scale and also the large city scale. Progressively, Plastic View has grown and resisted a number of disturbances to its internal resilience (Roux, 2012). Concurrently, articles refer to the pressure that its presence is placing on surrounding communities and the overall system has grown too. Predominantly local communities have been concerned about the uncertain future of Plastic View; would it be removed, maintained or formalised? This is one of the drivers behind fragile market perceptions that adversely affect property prices in the area (pre-recession) and alienate local communities (Roux, 2012). The second driver is that the informal settlements are linked to criminal activity in the surrounding neighbourhoods, triggering higher security measures as responses and subsequently higher criminal violence. The third driver is the loss of ecosystem services and reduced quality of the natural environment. Lack of sanitation and increased water use from the streams on site for cleaning and washing has led to pollution of the water courses and has negatively affected the overall environmental quality on site including the open space systems to which these streams connect in the intermediate and city-wide scale. Lastly, the recent court decision to formalise Plastic View creates a precedent for the city regarding its response to other informal areas within the region (Venter, 2012).

3.3 Press disturbances that created pulse disturbances within Plastic View

The last step looks at pressures that have led to pulse disturbances occurring within Plastic View which have thus far been overcome by the community. The first pulse disturbance deals with seasonal natural disasters. Winter shack fires are a reality due to a lack of building controls, shacks are built too close to each other without fire breaks or insulation; and due to a lack of municipal investment in clean or alternative energy for poorer communities, paraffin lamps and open fires are sources of heat in winter (SAPA, 2012). In summer, floods are a source of crisis. Plastic View is located on a flood plain with two streams running through part of the site. During heavy rains, the Rietvlei Dam upstream, as well as the storm water runoff from vast expanses of hard surfaces surrounding the site compounds the increased water flow (Mail & Guardian, 2008). Executed by the local authority, forced evictions have been a source of pulse disturbances; rising tensions from the local community propelled forced removals of a number of informal settlements in the area. For example in 2006 a clean-up project carried out by Metro Police resulted in shacks and their belongings being burnt in an effort to remove the Plastic View informal settlement and the homeless without any alternative accommodation provided, nor a court interdict (Venter, 2012). Another incident was repeated in a nearby informal settlement in 2010, this time carried out by the 'Red Ants' joint venture security guards (Hlahla, 2010). In turn, this resulted in another pulse disturbance, that of local non-government organisations intervening on forced removals by organising and offering assistance to the affected community, propelling a court case to secure the informal settlement onsite until alternative housing could be provided. The last pulse disturbance identified in the desktop study is the court decision to formalise Plastic View, leaving the informal community excited to have 'real homes at last' (Du Preez, 2012). Thus far, the internal resilience of the informal community has been strong, showing high degrees of adaptability and capacity for the continual process of change that is one of the often ignored positive characteristics of informal settlements (Huchzermeyer, 2008). How formalisation will impact on this resilience remains to be seen.

3.4 Multi-scale disturbance relationships

Having found press disturbances that have, and continue to affect the focal system of Plastic View, we move toward building an understanding of the multi-scale relationships that exist between them and the specific pulse disturbances that drive the study area. As pressure on the system intensifies over a long period of time, a release or collapse is usually an opportunity for reinvention, but only if a deeper consideration of the interplay between forces is understood. In the following section we begin by looking at the relationships between disturbances by referring to Figure 3, and describing these in narrative form.

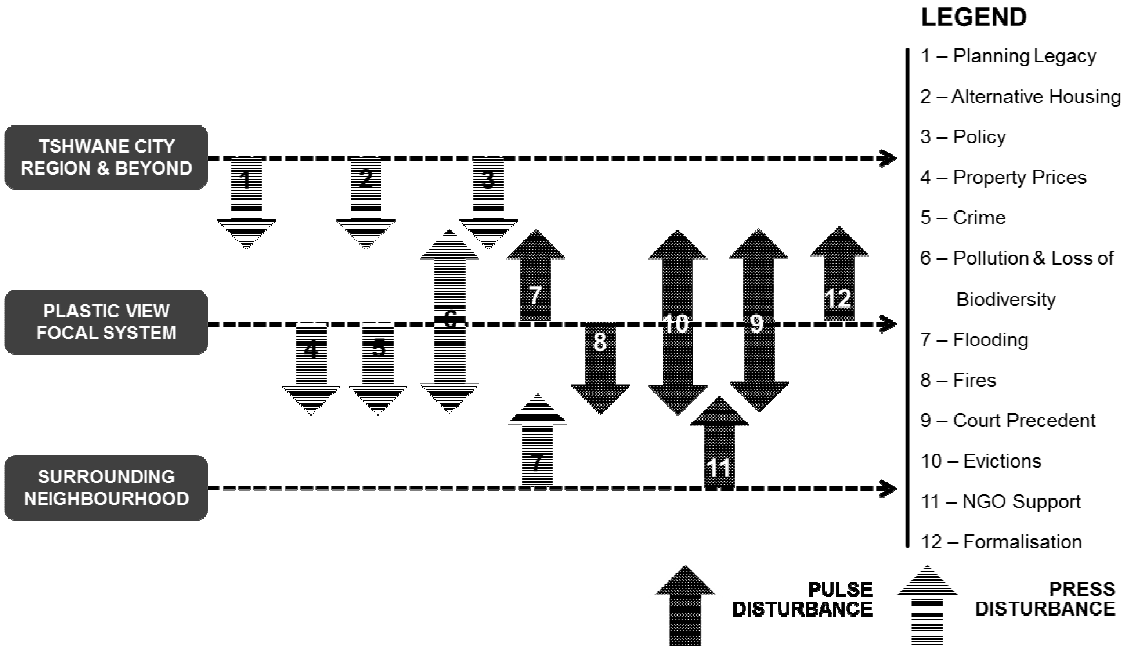

Figure 3: A diagrammatic representation of the relationships between press and pulse disturbances across the Tshwane Panarchy as seen from Plastic View (Authors, 2012)

The Apartheid city plan continues to influence the functionality of the South African urban landscape (Issue 1), most prominently through limiting access as the 'townships' continue to be disconnected from other areas in the city. The nearest formal 'township' where many marginal workers live, is called Mamelodi and is located at least 20km away, too far to walk and too expensive to drive. The cost and time required to use public transport consumes a large percentage of disposable incomes, especially when many only have temporary jobs in Moreleta Park and need to be in the area in order to get more work or to cut their travel expenses (Hlahla, 2010). In addition, despite investment by most tiers of government from national to local to provide affordable housing (Issue 2) for the poor, it has largely been located in the traditionally 'black townships', adding to the difficulties faced by poorer people in getting to places of employment and generate livelihoods (Herve, 2009). With current policy promoting subsidised housing, as well as laws protecting tenants and squatters alike from eviction (Issue 3), the informal market has filled an essential gap in the city: providing flexible housing opportunities close to work opportunities. Unless there is a revision to planning schemes, and potentially the subsidised housing and eviction policy, innovative solutions for alternative affordable quality housing solutions for marginal urban South Africans are limited, unlike Elemental's Quinta Monroy in Iquique, Chile (Elemental, 2001).

As general press disturbances intensify, they create conditions that make settlements like Plastic View possible. The presence of informal settlements next to high-income residential suburbs links back to Issues 1-3; these suburbs offer places of employment and opportunities to build a livelihood, as well as the possibility of 'jumping the queue' to get access to subsidised housing. As a consequence of its emergence, Plastic View has started placing press disturbances of its own on the surrounding community; property prices have become fragile (Issue 4), perceptions that crime in the area emanates from the informal settlement (Issue 5), and the increasing pollution and degradation of the city-scale watercourses and their biodiversity (Issue 6).

The ripple effects of built up press issues are felt up to the city-region scale. Tension in the surrounding community has led the council to disrupt Plastic View on a few occasions through attempted land evictions (Issue 10). However, eviction policy (Issue 3) and the assistance of local NGO's protecting and supporting the settlers (Issue 11), has meant that there has been little change to the growth and longevity of the informal settlement. Natural disasters like seasonal flooding and fires (Issues 7 & 8) have not collapsed the settlement. Instead, they emphasise the connection to issues 1-3; since estate typologies and the commercial boom resulted in developments with expanses of hard surfaces, increasing storm water runoff and putting pressure on natural streams and storm water systems.

As press and pulse disturbances continue to impact on the panarchy, a recent pulse disturbance may have the greatest effect on the focal system. The recent court decision to formalise Plastic View (Issue 9) and permanently locate its legal residents in the area, sets a precedent for other similar instances of informality in the city (Issue 12). This will also have consequences for Issues 1-3: a) it will be an opportunity to integrate lost spaces in the disjointed city (Issue 1), by locating marginal workers closer to places of employment and spatially stitching communities together; b) it offers the poor alternatives to housing close to where they need to be to generate livelihoods (Issue 2) and c), it offers an opportunity to revisit current policy and find innovative ways to build adaptability and resilience into planning strategy (Issue 3). Issue 9 also affects the Plastic View community. It offers an opportunity to build resilience against natural disasters by applying methods that integrate natural processes and alternative planning, and also to build social resilience, strengthening the quality of educational, health, food security and recreational amenities for the informal settlement. Lastly, pulse Issue 9 has consequences for surrounding neighbourhoods; it offers the certainty of a workforce close to home and the possibility to build symbiotic networks of livelihoods that not only benefit the marginal workers in the informal settlement, but also most of the neighbourhoods around it.

Narrating these multi-scale relationships has highlighted the interconnectivity of disturbances in the panarchy and offers insight into understanding that as a system most events have an effect on the system as a whole, whether over a long period or suddenly, and that this effect filters through to other scales of the system (Capra, 1996). Further investigation of these relationships may enrich the research into mapping urban resilience of the City of Tshwane and may highlight that a necessary change is required in the way we think about development and planning for the future of South African cities. It shows that professionals, practitioners, academics and government officials involved in the built environment, need to rethink how we view change in urban systems (Wilkinson, Porter, & Colding, 2010) and identify potential therein for positive growth of urban systems in aspirational cities.

4. Conclusion

Having looked at the systemic pressures affecting the Tshwane city panarchy, from the perspective of an informal settlement called Plastic View, the understanding gained has shown that not only are the pressures exerted on the system multi-scaled, but also highly interconnected and interrelated. This understanding has led to the conclusion that current models of development are insufficient in dealing with press disturbances placed on

transitioning urban systems in South Africa while trying to cater for the demands of an increasingly Afropolitan society. This stems from lack of awareness about the interplay between press and pulse disturbances and their effects in the city. This understanding could assist in building resilience across the panarchy. Plastic View has demonstrated high levels of internal resilience while the surrounding neighbourhoods demonstrated weaker levels of resilience, partly due the uncertainty regarding the future of Plastic View. However, given the recent court decision to make it permanent, the integration of a lower income settlement close to wealthy suburbs may build diversity and capacity for overall system resilience, because its cross-scale networks are strengthened. This perspective offers an adaptable, dynamic and robust approach for assimilating changes into regenerative processes in the urban social-ecological system. Systemic change cannot be viewed as a linear concept, but rather as a dynamic framework (Wilkinson, Porter, & Colding, 2010) of interconnected and interdependent processes that collectively increase or decrease resilience.

Acknowledgements

The authors are grateful to the National Research Foundation who supported the production of this paper through NRF Grant no 78649.

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Product platform considerations on a project that develops sustainable low-cost housing for townships

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Abstract

Construction companies in Denmark are often working with profit margins as little as 1-3% in situations where they deliver high-end buildings to the local market. Even though customers are willing to pay a premium price for high quality, construction companies earn very little on their products. Consequently one Danish company took the decision to produce sustainable low-cost houses and to sell them to developing countries that have township housing programmes. But why would this company believe it could make a profit in the low-cost housing segment abroad, when there is almost no profit in the high-end segment at home? As the research described in this article shows there are three main reasons for their optimism: 1) The successful introduction of a product platform for low-cost houses, 2) a modular approach to the design of low-cost houses, and 3) the application of requirements management as described by INCOSE. 1) to 3) have been studied using action research on a case project.

The case company´s success contributes to people currently living without decent housing by providing insulated, low-cost houses based on the latest technology. The fact that those low-cost houses are solid gives their new owners the possibility to take a loan out on their building which is expected to contribute to more businesses being started up and thereby strengthening the domestic economy. As a consequence of this, additional research is needed in how to further optimise the economy of sustainable low-cost housing based on life cycle considerations. Moreover, it has to be examined how the experience gained can support in maximising the high-end segment in countries like Denmark.

Key words: Low-cost housing, product platform, construction industry, practical implementation, action research

1. Introduction

This section will introduce the trend of population growth and the concept of product platforms which are core to the business opportunity of the research case detailed in this paper.

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1.1 Population growth in developing countries

It is estimated that about 1.6 billion people around the world live in sub-standard housing and over 100 million are homeless. If no serious action is taken the number of slum dwellers is expected to rise from one billion people today to two billion within the next 30 years (Habitat for Humanity, 2013). This leaves many developing countries with a problem that is hard for them to overcome. South Africa is one of the countries that are taking action, as it tries to solve its housing problem by means of a centrally planned housing programme. Through this programme, since 1994 more than 2.3 million housing units have been made available to nearly 11 million people, where in 2010 alone about 219.000 housing units have been made. The goal for the coming years is to create 220.000 housing units a year. Despite such a tremendous number of erected units, the housing backlog has grown from 1.5 million units in 1994 to 2.1 million units today. This means that 12 million South Africans – a quarter of the population – are still in need of a better shelter (Ministry of national housing and social amenities, 2011).

Inspired by the housing programme of the South African government, the case company described in this article examined whether and how it would be possible to contribute to the housing problem of developing nations with its knowledge and technology. After a careful examination of the National Housing code (2009), the decision was taken to develop a low-cost product platform that could co-exist with both the existing, high-end and re-insulation panel product platforms and to make an offer to the South African housing programme.

1.2 Product platform definition and strategy

The product platform concept has widely been discussed in literature, where accordingly a number of definitions have been introduced by e.g. Muffatto and Roveda (2002). Halman et al. (2009, page 151) for example, refer to McGrath's definition of a product platform: "a set of subsystems and interfaces that form a common structure from which a stream of related products can be effectively developed and produced". The authors base their research on this definition, as it incorporates both the physical and economical aspects of a platform concept. An overview of the product platforms that exist in the case company can be seen in Figure 1.

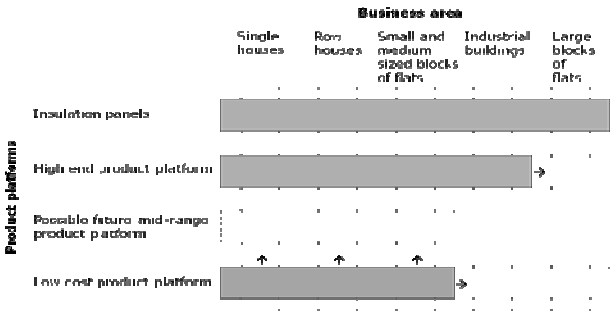


Figure 1: The product platforms that exist in the case company

As illustrated in Figure 1, the insulation panels aim to cover all business segments, while the other two product platforms address only parts of the market, but still keeping the possibility

of expanding open. The reasons for believing in the success of a product platform that did not even exist at the time the offer was made were:

- The product platform approach had been rooted in the organisation and the staff of the case company had been trained in product platform thinking for several years
- The successful implementation of requirements management in the case company
- All the desired European safety and product approvals had already been received
- The technology the case company wanted to use had successfully been tried out in several buildings in Denmark (see Figure 2 for an example)
- The senior staff have a long history of successfully executed building projects

The above listed points indicate that a strong base had indeed been established which made it possible for the case company to continue building upon. At the same time the case company was also aware of the main obstacles that had to be overcome. To begin with, the government subsidy for a 40 m2 stand-alone house only amounts to 55.706 ZAR (= 4.926,87 € using exchange rates from December 25th 2012) (Coetzer, 2010), which is considerably less than what a house based on the high-end product platform costs. Moreover, unskilled labour is to be used, whereas the usual approach of the case company is one of automation and efficiency in combination with a skilled work force. There is also a risk of facing problems using the local building materials with unknown properties and quality. However, the management of the case company had full confidence in being able to produce 40 m2 low-cost houses at a price that did not exceed the government subsidy. Working with unskilled labour and having to use local building material were treated as risks. Therefore, risk mitigation plans were made for those two points as described in the PMBOK (2008).



Figure 2: A building based on the high-end product platform

Studying the situation resulted in the main hypothesis that creating and introducing a platform concept to low-cost markets would support both, developing countries in overcoming their housing problem in an effective manner, and construction companies to improve their performance in the domestic markets. To this end, this article in particular addresses the following aspects:

a) It is possible and beneficial to develop a low-cost product platform that can be used for making low-cost houses
b) It is possible to make several variants of houses based on that low-cost product platform

c) The new knowledge gained by developing and implementing a product platform for low-cost housing will contribute to improved efficiency and reduced prices in the high-end platform

This paper therefore deals with the question on how to successfully introduce a product platform that supports modularity to the low-cost housing segment of the construction industry. To answer this question, after a literature review (Section 2), an explanation of the applied research and design methods (Section 3) and a description of the case (Section 4) will be provided. Section 5 then gives a brief overview on the key observations that have been made when developing the low-cost product platform and building houses. In Section 6 the thereby achieved results have been analysed. A final conclusion is drawn in Section 7, where the most important findings are summarised and recommendations for future research are given.

2. Literature review

Even though the work on the case project was mainly of a practical nature, a lot of knowledge has been drawn from literature, where both academic publications as well as literature from seasoned practitioners have been consulted. Table 1 below gives an overview showing the main references considered for this article and what they cover in the context of this research:

Table 1: Main literature considered in this research

	Ulrich and Tung (1991)	Thuesen and Hvam (2011)	Mortensen et al. (2008)	Simpson et al. (2011)	INCOSE Systems Engineering Handbook (2011)	Huang et al. (2005)	Roy et al. (2003)	This article
Product platform		X	X	X		X	X	
Product platform in construction		X					X	
Product platform in construction – low-cost housing								X
Product variants / family	X		X	X		X	X	X
Modularization of products	X	X	X			X	X	X
Requirements management					X		X	

The concepts of product modularization (Ulrich and Tung, 1991) and product platforms have extensively been discussed in literature. Huang et al. (2005) for example have studied several companies in different industries using product platforms. In addition, Hvam (2011), Mortensen (2008), and Simpson (2011) provide a number of publications on the application

of product platforms, where the approach of using product platforms has mainly been put in the context of consumer electronics, car, aerospace, and software industries. However, at the same time very little theoretical contribution could be found on how to apply product platform principles to the construction industry (Roy et al., 2003). As of today, there are in particular no published attempts to practically implement a product platform which facilitates modularity and product variants for low cost housing in this industry.

3. Research and design methods

The research described in this article makes use of action research (AR) defined by Coughlan and Coghlan (2002) as well as Checkland and Holwell (1998) for creating the needed models and tools. The approach was applied to a case project, where full access to all key people and complete access to all documents relevant to this research, including minutes of meetings in addition to documents containing the future strategy of the case company and its products, existed (Voss et al., 2002 and Yin). In order to cover all parts of the case project's value chain (see Figure 3), including the sub-projects described in Section 4 "Description of case", several interview rounds with key persons from the construction industry and the case project have been conducted.

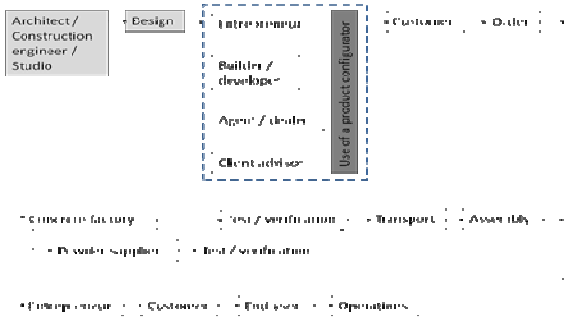


Figure 3: The value chain of the case project

For reasons of comparability and consistency interviews were conducted using a question template from previous research for all participants, resulting in a master document that covered a wide range of different requirements: from functional, non-functional, technical, market and organisational requirements, to requirements towards the project manager and finally to requirements of the stakeholders themselves. This was used to implement requirements management on the case project and was actually (at that time unconsciously) the first step towards a low-cost product platform. During the analysis of the second out of four AR cycles it became clear that requirements management on the case project worked well (Wörösch, 2012), as it significantly contributed to having a clearly defined scope of the case project, its sub-projects, and the different product platforms – the two existing ones as well as the one that needed to be developed.

When linking the requirements of the low-cost product platform to the company and product strategies, modularity of the houses based on this platform could be ensured. In an architectural perspective, a definition of the term modularity that fits well with this research has been described by Ulrich and Tung (1991). The authors refer to "the construction of a building from many instances of standardised components. In manufacturing the term often

refers to the use of interchangeable units to create product variants" (Ulrich and Tung (1991, page 73)). Examples of the hereby achieved modularity will be given in Section 6.

4. Description of case

Despite of operating in construction, the case company is unique within its industry in several aspects. Firstly, it produces sandwich elements and insulation panels from High Performance Concrete (HPC) that are used to build and renovate houses to have greater energy efficiencies. Secondly, the company constantly develops new technologies and products resulting in patents. Therefore, already today, it offers buildings that live up to the European Union's 2020 energy saving requirements, covering the complete value chain (see Figure 3), where responsibility is not pushed down to sub contractors. The uniqueness of this case is reflected in the structure of the case project that consists of four different types of sub-projects, which will in the following section be shortly introduced:

1. Technology development used to develop new insulation and HPC material as well as different mounting systems
2. Product development with the goal to develop new sandwich elements, insulation panels, and jointing in different dimensions
3. Development of low-cost, high-end, and insulation panel product platforms
4. New building projects (such as the erection of 40 m2 prototype buildings in Delft, Cape Town, South Africa)

1) to 4) deliver and share human and financial resources as well as processes, which simultaneously results in constraints, where 4) depends on the success of 1), 2), and 3).

5. Observations

When developing the low-cost product platform and building the houses, a series of key observations, that are further grouped and described in detail, has been made.

5.1 The low-cost product platform

- On a conceptual level there were many elements that could be re-used from the high-end product platform; e.g. the basic methodology when describing a platform structure and how to phrase requirements. Previously, there was not much reuse between the two other product platforms
- A solution for the design of the HPC elements has been found that required only few tools for assembly. Buildings can even be assembled without using power tools, since stable electricity sometimes is absent on some building sites. An assembly where only few tools are needed also makes teaching of staff easier and leaves less room for error
- Even though unskilled labour and no high technology production are being used, many houses can be produced during a year. This is due to the production of only few different kinds of elements, which are strongly standardised and can be used across the product variants. Using unskilled labour and no high technology also changes the

description of requirements from being database and specification focused to being expressed in photographs and drawings wherever possible

- Once the HPC elements with their pre-mounted windows and doors are ready for assembly, a Type 1 house (see Figure 4) can be assembled within one working day. This fast assembly also contributes to the possibility of building many Type 1 houses in the course of a year and at the same time it prevents theft or unauthorised occupation, as the houses are closed in the evenings
- The local building materials (about 99%) can be used without any quality problems. The only exception to the use of local material is a special concrete binder that is sent from Denmark. In result, the use of local material creates domestic jobs and reduces CO_2 emission that otherwise would have been caused by transportation from abroad
- The scalability of the low-cost platform is high. This means that when, for example, the production has to be doubled or halved it can be done relatively fast at low cost
- The price of a 40m2 stand-alone house (basic model) based on the low-cost product platform does not exceed 55.706 ZAR. This means that the case company can continue building the low-cost houses without generating losses and the housing programme can accordingly achieve its yearly targets

5.2 Modularity

Modularity has been achieved in several facets. For the customers this means that they can upgrade their houses with extra rooms, a veranda or a bigger kitchen at a low price at the time of ordering. Upgrading is possible in all situations where the housing programme facilitates a contribution of the end user. Besides, modularity can also be achieved by using additional means; e.g. by giving the customer or resident the possibility to enhance the house by adding a rainwater collector that gathers rain water from the roof facilitating cultivating a garden for the house. Another benefit of achieving modularity is that it also is possible to improve the houses with solar panels for generating power for hot water, lighting, charging computers, cell phones, and other consumption. Also, here the housing programme has to allow this kind of improvement.

5.3 Knowledge transferred back to the high-end product platform

- The high degree of standardisation contributes to a high throughput in production. The high-end product platform needs to be examined for possibilities to increase standardisation and to get away from the current high level of uneconomic flexibility
- The use of prototype elements, drawings, and verbal explanations instead of lengthy documents has been very successful. This method of controlling the scope for a product platform could also be introduced to the other product platforms, which, however, would mean to go away from a systems engineering best practice approach as described in the INCOSE Systems Engineering Handbook (2011). It has to be examined to what degree this could be done while still maintaining sufficient documentation and living up to described processes
- The rather effective way of teaching new local staff and the team, created a very inspiring feeling during the teaching sessions and should further be applied to staff working on the other platforms as well. Flying the key personnel of the case project to

South Africa in order to participate in building low-cost houses could be one way of transferring the new knowledge and a positive team spirit back to Denmark

- This new knowledge gained by developing and implementing a product platform for low-cost housing will contribute to improved efficiency and reduced prices in the high-end platform, as many decisions that had been taken on the high-end product platform have been seriously challenged. An example is the very high focus on the factor cost for the low-cost platform that has never been enforced to such a degree on the high-end product platform

Having summarised the main observations, in the next section the results of implementing a low-cost product platform into the case project are discussed.

6. Discussion of results

By the end of action research cycle two, the research conducted in the case project had given a series of theoretical and practical results. The main results have been listed below.

6.1 High level results of making a low-cost product platform

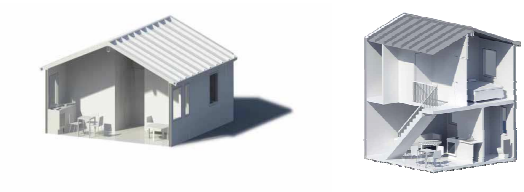
As anticipated, from a technical and process point of view, it was indeed possible to develop the low-cost product platform and build houses based on it within the estimated time. Due to the active use of requirements management, the scope of the new product platform was clearly defined, while market segment-wise there was no overlapping with the existing product platforms. From a societal point of view, building low-cost houses at high speed helps ensuring that more people have decent housing and thereby producing an increase in quality of life. Furthermore, a relatively fast, cheap and secure assembly, contributes to reducing the large backlog in the low cost housing area. Thus, as demonstrated by the case company, local job opportunities together with relevant education and training are created. This increases the standard of living and improves future chances for personal development. Houses made from HPC are solid and have according to Danish Standard (2001) a minimum life expectancy of 50 years, while in practice concrete companies often calculate with 70 or more years. This is much higher than what most housing objects currently have. This longer life expectancy makes it possible for a house owner to take a loan out on their house, which in turn can contribute to starting up financial businesses and thereby to strengthening the domestic economy.

6.2 Results related to the main hypothesis

6.2.1 The low-cost product platform and the use of modularity

The low-cost product platform currently supports three types of houses, of which two will be explained further in this paper. All houses based on this platform can only be ordered in a light or in a dark version. Each of them comes with two different surface structures, a smooth and a brick-like one. Altogether the customer is offered a limited number of choices, as all concrete elements, windows, doors, materials, sizes, and interfaces are completely standardised. This radical standardisation is the main difference from the high-end product

platform, for which more variety and a higher degree of customisation is available. Figures 4 (Type 1) and 5 (Type 2) show two types of 40m2 houses, that are based on this new low-cost product platform.



Figures 4 and 5: Two different 40 m2 buildings made from HPC – Type 1 and Type 2

Modularity on the low-cost product platform exists on two levels. On the element level, the HPC elements are prefabricated and scaled to approximately 1,2m in width. Figure 6 illustrates the conceptual assembly of a Type 1 house based on those elements. On the building level, several variants of the Type 1 and Type 2 house exist. The Type 1 house can be produced as basic 40 m2 model or as one of four variants, where modules like a veranda or extra rooms can be added. Depending on what modules are added, the size of a Type 1 building can go up to 56 m2, as depicted in Figure 7.

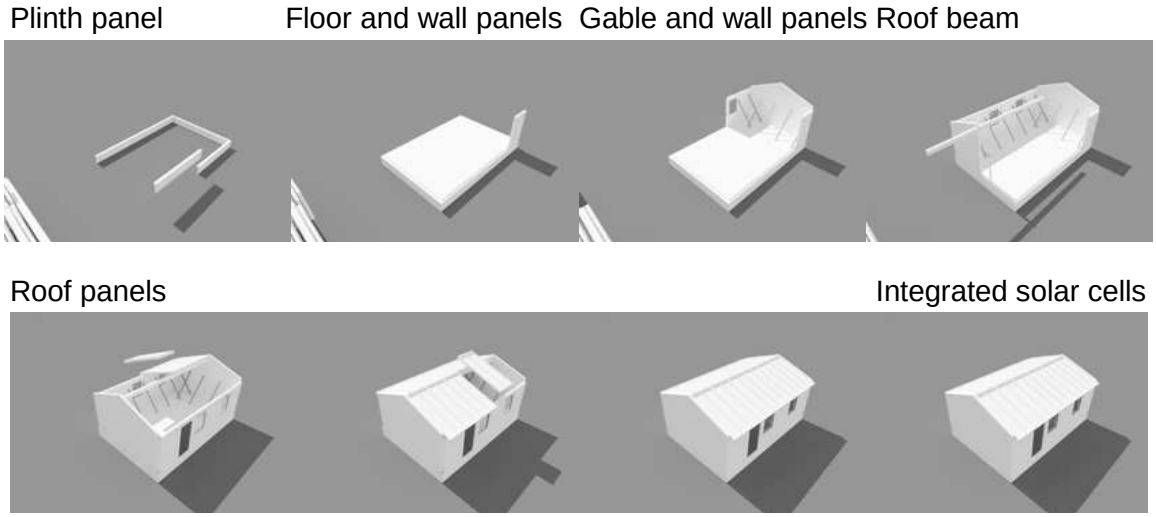
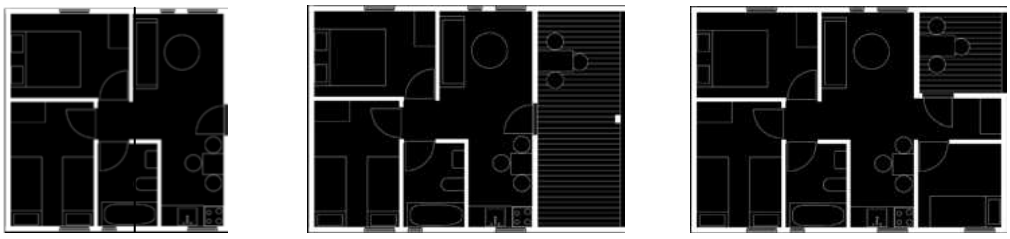
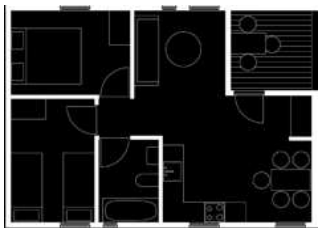
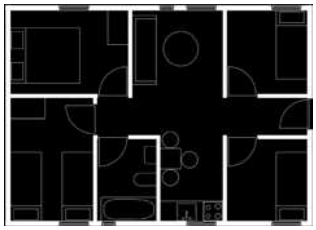


Figure 6: A Type 1 house assembled from prefabricated HPC elements



40 m2 basic model + 2 modules veranda 40 m2 + 2 modules veranda, extra room 50 m2





+ 2 modules veranda, larger kitchen 50 m2 + 2 modules 2 extra rooms 56 m2

Figure 7: The five variants of the Type 1 house (Figures 6 and 7 have been taken from a sales offer to the South African Housing Programme)

6.2.2 Knowledge transferred back to the high-end platform

A lot of knowledge has been gained when making the low-cost product platform. Some of the key learning points were:

- Even though there were only a few choices the customers could make, when ordering a house, the offered variety appeared to be suitable for this market segment. This will result in a review of the high-end product platform, to ensure that customers are not offered an infinite degree of variety and that the financial contribution per variant is high enough. Non-profitable variants should be removed from the platform
- Starting the low-cost product platform from scratch, rather than trying to take the high-end product platform as a starting point for scraping off layers, turned out to be the right decision. In hindsight, it is our belief, that it would not have been possible within the given timeframe to achieve the cost goal per unit using this approach
- This was the third product platform the case company developed. Since the high-end and insulation panel product platforms were well defined and linked to the company strategy, developing a third product platform took considerably less time. The experienced staff and the right software tool support, such as the use of product configuration systems (Bonev and Hvam, 2012), contributed strongly to the fast development of this platform

7. Conclusion

In this article it has been described how a low-cost product platform has successfully been developed and implemented in the low-cost housing segment within the construction industry. The houses based on this platform are built up in a modular approach, where modularity has been achieved both on element and on building level, resulting in buildings which can be delivered in several types and variants. The main difference compared to a coexisting high-end product platform is the high degree of standardisation and the limited number of commercial variants, which has been adapted according to the requirements of this market segment. Besides, the application of requirements management as described by INCOSE has resulted in working descriptions containing much less text, but with more pictures and drawings instead. This positive attempt to use product platforms in the low-cost segment of the construction industry confirmed the main hypothesis of this research (Section 1) and shows that the product platform approach is a valid strategy for meeting the low cost

housing demand of developing countries. Hopefully the described case inspires other construction companies to introduce a product platform concept for their products.

Despite the promising results, further research is needed in the following vicinities: Since there is a high need for decent housing, smart solutions have to be found for quickly producing a high amount of houses, which are cheap and long lasting. If companies find a way of addressing this issue in a profitable manner, they are more likely to participate in this enormous task. At the same time it is important that the applied housing solutions are sustainable, as according to EU, 2010, residential and commercial buildings are responsible for about 40% of the total energy consumption and 36% of the total CO_2 emission in the European Union. Other parts of the world will soon face similar situations to those described above, if there is no sufficient focus on sustainability when producing such a vast amount of buildings. To this end, further research is needed in how product platforms, by means of effective development and production, can further contribute to the low-cost housing segment and to the construction industry in general. Finally, it is necessary to further optimise the economy of sustainable low-cost housing based on life cycle considerations. Once this has been done, it has to be examined how the gained experience can support in maximising the high-end segment in countries like Denmark.

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A Case Study of the Glen Acres University / Community Partnership to Reduce Energy Consumption in Existing Housing

Mark Shaurette, PhD[1]

A Case Study of the Glen Acres University / Community Partnership to Reduce Energy Consumption in Existing Housing

Existing building stock in the developed world is responsible for approximately 40% of all energy consumption. Replacement of the existing built environment with more efficient structures is not only impractical but also abandons much of the embodied energy already present in the extant materials. As a result, attempts to significantly reduce the operational energy consumption in existing buildings must be based on a combination of energy related retrofit of existing buildings and behavioural changes by the building's occupants.

Due to the common attributes of existing residential buildings, this sector offers large scale opportunity for energy related retrofit. Nevertheless, while the technologies for insulation, climate control, lighting, consumer appliances, and water consumption common to domestic structures are often similar within communities, many complicating factors exist which limit production scale energy retrofit. Unlike new housing construction which has, in many parts of the world, become uniform and systematized, energy related housing retrofit is done on a per house basis and continues to be restricted in scope. The limitations stem from a fragmentation of ownership, a dearth of construction organizations offering whole-house energy retrofit as a primary service, limited funds to advance the process, and housing valuation practices that fail to recognize the value created by energy related retrofits.

This paper is a detailed examination of a community-wide energy retrofit project which was financed using stimulus funds from the U.S. government and distributed to a small community adjacent to a major research university. The original concept of market transformation for energy retrofit expected from the program is presented along with the university's participation in program design, program management, related educational activities, student involvement, and resulting benefits to both the university and the community. In addition, some unexpected challenges which continue to constrain market transformation for energy retrofit are included.

Keywords: Energy Conservation, Community Partnership, Market Transformation, Retrofit, Housing, Stimulus Funds

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1. Introduction

Buildings are tremendous users of electricity, accounting for more than 72% of electricity use in the United States. This contributes 39% of the carbon dioxide (CO_2) emissions in the United States per year, more than either the industrial or transportation sector of the economy (The U.S. Green Building Council, 2009). Adopting energy conserving measures and alternative sources of energy production for use in buildings offers vast opportunity toward reaching the national goal of energy independence and reducing climate change.

An October 2008 report of the National Science and Technology Council titled *Federal Research and Development Agenda for Net-Zero Energy, High Performance Buildings* notes the general lack of informational guides and incentives, and the misinformation that exists about energy consumption in buildings. The report recommends effective technology transfer through improved tools and guides, education and training, and market-based building valuation metrics. The basis for this technology transfer would be research and demonstration coupled with private industry activity. This paper describes a program that provides a vehicle for the suggested education and technology transfer specifically targeting residential properties and the conditions encountered in the State of Indiana, USA.

The City of Lafayette, located in a small metropolitan area of less than 200,000 residents, was awarded grant funding from the U.S. federal government for approximately 80 energy conserving retrofits in the Glen Acres and Vinton communities through a retrofit ramp-up program. Lafayette administered these funds through the use of staff currently employed under a Comprehensive Neighborhood Revitalization Fund for Glen Acres. The fund for this Neighborhood Stabilization Program (NSP) financed the acquisition of foreclosed properties that are rehabilitated for sale to low income individuals. As the primary outreach vehicle for the retrofit ramp-up program, this NSP funding facilitated the acquisition of a home for a deep-energy retrofit demonstration.

The neighbourhoods of Glen Acres and Vinton are comprised of starter homes built from 1950 – 1970. A significant challenge for market transformation in these communities was the limited ability to communicate directly with homeowners. Because Glen Acres and Vinton are conventional post World War II first ring suburban communities, no community centre or other social meeting place is available for marketing outreach. As a result, no venue existed for the purpose of educating homeowners about the benefits of energy conserving retrofits or available opportunities for grant assistance to implement appropriate retrofits for low income homeowners.

As part of the Lafayette program, ultimately named the Lafayette Energy Assistance Program (LEAP), outreach opportunities and potential for homeowner education was provided by a high-profile, deep-energy retrofit demonstration home located within the Vinton community. The use of a deep-energy retrofit demonstration home within the community provided marketing outreach needed to encourage participation by community homeowners. Locating the home within the community helped to make grant implementation convenient for the community within a location appropriate for social interaction, and provided a path for bringing the retrofit program message to individuals who may not be exposed to it in the

mass media. The demonstration used established energy conservation retrofit strategies as well as alternative energy sources, some of which are beyond the current capability of participating homeowners to adopt, to draw as large an audience as possible. The program exposed homeowners in the target neighbourhoods and the larger Lafayette community to currently available retrofit technologies as well as the available grant incentives.

In a December 2010 review of U.S. whole-home retrofit programs, the National Home Performance Council noted that utilities sponsored the majority (113) of the 126 whole-home retrofit programs identified in the study. Of this group, 38 met the home performance guidelines of the Energy Star program sponsored by the U.S. Department of Energy (DOE) and the U.S. Environmental Protection Agency (EPA). To receive a Home Performance designation under the Energy Star program all of the following components must be included in the program. Similar components were used for the LEAP, specifically:

- An assessment of the home by a certified energy specialist using visual and diagnostic methods;
- A set of recommendations for improving the home based on the assessment;
- Assistance for homeowners in identifying contractors who can implement the recommendations;
- Verification that work was installed and that health and safety issues were addressed; and
- Quality assurance measures.

The following narrative presents a synopsis of the Lafayette Energy Assistance Program (LEAP), how it was conceived for funding by the U.S. Department of Energy (DOE), and the basic program implementation. The presentation of case study material introducing the program description and a narrative discussion of steps taken by local program administrators is intended to be instructive for those wishing to develop and implement similar community-scale retrofit programs. This case study is limited to the experiences of the author who has served in the role of technical advisor to the City of Lafayette during the initial funding request period and program administration.

2. Partnership Funding and University Participation

As part of the economic stimulus program in 2009 the U.S. government chose energy efficiency as an area where federal funds could be expended to achieve multiple goals. The funds appropriated by the American Recovery and Reinvestment Act of 2009 were primarily intended to stimulate the economy and create jobs. The Energy Efficiency and Conservation Block Grants (EECBG) Program, funded for the first time by the Recovery Act, supported a Presidential priority to promote energy efficiency and the use of renewable energy technologies. Using up to $453.72 million in Recovery Act EECBG funds for a funding opportunity announcement (FOA), the Retrofit Ramp-up Program was initiated.

Purdue University saw the Retrofit Ramp-up Program as an opportunity to utilize the skills and resources available in the College of Technology Department of Building Construction Management to assist the limited staff available in the City of Lafayette obtain support from this funding opportunity. The City of Lafayette’s close proximity to campus and recent

collaboration to seek funding from the State of Indiana for an energy related retrofit demonstration home, which generated interest but was not funded, led to a partnership to develop a Retrofit Ramp-up proposal. Although Lafayette was eligible to receive funding, it was necessary to team with the City of Indianapolis, the nearest major metropolitan area, to generate a funding request large enough to meet the program requirements.

The proposal was chosen as one of 25 awards throughout the US in April of 2010. Indianapolis received a grant totalling $10 million of which just over $1 million was allocated to the City of Lafayette. Although no grant funds could be expended beyond April of 2013, delays in final program guidelines from the Department of Energy prevented the agreement between Purdue University and the City of Lafayette from being drafted until late summer of 2010. Purdue University as a subcontractor to the City of Lafayette, a sub-grantee, was relieved from many of the reporting requirements of the program, but retained a substantial requirement to assist the city as the primary advisor to the program.

The City of Lafayette community development and redevelopment departments cooperated in choosing a neighbourhood for the retrofit ramp-up that would facilitate community-wide housing retrofit for improved energy performance. Retrofits would be funded through grants to low income homeowners with the deep-energy demonstration of housing retrofit serving as a highly visible example of possible outcomes in a typical neighbourhood home. The Glen Acres and Vinton communities are located in an area with a significant number of foreclosed post World War II homes that are appropriate for energy retrofit. Funds from a U.S. government Neighborhood Stabilization Program (NSP) grant to the City of Lafayette for a comprehensive redevelopment of the same communities was used to provide the necessary city planning staff to complete the project.

The NSP funding is intended to finance the acquisition of foreclosed properties that are then rehabilitated for sale to low income individuals. This financing provided the means for Lafayette to purchase a deeply discounted home in foreclosure that would serve as the basis for the deep-energy retrofit demonstration. The two programs utilized had different but compatible goals. The DOE Retrofit Ramp-up Program, later renamed Better Buildings, had the major goal "*to stimulate activities that move beyond traditional public awareness campaigns, program maintenance, demonstration projects, and other "one-time" strategies and projects … to stimulate activities and investments which can 1) Fundamentally and permanently transform energy markets in a way that make energy efficiency and renewable energy the options of first choice; and 2) Sustain themselves beyond the grant monies and the grant period by designing a viable strategy for program sustainability into the overall program plan*" (Department of Energy, 2009). Others have noted the urgency of energy market transformation that is outlined in the Retrofit Ramp-up funding opportunity because "*The full deployment of cost-effective, energy-efficient technologies in buildings alone could eliminate the need to add to U.S. electricity-generation capacity*" (National Academy of Sciences, 2010).

In contrast, the NSP funding goals sought to stabilize neighbourhoods experiencing significant foreclosure activity through community infrastructure improvements and elimination of vacant housing units. The NSP directly funded housing renovation, or in some

cases, demolition. Because NSP funds were available to improve both the physical condition as well as the current market viability of the home selected for the deep-energy retrofit, the demonstration home was able to showcase the cosmetic and lifestyle upgrades often chosen by homeowners along with the energy related retrofits being funded under the DOE program. Combining these two grants provided a showcase for a whole-house view of refurbishment services. Whole-house retrofits provide savings in cost and complexity by completing energy conserving measures at the same time that repair or cosmetic upgrades are implemented. A significant example of this was experienced in this case of the deep-energy demonstration home. Air sealing and insulation upgrades were completed with lower cost and complexity because the exterior siding for the home was already being replaced.

In parallel with technical research for selection of energy conserving measures (ECM) for the deep-energy retrofit demonstration by faculty and students at Purdue University, a weekly meeting was held with the builder and the NSP program manager. The ECM selection was based on the following guiding principles:

- ECMs should be appropriate for most homes in the communities
    - Easy for local building trades to understand and install
    - Materials available through traditional supply channels without delay
    - Performance was assessed from a whole-building viewpoint
    - With near term potential for positive payback but with no specific cut-off
    - Priority was given to retrofits that could be funded by program grants
    - Promote energy conservation first with introduction of alternative energy sources only when energy consumption has been minimized
- ECMs obvious to visitors and individuals that passed by the demonstration home were desirable for program visibility and ease of endorsement

The combined management of the NSP funding and the DOE funded grants for the Lafayette Energy Assistance Program created a positive synergy. Nevertheless, the local program manager initially involved with the NSP program possessed little knowledge of building technology or energy related construction and at times exercised poor financial management. Delays resulted that prevented the construction activity from progressing at a normal pace. Because of these delays, it was not possible to use the demonstration home as originally intended. A change in the program manager position by the City of Lafayette was made after approximately six months, but the LEAP was well behind schedule.

The intended use of the demonstration home was to provide the LEAP marketing outreach. Glen Acres and Vinton are communities with substantially more low-income and minority population than the overall Lafayette population and no venue exists within the communities for the purpose of educating homeowners about the benefits of energy conserving retrofit or available opportunities for assistance in financing and implementing appropriate retrofits for their home. The construction delays prompted the feeling that the demonstration home alone could not be counted on as a source of community outreach. To overcome this possible shortcoming, signage at the building site, frequent public service press and radio releases through Purdue University press outlets, meetings at a community school advertised by neighbourhood signage, and word of mouth from early grant recipients helped to keep the grant program on track.

3. The Deep-Energy Retrofit Demonstration Home

A detailed description of the ECMs chosen for the demonstration home is beyond the scope of this paper. The following list provides basic information about the ECMs.

Windows: R-5.56 triple glazed casement
Sun Tube: One in each bath with dimmer to provide daylight illumination
Exterior Doors: Insulated steel, thermal break frame, magnetic weather-strip, polyurethane core R-8.3
Crawl Space: Damp Proof w/ sealed 20 mil poly floor cover
Attic Access: R-40 insulated, weather-stripped attic closure system
Air Seal: Air seal all top plates and ceiling penetrations with closed cell foam
Expanding foam seal all exterior wall penetrations
Insulation: Attic – R-60 Loose Fill Cellulose
3" closed cell foam - 3' at roof edge (R-20+)
Crawl Space – 2" closed cell foam on interior of crawl wall and band joist (R-13+)
Exterior Walls – R-11 batts @ 2x3 wall cavity plus 4" (R-20) extruded polystyrene sheathing (2 layers of 2” foam with lapped and taped joints)
South Overhang: Extend to 16" for summer shading and add continuous vent
Hot Water: Heat Pump Water Heater min. COP rating of 2.0 or greater
Renewable Energy: Nominal 4 KW Solar PV System
Furnace & AC: multi-speed air handler, min. 25,000 BTU gas furnace, 1 ton AC
Mastic Seal All Ductwork
Energy Recovery Ventilator: min. 60% heat recovery, unit and ductwork installed in conditioned space
Thermostat: 7-Day Setback
Appliances:

Washer	Front Load	Energy Star Rated
Dryer		Energy Star Rated
Refrigerator	Top Freezer Model	Energy Star Rated
Dishwasher		Energy Star Rated

Lighting/Electrical: 44 circuit energy monitor, real-time internet energy use dashboard
All lighting CFL or T-8 florescent except LED kitchen task lighting
Window Coverings: Living Room Insulating Cellular Shades with air sealing tracks

Because the deep-energy retrofit home was also a NSP remodel project, the builder chosen to complete the work was a low bidder under the qualification rules of the NSP funding. They had a typical background in residential construction with no special expertise in energy related building. The weekly meetings used in the ECM selection process were an opportunity to provide the builder and some of his subcontractors with the technical requirements of the most unusual of the ECMs. A PhD student made weekly visits to the project site to meet with the builder, the program manager and any subcontractors or material suppliers involved that week. With the builder in charge of day to day work and quality control, occasional performance issues were anticipated.

While no serious quality control issues were apparent, several things did occur that are indicative of common oversights that can be experienced in energy related retrofit. To verify the energy performance of the demonstration house, an energy auditing firm was hired to complete a post-construction inspection using a blower door and duct blaster to confirm the success in air sealing the structure and ductwork. A preliminary use of the blower door was also utilized before completion of the interior wallboards. At this point the ceiling was complete and all air sealing measures were completed by the builder's subcontractors. Within a very short period of introducing negative air pressure to the structure, significant flows of cold exterior air were noted entering. Figures 1 and 2 are examples of a few of the many poorly sealed penetrations.

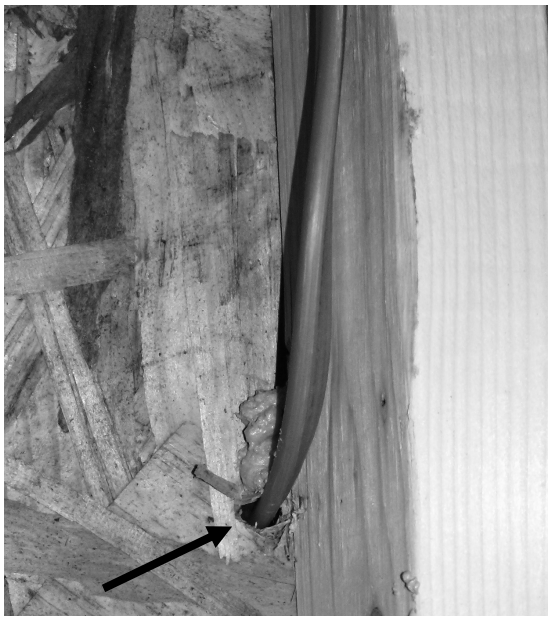

Figure 1: Poor Foam Air Sealing



Figure 2: No Foam Seal at Exterior Penetration

Failure to commission HVAC equipment is common in residential construction. It was no different in the demonstration home. The first time the air conditioning was turned on the air volume from the air handler was so high it caused significant noise within the home and caused papers to blow if located close to an air supply outlet. The multi-speed fan for the system was capable of servicing a range of capacities from 1.5 to 6 tons of cooling. Rather than setting the system for the design parameters, the HVAC installers left the factory preset values in place.

In addition to verifying the air infiltration and duct leakage of the completed demonstration home retrofit, the energy auditing firm completed a common U.S. home energy rating called the Home Energy Rating System (HERS). The HERS rating is an index using a score of 100 to represent the performance of homes based on a reference home built to meet the 2006 International Energy Conservation Code. A net-zero energy HERS home score is 0. The lower a home's HERS score, the more energy efficient it is in comparison to the HERS reference home. Figure 3 is the rating certificate with a score of 17 for the deep-energy demonstration home.

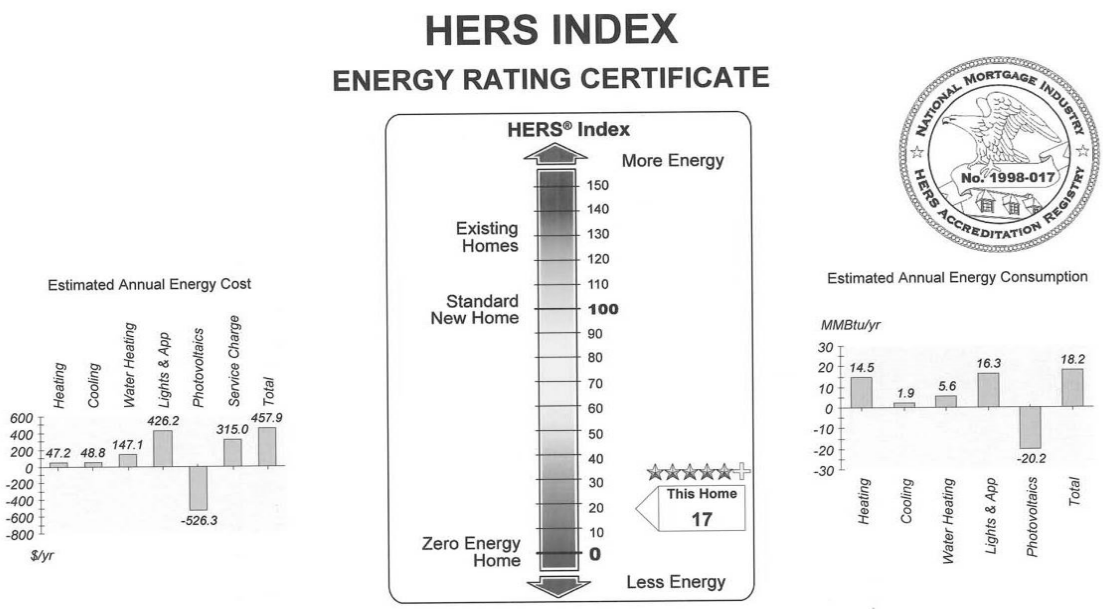

Figure 3: Demonstration Home HERS Rating Certificate

While it is not possible to separate all costs related to the energy related retrofits from the major modifications to fully rehabilitate the demonstration home, the final energy retrofit costs were 18% less than original budget for the deep-energy retrofit. Some saving came from carful selection and purchasing of ECMs, but the bulk of the savings resulted from the significant reduction of installed cost for solar PV systems that took place between 2009 when the initial budgeting was completed and the actual installation in 2012. The budget savings allowed three additional grants to be made from program funds for low income homeowners.

4. Program Educational Activities

Community outreaches were extensive for the deep-energy retrofit home and retrofit grants. A combination of press coverage, community meetings, open houses, printed handouts, displays, as well as educational seminars for homeowners, contractors and the academic community were utilized. Press coverage began as soon as the funding award was announced, generating interest almost immediately. This was followed by press releases from the City of Lafayette, Purdue University, and the media group in the College of Technology. Press releases were strategically timed to coincide with phases of the project and opportunities for community interaction throughout the grant period.

The most significant evidence of community interest came during the open house period in the summer of 2012. The deep-energy retrofit home was staffed by students every weekend. Newspaper and radio advertisement, as well as street signage and word of mouth contact throughout the community supplied a steady attendance. Weekly attendance ranged from 20 to 35, with visitors coming from the entire Lafayette metropolitan area rather than just the targeted neighbourhoods. The consistent attendance prompted the decision to extend the open house period several weeks beyond the original plan.

To extend the outreach penetration, the demonstration home was included in several activities not directly related to the LEAP. The first was inclusion as part of the International High Performance Building Conference at Purdue University in July of 2012. This conference included a short course on net-zero homes conducted by the author and several others from the College of Technology and a tour of the demonstration home open to all conference attendees. The researchers who attended the tour included individuals with interest in high performance buildings, HVAC performance, and compressor design. Several weeks later the home was included as part of the Parade of Homes conducted each year by the Builders Association of Greater Lafayette.

At each of the open houses and special events contact information was collected from individuals interested in more in-depth energy related retrofit education. Over 40% of the visitors provided contact information. This strong response is an indication of the keen interest the visiting homeowners had in learning more about how they can reduce the energy consumption in their homes. To accommodate this interest, a half-day educational seminar was offered for homeowners. Presentations were given on the following topic areas by the author and the PhD student who was involved with supervision of the deep-energy retrofit.

- Why save energy?
- Energy audit & testing
- Specific technologies to reduce home energy consumption
- Renewable energy systems for the home
- Energy use impact of landscaping, overhangs, site plans
- What to watch out for when contracting for a home energy retrofit
- Choosing appropriate energy conserving upgrades
- Energy Monitoring

The handouts and curriculum developed will be used for one additional wintertime open house and homeowner seminar. In the future these materials will serve as a template for anticipated educational outreach for other programs.

An additional half-day educational seminar was offered for contractors and suppliers using topics similar to the homeowner seminar. Greater technical depth was offered and the discussion was oriented to the concerns contracting organizations have as they consider business opportunities in energy related retrofit. Attendance at this seminar was built through the contacts that the Purdue University Department of Building Construction Management has developed by working on a number of projects with the Builders Association of Greater Lafayette.

5. Discussion

University and student involvement in the project provided benefits to the program outcomes, university community relations, future university research, and student growth. Without the participation of Purdue University, the City of Lafayette would not have initiated a proposal to obtain funds from the DOE retrofit ramp-up. The resulting grants allowed low-income individuals to reduce monthly costs to help them maintain homeownership in the two foreclosure prone communities. Purdue University received significant notice in the mass media for their participation, emphasizing positive public relations with the City of Lafayette.

Homeowner education provided detailed information for numerous individuals who did not obtain retrofit grants but were prompted to investigate energy efficient retrofits for their homes. These benefits to the community will continue to accrue for years to come.

Two graduate students and six undergraduate students were funded by the program to participate in planning, supervision or community outreach activities. In all cases these students learned a great deal about home energy conservation. In addition, many improved their skills in public interaction. One graduate student is completing his Master of Science thesis on measurements of success in energy use reduction from retrofit work supported by the homeowner grants. Additional research will be conducted on the deep-energy retrofit home performance and on long-term energy use of the homes retrofit through grants.

Despite all of the very positive outcomes of the LEAP partnership, not all of the goals of the original retrofit ramp-up concept have been realized. One of the original objectives of the Lafayette program was to reduce the risks that a single construction organization must undertake when they choose to provide energy retrofit services for smaller-scale projects. Most small construction organizations choose not to initiate whole-house energy services activity. They typically lack skills to assess, sell, and complete affordable residential building energy improvements that maximize energy savings for individual homeowners.

The need for market transformation based on contractor competency was emphasized in the conclusions of a 2008 report to the State of Vermont reviewing existing programs in the United States that attempt to eliminate first cost barriers for energy efficiency improvements in the residential sector. The report by Merrian Fuller makes six recommendations to the state. The only recommendation not directly related to financing energy related improvements was to expand the network of energy improvement contractors. The report's author felt that support and action was needed to train more contractors and their crews in a way that will increase the capacity of businesses to serve more customers. They also noted that the programs with the highest volume of energy related loans had a strong contractor network and included regular communication with the contractor network.

Within the Lafayette metropolitan area the number of contractors qualified to undertake whole-house energy related retrofits is very limited. In the two years prior to implementing the LEAP, the City of Lafayette had undertaken home renovations which included substantial energy upgrades under the NSP. Only three qualified construction organizations responded to the call for bids even though during this period an economic recession limited participation in other construction activity. The LEAP initially intended to attract small scale residential renovation contractors who would like to expand into energy services contracting. The potential for up to 80 government funded home retrofits in two contiguous communities provided strong market potential. If successful, at the end of the three year program a qualified group of whole-house energy services contractors would be operating in the Lafayette metropolitan area.

Subsequent to the final funding document preparation for the Lafayette award, the DOE administrators released guidance about applicability of Davis Bacon wage rules for retrofit activities. Davis Bacon is a series of related acts of the U.S. Congress administered by the

U.S. Department of Labor (DOL) which require all contractors and subcontractors performing work on federally funded contracts in excess of $2,000 to pay wages and fringe benefits equal or greater than the prevailing wages in the area of the project. In some geographic areas the prevailing rates are established wage rates paid to unionized labour. For small residential projects, the prevailing wage rates may not be heavily influenced by union negotiations. Nevertheless, the current Davis Bacon rules require substantial recordkeeping and reporting. These reporting requirements typically prevent small contractors from participation in federally funded work. As a result, all LEAP retrofit work for homeowners receiving grants were completed under the management of a large general contractor. This conflict of priorities constrained the growth of a viable small contractor base for energy retrofits. Market transformation through growth of a qualified group of whole-house energy services contractors in the Lafayette market did not take place.

6. Conclusion

This case study introduces one approach to the world-wide residential energy use challenge presented by the large number of individually owned and operated homes that were constructed when the energy consumed to operate these structures was not a consideration in design and construction. By combining multiple government programs, cosmetic and lifestyle upgrades were completed along with energy efficiency upgrades. This showcase for a whole-house view of refurbishment services where savings in cost and complexity can result from completion of energy conserving measures while completing other housing repairs or cosmetic upgrades is an example for both subsidized and market-rate retrofit.

The author's experiences with this case demonstrate the need for program managers that understands the complexity of energy related retrofit. The case also demonstrated that quality control is a major challenge to successful energy retrofit programs. Over the upcoming years both the demonstration home and the subsidized retrofit homes will be monitored for research to confirm the actual energy reduction benefits of the program.

Major benefits accrued to the Glen Acres and Vinton Communities but questions remain about how well the program achieved the originally intended goals. No market transformation took place to increase the supply of contractors pursuing energy services work. Contractor knowledge was improved somewhat, but for the overall city a skills gap persists. In the U.S., natural gas prices are falling, which offers little financial incentive for energy conserving retrofit. Homeowners continue to show a personal preference for visible upgrades. In addition, financing and valuation norms support visible upgrades while at the same time ignoring energy related upgrades. Contractors have no compelling reason to close the skills gap and sell energy related upgrades unless government programs finance the work and promote the energy related investment. In this case conflicting priorities from government wage rate support essentially nullified any incentives for contractors to participate.

Thirteen jobs were created by the program in the most recent quarterly report for the DOE grant (Department of Energy 2012), but job creation reporting was not required by small sub-recipients of funding such as the City of Lafayette. As a result, it is not clear if any

Indianapolis or Lafayette jobs were included in the report. Job growth was probably negatively impacted by the Davis Bacon wage rate recordkeeping and reporting requirements as well. These observations serve to demonstrate the potential for failure when competing regulatory interests are not considered in program design. The sharing of additional case study experiences as new energy conserving programs are developed and put into action is encouraged so that others can learn from the experiences and outcomes of each new program. Above all future programs need greater engagement of small contractors typically employed for residential retrofit in program activities. Engaging students in similar programs as part of their normal coursework is also advisable.

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What do we learn for our buildings' users?

Quentin Jackson[1]

Abstract

This paper presents a case study of users' responses to two commercial office buildings in NZ. The Meridian Building is a four storey 5,000m^2 5 Star Green Star – Office Design Version 1 rated building. The 15 storey Asteron Centre is a 33,000m^2 5 Star Green Star – Office Design Version 1 rated building, with the main tenancy receiving a 4 Star Green Star – Office Interiors 2009 rating.

Prior to commissioning the design of these buildings, both major tenants spent time understanding how their current office buildings were working and what they could learn from their staff about what makes their working environment productive, via a pre-occupancy evaluation. This was done using an occupant survey method developed by Building Use Studies (BUS) to assess occupant satisfaction with internal conditions of their existing premises, and to compare this with the Building Use Studies' New Zealand and international benchmarks.

Using this information, a Building Performance Specification (BPS) was created to help guide the design team with the goals, aspirations and required performance metrics the two tenants required. The design team was required to constantly report on their progress against this BPS throughout the design and construction period of the new buildings.

After a year of occupation of the new buildings (allowing staff a chance to get over the "holiday effect" of simply enjoying their new offices), the same occupant survey was applied to determine if the buildings met the performance requirements set down by the organisations during the design phase.

The results of these Pre and Post-Occupancy Evaluations allow building occupiers and managers to understand how a building is used by its occupants and to undertake optimisation of the building's systems. This can result in a building providing a more comfortable working environment for its users while potentially improving energy efficiency.

Keywords: Green, Evaluation, Occupancy, People, Performance

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1. Introduction

How often do we actually not only ask people what they think of their work environments and how it affects them, but actually follow up? More often than not, as designers we rely on the absence of feedback to imply that our designs are successful in providing a productive work environment and meeting users' needs.

The investment in office buildings (and indeed other building types) is now being driven by more than just capital expenditure. Investors, developers, building owners and tenants are looking for buildings that improve productivity, have low environmental impacts and are good long term investments. Leaman (2005), in his paper on 'What the Users Say', stated "Buildings which work well in all three categories are very rare - one in a hundred is an optimistic estimate".

Two New Zealand organisations, Meridian Energy (Meridian) and the Department of Inland Revenue (IRD), recognised early on the need to provide productive workplaces for their staff. They employed Environmentally Sustainable Design (ESD) consultants to undertake evaluation of their staff so as to understand how their existing office buildings were working, and what they could learn from their staff about what makes their working environment productive. Both Meridian and IRD were looking to move into new buildings and create new head offices for their respective organisations, and wanted to help guide the design team.

This paper presents the results of the 'pre' and 'post' occupancy evaluations of the Meridian and IRD office staff in Wellington, New Zealand and what lessons we can learn from these buildings' users.

2. The Buildings

2.1 The Meridian Building

Completed in 2007, the Meridian Building is a four storey 5,000m^2 5 Star Green Star – Office Design Version 1 rated building. Meridian Energy occupies all office floors of this landmark building on Wellington's waterfront in New Zealand. It was one of the first buildings in New Zealand to achieve a Green Star rating from the New Zealand Green Building Council.

This building provides Meridian with accommodation aligned with the company's focus on positioning itself as a global reference company in renewable energy. The project had goals to achieve ambitious targets of using 60% less energy and 70% less water than comparable buildings at the time.

The key features of this building include:

- a 'mixed mode' ventilation system allows operation using natural ventilation when conditions are appropriate, or energy efficient HVA C mode with enhanced ventilation rates;

- over 90% of office area within 8m of an external view, with high levels of daylight to over 60% of the office areas;
- a climate responsive active façade that automatically adjust to suit ambient weather conditions, with ventilated double-skin façades and automatic retractable blinds, plus fixed and motorised solar shading systems;
- an active chilled beam HVAC system, with energy recovery ventilation; and
- low volatile organic compound and low formaldehyde materials used throughout.

2.2 The Asteron Centre

The IRD are major tenants in the Asteron Centre. It is currently the largest office building in Wellington, New Zealand with a floor area of 48,000 m^2, 12 office floors and has achieved a 5 star Green Star Office Design v1 rating. The building incorporates ESD principles in the water, heating, lighting, ventilation and building management systems.

The client for this project was a leading property developer and a long term building owner so whole of life costs and sustainability were critical drivers for this development. By using an innovative active chilled beam air conditioning system with heat pump chillers and sophisticated lighting controls, this building that consumes significantly less energy and other resources than comparable buildings in Wellington.

Key features of this building include:

- Harvesting and reusing storm water for flushing toilets;
- waste heat from the cooling process is used to provide heating to the building and to preheat the domestic hot water;
- 50% greater than code levels of fresh air with CO_2 monitoring;
- low volatile organic compound and low formaldehyde materials used throughout;
- occupancy and daylight sensors that dim and turn off lights when not required; and
- energy and water metering connected to Building Management System;

The fitout of the IRD floors has also achieved a 4 Star Green Star – Office Interiors 2009 rating.

2.3 Surveying People in Buildings

Evolved over decades of research and application, Building Use Studies (BUS) has developed a two page questionnaire occupant survey method to assess occupant satisfaction with internal conditions. It measures perceived satisfaction of the buildings; the survey asks 63 questions covering 12 areas. This survey is used to assess how the building performs on ten important variables (comfort, lighting, noise, design etc.).

The occupant survey originated from a full PROBE (Post-occupancy Review Of Buildings and their Engineering) process which also included a building pressure test and energy audit (see BRI Special Issue, 2001).

This survey method was used and successfully implemented because it is:

- easy to understand for most building users;
- quick to fill in (10 minutes maximum);
- rapid to administer (only takes a day);
- not a threat to anybody (managers can veto questions if they wish);
- a wide selection of coverage (over 40 variables);
- provides sufficient information for different viewpoints (e.g. architecture, building services, facilities management);
- has benchmarking capability;
- balanced between qualitative and quantitative data;
- reasonably easy to analyse, given the complexity of buildings;
- can be used by others;
- costs can be kept down, especially using the standard version; and
- uses a database, so data can be further interrogated if required.

Why do this? We are trying to find simple answers to difficult questions about buildings and their occupiers which will be of use to designers and managers in procuring and designing new buildings and to improve existing buildings.

The purpose of the survey is to provide occupants' feedback on the performance of the building, and to compare their ratings with the BUS international benchmarks. This benchmarking capability is by far the most valuable component of this survey method. It allows the survey recipient to understand where their buildings fits on a world scale and if a score of 5 out of 7 for lighting is indeed acceptable or not (for example).

The results of the surveys allow building managers to understand how the building is used by its occupants and to undertake optimisation of the building's systems. This in turn results in the building providing a more comfortable working environment for its users while potentially improving its energy efficiency.

3. Pre Occupancy Survey

Prior to commissioning the design of the new buildings, both Meridian and IRD spent time understanding how their existing office buildings were performing, and what they could learn from their staff about what makes their working environment productive (or not).

A 'Pre Occupancy' survey was undertaken of both buildings using the BUS Survey Method, this allowed benchmarks to be set for the design brief, lessons to be learned on what staff saw as helping or hindering their productivity in the building along with a raft of other performance metrics (albeit self-assessed).

BUS uses a number of scale types for assessing the buildings, generally a 1 – 7 point scale where 1 is "very poor" and 7 is "very good". Summary Indexes scores (measured on a -3 to +3 scale) were used to give a more detailed measure of building quality. Main study variables use three "Traffic Light" ratings - green shows that building is performing better

than the dataset, amber is the average, red shows the building is underperforming and that there is room for improvement.

3.1 Meridian Building Pre Occupancy Survey Results

The Pre Occupancy survey of Meridian's three existing buildings in Wellington was carried out in June 2005 (Building Workshop, 2005). There were 94 respondents to the survey giving a reasonable response rate of 65%.

Using the BUS overall rating system, BUS rated the buildings as "Average" (rated 4) on the 7-point scale, with 55 points on the 100-point scale. The Meridian Buildings scored as follows:

- Comfort Index (based on overall comfort, lighting, noise, temperature and air quality scores) of +0.13 (just above average).
- Satisfaction Index (based on design, needs, health and productivity scores) score of -0.2 (just below average).
- Summary Index of +0.06 (average). The Summary Index is a measure of building quality calculated by averaging the comfort and satisfaction indices.

Table 1 summarises the 'next level' scores for each of the main study variables.

Table 1: Meridian – Summary Results for Main Study Variables

Study Variable	Traffic Light Rating	Mean Score
Comfort Overall	🟡	4.32
Temperature in Winter	🟢	4.54
Temperature in Summer	🟡	3.84
Lighting	🟢	4.70
Noise	🔴	3.72
Space at Desk *(value closer to 4 is better)*	🟡	3.70
Furniture	🟢	4.83
Availability of Meeting Rooms	🟡	3.70
Suitability of Storage	🟡	3.43
Design	🟡	4.59
Needs	🟡	4.49
Image	🟡	4.70
Health	🟡	4.54
Productivity %	🔴	-6.37

Overall Meridian staff didn't rate their existing premises well, with most scores either average or below. At the time of the survey the New Zealand benchmark for productivity was -1.87%, so this drove Meridian to set a goal of improving their productivity score in the new building.

3.2 IRD Building Pre Occupancy Survey Results

The Pre Occupancy survey of IRD's existing buildings in Wellington covered four separate buildings and was carried out in August 2006 (eCubed Building Workshop, 2006). There were 254 respondents to the survey, giving a reasonable response rate of 65%.

Using the BUS overall rating system, the buildings were rated as follows:

Table 2: IRD – Overall Ratings

Building	7-Point Scale Rating	100-Point Scale Rating
1	7 (Exceptional)	86
2	3 (Below Average)	32
3	5 (Above Average)	58
4	7 (Exceptional)	92

What was interesting in these surveys was that three out of the four buildings scored fairly highly, but comments in the surveys suggested otherwise.

As with Meridian Summary Indexes are used to give a more detailed measure of building quality (scores on a -3 to +3 scale), the IRD Buildings scored as follows:

Table 3: IRD – Summary Indices

Building	Comfort	Satisfaction	Summary
1	0.89	0.45	0.67
2	-0.37	-1.21	-0.79
3	0.10	-0.52	-0.21
4	0.94	0.70	0.82

Table 4 summarises the 'next level' scores for each of the main study variables.

Table 4: IRD – Summary Results for Main Study Variables

Study Variable	Building 1		Building 2		Building 3		Building 4	
	Traffic Light Rating	Mean Score	Traffic Light Rating	Mean Score	Traffic Light Rating	Mean Score	Traffic Light Rating	Mean Score
Comfort Overall	●	4.90	●	3.72	●	4.30	●	4.97
Temperature in Winter	●	4.77	●	3.87	●	4.14	●	4.70
Temperature in Summer	●	4.50	●	4.12	●	3.65	●	4.22
Lighting	●	5.22	●	4.22	●	4.86	●	5.17
Noise	●	4.35	●	3.45	●	4.45	●	4.94
Space at Desk *(value closer to 4 is better)*	●	4.52	●	3.47	●	4.20	●	4.59
Furniture	●	4.90	●	4.62	●	4.51	●	5.64

Availability of Meeting Rooms	●	4.50	●	3.00	●	3.77	●	5.28
Suitability of Storage	●	4.04	●	3.30	●	3.86	●	4.82
Design	●	5.02	●	3.25	●	4.32	●	5.30
Needs	●	4.92	●	3.31	●	4.32	●	5.57
Image	●	4.60	●	2.81	●	4.12	●	4.97
Health	●	3.81	●	3.22	●	3.13	●	3.41
Productivity %	●	-2.39	●	-11.88	●	-8.11	●	2.77

At the time of this survey the UK benchmark for 2006 was minus 1.87% (noting IR elected to go with an international benchmark dataset). The average productivity score for all buildings was minus 4.9%. This should be read to mean that 'occupants think the building reduces their productivity at work by about 5% compared with their experience of other working environments'.

As with Meridian, IRD were keen on ensuring that they provided a new facility for their staff that was as conducive to productivity as possible.

4. Building Performance Specification

The goals of both Meridian and IRD was that their new office buildings were to be designed with ESD principles in mind, with state of the art and appropriately valued solutions to services design, architecture, material choices and environmental management. Designs were also to be in line with Green Building Council Office Design rating tools (at the time of the Meridian Building a New Zealand tool was not yet available). The aims of the BPSs were to:

- review the design against current best practice in sustainable design;
- set measurable goals and targets for the sustainable design;
- set up a working process to be used by the design team to drive the sustainable design; and
- set up a project specific ESD worksheet to monitor and record the sustainable design process.

The projects were to include best practice and practical measures with respect to:

- energy efficiency;
- water conservation;
- healthy and sustainable materials;
- landscape and stormwater;
- site and transport; and
- ongoing operation of the building.

For both Meridian and IRD, the Pre Occupancy Evaluations were used to help create a Building Performance Specification (BPS) to guide the design team on the goals, aspirations

and required performance metrics they required. The design team was required to constantly check their progress against this BPS throughout the design and construction period of the new buildings.

ESD performance in use was also monitored initially on a monthly basis during the first quarter and then quarterly for the first year of operation with any fine tuning or corrective actions required being identified to meet performance targets.

5. Building Tuning

When a building reaches practical completion it is normally unoccupied. This means that the plant and systems are signed off at best under simulated operating conditions. The tuning process enables a building's plant and systems to be tuned to suit the building's actual operating conditions under full tenant occupancy. It also allows systems to be adjusted and optimised for energy efficiency and tenant comfort in a way that is not possible during the construction process.

Both Meridian and IRD ensured that as part of the contract for designing and constructing the building, there was a requirement for a one year fine tuning program. This program involved the owner/manager, construction company, services engineers (all relevant trades), services contractors (all relevant trades); and controls suppliers (mechanical and electrical).

The tuning process involved a number of investigations and processes which included:

- Investigating the Building Management System (BMS) – the tuning engineer gained an in depth knowledge of the BMS and based on their experience quickly established what systems appeared to be operating correctly and what did not.
- Detailed plant analysis – once the tuning engineer had established and dealt with any obvious system performance issues, an in-depth check was carried out on every piece of plant indicated on the BMS. During this process patterns became apparent which pointed to any problems with specific plant items or control logic.
- Daily visual checks – quick daily visual checks were carried out on the BMS. This helped the tuning engineer gain an understanding of seasonal weather effects on the building, enabling control logics to be adjusted as necessary to suit. It also indicated any zones or plant consistently underperforming which could then be further investigated.
- Sensors – sensors of all types were randomly checked for accuracy.
- Lighting controls – lighting controls and power meter checks including visual checks that lighting control systems were working. Checks included things like a visit externally to site at night to check the control systems had turned off all lights.
- Excessive power and water use – checks were carried out on plant or equipment fed from any meters indicating excessive power or water use. A key check was usually weekend power and water use which would indicate any zones using power that should not be.
- Meter calibration – cross checks between utility company meter readings and BMS meter readings were made.

- Tenant complaints – tenant complaints were investigated. This was limited to ensuring that plant in the relevant zone was working correctly.
- Time schedules – all plant time schedules were reviewed to ensure the plant operated for the correct periods and was not working after hours (as it should not usually be on at these times).
- Data recording – key data was recorded on a monthly basis and graphed for benchmarking purposes.
- Quarterly tuning reports – quarterly tuning reports were a vital tool of the tuning engineer and were used to provide in-depth on site performance checks. These checks were based on the investigations carried out by the tuning engineer. These reports included various tasks to be carried out including:
    - Water use checks e.g. things like toilet cisterns checked for leaks, meter accuracy checks etc.
    - Power usage checks e.g. lighting controls checked for areas, meter accuracy checks etc.
    - Cooling and heating tater flow check e.g. pumps, terminal unit flows etc.
    - Airflows e.g. AHUs, terminal units etc.
- User guide – a guide was produced (or updated if one already existed) at the end of the tuning process to provide ongoing guidance on the running of the building.

Substantial savings have resulted from the tuning, with the Asteron Centre building owner even commenting that the tuning bill is one of the only bills he has actually enjoyed paying as he sees real long term (and short term) benefits.

6. Post Occupancy Evaluation

After at least a year of occupation of the new buildings (allowing staff a chance to get over the "holiday effect" of simply enjoying their new offices) the same occupant survey was applied to determine if the new building had met the standards and requirements set down by Meridian and IRD during the design phase.

Of all the statistics produced from this survey, perceived productivity receives the most attention, although it is the most difficult to define and measure properly. Although productivity is based on occupants' subjective estimates of performance (there is no practical method of measuring productivity "objectively" in a building), the technique has been used across many buildings and gives a relative picture. Both Meridian and IRD saw this figure as one of the key variables in determining the success of the new buildings.

6.1 Meridian Post Occupancy Evaluation

The Post Occupancy survey of Meridian's new head office building in Wellington was carried out in August 2008 (eCubed Building Workshop, 2008). There were 111 respondents to the survey, giving a reasonable response rate of 57%.

With comparison to the original Meridian Buildings the new building scored as follows:

Table 5: Meridian – Summary Results Comparison

Rating	Original Building Score	New Building Score
7-Point Overall Scale	4	7
100-Point Overall Scale	55	100
Comfort Index	+0.13	+1.58
Satisfaction Index	-0.20	+2.58
Summary Index	+0.06	+2.08

Certainly from an overall summary perspective the staff in the new Meridian Building rated it as outperforming the former buildings.

Table 6 summarises the 'next level' scores for each of the main study variables.

Table 6: Meridian – Summary Results for Main Study Variables

Study Variable	Original Building Rating	New Building Rating
Comfort Overall	🟡	🟢
Temperature in Winter	🟢	🟢
Temperature in Summer	🟡	🟢
Lighting	🟢	🟢
Noise	🔴	🟢
Space at Desk *(value closer to 4 is better)*	🟡	🔴
Furniture	🟢	🟢
Availability of Meeting Rooms	🟡	🟡
Suitability of Storage	🟡	🟢
Design	🟡	🟢
Needs	🟡	🟢
Image	🟡	🟢
Health	🟡	🟢
Productivity %	🔴	🟢

Comparatively speaking, the new building outperforms the former Meridian office buildings in almost all areas, particularly perceived productivity. At the time of the survey in 2008 the New Zealand benchmark for productivity was minus 2.69%, with the international benchmark at plus 3.45%. The productivity score at the Meridian building is plus 8.96%. Therefore occupants think that the new building boosts their productivity at work by about 9% compared with their experience of other working environments. The Meridian Building was rated highly by staff, achieving a level of occupant satisfaction in the top ten-percentile of the 2007 BUS New Zealand Benchmark data-set relevant to comfort, and rated number two (out of the approximately 20 buildings surveyed at that time) in New Zealand of all the buildings surveyed. On this basis, the Meridian Building is considered very comfortable, with excellent scores for satisfaction and comfort and comparing well in the national and international markets.

6.2 IRD Post Occupancy Evaluation

The Post Occupancy survey of IRD's new head office building in Wellington was carried out in May 2012 (Aurecon, 2012). There were 805 respondents to the survey giving a reasonable response rate of 46%.

With comparison to the original IRD Buildings the new building scored as follows:

Table 7: IRD – Summary Results Comparison

Rating	Original (average) Building Scores	New Building Score
7-Point Overall Scale	5.5	6
100-Point Overall Scale	67	73
Comfort Index	0.12	0.61
Satisfaction Index	0.39	1.18
Summary Index	-0.15	0.90

Table 8 summarises the 'next level' scores for each of the main study variables.

Table 8: IRD – Summary Results for Main Study Variables

Study Variable	Original Building 1 Rating	Original Building 2 Rating	Original Building 3 Rating	Original Building 4 Rating	New Building Rating
Comfort Overall	🟢	🔴	🟡	🟢	🟢
Temperature in Winter	🟢	🟡	🟡	🟢	🟢
Temperature in Summer	🟢	🟡	🟡	🟢	🟢
Lighting	🟢	🟡	🟢	🟢	🟡
Noise	🟢	🔴	🟢	🟢	🟡
Space at Desk *(value closer to 4 is better)*	🟡	🔴	🟡	🟡	🟢
Furniture	🟡	🟡	🟡	🟢	🟢
Availability of Meeting Rooms	🟢	🔴	🟡	🟢	🟢
Suitability of Storage	🟡	🔴	🟡	🟢	🟢
Design	🟢	🔴	🟡	🟢	🟢
Needs	🟢	🔴	🟡	🟢	🟢
Image	🟡	🔴	🟡	🟡	🟢
Health	🟡	🔴	🔴	🟡	🟡
Productivity %	🟡	🔴	🔴	🟢	🟢

Comparatively speaking, the new building outperforms three of the four the former IRD office buildings in most areas, particularly perceived productivity. It rated at a similar level to one of the former buildings, with lighting and noise perceived as worse. At the time of the survey in 2011 the New Zealand benchmark for productivity was minus 1.93%. The productivity score at the Asteron Centre building is plus 2.18%. This means occupants think

that the building boosts their productivity at work by about 2% compared with their experience of other working environments.

7. Conclusions

The results from the IRD and Meridian projects has shown that using a collaborative design process, the buildings have achieved sustainability through the fundamentals of good design and delivered robust, effective systems that balance environmental concerns with financial constraints.

Increased comfort, productivity and health reported by staff in the new buildings could prove to save these organisations in the future by way of reduced sick days, absenteeism and increased productivity.

Some of the lessons learned on both projects support the culture shift that the "Soft Landings Framework" (Bunn R, 2009) suggests we need to undertake as designers to close the gap between expected and achieved performance:

- the need to have a better understanding of how buildings actually work;
- building users can provide valuable insight;
- review, brief setting and fine tuning result in higher quality building outcomes; and
- closing the loop with post occupancy evaluation provides valuable experience and lessons learned that can be fed back into exiting projects and future work.

No longer is "I have been doing it like this for years and had no complaints" an excuse for complacency within design teams, they must respond to what we are learning from our buildings' users.

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Is there a maximum age to be a construction worker?

Dieter Schlagbauer[1], Detlef Heck[2]

Abstract

The loss of physical capacity caused by age is of common knowledge. Looking at the changing age distribution in different countries everybody involved in the construction industry has to reconsider his own opinion of the aging workforce and therefore it is also one of the main topics for occupational health and safety.

Knowledge on ergonomics postulates a decline of physical working capacity in connection to the age of a person. Looking at the main indicators of workload – e.g. heart rate (HR), oxygen uptake (VO2) and energy expenditure (EE) - the ergonomic literature provides different limits, which can be calculated based on a person's age and other personnel parameters. Within this paper some key limits are presented to protect the workers from exhaustion and equations are provided to calculate limits for different ages. Afterwards different sources for the determination of the workload are demonstrated and compared to before presented limit values. It will be shown that for specific trades of the construction industry the workload exceeds the limits even within the group of young workers.

The combination of knowledge on workload specific data with the individual's limits can lead to a different work distribution. Additionally occupational health and safety goals can be reached, by preventing injuries, incidents and accidents when the workload is observed and maybe reduced used in the early stage of the project scheduling.

Keywords: workload limits, heart rate, energy expenditure, aging worker, OHS.

1. Introduction

Investigating the aging population it becomes clear that without any thoughts on the special needs and interests of elderly people, a lot of workforce gets lost for physical (high demanding) work. De Zwart et al. (1995) showed the problem between the decline of the physical working capacity and stable physical working demands (See Figure 1). Whilst the capacity decreases by referring age, the demands remain on the same level for the whole work life. Especially when no measures were set to take the age of labourers into account.

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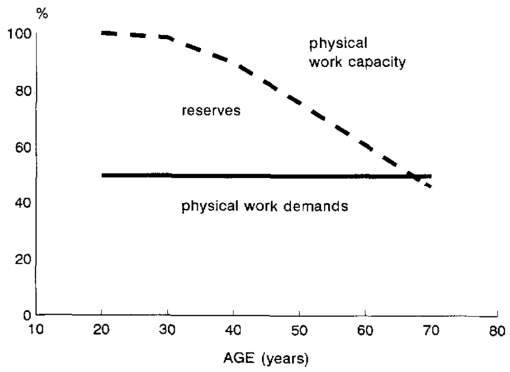

Figure 1: Relation between physical work capacity and physical work demands with age (Ilmarinnen et al. 1991 in: De Zwart et al. 1995)

Especially the construction industry with its high physical straining tasks - for example in refurbishment projects with little or no machinery support - could get into big troubles if the workload is not integrated in the work flow and task distribution planning process. The possibility to integrate workload into scheduling and distributing breaks according to the work flow was shown in different resources but hardly used until now.

2. Literature review

2.1 Aging of the population

The population of the world is still growing; it increased in the period from 1950 to 1970 by more than 50 %. Since 1975 two areas of growth can be seen: (1) in the developed countries (mostly found in Europe, North America, Asia and Oceania) the growth remained on a low level and in some countries a decrease started; (2) in the less developed countries (mostly found in Africa, South America) the population growth is on a high level and especially the growing of the city-population is much higher than in the developed countries. The current population of the world counts about seven billions people and prognoses say that it will rise until 2050 up to more than nine billions.

Beside the rise of the population the demographic dividend will be an important factor to have a reservoir of trained workers for the various economies in different countries. In the following figures the demographic dividend for the World, North and South America are displayed for the years 2010 and 2050 (US AID 2012):

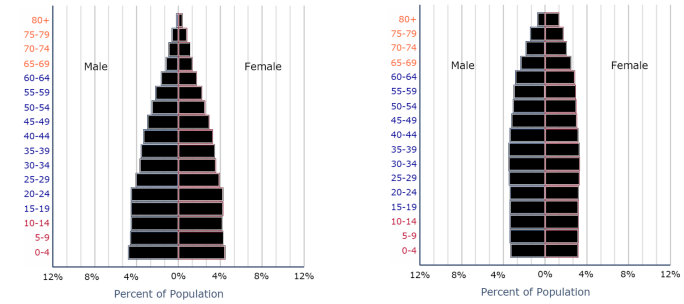

Figure 2: Demographic dividend for the population of the World in 2010 and 2050 (US AID 2012)

Comparing 2010 and 2050 for the entire world only a small change can be stated for the ages between 15 to 64 years: 2010 approx. 80% of the population and 2050 approx. 83%.



Figure 3: Demographic dividend for the population in North America in 2010 and 2050 (US AID 2012)

However when looking at individual regions, the change within 40 years can easily be seen: Examing a high developed region like North America, it can be seen that the change in the age distribution is not that big but the share of older people (> 64 years) is growing from 6.3% up to 9.5% of the population.

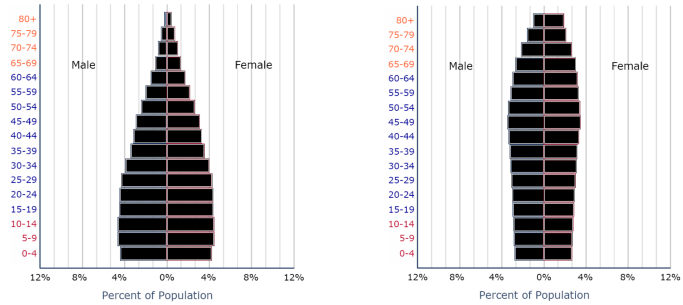

Figure 4: Demographic dividend for the population in South America in 2010 and 2050 (US AID 2012)

The trend in South America is much more recognizable and again the share of older people is growing rapidly (from 3.3% up to 8.4%). Additional to the demographic dividend the McKinsey Global Institute (2012) shows the distribution of global labor markets.

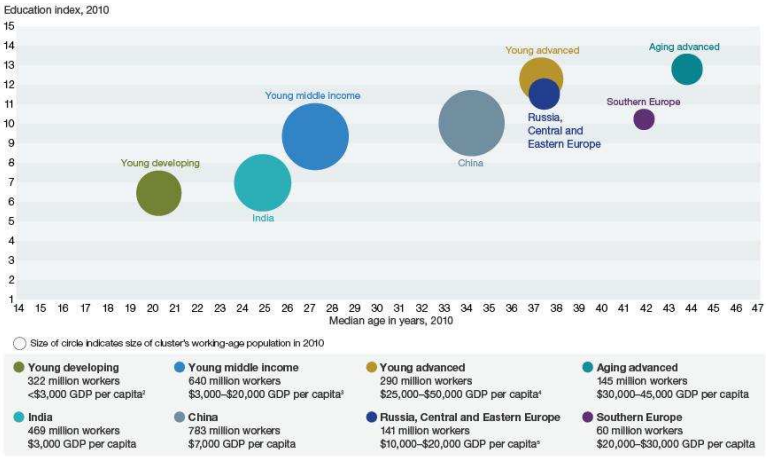

Figure 5: Global labor markets clustered and positioned in terms of age profile and educational attainment (McKinsey Global Institute, 2012)

Figure 5 presents eight clusters of labor workforce, positioned in terms of mean age and education. Again, a trend can be seen by a lower amount of older labor in the more educated regions worldwide.

2.2 Workload limits

These demographic changes are even worse for the construction industry, as within a lot of manually performed tasks have to be fulfilled and cause fatigue according to the level of strain. To keep the workload within an acceptable range different limits to protect labor work force a stated.

2.2.1 Individual limits:

These limits arise due to the physical conditions (e.g. age, weight, height and muscle strength) and can be defined as a value over the resting heart rate (HR_{rest} + 40 bpm) (Müller 1962; Kuhlmann 1986; Abdelhamid and Everett 1999) They can also be established by the heart rate at the first lactate turn point (HR_{LTP1}) (Pokan et al. 1997; Hofmann and Tschakert 2011; Wultsch et al. 2011) as well as the amount of the oxygen uptake ($\%VO_{2,max}$) (Åstrand 1960; Legg and Myles 1981) or the energy expenditure as a function of work time (EE(t)) (Bink 1962; Lehmann 1962; Wultsch et al. 2011).

1. Determination of HR_{LTP1}: An accurate determination of heart rate at LTP1 may only be provided through a cycle ergometric analyse, as the HR_{LTP1} depends on the individual. Even though, this limit was published the first time in 1994 (Hofmann et al. 1994), there is no general formula in the literature until now. Schlagbauer (2012) provided an equation based on seven studies investigating 17 different volunteer groups – resulting in a total of 458 participants – carried out by various literatures (Hofmann et al. 1994; Hofmann et al. 1995; Pokan et al. 1997; Hofmann et al. 1997; Hofmann et al. 2001; Hofmann et al. 2005; Wultsch et al. 2011). The result was a highly significant correlation (p-value ≤ 0.001) for the multiple regression analysis of the data series for P_{max}, HR_{max} and HR_{LTP1}, which leads to the following equation:

$$HR_{LTP1} = 2{,}420 + HR_{max} * 0{,}635 + P_{max} * 0{,}018 \quad (1)$$

   Therefore the determination of the maximum power (P_{max}) can be undertaken by laboratory tests but these are not always executable; instead the expected maximum power ($P_{max,\ calc}$) can be predicted as an approximation using weight (W), height (H) and age (A) for male by the equations (Wonisch et al. 2008):

$$P_{max,calc} = 6{,}773 + 136{,}141 * KO - 0{,}916 * KO * A \quad (2)$$

$$KO = 0{,}00714 * W^{0{,}425} * H^{0{,}725} \quad (3)$$

2. For the limit of VO_{2max} Legg und Myles (1981) presented an overview and stated levels between 21 % and 50 % depending on the research design and the investigated

volunteers. Åstrand (1960) did the only investigation connected to the construction industry and set the limit at 40 % VO_{2max}; therefore this limit will be used later on.

3. Using the energy expenditure (EE) as a limit, Bink (1962) introduced an equation to calculate the maximum working energy expenditure (WEE) according to the length of the workday (t) and the individual aerobic capacity (a) based on the findings of Åstrand (1960):

$$WEE=[\log 5700- \log (t)]/3{,}1*a \qquad (4)$$

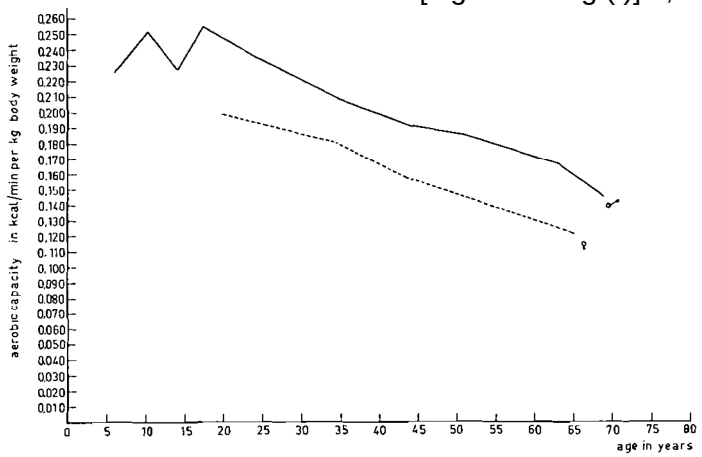

Figure 6: Aerobic capacity according to Åstrand (1960)

2.2.2 Absolute Limits:

Established literature also provides limits which are stated for all laborers, independently on the workers physical conditions. The best known limits are the mean heart rate of a 8h workday ($HR_{mean,8h}$) (Brouha 1967; World Health Organization 1969), the volume of oxygen uptake (VO_2) (Abdelhamid and Everett 2002) and the energy expenditure (EE) (Müller 1953; Lehmann 1962; Bink 1962; Legg and Myles 1981; Oglesby et al.1989; Åstrand and Rodahl 1986):

1. The limit of the heart rate is set for 110 bpm as the mean heart rate for 8 hours of work according to the finding of Brouha (1967) by the world health organization (1969).

2. The limit for VO_{2max} is set for 1 l/min as the mean amount of the oxygen uptake for an 8 hour work day Abdelhamid and Everett 2002).

3. The Limit for the energy expenditure (EE) was set with 5 kcal/min as the mean energy expenditure for an 8 hour workday (Oglesby et al. 1989). This value includes a basal metabolism value of 1 kcal/min. Additional Mueller (1953), Lehmann (1953), Bink (1962), Legg und Myles (1981) and Åstrand und Rodahl (1986) presented investigation results for WEE (8h) and set a value of 4 kcal/min.

Taking one of these limits, it is the decision of the user which kind of problem he wants to solve: (a) using the absolute limits the individuality of a person is negotiated but these limits can be used easily for a lot of people; (b) using the individual limits it is much more an intrusion into privacy and some very personal information has to be used or tests have to be

computed. Also the effort to calculate the limit for every individual rises enormously when computing the limits for a lot of laborers.

This shows that both methods have their fields of application but when the decision is made for one of the limits the circumstances and limitations should be kept in mind. The later application of different limits will show the big differences that can occur using them.

2.3 Impacts by age on the limits

The age has an effect on a lot of biological measures (see figure 7); in connection within the above presented limits the maximum heart rate (HR_{max}), the maximum oxygen uptake (VO_{2max}) are two important parameters which decline with the age of a person.

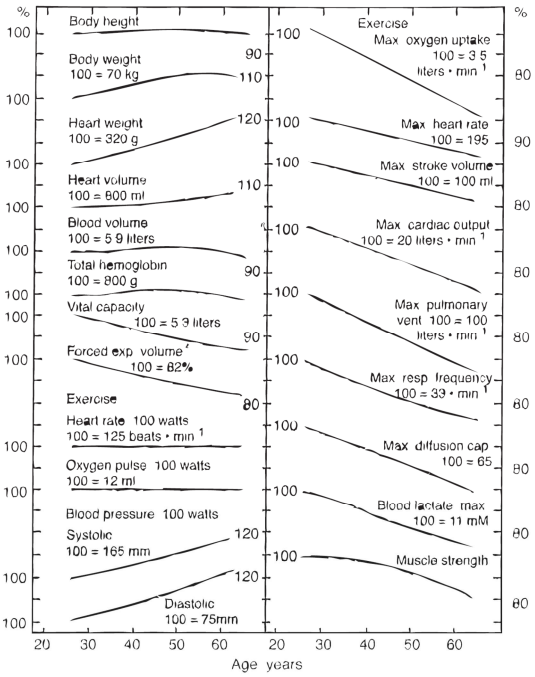

Figure 7: Variation in some biological measures with age (Åstrand 2003)

2.3.1 Calculation of the maximum heart rate (HR_{max})

The calculation of HR_{max} can be performed by using the formula by Åstrand (1960):

$$HR_{max}=211{,}30 - 0{,}922*Age \quad (5)$$

It can be seen, that the age is for this parameter the only and directly connected influence and therefore a problem can arise when a limit is set without a regard to the age.

2.3.2 Calculation of the maximum oxygen consumption ($VO_{2\,max}$)

$VO_{2\,max}$ can be calculated based on three different methods:

(a) Jackson and Ross (1996) combined the influence of age, height, weight, sex and the trainings level (SRE, range 0-7) and discovered the following equation (6):

$$VO_{2,max}=[(56.363+(1.951*SRE)-(0.754*BMI)-(0.381*age)+ (10{,}897*sex)]*{}^{weight}/_{1000} \quad (6)$$

(b) Duque et al.(2009) combined height, weight, sex and physical activity during leisure (PALT, range 1-4) in equation (7):

$$VO_{2,max}=[(35.3377-(0.475411*BMI)+(0.155232*PALT)+7.98682*sex)]*^{weight}/_{1000} \quad (7)$$

(c) Bradshaw et al. (2005) used sex, age, body mass index (BMI), perceived functional ability (PFA, range 2-26) and current physical activity level (PA-R, 1-10) and explored equation (8):

$$VO_{2,max}=[(48.0730+(6,1779*sex)- (0.2463*Age)-(0.6186*BMI)+(0.7115*PFA)+ (0.6709*PA\text{-}R)]*^{weightt}/_{1000} \quad (8)$$

Like for the calculation of HR_{max} the age is also integrated in the equations for VO_{2max}which has a major impact on the parameter when used as workload limit.

2.3.3 Calculation of the maximum working energy expenditure (WEE)

Bink (1962) provided a formula to calculate the maximum working energy expenditure (WEE) in connection to the length of a workday. As an input he used the information of the aerobic capacity (a) according to Åstrand (1960), which can read off her drawing (see figure 6). Again the age is the only input variable for the aerobic capacity; looking at figure 6 a decline starting at the age of about 20 years can be found.

2.3.4 Estimating the resting heart rate

Identifying the resting heart rate (HR_{rest}) is not as quite simple as the determination of HR_{max} as there are no definite researches to determine HR_{rest} so far. For estimation, the numbers in table 1 can be used, as they present usual HR_{rest} for different training levels and ages.

Table: 1 resting heart rate according to age and training level (Topendsports 2012)

Resting Heart Rate for MEN						
Age	18-25	26-35	36-45	46-55	56-65	65+
Athlete	49-55	49-54	50-56	50-57	51-56	50-55
Excellent	56-61	55-61	57-62	58-63	57-61	56-61
Good	62-65	62-65	63-66	64-67	62-67	62-65
Above Average	66-69	66-70	67-70	68-71	68-71	66-69
Average	70-73	71-74	71-75	72-76	72-75	70-73
Below Average	74-81	75-81	76-82	77-83	76-81	74-79
Poor	82+	82+	83+	84+	82+	80+

2.4 Calculation of different limits based on the age of a construction worker

Using the equations presented above the limits for different ages were calculated as following. All input parameters were kept for all calculations at the same level and were therefore set as: sex: male; height: 185 cm; weight: 85 kg; SRE: 3; PALT: 2; PFA: 15: PA-R:

5; Training level: average. Using the equations 1 and 4 to 7 the results for different ages are presented in table 2:

Table 2: Limits for different age according to different literature

Age	HR_{LTP1}	$HR_{rest+40}$	40 % $VO_{2,max}$			WEE (8)	HR (8h)	$VO_{2,max}$	EE (8h)	WEE (8h)
	eq. (1)	Table 1	eq. (5)	eq. (6)	eq. (7)	eq. (4)				
	bpm	bpm	l/min	l/min	l/min	kcal/min	Bpm	l/min	kcal/min	kcal/min
18	130.65	110	1.62	1.09	1.63	7.22	110	1	5	4
20	129.41	111	1.59	1.09	1.61	7.13	110	1	5	4
25	126.31	112	1.53	1.09	1.57	6.78	110	1	5	4
30	123.22	113	1.46	1.09	1.53	6.63	110	1	5	4
35	120.12	114	1.40	1.09	1.48	6.19	110	1	5	4
40	117.02	114	1.33	1.09	1.44	5.89	110	1	5	4
45	113.92	115	1.27	1.09	1.40	5.60	110	1	5	4
50	110.82	116	1.20	1.09	1.36	5.45	110	1	5	4
55	107.72	115	1.14	1.09	1.32	5.16	110	1	5	4
60	104.62	114	1.07	1.09	1.27	5.01	110	1	5	4
62	103.38	112	1.05	1.09	1.26	4.86	110	1	5	4
65	101.53	111	1.01	1.09	1.23	4.42	110	1	5	4

The results presented in table 2 show the differences between the limits. Especially the individual characteristics have a big influence, but have no direct impact on the absolute limits.

3. Workload of construction work activities

After the identification of various limits, different sources for the workload of construction labor are presented. They will be compared to the calculated limits in table 1.
One source is Hettinger et al. (1982), who presented tables to calculate EE for different physical work. For the construction industry some of their results are presented:

Table 3: EE of different trades (Hettinger et al. 1982)

Work	Laying bricks	Concreting work	Reinforcement work	Preparation work
EE [kcal/min]	2.10-2.70	2.91-6.64	2.82-4.99	2.80-5.97

Combined with the distribution of tasks provided by Zimmermann and Haas (2009) a mean EE can be calculated. They stated that 39 % of the work day were main activities; 37 % were additional activities; 13 % were personnel depended interruptions (PI); and 11 % were other interruptions times (OIT). Setting an EE of 1.3 kcal/min for PI and 1.8 kcal/min for OIT a mean EE for the workday can be calculated with 2.38 for bricklaying and 8.43 for concreting work.

Abdelhamid and Everett (1999) also investigated the energy expenditure and presented different EEs: for bricklaying 2.5-4.0 kcal/min; for carpentry work 4.0 kcal/min; for resting on

the job 1.5 kcal/min; and for Painting inside 1.9-2.4 kcal. In a later paper Abdelhamid and Everett (2002) presented more values for EE and additional measurements of the heart rate (HR) for different trades, which are presented in table 4.

Table 4: Range of energy expenditure and heart rate by construction trade (Abdelhamid and Everett 2002)

Trade	Range of average energy expenditure	EE for the example worker (85kg)	Heart rate	
			mean	SD
	kcal/kg*min	[kcal/min]	bpm	
Bricklayer	0.028 - 0.055	2.38 - 4.68	104 □±□	10
Carpenter	0.031 - 0.081	2.64 - 6.89	109 □±□	23
Cement finisher	0.027 - 0.073	2.30 - 6.21	107 □±□	29
Drywall installers	0.035 - 0.062	2.98 - 5.27	114 □±□	21
Electrician	0.027 - 0.055	2.30 - 4.68	98 □±□	11
Glazier	0.042 - 0.048	3.57 - 4.08	120 □±□	2
Ironworker	0.019 - 0.071	1.62 - 6.04	112 □±	17
Laborer	0.023 - 0.084	1.96 - 7.14	115 □±□	15
Pipe fitter	0.022 - 0.064	1.87 - 5.44	105 □±□	12
Sheet metal worker	0.030 - 0.065	2.55 - 5.53	102 □±□	17

Schlagbauer et al. (2011) also investigated the load of bricklaying and concreting work and presented results of the observed working days for 8 laborers: (i) mean values for HR: 93.62 – 110.24 bpm; (ii) mean values for VO_2: 0.69 – 1.22 l/min; (iii) mean values for EE: 3.43 – 6.51 kcal/min.

4. Comparison of the investigated results with limits for different ages

In the next two figures different workload levels from the findings presented previously were compared to calculated limits presented in table 4:

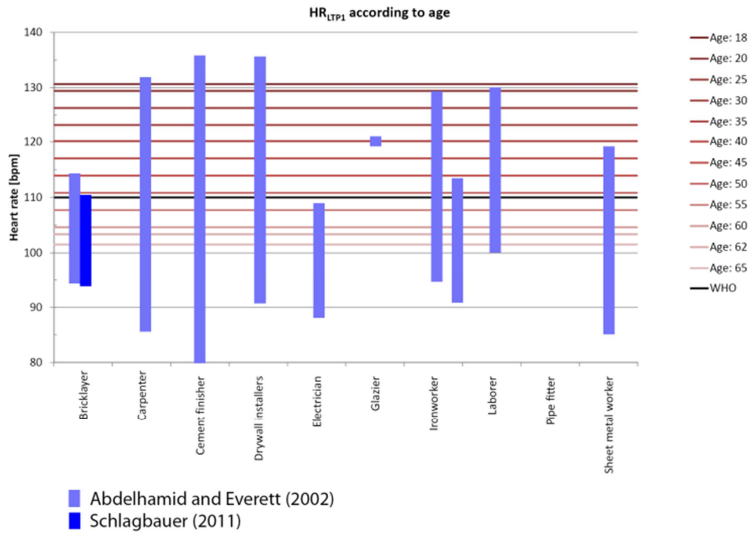

Figure 8: Comparison between HR_{LTP1} for different ages and workload of trades

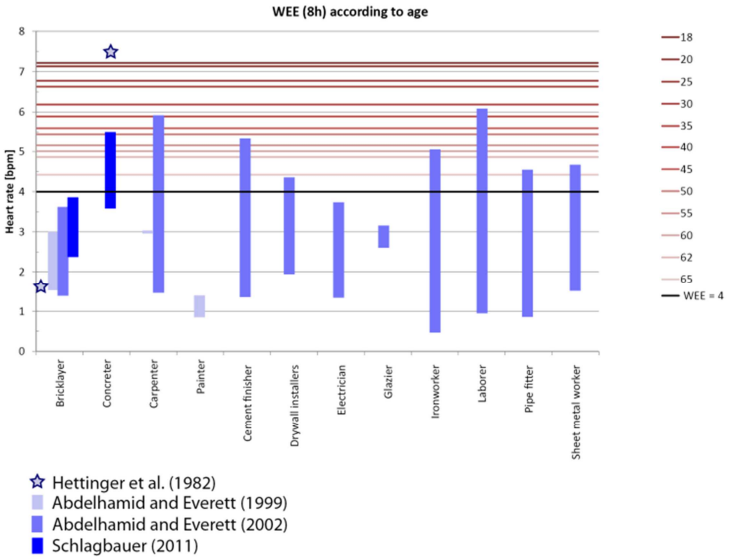

Figure 9: Comparison between WEE(8h) for different ages and workload of trades

Based on the facts presented in figures 8 and 9 it can be stated that by performing different trades the workload does exceed the individual and absolute limits.

Looking at the heart rate it becomes notable that for three of the presented trades (Carpenter, Drywall installers and Cement finisher) even the limits of an 18 year old worker are exceed and the maximum heart rate of all presented trades do exceed the limit of a 55 year old worker.

The comparison of the energy expenditure shows a slightly different result (see figure 7); five trades (bricklayer, painter, drywall installers, electrician, glazier) do not reach the calculated limit for an 65 year old healthy worker, but the absolute limit of 4 kcal/min is reached or even exceeded by nearly all displayed trades.

5. Conclusion

The loss of physical capacity according to a higher age is of common knowledge but within the construction industry until now only little investigated. But looking at the changing age distribution in the developed countries everybody involved in the construction industry has to consider the fact of the aging of the work force and how he wants to handle the change.

Beside the right work assignment health and safety of labourers is a main topic for the future. Different research results show, that when the workload is close to or over the individual workload level the injury, incident or accident rate rises disproportionately.

In order to prevent these increases in injuries, incidents and accidents the workload should be integrated into work flow planning and project scheduling. But until only a few useable data sets are provided but until now hardly used as they are often unknown by the companies. So, this has to be one of the goals for further researches: provide new and applicable information for all parties involved.

Using this knowledge the amount of money spent on healthcare and recovery training as well as absence time can be reduced and will have a positive impact on the whole economy. But it is important, that these researches don´t stay in the scientific community but were brought to the people who are affected by these solutions. There the unions in combination with insurance companies are requested to support and strengthen the starting researches worldwide.

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IS THE AGE OF FACILITY MANAGERS' PAPER BOXES OVER?

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Abstract

Seamless and accurate hand-over of building information is a major bottleneck in promoting an automated facilities management (FM) practice and an integrated and life-cycle-oriented construction. Few Building Information Modelling (BIM) tools have so far been developed specifically for facility managers. Current data input methods applied for conventional Computerized Maintenance and Management Systems (CMMS) are prone to duplicate information entries and information loss. Such an approach to data management builds up additional costs and seriously hampers fulfilment of environmental goals.

In search of a thorough acknowledgement of both technical and process-based requirements for dealing with the aforementioned deficiencies, this descriptive theoretical study takes a qualitative approach and focuses on status quo and potentials for migration of building information and analytical capabilities from AEC-centric BIM tools to facility managers, owners, and users. Data has been collected mainly through literature and workshops. It has been complemented by a number of exploratory studies on existing technologies. This is a basic research aimed at illuminating the path for further applied research activities.

Results show that the bulk of the FM sector still confronts substantial challenges regarding appropriate access to building information that is often caused by deficiencies with current workflows, contracts, and IT infrastructure. Thorough implementation of established and developing standards such as IFC and COBie to be used in BIM-enabled FM systems entails a complete shift from as-designed and as-built documents to their as-commissioned and as-operated successors. In an interoperable FM information system based on or closely connected to post-constructional BIM technologies, performance data, and sensor data from Building Automation Systems (BAS's) will be cycled back to inform both better design and better operation.

Keywords: FM:BIM, facilities management, BIM, CMMS, FM:BIM:BAS

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1. Introduction

The final destination of any construction project is its operation phase. Facilities management (FM) activities during the operation phase are key contributors to sustainable performance of the building (Ding et al., 2009). By average, every building operating firm annually spends $15 to $20 per square meter for energy purchase (Hodges & Elvey, 2005). Therefore, building owners increasingly strive for better control over resource utilization rates of their facilities (East, Bogen, & Rashid, 2012) aiming for a more economic, environment-friendly, and optimized FM experience. An efficient FM practice is also an influential business enabler that substantially increases corporation's return on investment (ROI) (Ding et al., 2009).

Implementation of Building Information Modelling (BIM) throughout the entire life cycle of the building benefits the owners the most among all stakeholders by significantly increasing the value of the information in their possession (Figure 1) and accruing the amount of ROI via an integrated project delivery process realized by use of BIM (Eastman, Teicholz, Sacks, & Liston, 2011; Khemlani, 2011; Sabol, 2008). The life cycle approach to building modelling and the ability for using the BIM model after design and construction also through the operation and maintenance (O&M) phase has been emphasized by many scholars (Tarandi, 2012; Khemlani, 2011; Young, Jones, & Bernstein, 2008).

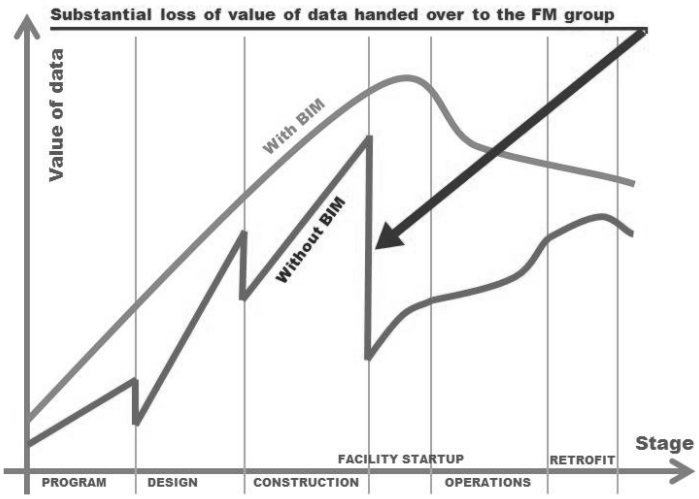

Figure 1: Comparative diagram of building information value degradation through the entire life cycle of the building with and without deploying BIM tools (after Eastman et al., 2011, p. 153).

The aim is to eliminate the delays, confusion, and inaccuracy generated by traditional O&M documents namely as-built drawings, O&M manuals, maintenance schedules, room datasheets, asset performance data documents, and cost datasheets in either paper format or static digital formats such as Portable Document Format (PDF) and scattered spreadsheets (Schevers et al., 2007). This enables the owners to make intelligent and informed decisions in the pursuit of strategic management e.g. choosing between in-house and external contractors and suppliers for specific services (Ding et al., 2009; Young et al., 2008).

1.1. Background

While the dominant challenge of recent decades for facilities knowledge management practitioners has been replacing paper documents by digital equivalents, now they seem to be keen to go even one step further towards more intelligent and interoperable tools and techniques by fully expelling manual data entry and retrieval work. Moreover, the ever-increasing capacity of computers perpetually underpins development of more complete and accurate building models (Ding et al., 2009) and FM systems.

Advert of BIM in building design and its propagation to construction both demanded and facilitated a better coordination and automated interaction among *as-designed* and *as-built* documents (Owen, 2009) and a reconciliation among design-intent and construction-intent building models (Young et al., 2008). The final destination is however gradual promotion of current BIM models to be also deployed as *as-commissioned*, *as-operated,* and *as-maintained* models (Ding et al., 2009).

There are a handful of success stories regarding use of BIM in FM: In the case of the Coast Guard Facility Planning, implementing BIM surprisingly helped reduce the time and effort to construct and update the FM database up to 98% (Eastman et al., 2011). The Sydney Opera House (SOH) is one of the most prominent examples of application of a BIM-enabled FM system (Ding et al., 2009). The integrated FM system for SOH is based on a spatial breakdown order of the facility components including location zones, functional spaces, stories, and rooms and subsequently propagating this hierarchical ontology to data exchange streams among various tools and databases (Schevers et al., 2007). A central data repository was created to accommodate all objects and their relationships (Sabol, 2008). Yet, such examples are not ubiquitous and do not represent the mainstream (Khemlani, 2011). Owners have traditionally been and still are far behind other actors in building industry with regard to use of BIM (Young et al., 2008).

1.2. Scope of the study

Facilities Management may cover a wide temporal and disciplinary range of activities ranging from ordinary O&M jobs through financial asset management, operation simulation, and performance monitoring to major refurbishments and upgrades (Eastman et al., 2011; Ding et al., 2009). From a *scale* point of view, it will be more appropriate to replace the term *facilities management* by its broader counterpart, *property management* where underground utility systems, parking lots, roads, drainage structures, and grounds are also included (Sapp, 2011).

A variety of disciplinary actors are involved in facilities management namely O&M directors, facility managers, facility engineers, O&M planners, maintenance supervisors, craftsmen, tradesmen, and janitorial, custodial, and housekeeping staff. Investigated characteristics of the BIM-enabled tools for FM such as user-friendliness, functionality, and interoperability are therefore studied and assessed with regard to the aforementioned user groups and the degree and scope of their need for building information.

The scope of this study is an analysis of BIM-enabled tools for facilities and operation management. *Owner* is alternately used instead of the *facility manager* agent of the owner. Among the variety of fields influencing use of BIM in FM, this study prioritizes and focuses on implications of information technology and building information modelling tools and techniques.

1.3. Our goal

This articles aims to report a thorough study on the importance, implications, and issues of implementing BIM-enabled tools in the facilities management and operation phase of the building's life cycle. Findings can be used for orienting and providing further applied research activities in the field with a comprehensive theoretic insight. The term "BIM-enabled" refers to those applications that are capable of interacting and exchanging information with BIM tools. As a matter of practicality, the term "BIM-enabled FM systems/tools" is alternately replaced by "FM:BIM systems/tools" in this paper.

1.4. Methodology

This basic research is a descriptive theoretical study totally based on the data collected from existing literature and complemented by inputs from workshops, interviews, webinars, face-to-face and online conversations, and exploratory studies on existing tools and technologies. In the closing sections of the article (*Solutions* and *Conclusion*), a qualitative comparative approach is taken for evaluating existing tools and applications.

2. BIM for facilities management

A BIM-enabled FM system dramatically enhances maintenance, business, and benchmarking processes (Mitchell, Ballesty, Drogemuller, Schevers, Linning, Singh, & Marchant, 2007) even at such highly detailed levels as inspection, updating, and recording of fire-rated walls and sealant condition between tiles (Ding et al., 2009). East et al. (2012) contend that FM-enabled tools are much more efficient for evaluation of environmental performance of buildings compared with methods such as *energy-reduction targets* and *checklists*. BIM solutions for FM (FM modules) are often developed in-house or by third-party developers (Khemlani, 2011). No BIM application is capable of undertaking the entire diversity of FM activities mentioned above. Instead, FM:BIM tools are in most cases designed to communicate, interact, and exchange data with domain-specific knowledge management FM systems.

Applications of BIM in FM can be alternatively categorized into the following groups of activities: **facility / property strategic management, financial management, building performance evaluation, cleaning services, end-user services, security schema, and renovation planning and management** (Jokela, Laine, & Hänninen, 2012; Eastman et al., 2011; Schevers et al., 2007). These major categories can in turn be broken down to activities such as move management, data mining, room scheduling, lease management, tendering, risk management, long-term planning, communication, operation simulation, management of maintenance, inspection planning, condition management, repair

management, document management activities, financial operative planning, budgeting, and budget follow-up, monetary transactions, accounting, and pro-forma analysis. The aforementioned can be addressed, enhanced, and optimized using BIM.

2.1. Performance evaluation

Evaluation of program compliance, real-time monitoring of building performance, energy and environmental assessment, survey of hazardous wastes, consumption monitoring, sensor and control monitoring, and change tracking are some components of building performance evaluation. BIM helps automating registration of the variety of operational data pertaining to general appearance, tidiness, and cleanliness of rooms and spaces. Such data are regularly collected for evaluation of building performance. Timed values of *Building Condition Index* (BCI) are composed of *Building Fabric Index* (BFI) and *Building Presentation Index* (BPI) subcategories (Schevers et al., 2007). These are normally registered in a percentage-based scoring format in corporation's *Computerized Maintenance and Management System* (CMMS) (Sapp, 2011) and are deployed for contractual purposes. Ding et al. (2009) also mention *Key Performance Indicators* (KPI) criteria that are used for the purpose of internal benchmarking. KPIs address multidimensional non-financial parameters such as services quality, facility condition, energy consumption, accessibility, security, and response to urgent work (Ding et al., 2009; Mitchell et al., 2007). Implementation of tablets and Smart phones instead of printed forms for collecting data to populate BFI, BPI, and KPI databases will enhance automation of FM and further accelerate development of integrated FM:BIM applications.

2.2. BIM for operating and maintenance management

Operating and maintenance actions are performed on a daily basis in order to sustain the quality of acquisition of both fixed and dynamic facility and equipment assets in a way that they truly perform their intended function (Sapp, 2011). Incorrect, fallacious or non-optimized operation routines may result in unnecessary downtime, voiding warranties, and reduced service time of facilities and expected useful life (EUL) of their fixed assets (Sapp, 2011).

It is sometimes more practical to fully differentiate among digital systems that are used for maintenance and the rest of FM activities. In the case of Sydney Opera House, for instance, computer-aided facilities management (CAFM) and computer-aided maintenance management (CAMM) systems are devised as two separate sets of applications (Schevers et al., 2007). All in all, in order for an FM:BIM application to efficiently administer the operation phase of a building, the variety of facilities operation and maintenance activities e.g. reactive, predictive, and preventive maintenance should be addressed in the system and mapped onto a detailed schema encompassing their work order breakdown.

3. Shortcomings

Owners' cost estimations often include contingencies as high as 5-50% (Eastman et al., 2011); expenses that can be avoided by implementing an accurate, reliable, and information-rich building model for a more thorough control over financial resources prior to and during

operation of the building. Yet few BIM-enabled tools have been developed specifically for owners (Eastman et al., 2011); while owners are exposed to the biggest loss among all stakeholders in building industry for inadequate interoperability and confronting errors and inaccuracy when using BIM (Young et al., 2008).

Problems that arise in sustaining a smooth flow of information through the entire life cycle of the building to the operation phase can be classified in the three areas of **workflows**, **contracts**, and **information technology**. This categorization is derived from a recapitulation of the variety of issues declared in the literature and can roughly be aligned to Owen (2009)'s three alleged industry foundations underpinning IFC standard: *processes*, *people,* and *technologies*.

3.1. Workflows

In general sense, throughout the varieties of disciplinary and sequential branches of AEC industry, change of workflows is perpetually recommended for acquisition of the full merits of BIM (Eastman et al., 2011; Young et al., 2008). Traditional work order sequences are quite time-consuming and inefficient. According to Eastman et al. (2011), payments to the employees who work with FM account for 92% of the life cycle costs of a building. Improvement of daily FM routines by means of insightful data management tools will dramatically cut such expenditures over time.

A major part of investments in operational phase corresponds to data inventory required for issuing and implementing scheduled and non-scheduled O&M work orders. There are indications that a 28% cut in the time spent on O&M work order process is perceived by use of BIM in the facilities management phase (Forns-Samso, 2010); yet further field studies, surveys, and interviews with practitioners are needed to confirm this finding. Short-sightedness of the owners is quite often mentioned as the main factor that impedes such an auspicious gain (Eastman et al., 2011). Khemlani (2011), too, notices the need for changing mind-sets of FM professionals. Established roles and practices, risk avoidance, short-term business relationships, document-based thinking, and silo mentalities (Owen, 2009) are major hindrances against improving and enhancing FM business processes using BIM.

3.2. Contracts

Drifting towards more collaborative and informed workflow configurations in building industry demands for new types of contracts. Some take on to mandate an integrated approach to design and construction, namely *Integrated Project Delivery* (IPD) (Eastman et al., 2011). In order that the owners can genuinely benefit from BIM, a number of changes in deliverables of design and construction business activities should be realized. As-built deliverables to the client and specifications should be substituted by updated as-built BIM models (Jokela et al., 2012; Eastman et al., 2011). It requires that owners are sufficiently perceptive about virtues of BIM and motivated and prepared to receive BIM models instead of traditional documents. Elsewise, consulting and construction bodies will end up in cumbersome and iterative workload of transforming their BIM models into traditional 2D documents which is a loss of time and money.

Problems associated with ownership of the building model should also be tackled in contracts. This entails introduction and implementation of contract forms radically different from traditional ones (Khemlani, 2011). Tarandi (2012) and Owen (2009), too, emphasize the importance of intellectual property management for promoting integrated design and delivery solutions.

3.3. Information technology and building models

Using traditional FM database systems and cumbersome manual procedures of setup of FM database systems, integration of FM with back-office systems and occasional use of outdated as-built documents are among the most serious loss-making factors for building owners during the post-construction era (Eastman et al., 2011; Smith & Tardiff, 2009). Disparate commercial FM applications should yet undergo sizable changes to be capable of receiving the full magnitude of building data from BIM models (Mitchell et al., 2007).

Failure in efficiently coupling BIM and FM systems is partly due to data handling issues. The inability for integrating diverse and sometimes redundant data sources is normally caused by inadequate interoperability which is in turn triggered by issues with standards and file formats (Eastman et al., 2011). Traditional space identification methods such as polylining should be replaced by more intelligent transfer of building information to FM (Khemlani, 2011). Besides, FM applications have been repeatedly criticised for not having graphical interfaces (Sabol, 2008). Competitive commercial interests, too much focus on technology rather than construction, and costly and time taking development procedures are some of the hurdles with developing virtuous digital FM:BIM solutions (Owen, 2009).

Deficiencies of BIM tools, FM applications and mediating software packages do not represent the full picture. Scarcity of information systems that are capable of embracing various data types through the entire life cycle of the building is also a major issue (Tarandi, 2012). Advert of even more sophisticated operational equipment, namely Building Automation Systems (BAS) further increases the need for more intelligent FM:BIM tools (Sapp, 2011). In practice, a considerable number of facility managers deactivate their sensor systems since owners cannot afford the high expenditures of purchase and use of data processing tools (East et al., 2012).

4. Solutions

The ultimate integrated FM:BIM solution should encompass a federated array of minor solutions for the problematic areas mentioned above. Owners' constant supervision over the building process e.g. by means of IPD contract frameworks facilitates an integrated building design, construction, and operation practice (Young et al., 2008). This helps satisfying the client's requirements and insures program compliance of the final product. Training FM staff also helps benefiting the most out of the built facilities (Sapp, 2011). This is however more a general prerequisite for a healthy FM practice indifferent of how informed and automated FM systems are and is thus not pertinent for the purpose of this study.

Development of IT-based initiatives is the lowest-level category of FM:BIM solutions, yet a substantial requirement which is the main focus of this study. Generally speaking, FM:BIM systems should be scalable and flexible enough to allow change in business plans. They should also be based on a flexible and extensible semantic system and ontology structure, since ontologies at different corporations are developed and enhanced so as to clearly address spatial decompositions of those firms and truly satisfy those corporations' specific business needs (Schevers et al., 2007; Mitchell et al., 2007).

4.1. Standards

As mentioned above, non-standard data transfer formats account for a large share of parted and non-compatible design, construction, and operation data authoring and management systems. Tarandi (2012) suggests that a building data model supporting Product Life Cycle Support (PLCS) is the key to a life cycle approach to building information management. Implementation of such systems requires established standards for building data models such as IFC and COBie.

4.1.1. IFC for FM

The most salient example of non-proprietary and object-based building data models is *Industry Foundation Classes* (IFC) which aims to help make the data more future-proof (Mitchell et al., 2007; Khemlani, 2004). IFC is developed by the international non-profit organization, buildingSMART and is a semantically rich model that bears the capacity for whole facility life cycle management. According to Schevers et al. (2007), the very first generation of IFC-compliant FM systems were already available half a decade ago.

IFC already supports FM activities such as performance evaluation, procurement, and service delivery (Mitchell et al., 2007). Sabol (2008) asserts that implementation of IFC fostered faster and more efficient FM practices at SOH in a variety of ways including sharing and reusing data by all contractors and staff, providing analytic capacity for design of upgrading and refurbishment projects, providing the ability for whole-life-cost-estimation thus better control over building performance and environmental data, and the ability for tighter budget planning. The ultimate IFC-compliant FM systems should also enable automated integration of the data in BFI, BPI, and KPI into the BIM model.

A very basic requirement of building modelling for use in FM is that native BIM models produced during design and construction phase can be exported to workable and accurate IFC files. Nevertheless, IFC models can never completely replace original disciplinary BIM models (Jokela et al., 2012). IFC-compliant viewers are greatly useful for owners / FM managers when used in combination with FM systems. TeklaBIMsight, Autodesk Navisworks, and Solibri Model Checker are some examples (Jokela et al., 2012). Furthermore, a variety of IFC-compliant data analysis tools including energy prediction models have been in place for a long time (Mitchell et al., 2007). Integrated implementation of IFC-compliant and semantic web applications (e.g. RDF and OWL) is a suggested approach for developing automated and informed FM knowledge management tools (Schevers et al., 2007).

4.1.2. COBie

As in any other multi-disciplinary career, a set of standardized data exchange protocols are required for facilitated handover of building data through sequential stages to the operation phase. Such standards will guarantee that the building information produced during design and construction by architects, contractors, and subcontractors will eventually be available and accessible for the FM team (Jokela et al., 2012). In search of a solution for regulating FM-specific data provision requirements, the COBie initiative (*Construction Operations Building information exchange*) was developed at CERL Lab of the Engineering and Construction Department of the U.S. Army Corps of Engineers (Young et al., 2008). COBie is an open data transfer specification for initiating registration of the information needed for FM early in the design and construction phase (Sabol, 2008).

A fundamental principle of COBie is that the designer should provide a set of conceptual information such as flow, space, and equipment layouts in the form of a BIM model, while the contractor complements it with more specific and market-based data namely make, model, and serial number (Eastman et al., 2011). Data that are not needed in the BIM model are delivered to the owner in the form of COBie documents i.e. low-level formats such as Excel spreadsheets (East & Carrasquillo-Mangual, 2012; Khemlani, 2011). The overall rationale behind the necessity for supplementing IFC with additional standards such as COBie is in fact what Tarandi (2012) articulates as not all types of information being manageable and transferable via neutral formats and geometry-based building models.

The main obstacle against discipline-wide implementation of COBie is provision of clear description of practical routines for evaluation and validation of deliverables and checking for discrepancies among COBie documents delivered by different actors at different stages. Moreover, problems with conflicting names will not be fully lifted before global standards such as International Framework for Dictionaries (IFDs – also termed as buildingSMART Data Dictionaries) are in place. More clarification is required on how to replace more detailed and more precise data in updated COBie sheets in practice as the project progresses.

4.2. FM:BIM tools and applications

Efficiency and profitability of an FM tool can be evaluated by meticulously measuring parameters such as the number of work orders per year, average time spent on work orders, ease of access to information, and accuracy of as-built / as-operated information (Forns-Samso, 2010). FM applications are often termed as Computerized Maintenance and Management Systems (CMMS). The most commonly used CMMS's are IBM Maximo, TMA, FAMIS, FM:Systems, Facilty Link, Facility Focus, Archibus, AssetWorks AiM, Vizelia, and Rhyti (Khemlani, 2011; Schevers et al., 2007). Not all of these are yet fully compatible with BIM applications.

As in the case of building modelling applications, a variety of proprietary FM:BIM tools have been introduced by prominent market actors namely Autodesk's FMDesktop (linked to Revit), Graphisoft's ArchiFM (connected to ArchCAD), and Bentley Facilities (built on top of MicroStation and linked to ProjectWise) (Khemlani, 2011).

4.2.1. FM:BIM:BAS tools and applications

One of the most recent approaches to FM:BIM is the mixed software / hardware solutions for also integrating sensor data to FM:BIM systems suggested by Cahill, Menzel, & Flynn (2012). They suggest a combined use of object-oriented and web-based ITOBO platform together with BiMserver data repository (van Berlo, Beetz, Bos, Hendriks, & van Tongeren, 2012) and Oracle's Berkeley Database. Information Technology for Optimized Building Operation (ITOBO) is a project conducted by a consortium of Irish and international agents from academia and industry including University College Cork and Environmental Research Institute. This initiative seeks solutions for integrating data such as CO2, humidity, lighting, wind speed, total, and diffuse solar radiation, air velocity and water flow sourced from wired and wireless sensors into the BIM system. The aim is automating FM practices to better satisfy specific business needs. Cahill et al. (2012) refer to documentation revision control and timed meter readings as two essential functionalities of the FM:BIM tool of tomorrow.

Sensor Fusion Platform initiative, introduced by East et al. (2012) follows a similar thread. The core idea is implementing a sensor data capturing system coupled by the open-source BiMserver engine and oBIX-based OX Framework. Onuma System's solution is another example that implements COBie format and benefits cloud computing for a faster and more collaborative building data management. They have developed platform-accustomed applications for smart-phones and tablets as well as a BIM tool for data exchange with BAS's (Khemlani, 2011). EcoDomus' products are perhaps the most interoperable contemporary FM:BIM solutions which are also coupled with BAS's (We refer to such integrated systems as FM:BIM:BAS systems in this article). They serve in fact as links among FM:BIM and CMMS tools. EcoDomus tools are compatible with a variety of BIM models, Geographic Information Systems (GIS), and BAS's, namely Revit, Bentley BIM, and IBM Maximo. They are COBie-compatible and also cover the construction phase – something that was missing in Autodesk and Graphisoft's FM:BIM solutions (Khemlani, 2011).

5. Conclusion

The user should be able to access O&M manuals, specifications, performance data, parts list, schedules, and relevant CMMS features right in the BIM model in a non-complicated, flexible, scalable, and visual fashion. However, creating a full scale FM:BIM system is neither feasible nor wanted (Schevers et al., 2007); rather – as in the case of contemporary FM:BIM and FM:BIM:BAS tools - an efficient integrated FM:BIM system would most probably be composed of a set of loosely coupled software applications with web-based interfaces where the FM application is capable of bidirectional exchange of data with updated as-built BIM applications. A BIM in sync with the latest building performance data further strengthens reliance on and use of BIM systems by all actors (Cahill et al., 2012).

A fully functional FM:BIM integration should also be usable for minor and major refurbishment construction works by enabling analysis of technical criteria such as structural feasibility, acoustic outcomes, smoke management in fire mode, etc. (Ding et al., 2009; Sabol, 2008). The ability of directly seizing the timed values of BPI, BFI, BCI, and KPI criteria

as well as sensor and control data from BAS's underpins such an approach. This assortment should be complemented by a central BIM repository that performs document submission management and automated, yet controlled synchronization of documents throughout the entire life cycle of the building including facilities management and operations phase (Tarandi, 2012). The shift from proprietary and vendor-specific solutions to FM systems that are compatible with open standards for building data is thus a central requirement.

A more comprehensive outline for FM:BIM applications, however, requires a more thorough evaluation of effectiveness of contemporary FM routines, problematic areas, and the true sources of such deficiencies by means of interviews and surveys. The O&M staff is usually one of the best sources of information on how existing facilities are performing and how new equipment should be incorporated for a more efficient use of assets and raised ROI's (Sapp, 2011).

While maintaining the linkage among GIS and BIM applications is perhaps the most challenging area from a *scale* point of view, FM is at the time the final frontier of BIM from a *life cycle* perspective (Khemlani, 2011). The moment appropriate tools are in place and ubiquitously used by all actors, facility managers' paper documents will become obsolete the way their counterparts in design and construction are now about to vanish from offices and sites.

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A Sustainable Urban Collaboration Hub – SUCH

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Abstract

The challenge nationally and internationally, is to develop sustainable buildings and cities. To do that requires continuous information about the real estate and city properties. The information needs to be collected, stored, processed, integrated, extracted, visualized and interpreted. The proposal of this paper, the Sustainable Urban Collaboration Hub, SUCH, is based on the experience and results from the BIM Collaboration Hub and the research in the EU project InPro. It is expanding the scope of both CIC, Computer Integrated Construction, and BIM by defining the architecture and concepts of the virtual world. The development of SUCH is taking place at KTH in Stockholm, Sweden.

With projects becoming more and more complex, and the focus changing from files to a multitude of objects, a need for BIM repositories or BIM servers will become a necessity for the ability to manage changes and consolidations/synchronizations of heterogeneous applications. In addition to heterogeneous applications the support of heterogeneous data models will be an additional requirement as the scope of the information management expands from the individual building to groups of buildings and also to the infrastructure and civil works in cities.

A BIM standard like IFC can manage snap-shots of the information, but to manage the whole life cycle, there is a need for a standard like PLCS, Product Life Cycle Support, which supports some critical business needs faced by companies as they seek to implement Product Lifecycle Management (PLM) and other broad enterprise-based initiatives.

SUCH will extend the application of BIM to city blocks, cities and infrastructure. These domains have never had any sustainable support for data models and tools.

Keywords: BIM repository, IFC, PLCS, through life support, sustainability

1. Introduction

The challenge nationally and internationally, is to develop sustainable buildings and cities. To do that requires continuous information about the real estate and city properties. This information is of many kinds, such as material properties, energy consumption, concentration of air pollutants and flows of people. The information needs to be collected, stored, pro-

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cessed, integrated, extracted, visualized and interpreted, something that requires advanced information systems and deep domain knowledge.

BIM, Building Information Modelling, represents an important step in the development. What is still missing is the life-cycle perspective, i.e. the endurance dimension combined with BIM.

To date, BIM has mainly addressed buildings, but in the future there is a need for additional structured and open information related to infrastructure, roads and other constructions necessary for modelling real estates and cities. To monitor and control the real estates and characteristics of cities over time requires new and more sophisticated information systems that combine the benefits of BIM with the value of life cycle assessments (from requirements, planning, production, operation, and finally to recovery).

This paper relates to development and commercialization of such a system/platform, which extends the application of BIM to city blocks, cities and infrastructure. These domains have never had any sustainable support for data models and tools.

The goal is to develop a scalable platform that consists of a unique and effective web-based tool / system that supports monitoring, support and control of planning, construction, operation and management, and recycling of buildings and entire cities. Information is integrated, shared and analysed; ideas and proposals are developed, presented and communicated through the city planning processes.

To enable a long-term working collaboration, between the various stakeholders of the city, both integration and consolidation of information models in a common information platform is needed. BIM repository, BIM server, and Model Server are some of the names on this emerging concept.

2. BIM repositories

IFC, and many other exchange standards, can only handle snapshots of the information. In order to manage the entire life cycle of a construction, there is a need for standards like PLCS, Product Life Cycle Support (ISO 10303-239, 2012). The BIM Servers like the BIM Collaboration Hub (Tarandi, 2011) can secure collaboration both within the organization, as well as within Extended and Virtual Enterprises with their various actors involved. The PLCS standard, Figure 1, will enable linking of product information to maintenance information throughout the product lifecycle, called Through Life Support (TLS), which is applied in other industries, e.g. in the aerospace industry.

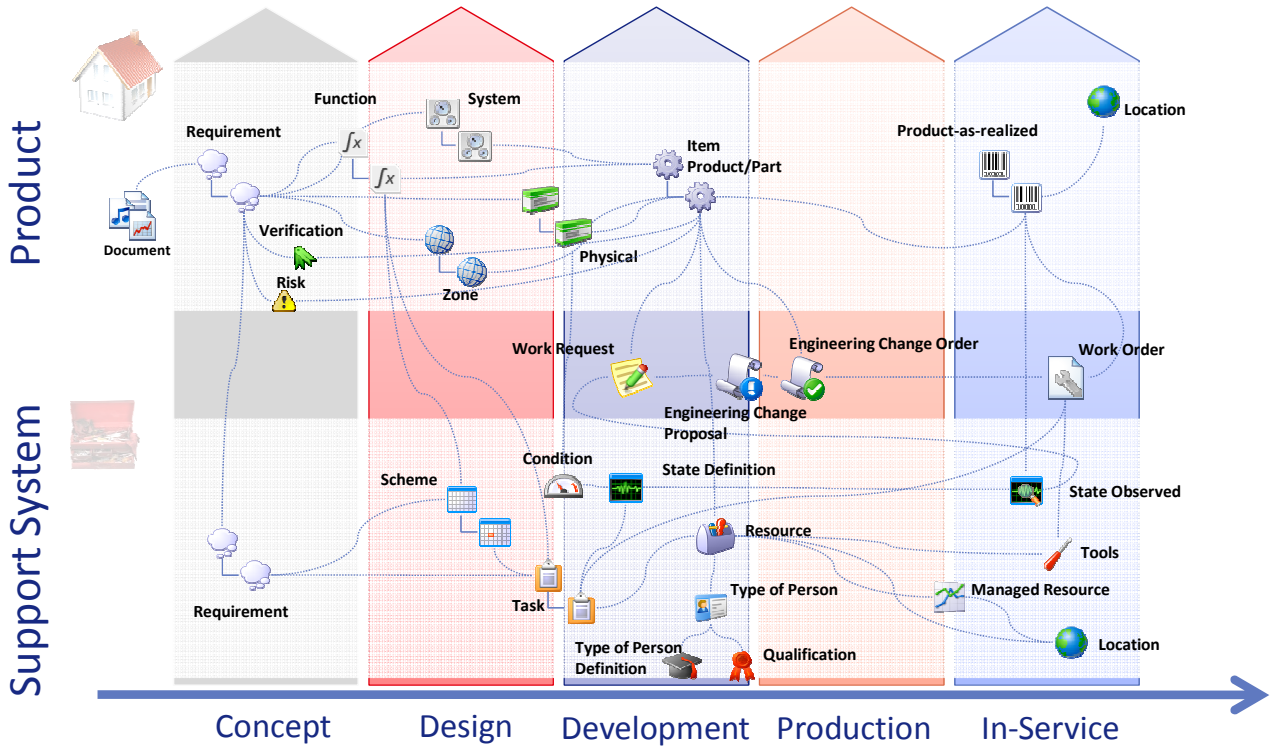

Figure 1: Main Business Objects of the PLCS standard.

Now this is applicable also for the construction and real estate sector, as demonstrated in the EU project InPro (Tarandi & Houbaux, 2010; Tarandi, 2011) by the implementation of the BIM Collaboration Hub. For the construction sector TLS is a new approach and has few international and national implementations. Only a few platforms based on the open international standard PLCS are available today, and in these cases only limited support is utilized.

In the discussion of justification for BIM utilization, Jung and Joo (2011) compare two current views on structuring information and processes in the construction industry – Computer Integrated Construction, CIC, and BIM. They formulate a framework to capture characteristics of different aspects for comparison of the business benefits of different solutions. Their findings show that both these ways of looking on the tools and activities are converging and also being depending on the distinct characteristics of organizations and projects. The CIC view focuses on the integration of multiple dimensions, like 3D, time and cost. Without a common data model as a base, it proves to be difficult. The same is valid for BIM, when it comes to the need for a common data model. According to Jung and Joo (2011) there is no significant difference between the concepts of CIC and BIM.

The proposal of this paper, the Sustainable Urban Collaboration Hub, SUCH, is based on the experience and results from the BIM Collaboration Hub and the research in the EU project InPro. It is expanding the scope of both CIC and BIM by defining the architecture and concepts of the virtual world, the Mirror World (Gelernter, 1992), where the objects – representing building elements, spaces, and processes of the real world are the information carriers rather than the existing authoring and managements tools of today's industry. "You will look into a computer screen and see reality" (Gelernter, 1992).

Eastman et al. (2011) identify the common information repository – the BIM server – as one promising emerging solution. They argue that the "evolutionary change in the AEC field from managing files to the managing of information objects has only begun to take place". With projects becoming more and more complex, and the focus going from files to the multitude of objects – very management and granularity dependent – a need for BIM repositories or BIM servers will become a necessity for the ability to manage changes and consolidations/synchronizations of heterogeneous applications.

Eastman et al. (2011) add the transaction granularity and frequency on the project, building, object, and attribute as fundamental for the configuration of BIM servers.

In addition to heterogeneous applications the support of heterogeneous data models will be an additional requirement as the scope of the information management expands from the individual building to groups of buildings, and also the infrastructure and civil works in cities.

The requirements on a BIM repository, according to Eastman et al. (2011), include:

- User access control
- Representation of users associated with a project
- Read, store, and write native data models
- Read, store, and write open standard model data
- Manage object instances and read, write and delete them
- Support product libraries for incorporating product instances
- Support storing product specifications and maintenance/service information
- Store e-business data, for costs, suppliers, etc.
- Provide model exchange capabilities for remote users, e.g. web access
- Manage unstructured forms of communication

Based on the arguments for a BIM Collaboration Hub, by Tarandi and Houbaux (2010), and Dumoulin, Benning, and Tulke (2011), the list can be extended by:

- The complete object model
- Aggregating models provided by different disciplines
- Exporting and importing partial models
- Managing workflows and changes
- Exchanging information with the hub using a neutral exchange format, e.g. IFC

The limited integration of information and automation systems supported by BIM applications of today are described in the CIB white paper on IDDS, Integrated Design & Delivery Solutions (Owen, 2009). To implement IDDS requires improvements in work processes, technologies and people's capabilities to span the entire lifecycle of the building creation related processes including environmental issues (Owen, 2009).

3. The Sustainable Urban Collaboration Hub

The development of the Sustainable Urban Collaboration Hub, SUCH, see Figure 2, is now on-going at the Royal Institute of Technology, KTH, in Stockholm, at the department of Project Communication. It is partly funded by Vinnova, the Swedish Governmental Agency for Innovation Systems, in the program “Sustainable Attractive Cities” (Vinnova, 2012).

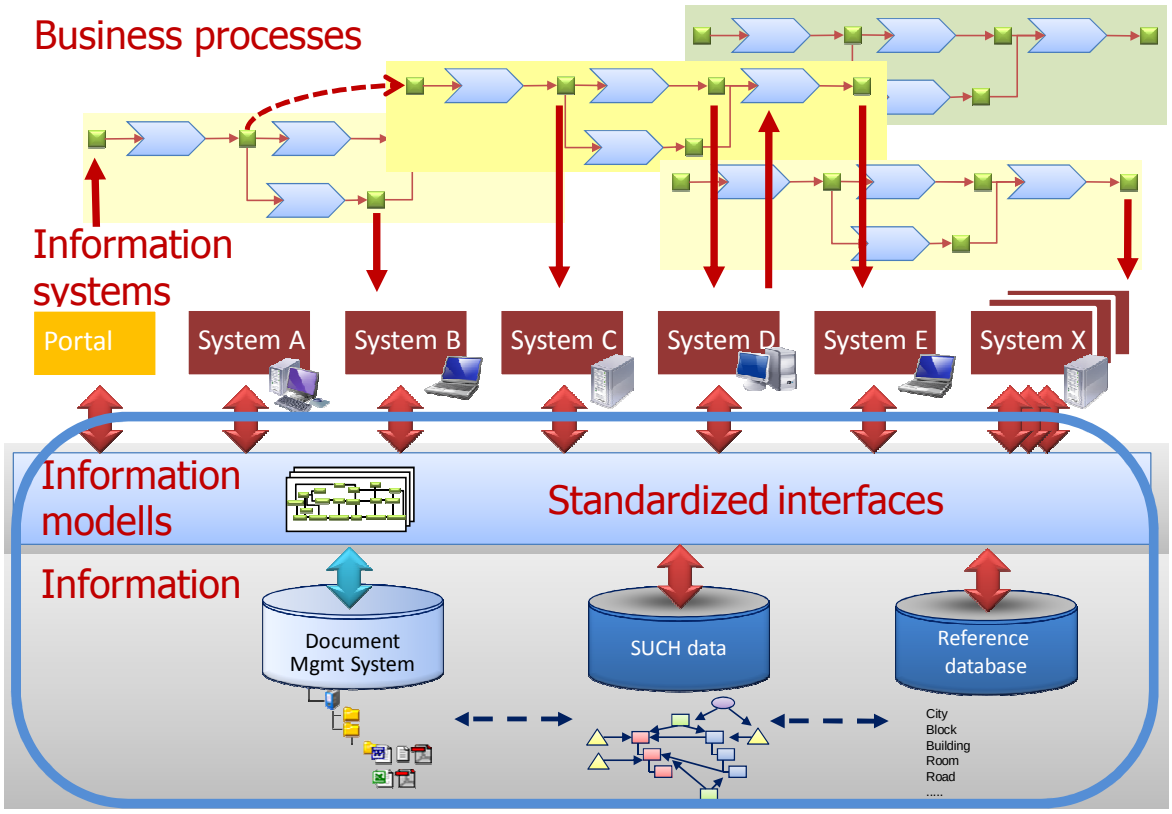

Figure 2: The architecture of the Sustainable Urban Collaboration Hub, SUCH

A further development of the BIM Collaboration Hub for building design, production, operation and management to also include cities and infrastructure, supporting analyses, evaluations, and guidance towards sustainability goals will be the result. The different applications and associated methodology will be productified and packaged by actors in society through the access to relevant and valid life-cycle oriented information.

With a collaborative environment and developed methodologies, software support and defined information content, conditions are created for development of new services, see Figure 3, where the real world and the mirror world are related by e.g. sensors.

The base for SUCH is the result from the InPro project – Open Information Environment for Knowledge-based Collaborative Processes throughout the Lifecycle of a Building – which was a project within the 6th framework of the European Commission ending in November 2010 (Sebastian, 2011). One result of InPro was the BIM Collaboration Hub (Tarandi, 2011), which was the platform for the model-based and collaborative work over the life cycle of the construction, in InPro mainly buildings. The implementation of the BIM Collaboration Hub was based on the model server Share-A-space from Eurostep (2012).

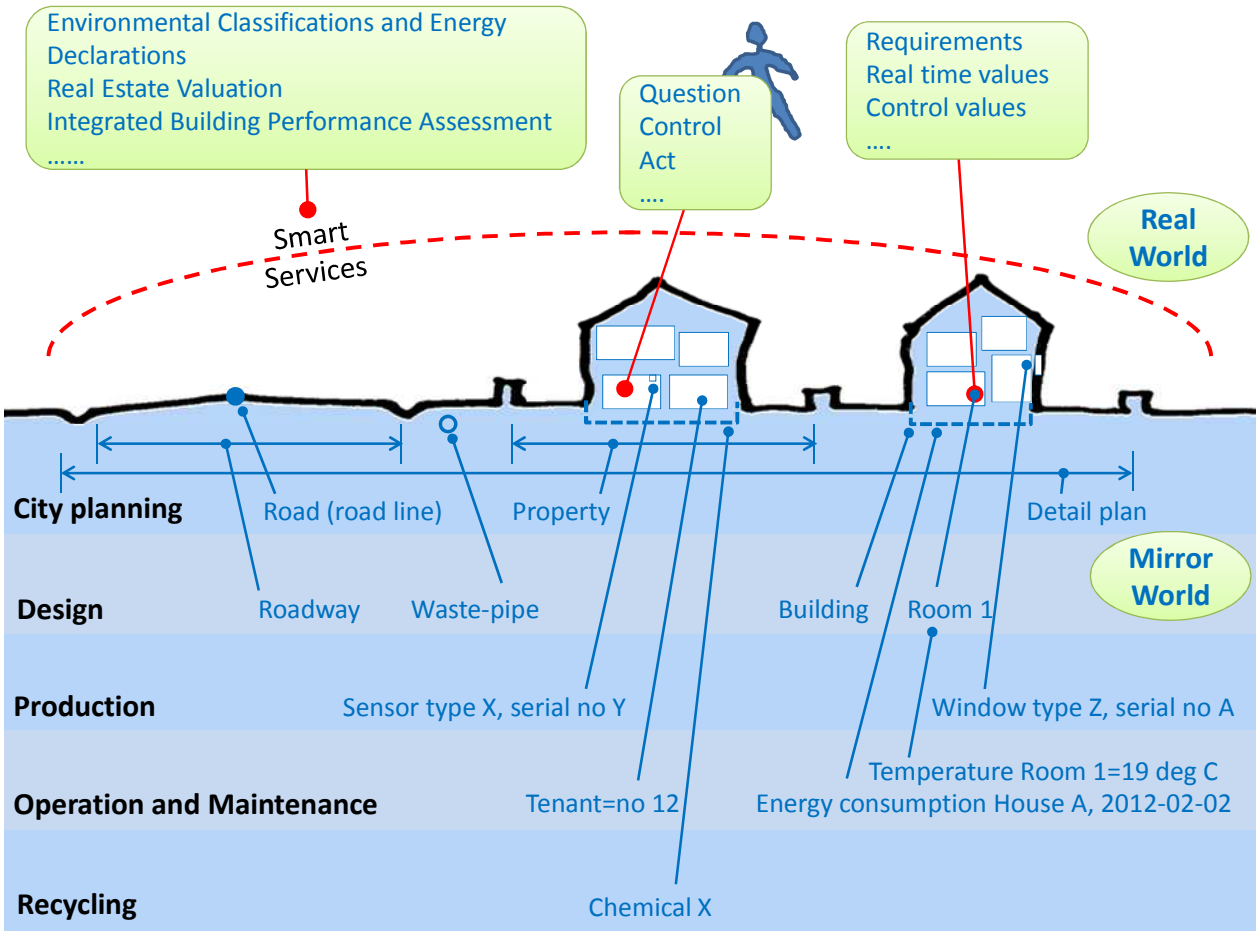

Figure 3: Information in the Mirror World, with services for the Real World. (The values of properties are examples only)

The different views on information models and their usage in the industry confirm that the SUCH proposal is in line with them and fulfil most of the requirements. With design change proposals and workflows related to the object model, an efficient platform can be built.

The BIM Collaboration Hub was based on the open BIM standard IFC 2x3 (buildingSMART, 2011), and PLCS, Product Life Cycle Support, ISO 10303-239 (ISO, 2012) an open exchange and sharing standard was added as the framework to support the life cycle related information exchanges, not covered by IFC. In the InPro work, with all the key processes defined for early project phases, structured requirements, documents and information from other data models than IFC needed support and linking to the building information. This need to extend the scope of BIM has also been identified in the development of the IDDS white paper, where it is described as the next step in the evolution (Owen, 2009). In the definition of the scope for SUCH, the need for extending the BIM model into support of blocks, cities and infrastructures was evident.

The need for managing multiple heterogeneous data models was identified and the solution was to continue with the work started in InPro. Multiple data models to map to one common and neutral information model, PLCS, where the commonly agreed concepts are the targets. These targets were in the BIM Collaboration Hub the concepts corresponding to the building and spatial elements of the IFC data model, (buildingSMART, 2011).

3.1 Mappings from IFC data models to the BIM Collaboration Hub

The mapping of IFC to PLCS is one central function of the BIM Collaboration Hub. The typical IFC structure is shown in Figure 5 to the left. To the right is the corresponding high level structure mapping to PLCS. In the mapping, all the object geometries are treated as individual files linked to the objects. In the IFC mapping, the files are self-consistent IFC files. Reference geometry is taken out of the files to give location and rotation to the individual object.

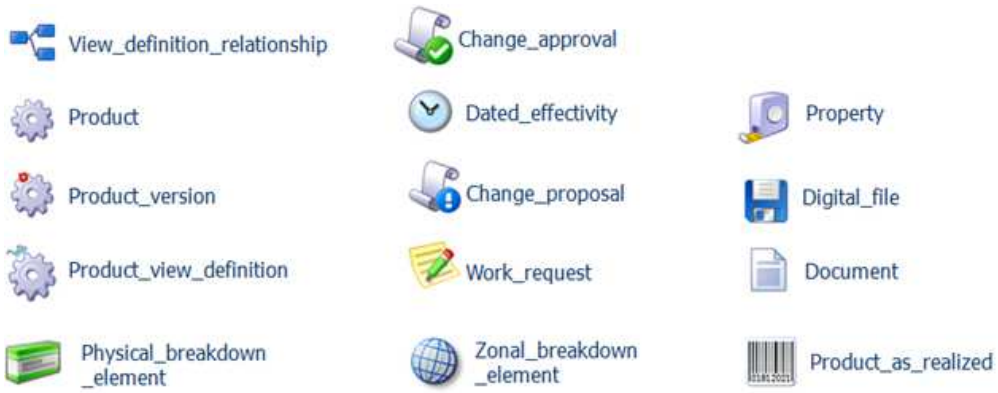

Figure 4: Legend – PLCS concepts

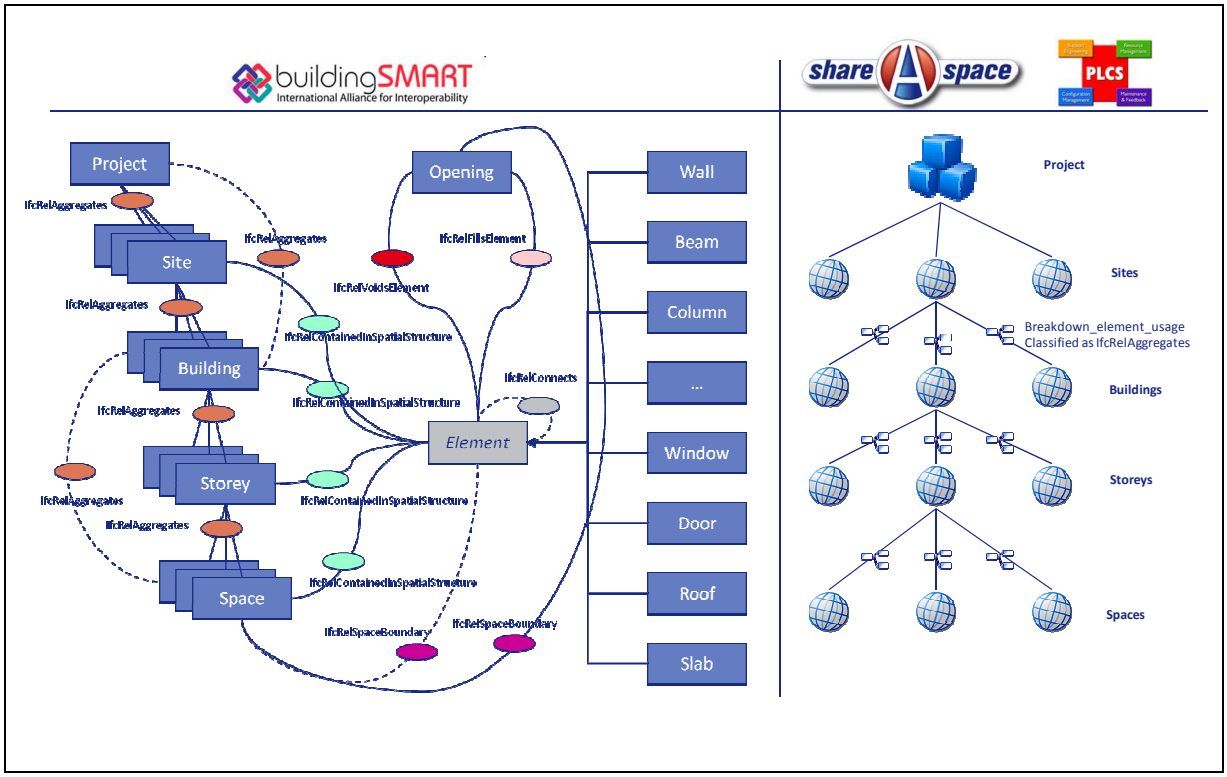

Figure 5: Typical IFC data exchange file structure and high level structure mapping

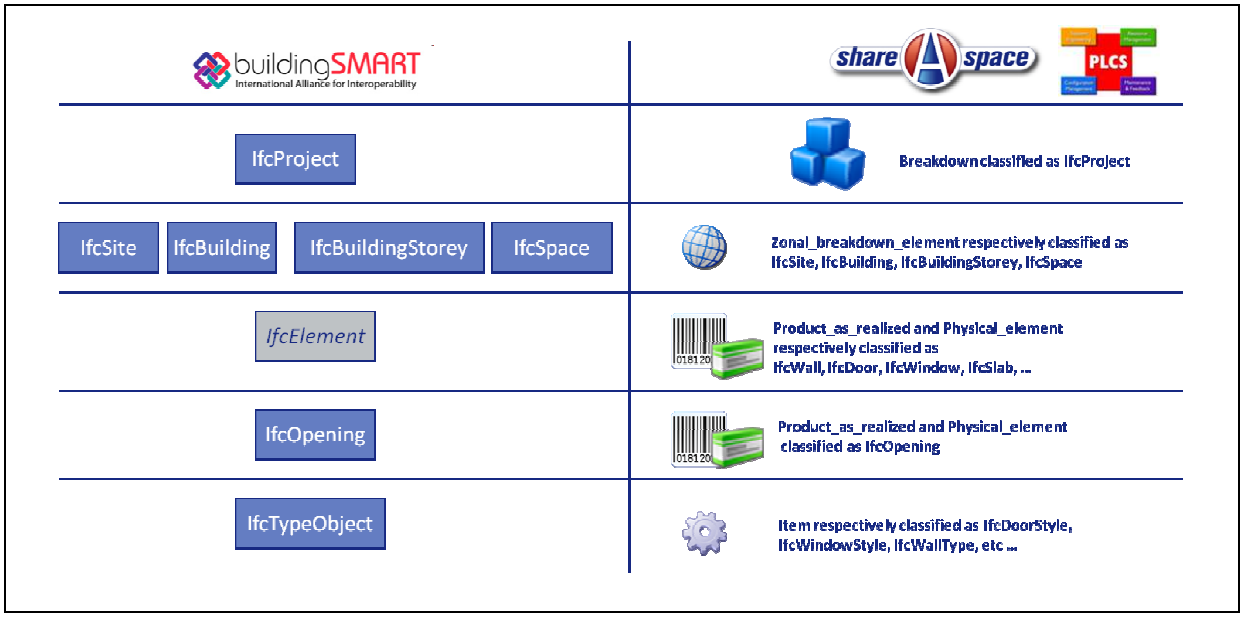

Figure 6: High level mapping from IFC to PLCS/SAs

The concepts of IFC are mapped to corresponding generic concepts of PLCS, see Figure 6. In the following figures, a number of important PLCS structures are illustrated for IFC model examples. In Figure 7, a Wall with the identifier 231 has 2 versions v1 and v2. v1 exists in the architecture design view, v2 exists in the architecture design and structural design views. The relationships are ordered and have different meanings if they are between versions or between views.

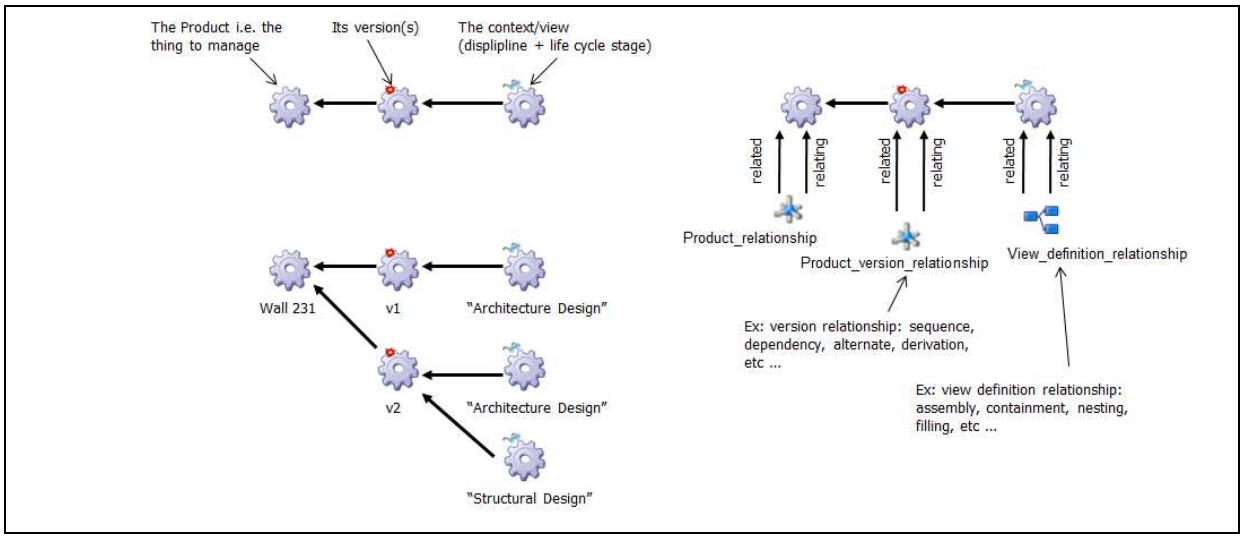

Figure 7: Products – product/version/view and relationships

Figure 8, illustrates how properties and documents are assigned to a product in the context of a view. The version v1 of the wall 231 has the properties (height and length) in the “Architecture Design” view and has 3 thermal properties in the “Thermal Design” view. The version v1 of the document YXZ is assigned to the version v1 of the wall 231 in the context “Architecture Design”. This document version has 2 digital_files (one in html format and one in pdf format). Assembly relationships in PLCS are subtypes of view_definition_relationship, see Figure 9. This enables the definition of an assembly in the context of a view.

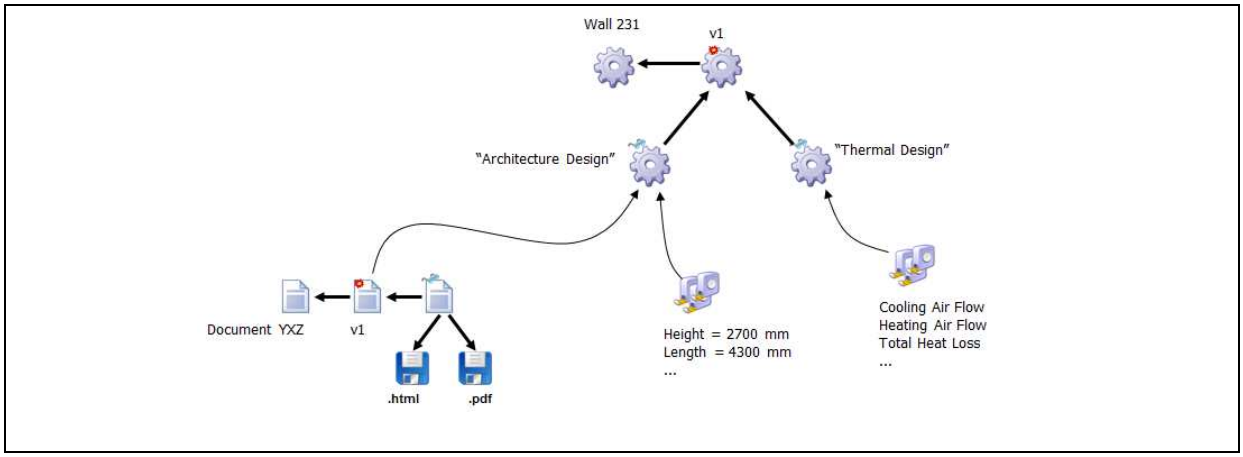

Figure 8: Products – properties, documents

In this example, the version v1 of the Wall 231 is nested by the version v2 of the Opening ABC in the “Architecture Design” view. If an effectivity is assigned on the assembly relationship, the validity of this structure can be controlled. It could be a proposed start date to indicate a proposal.

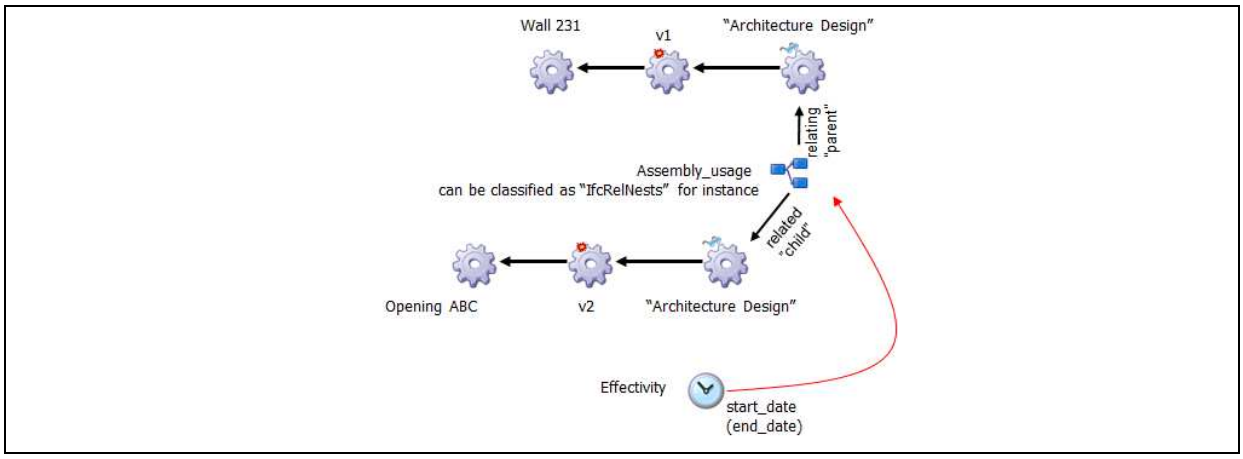

Figure 9: Assembly / structure / breakdowns – effectivity controlled

In Figure 10 and Figure 11 two examples of mapping between IFC and PLCS are shown.

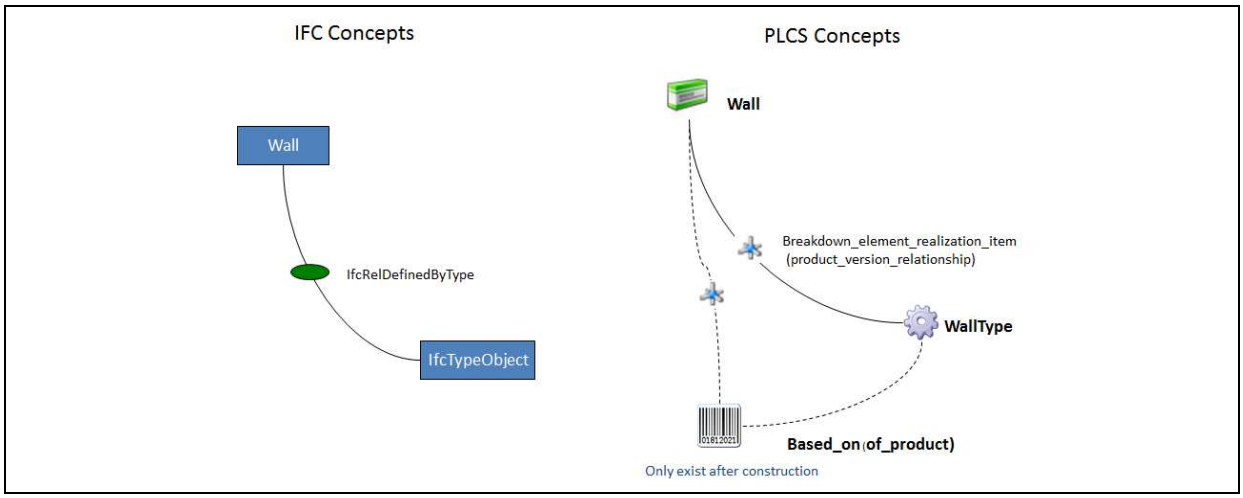

Figure 10: Mapping IFC to PLCS – Wall with type definition

The first illustrates how the physical_breakdown_element, the type, and also the realized product are related for a wall. In the second example the representation of a wall with an opening is presented.

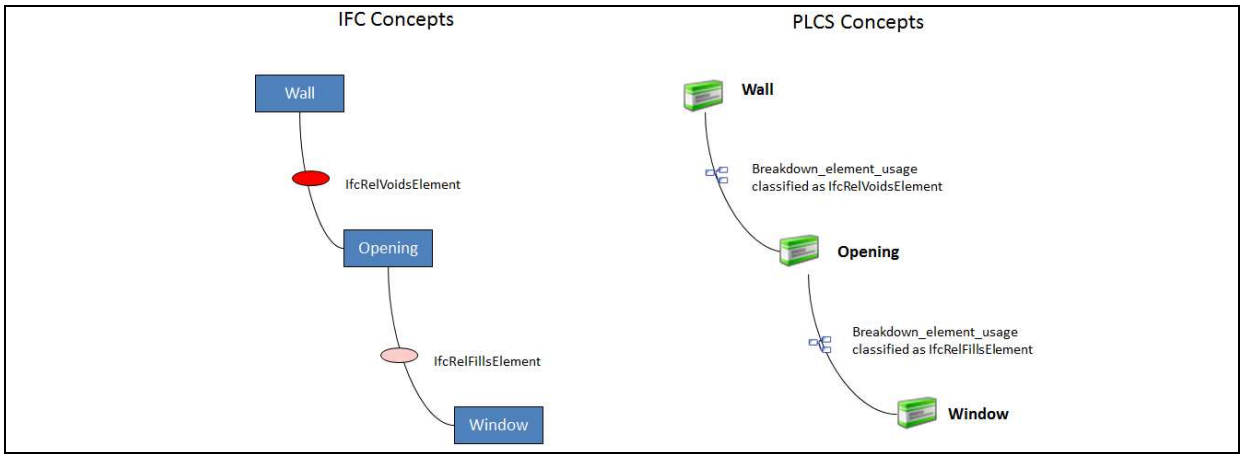

Figure 11: Mapping IFC to PLCS – Wall with window

3.2 Mapping from heterogeneous sources with different taxonomies/ ontologies

In Inpro the mapping was done between the IFC data model and the PLCS generic breakdown structures for zonal and physical breakdown elements. IfcSite, IfcBuilding, IfcBuildingStorey and IfcSpace are all mapped to zonal_breakdown elements. For another type of construction, like roads with their specific spaces like lane spaces etc., the mappings can also be done to zonal_breakdown elements with their specific classifications attached. In the PLCS data model these different object structures can then be linked using the View_definition_relationship, classified for specific usages. In Figure 12 the mapping of a new data model X to the PLCS data model is illustrated.

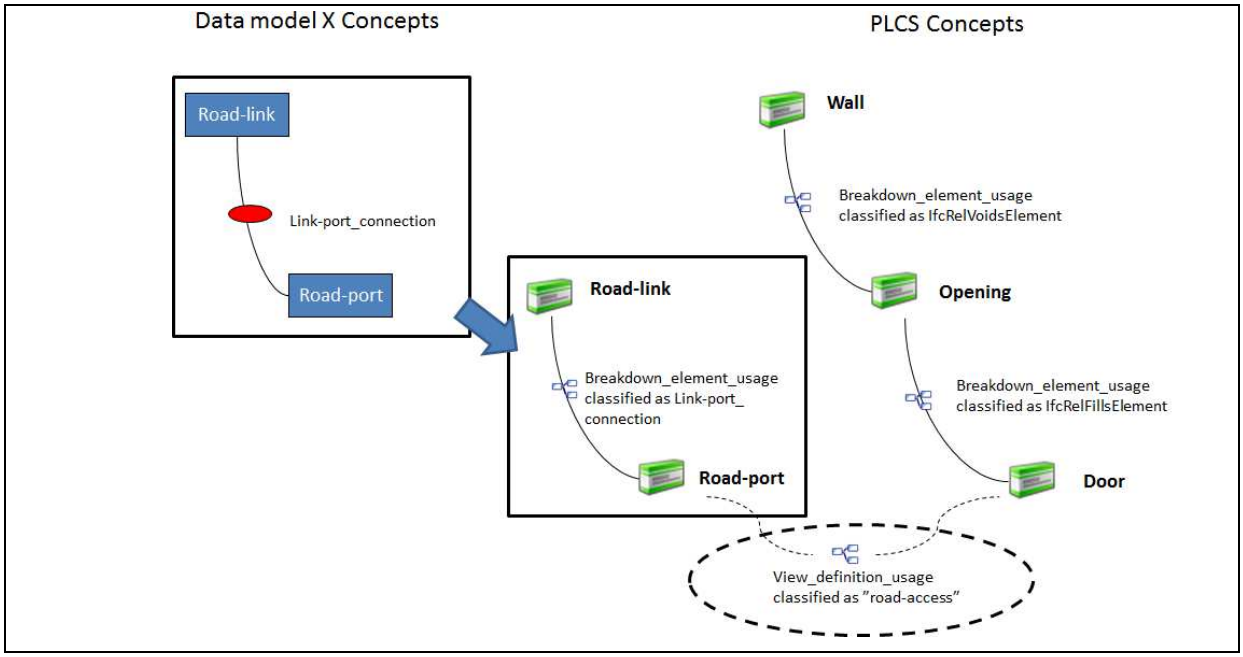

Figure 12: Mapping of instances of data model X to PLCS and linking them

The instance example is then linked to an existing model object, Door, which can be automatically done if relationships or identities are associated with the imported data. Else, the linkage can be done manually through data base interfaces or by using other tools.

The number of possible data models for the Sustainable Urban Collaboration Hub is large to cover the area of interest. There are multiple overlapping data models for different phases of the life-cycle of constructions. In Figure 13, IFC and a number of other data models illustrate the possible extensions, overlaps and links between them. For each of them different exchange formats are used today.

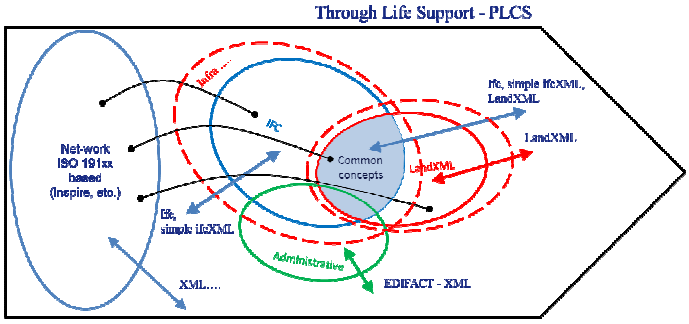

Figure 13: Integration of standards for buildings and infrastructure

The heterogeneous data models can be mapped to the common neutral through life supporting standard PLCS as illustrated by Figure 14.

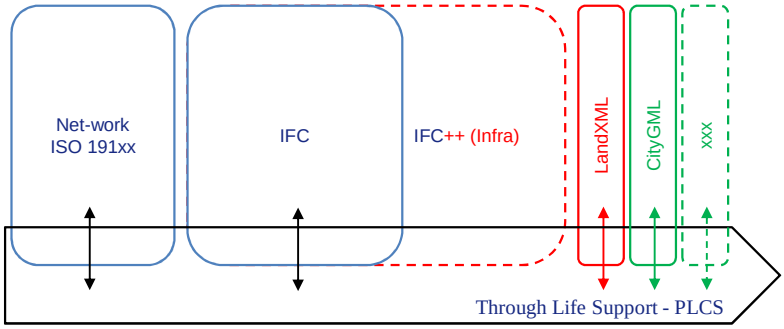

Figure 14: Integration of standards for infrastructure

All the concepts for the domain of interest must have a definition and name in PLCS, to be a valid alternative for mapping. E.g. there must be concepts for roads, road-links, road-nodes that are accepted by the users of the collaboration platform. Preferably this is based on existing open international standards. The concepts for the building domain are directly taken from the IFC standard (buildingSMART, 2011).

4. Conclusion

This paper presents the Sustainable Urban Collaboration Hub, a development based on the web-based Open ICT Platform, the BIM Collaboration Hub, from the InPro project. The architecture of the BIM Collaboration Hub with mapping of a generic data model to the through life supporting open international standard PLCS, opens for the integration of multiple heterogeneous data models/standards to enable the integration of information from different sources, phases and actors for the support of sustainable information for individual construction works and assemblies like cities.

The coming implementation will be done at KTH, Royal Institute of Technology, in Stockholm, Sweden. The platform will support multiple services, which will be defined and developed in cooperation with the construction industry.

One pre-requisite for implementing SUCH is to agree on common concepts for the domain – e.g. road, city block, and building, most of them to be taken from the IFC standard. Some potential problems and difficulties are lack of extensive classification of objects and properties, poor versioning of objects, and limited use of change management in applications and in the industry.

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Improving Construction Industry's Contributions to Society: A View on Culture's Role

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Abstract

Now that the global economic crisis has had an enormous effect on construction industry in for example the European construction market, one can see still some signs of partial recovery. But on average there is also still a strong need for the -economic- recovery of the industry. However, to play again a significant role in society as being one of 'the' drivers to build new or restructure existing facilities, there emerges quite a strong challenge for construction industry to reposition themselves again properly: For example, during the recent past, several countries had scandals within their construction industry as being influenced by collusion, bad-quality, high-pricing, non-communication etc. In short: a 'disaster' for clients…

Nevertheless, since the fact that during crisis-times several governments use the anti-cyclic approach of increasing their investments in construction projects (for example in infrastructure-works, because it serves the society three times, that is: Construction-prices are lowered, it helps to reduce unemployment, and it brings new/improved infrastructure), these increased activity at one hand is accompanied by a production decrease on the other hand. So how to balance the construction industry's interests properly? And how to use the momentum in a possible change -or even to make a transition- towards a more client-friendly culture? This paper describes and analyses literature related to the above themes, being positioned as a view on culture's role in the nowadays improvement-activities for construction-industry's contributions to society. It concludes that if the conclusion from analysed literature is right that transition activities in general focus too much on technology-aspects alone, instead of the at least equally important behavioural aspects, this might indeed result into a stronger need for research into business-cultures in construction-industry (and the ways on how to understand and to improve them) to become a positive effect for construction-industry and it's contributions to society.

Keywords: Anti-cyclic, Business-culture, Construction, Social-media, Transition.

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1. Introduction

Since circa 2008, several of the different world-economies are suffering within a deep crisis, although there are differences. Looking for example to the Euro-zone, the crisis is obvious, which is also the casefor the USA. Parallel to this, the so called 'BRIC-countries' (that is Brasil, Russia, India and China) still show considerable growth of their national economies. Although strongly focused on exports of products (for example China and Brasil), investments (for example China and Russia) and energy-resources (for example Russia) and technologies (for example India), they also have a strong import of products; but also and especially they attract foreign investments etc., for example for the growth of their national markets. Such developments one can see increasingly in the field of for example public infrastructure: Their increased need for improving such facilities does not always has the same 'speed' with the growth of their national production; that is, despite the strong growth of production-output/exports, the inflow of capital does not 'automatically' lead to public and/or private increase of infrastructure-investments. This discrepancy seems to be solved increasingly by the tendering of (mainly) infrastructure-ppp's (public private partnerships) on the international market. Not only by those BRIC-countries themselves [Chopra et al, 1995], or by competing companies from those BRIC-countries as participants for such -international- tenders [Goodman, 2004; Oster, 2007], but also by other -smaller-countries [Aruba, 2011]. In fact, examples as the BRIC-countries try to profit now from their positive image and developments, thus being able to attract sufficient -foreign- capital; whereas for other -often smaller- countries, the attraction of foreign capital often is their 'only left hope to survive' and/or modernize their (infrastructure)facilities…

2. Economy and construction industry: An anti-cyclic approach

Regarding the decribed characteristic increase in the field of internationally tendered infrastructure-ppp's, this leads to a point of view that the construction industry as a whole played and still plays a strong role as one the 'drivers' for recovering or growing an economy. And this, despite several earlier 'critical' situations, not just related to economic tide, but for example merely related to bribery, collusion, etc. [Egan, 1998; Vos et al, 2002]. Such negative sentiments and habits, existing until the late 1990's and early 2000's, have hit the (international) construction industry quite severe, thus damaging the image and attractiveness of the industry very bad. Nevertheless, gradually the construction industry had gained positive attention again during recent years since ca. 2003. However, although the average positive recovery, the construction industry still was not recovered enough to overcome the big economic crisis within the industry's (home)countries, starting in circa 2008. That economic crisis has started a strong downturn into the construction market in especially the USA and Euro-zone.

Remark 1:
From a totally different viewpoint one can imagine that stimulating construction industry, because of the need for rebuilding post-war countries, is a very special situation; such situation exists for example in the nowadays Iraq situation, in which the national government tries to attract the necessary foreign capital and construction-capacity by using the growing income from their recovered oil- and gasfields, trying to implement kind of concession-models (that is market-investments, gradually paid back by the income from the projects; etc.). However, although the enormous need for projects, the international community still considers the actual (political) situation still quite risky to be 'simply' attractive for large-scale direct investments; a governmental 'guide' towards succesful business is obviously needed within such environments [Republic of Iraq, 2012]. Therefore, improving construction industry's role in the improving of a society cannot be just a 'sectoral' approach: It also needs a well balanced and organised (political) society, in which it can bring added value by delivering good quality projects, with the help of well-equipped and trained employees. But obviously, actual situations in construction industry within its societal environment often leads to just using low-cost labour, often leading to unsafe construction-sites with low-quality projects as one of the negative results.

Remark 2:
Although after the years of scandals in construction industry, for example as shown above the previous part by the British and Dutch references, one can still see that specific complex projects are suffering the risk of 'typical' situations, for example characterized by untransparant transactions etc. Such complex -and costly- projects often occur within the (public) infrastructure-world, where several stakeholders are often 'dancing' around the project's investment-funds, trying to gain profit by every possibility, thus often damaging society's interests seriously [Soetenhorst, 2011].

Despite the above mentioned 'specific' situations within construction industry, having a positive as well as a negative impact on society, governmental bodies in general still see the positive effects of investments in construction industry projects as creating a strong and positive spin-off to other parts of the economy (for example to supplyer-industries, logistics-industries, etc.). In this sense, the construction industry indeed is part of a strong network-organisation, having its relationships with a lot of different companies/stakeholders, serving all one goal: delivering the project for their 'best' price. In fact such networks do collaborate within a kind of 'mesh', influencing themselves vice-versa and being able (or should being able, if focusing on an innovative business-approach…) to adapt quite easily towards changing customer-needs and market-situations [Mulholland & Earle, 2008]. Nevertheless, without restrictions/rules and/or (loose) coupling between the several parties within such networks, innovation might not become that succesful, as Hofman described for architectural and supplier-segments of the construction industry [Hofman, 2010]. Therefore, the underpinning of the importance of regulations for construction industry might not only be needed to create and maintain a fair and transparent market, but might also improve the innovative climate of the industry.

However, such considerations do imply a necessary active push and/or pull role for governments: They should actively be supporting the industry, for example by using an anti-cyclic approach; not only because the industry is to a very large extend exposed to times of economic crises, but also because that an investment of any Euro or Dollar or whatsoever in the construction industry has a strong ‘network’ effect on the several (loosely) coupled parties within the industry. Another reason for governments’ role in an anti-cyclic approach might be the need for long-term investments (for example the total costs per period), thus also creating better conditions for private investors to join in this by adding their own (for example shorter-term) investments (for example the total direct investment) in for example housing-projects, as Tempelmans Plat described [Tempelmans Plat, 1984].

By taking the governmental lead for such (public) investments, which can be in a direct way by for example investments in project(parts), or in an indirect way by for example incentives via tax-regulations, the individual (private) investor will be better able to act on the (project)market. See also figure 1, in which the situation is represented that a government is completely compensating the economic decline and growth on any moment in the cycle, thus creating a totally anti-cyclic approach with a steady economic result during the cycle:

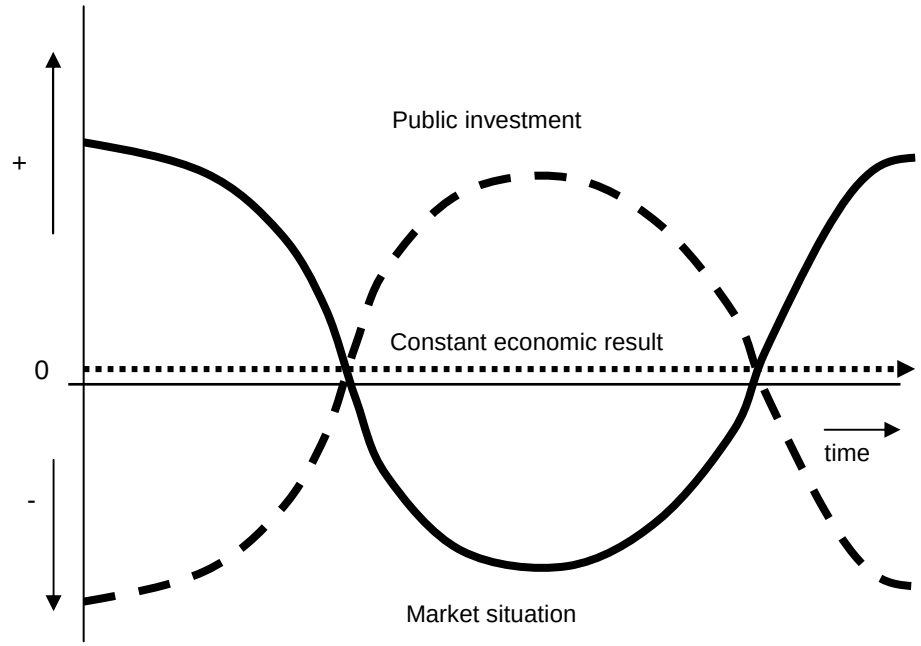

Figure 1: A totally anti-cyclic approach, by government’s compensation for economic decline and growth, on every moment in the cycle.

And although this situation might sometimes be the case, in practice it is still a quite difficult one, as it indicates a totally regulated economy. And parallel to such ‘ideal’ characteristics, in practice one can also signalize that the foreseen effects of such regulations do not emerge

immediately at the wished moment, but often occur within a timeframe after implementing the compensation-measurements. Considering also this, generally spoken, the intervention and its effects by governments in compensating economic decline and growth often occurs in more ‘delayed’ ways, and not on every moment in the the cycle. This thus leads to the fact that there is a dynamic difference in economic results during the cycle. See also figure 2:

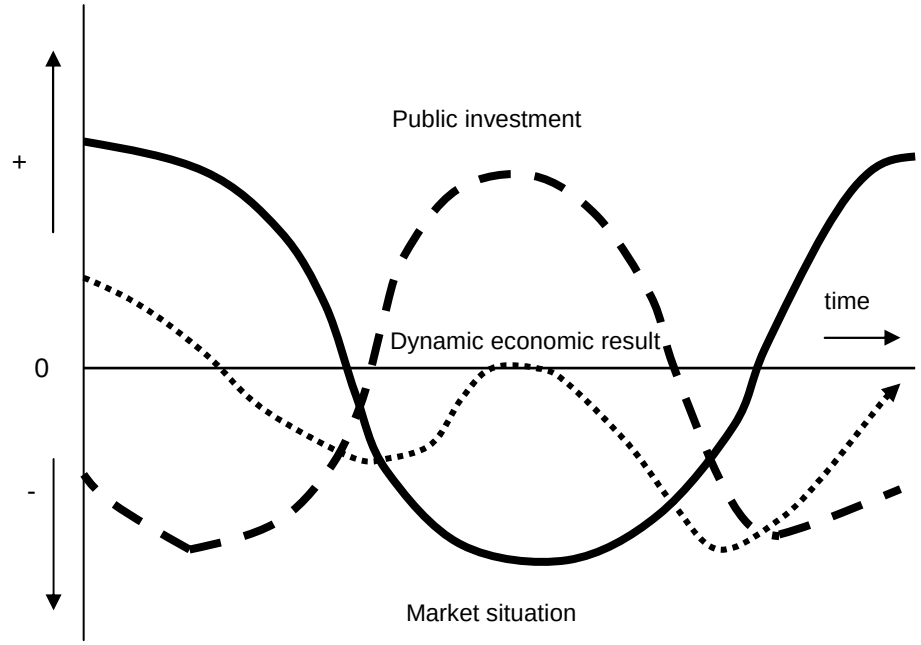

Figure 2: A ‘delayed’ anti-cyclic approach, by government’s compensation for economic decline and growth, not on every moment in the cycle.

Nevertheless, despite the way how governmental support is organized within construction industry, be it directly by for example ppp-projects or indirectly by for example special tax-regulations, any inflow of capital into the construction industry might help to attract also private investments again or to prevent private investments of being withdrawn from the industry. So from that viewpoint, a governmental policy according an anti-cyclic approach prevents the construction-industry for being ‘drowned’ during crises-times, and prevents it also for being ‘over-heated’ (with the often parallel growing untransparancy then) during properous times. Nevertheless, there are still discussions ongoing in society about wether it is useful or not to use governmental stimulation-programmes, because the ‘direct’ effects on society still cannot be measured properly; or at least they do have a more ‘delayed’ effect.

However, in relationship with such supportive compensating approaches, a government can connect their foreseen policy also with restrictions: For example, governments can oblige then construction industry to improve their practices (for example take care of the client, improving transparency, non-collusive behaviour, etc.). In other words, such policy might be

an extra ‘driver’ to improve construction-industry’s business-cultures towards improved functioning and competition-mechanisms. And this is obviously not a unique situation in business, as such type of governmental compensating policy is obviously also being used for other industries, resulting into a kind of ‘sector-regulations’; for example in compensating measurements regarding (global) competition issues between European and American aircraft industries, as described by Newhouse [Newhouse, 2007].

3. Opportunities for changing culture in construction industry

When analysing effects of governmental compensating policies, for example on the change of business-culture within construction industry, one needs to consider the structure of this industry more into detail. This structure is in fact a large network of parties involved; be it as shareholders and/or as direct or indirect stakeholders. When considering more into detail the effect of the network-structure of construction industry, as ‘the’ supplier of (infrastructure) projects to society, the nowadays influence of such networking capacities is tremendously; think for example at influencing power, now generated by clients via social media: A complaining client can now easily make or brake a company by the use of the webbased tools such as social media.

However, this increased use of such tools has also introduced a strong risk of abusing the same tools. For example how to prevent damage in the first moments if someone spreads false information about a contractor? Especially if the spreading is done by someone with a large (and thus often strong influencing) contactnetwork? Then it will take serious time and effort (and money; think at for example claims…) to solve the negative situation. In their book on business-cultures in international construction industry, Tijhuis & Fellows have described these social media networking activities as a serious tool and development, influencing stronly the nowadays and future construction industry. See also figure 3 [Tijhuis & Fellows, 2011]:

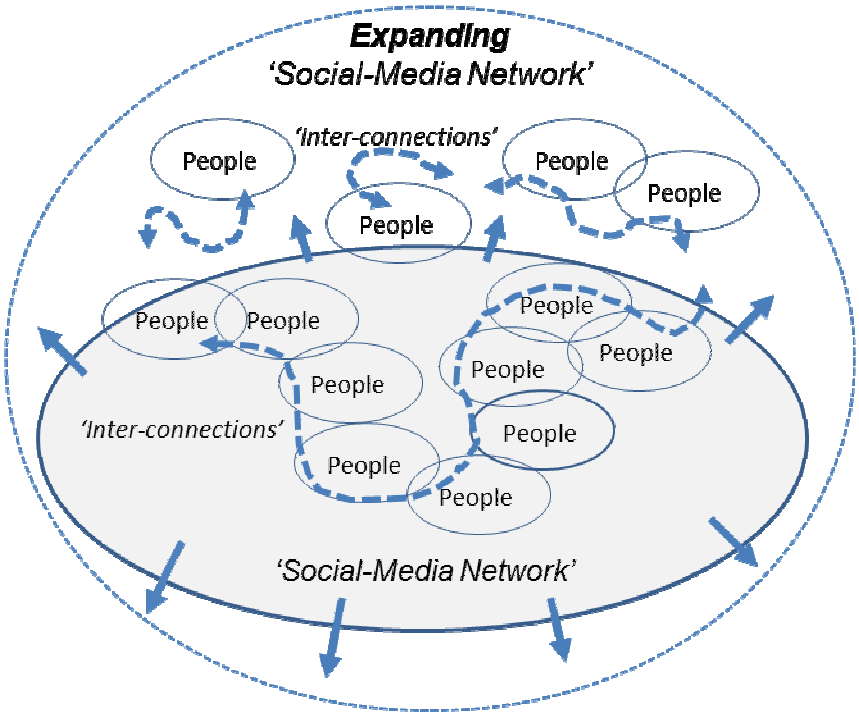

Figure 3: Schematic representation of social-media networks as a tool for 'inter-connecting' people, thus stimulating influencing opinions and/or harmonizing human behavior of (groups of) people [Tijhuis & Fellows, 2011].

Looking to this social-media effect, it leads more or less towards a more transparant society, where every fact and/or rumour turns itself into a 'viral'spreading over a growing number of people or 'followers', thus being able to inform people very fast and against very low cost; but it also carries the risk in itself, that it also easily turns fiction into (virtual) 'reality'… Therefore this effect is not only a positive one, but has also a negative effect, regarding its inherent risk for harming personal and/or corporate reputations, etc.

Nevertheless, this negative effect can also be turned into a positive effect, because it prevents certain groups of people/companies of behaving unprofessional. For example, if a contractor does not take his client's wishes and demands seriously, and refuses to repair his failures within the delivered project, the client could go then to court and/or into arbitration; of course these legal instruments are still available and (still often) effective, but still often take a lot of procedure-time and –costs. Alternatively, the use of the social media is then a very cheap and effective alternative for the same situation: For example, if the client writes his or her complaints about this contractor on the social-network (web), it will often immediately have its impact on the contractor's reputation, thus forcing him in practice to take serious actions (for repairing the project; and thus also for repairing his reputation…). Of course this all has to do with the use and/or abuse of such socail networking possibilities, but, rather than only put a lot of effort (and money…) in claiming for abusing one's name and reputation, somehow also a -parallel- positive action regarding a client's (dis)satisfaftion should at least also be delivered by the contractor in such cases. However, of course it

should not result into a kind of ‘web-terror’ etc., so keeping alert about what is discussed on weblogs and -fora etc. needs to be taken seriously nowadays by every party in the market.

Nevertheless, need for improvement and governmental support of nowadays construction-industry during the actual crisis-situation, combined with the rise of the social media, and reflected against the generally speaken ‘quite negative’ image of construction, can indeed help to make the construction industry a more open sector, driven by professionals and within a positive professional business-culture. It even can be a kind of pre-requisite for governments to oblige the industry to behave accordingly, before/during/after starting to help with direct and/or indirect (anti-cyclic) public support measurements. From that viewpoint, the momentum during crisis-times might be quite ‘perfect’ for changing the business-culture.

Nevertheless, altogether it is just merely about being honest, plus being able and willing to listen to the clients, thus focusing on delivering a (still profitable) added value, according client’s wishes and demands… But staying profitable will also need a client’s recognition of the construction industry’s ‘new’ performance then, leading again to a fair pricing-level. In that way, creating such transitions will not be a one-way approach, but indeed still a two-way vice-versa approach.

4. Discussion

Altogether, the above described developments according analysed (anti-cyclic) governmental support and the rise of the social media do lead to a more transparent situation within the market; not only for construction industry, but also for other business-to-business (B2B) or business-to-consumer (B2C) activites. For construction-industry, this potential to unlock the possibilities for creating a certain degree of transparency, should be able to lead to removing the old but often still heard non-professional ‘image’ and/or even illegal ‘practises’ within the industry; and not only practiced by private parties, but also by public parties. See for example the case of the collapse of the well-know ‘Ronan Point building’ on 16th of May 1968 in the United Kingdom: Several forensic analyses afterwards pointed out that the local building regulations had been neglected by the private parties to a large extend [Griffiths, Pugsley & Saunders, 1968], whereas the supervision on-site was not professional enough [Feld & Carper, 1997].

However, as Delatte also analyses, the accompanying ethical aspects of such collapses are even more important, because in that case several important parts of the information were hidden for the public; not co-incidently, but merely because at that time there were about six other realized buildings, being built with the same so called ‘Larsen & Nielsen’ prefab-construction system, ‘…and there was not enough money to strengthen them’ [Delatte, 2009].

So when using the transparency-theme as a ‘new’ driver for changing business-culture and to improve the construction industry’s image, it may lead to the following needs, defined for (a) *construction professionals*, (b) *governments* and (c) *clients*:

(a) *To stimulate professional transparent behaviour of people working within the construction industry, this ‘new’ business-culture needs to be on strategic agendas on board levels, and from there on branch-level;but it cannot survive without a recognition by clients and public regulations;*

And parallel to that:

(b) *Governments do need to behave also accordingly, with a willingness to publish results of (internal) investigations, leading to an honest set of regulations and measurements, thus improving a fair competion in the market;*

And last but not least:

(c) *Clients do need to take into account the importance of fair pricing, which is not just the lowest price, but has immediately to do with a real and fair balance between price and quality. This rewards the parties properly according their positive actions for behaving within a fair competition, thus merely balancing a ‘level playing field’.*

Wrapping up the above discussion, one can think that there is still a long way to go to improve the total image of construction industry. And indeed that still seems to be the case, especially during nowadays harsh competition, where there doesn’t seem to be a level playing field at all, especially within international construction markets.

However, if there is no start for action. for example by direct or indirect governmental measurements (as being quite big clients, also and probably especially even during crisis-periods), then one might be sure that indeed ‘everything will stay the same’. Thus, for creating such real transitions, one should indeed especially focus on the ‘frontrunners’, as positive examples in the market: Followers will follow, although somewhat later, but indeed will still follow. That approach reduces the need to take care for those, who are not able to follow anymore, thus being part of the ‘losers’ in the market. And although this is not in the direct interest for everyone, it still has the power for restructuring markets, by separating the ‘winners’ and the ‘losers’. And apart from ‘technology-driven’ approaches, the behavioural aspect for changing a market is of eminent importance.

In relationship to this, Van den Bosch concluded in her Ph.D.-thesis, related to transition experiments, that the current thinking about innovation remains too focused on technology; technology alone cannot create a sustainable society. At least of equal importance is the behavioural change [Van den Bosch, 2010]. And that is indeed a ‘positive’ aspect of the ‘momentum’, delivered during crisis times: It indeed forces people to change their behaviour, resulting into changing business-cultures, improving the construction-industry and it’s contributions to society.

5. Conclusions & Recommendations

Based on the above described analysis, the following conclusions and recommendations have been defined:

5.1 Conclusions

1. *Crisis-times might be felt as negative, but for construction industry they might also help for restructuring the market seriously.*

2. *Positive news travels fast, but negative news often travels even faster; this 'adagium' is also working on social media platforms, which functions therefore as a risk for a company's reputation, but parallel also as a positive chance to improve a company's reputation, influencing also the construction industry's reputation.*

3. *Transparent communication between public and private parties is not a one-way approach, but needs toe be done within a two-way approach. This obliges both government and industry to communicate on a well balanced way.*

4. *If the conclusion from the analysed literature is right that transition activities in general focus too much on technology-aspects alone, instead of the at least equally important behavioural aspects, this might indeed result into a stronger need for research into business-cultures in construction industry (and the ways on how to understand and how to improve them) to become a positive effect for construction-industry and it's contributions to society.*

5.2 Recommendations

a. *Especially in the situation when one wants to change the negative image of the construction industry, the attention should especially go to the 'winners' in the industry, helping the industry to set them as positive examples for future recovery and growth.*

b. *Being aware of the social media influence should stimulate companies in construction industry positively to use such tools by themselves also pro-actively, thus being alert on the company's prospect's and client's opinions, activities and future plans.*

c. *To create a level playing field for fair competition in the market, clients should focus on serious attention for fair pricing; this means especially not to focus just on the lowest price, but always balance it as a price/quality ratio.*

d. *The research into business-cultures needs a direct input possibility by providing behavioural data from real-life processes and/or projects within indistry. This implies the need for a good collaboration between industry and academia. The positive effect can be that industry sees the value of such*

actual behavioural data, co-analyzed and shared with academia, and implemented to industry again as results to improve business-culture.

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First PPP Application in the Urban Water Supply Sector: Performance and Lessons from Ghana

Ernest Effah Ameyaw[1], Albert P.C. Chan[2]

Abstract

Following decades of neglect, unstable political and economic conditions, under-investment and inadequate pricing policies, the urban water sector of Ghana fell into disarray. In June 2006, a management contract between Ghana Water Company Limited (GWCL) and Aqua Vitens Rand Ltd (AVRL) emerged as an alternative to bring efficiency to the delivery of urban water. Asset ownership and investment responsibilities remained with the GWCL while the operation and maintenance of the urban water systems was transferred to AVRL, for a monthly fee, and bonus payments for achieving or exceeding contractual targets. This paper presents a thorough study of the process and outcomes of Ghana's first urban water management contract, and draws attention to useful lessons for academia, reformers and policy-makers who are interested in PPP water supply projects in Ghana. Drawing on this case study, the authors find mixed outcomes, with noticeable improvements in labour productivity, revenue collections, energy efficiency and most importantly cost coverage, but no improvements in demand management, non-revenue water, and revenue collection period. The case study provides relevant experiences and lessons for both the private and public sectors entities planning to participate in water PPPs in Ghana.

Keywords: Management contract, water supply, performance, private sector, Ghana.

1. Introduction

Since the late 1980s, Ghana has made various sector-wide efforts at reforming its urban water sector by passing laws, developing appropriate policies, drawing up structural programmes, strategies and plans aimed at bettering service delivery to urban residents. Like other low-income countries, the challenges of Ghana's urban sector ranged from limited service/network coverage to grave inefficiencies and low quality service to customers following the disrepair and replacement of the aging water distribution infrastructure, a precarious financial situation, and chronic institutional weaknesses (Fuest and Haffner, 2007; Nii Consult, 2003; Whitfield, 2006; WaterAid, 2005).

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Remedying the situation, and ensuring improved service delivery has been an overwhelming task for various governments of Ghana, since the early 1990s. Following continuous international and domestic pressure, the government turned to the private sector in the form of public-private partnerships (PPP) not only to improve the financial viability, operational sustainability and the quality of urban water supply but similarly as acting as an instrument for institutional transformation (Ainuson, 2010; Ameyaw and Chan, 2012; Mugabi and Marin, 2008). Therefore, after 15 years of consensus building and five years of experimentation with a private management of urban water supply services, stocktaking of experiences and results is timely. This paper presents a thorough study of the process and outcomes of Ghana's first PPP management contract, and draws attention to useful lessons. Thus, it discusses the pre- and post-PPP status of Ghana's urban water sector. Specifically, the impact of the PPP on energy efficiency, demand management, cost coverage, labour productivity, and revenue collection efficiency are examined. Drawing on experiences over the years, PPPs in the water sector have been very controversial (Prasad, 2006) and complex for most governments. Their complexities vary according to specific country and project circumstances (Zheng and Tiong, 2010). A case study research, therefore, is a well-established methodology to study PPP practice to capture specific project characteristics, gain thorough understanding of its development and implementation, and draw relevant lessons (Meng et al, 2011; Zheng and Tiong, 2010). This paper, therefore, adopts a case study approach. The performance assessment draws on empirical data from credible sources, mainly reports from AVRL, GWCL, the sector ministry, the World Bank, and the International Benchmarking Network for Water and Sanitation Utilities (IBNET).

The choice of this case study by the authors is enthused by the fact that it is the first and only urban water PPP to be implemented and has been controversial, attracted national and international attention. The case study provides practical insights for private companies, policy-makers and reformers, water practitioners and academia at the time when government has fully embraced the PPP concept in its development policy, and more PPP projects are being planned in the water sector. Following on this introduction, the paper reviews the pre-PPP status of the urban water sector in section 2, while the justification for the management contract is summarised in section 3. The contract is presented in section 4, its performance is examined in section 5, and lessons are highlighted in section 6. Finally, concluding remarks are made in section 7.

2. Background and Pre-PPP status of the urban water sector

Following decades of neglect, unstable political and economic conditions, institutional weaknesses and fragmentation, poor management practices, under-investment and inadequate pricing policies, the urban water sector of Ghana fell into disarray. These problems are classified under technical and operational, commercial and financial, and human and institutional. This brief discussion captures the state of the public water utility prior to the participation of the private sector.

2.1 Operational and technical problems

Operational practices in the sector were inefficient; regular infrastructure maintenance was insufficient, fire-fighting maintenance approach was widely practised, supply was intermittent, and non-revenue water (NRW) was over 50% of total output (Fuest and Haffner, 2007; Ofosu, 2007) compared with international best practice of 10-20% in well-run systems (Haarmeyer and Mody, 1998). Given the level of NRW, the total volume of water that is effectively sold (280,000m^3/day) is less than half of daily demand of 763,300 m^3 (WaterAid, 2005), with a total of 350,000 private connections, as of 2006 (AVRL, 2011). Figure 1 presents some NRW ratios from 1996–2005. The high NRW levels resulted from apparent losses and real losses owing to leakages from poorly-maintained distribution networks and untimely replacement of aged and badly deteriorated systems (GWCL, 2008; WaterAid, 2005). Under these conditions, it is difficult to expand service provision to cope with the growing populations. Access rates remained notoriously low, coverage rates in 2004 and 2005 are 57.5% and 56% respectively (MWRWH, 2009) compared with 56% in 1993 (Haarmeyer and Mody, 1998).

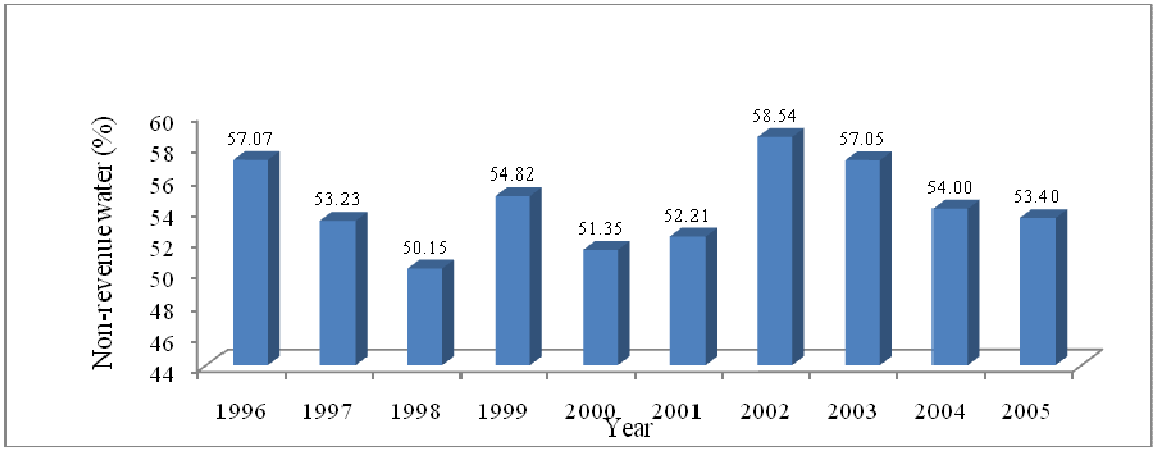

Fig. 1: Non-revenue water trends from 1996-2005 (Source: Authors)

2.2 Commercial and financial problems

In poorly-managed water utilities, consumption is hardly metered, or metering is limited and meter readings and billing of genuine consumption is not practised (Idelovitch and Klas, 1995). Metering and billing malpractices, such as manipulation of meter readings, understatement of actual consumption, poor classification of consumers, low metering ratios, and irregular meter reading, characterised the Ghanaian water sector (Nii Consult, 2003). The direct effect was a precarious financial situation of GWCL. In addition, unreliable consumer data and inefficient collection practices resulted in high commercial losses (AVRL, 2011), while disconnection of defaulted consumers was weakly and randomly enforced owing to clientele relations and political reasons (Fuest and Haffner, 2007). The utility, therefore, was financially weak and unable to deliver quality services. The water sector has long been plagued by non-commercial pricing, because successive governments were unwilling to approve cost reflective tariffs for political expediency, a situation that hampered the utility's ability to expand water services (Haarmeyer and Mody, 1997). Whitfield (2006)

noted that underinvestment in the sector, which saw the exit of professionals and a grave fall in operational efficiency, resulted from the late 1970s and early 1980s economic crisis.

2.3 Human and institutional problems

Public water utilities are often overstaffed, with 5 to 20 employees per 1,000 water connections, indicating the low productivity of public water utilities (Idelovitch and Klas, 1995; Haarmeyer and Mody, 1997). Employee ratio, as a measure of labour productivity, varies widely across utilities and countries. GWCL was overstaffed with 4,300 employees most of whom were unqualified professionals (Ameyaw and Chan, 2012). By industrial standards, Nii Consult (2003) found that 50% of GWCL's staff was redundant; for example, in 2006, labour productivity ratio was estimated at 60 employees per 1,000 connections (Kauffmann and Perard, 2007) compared with international best practice of 2–3 workers (Haarmeyer and Mody, 1997).

GWCL is plagued by political interferences and political appointments and inability to attract, nurture, and retain managerial talent and qualified professionals (Idelovitch and Klas, 1995). Experience has shown that appointments to the position of directorship and other high rank positions are based not necessarily on competence, but rather on allegiance to the ruling party (Alidu, 2011). Political appointments are devoid of competition and have led to overstaffing, low productivity and high wage bills that potentially weakened the commercial and financial sustainability of GWCL (Fuest and Haffner, 2007). These problems pushed the government to search for possible solutions to the ailing water sector, including a PPP. The following section briefly explains the justification for the PPP management contract.

3. Justification for a PPP management contract model

The earlier approach by the government of Ghana to resolving above problems was to invest in physical infrastructure, supported by technical and financial assistance provided through its development partners and international financial institutions. This approach seemed to have made limited improvements – given the multiple failings in all aspects of the public water utility. To remedy above problems, and to ensure long-term and sustainable improvements in the operations of GWCL, managerial and technical expertise had to be integrated within the utility's activities. Therefore, the government and its development partners embraced private sector participation as the most viable option. The object was to procure a strong, experienced and competent private operator with appropriate expertise for efficiency gains in the sector without huge increases in tariffs (Ameyaw and Chan, 2012).

Unfortunately, long-term PPP arrangements presented substantial risks to both the government and potential private water operators, giving the following conditions: (a) prevailing water rates were uneconomic for a revenue-based PPP to thrive; (b) sustained public resistance prevented any attempt for an ambitious contract with increased private involvement; and (c) highly deteriorated water infrastructure, and scanty and unreliable data on existing systems offered no incentives for long-term contracts. Management contracts have been used in such circumstances for stage preparation (WSB, 2010). Additionally, given the precarious financial situation of GWCL and the public sector's inexperience in

PPPs, a management contract promised several benefits due to its high flexibility, limited duration and restricted private ownership of assets, and greater government control over tariffs (Mugabi and Marin, 2008). In particular, the contract allowed the government, GWCL, consumers, civil society groups and the project sponsors to experiment with private management with only a short-term partnership.

4. The Partnership: contracting process and obligations

The process of engaging a private operator began in 2003, following a 13-year and heavily-contested policy process. The road leading to the award of the contract 'was a long and stretched out political process that involved' multiple stakeholders (Bohman, 2010). The contracting process began with a detailed analysis of the existing management problems. As indicated, areas of major concerns included: (a) widespread water leakage and wastage; (b) chronic water shortages and intermittent supply; (c) poor cost recovery; (d) high energy consumption; (e) low water quality; (g) low utilisation capacity; and (g) poor operating pressures. These are signs of management and institutional weaknesses, such as poor collection practices, bad maintenance culture, uncontrolled costs, and under-pricing regimes (Marin, 2009). The establishment of the key service problems and the reasons for private sector engagement guided the selection of performance measures corresponding to these problems, specification of the service targets to be attained and subsequent selection of the operator. The performance-based management contract can be best described as a hybrid, with the following characteristics: (a) control by private operator over funding for training programmes (US$1.5 million), repair and replacement (US$5million, and US$6.5 million was added later), and making yearly proposals for capital expenditure to GWCL; (b) private operator control over the water supply infrastructure during the contract period; (c) complete private operator control of operations, maintenance, water abstraction, treatment, and distribution to consumers, billing and revenue collection; (d) private capital of US$250,000; and (e) a performance incentive which allows the operator to keep a proportion of the incremental cashflow following enhanced operational efficiency and better performance.

The management contract was implemented within the frames of the Urban Water Project (UWP) which was funded by the World Bank (US$103 million), the Nordic Development Fund (US$5 million) and the government of Ghana (US$12 million), totalling US$120 million. The overall aim of the UWP was to upgrade the urban water infrastructure, expand access to piped water; and restore long-term financial sustainability of the urban utility. The project entirely had four components, presented in order (World Bank, 2004):

1. Network Expansion and Rehabilitation (US$88 million) – focused on increasing the quantity of bulk water for distribution, rehabilitation and expansion;

2. Public-Private Partnership Development – aimed at improving customer satisfaction and forms 8% of the project;

3. Capacity Building and Project Management (US$4.5 million) – focused on training of seconded staff and pursuit of sector reform of urban water supply; and

4. Severance programme – focused on financing the severance programme of the government.

On 22 November 2005, the 5-year contract for management and operation of 80 urban water systems was awarded to an international public sector joint-venture, Aqua Vitens Rand Ltd (AVRL), through an international competitive bidding process. The contract between GWCL and AVRL officially started on 5th June 2006. The overall objective of the management contract is "to restore GWCL to a sound financial footing and make a significant improvement in the commercial operations of the company" (MWRWH, 2009). GWCL remained the asset owner and responsible for investment, development and expansion of the water systems. It had an additional responsibility for day-to-day monitoring of the contract, with external assistance from technical and financial consultants. An independent regulator, Public Utilities Regulatory Commission (PURC), must approve all tariff revisions over the contract's life. As a partner, AVRL's core business included management of urban water systems, potable water production and distribution, billing and collection. The operator also provided key management team, with a 2,800 seconded staff from GWCL (AVRL, 2010).

AVRL was paid a fixed fee to run GWCL's operations, and a financial incentive for achieving or exceeding performance targets. Bonus payments were tied to critical quantifiable targets, such as improved collection ratios, reduced energy consumption and NRW, and increased water production and hours of water supply. In contrast, the operator's base fee was to be reduced by penalties based on the extent to which performance falls below targets. Like other management contacts, the base fee portion of the contract formed the basis for competitive bidding, and the AVRL was selected based on the lowest management fee of US$11 million for the 5-year period (Tucker et al., 2010). The management contract set out requirements for service quality: treated water quality, service continuity, water pressure and flow, customer service, revenue collection, non-revenue water, capacity building, energy consumption and chemical usage, demand management, and rehabilitation and replacement.

5. Performance evaluation

The partnership presented above ended on June 2011 after five years of GWCL–AVRL relationship. To what extent was there measurable evidence that the first partnership improved urban water services in Ghana? Following data deficiency, five key performance targets specified in the contract are investigated. In addition, the authors assessed whether the PPP implementation had any spill-over effects regarding policy and institutional development in the water sector.

5.1 Energy efficiency

The contract required that the operator presents a power reduction plan within 12 months of commencement and reduces power consumption (to be measured in kWh/m^3) as per the plan. The operator enjoys a financial incentive for reducing electrical consumption and suffers a penalty for failure. The 2006 baseline figure is used as the basis for assessment

because the set target is unknown. Overall, the total electricity consumption for water treatment plants reduced slightly. Table 1 indicates that GWCL recorded an 18.1% reduction in electrical energy consumption per m^3 of water treated during the contract period, from 0.83kWh/m^3in 2006 to 0.68kWh/m^3 in 2010/2011. However, it is worthnoting that out of the 89 treatment plants: only 26 reduced electrical consumption, 28 increased consumption, and the remaining 35 plants had no reliable data for assessment. According to AVRL, the reduction was due to correction of erroneous billing in previous years, tackling illegal electrical connections, and proper relocation of electrical meters closer to the treatment plants. However, from Table 1, annual electricity costs and electricity cost/$m^3$of water do not indicate falling trends. For example, cost/m^3 increased from Gh¢0.066 in 2006 to Gh¢0.12 in 2010, representing a 45% cost increase. Possible reasons include increased inflation/energy prices, and low quality of raw water.

5.2 Demand management

One of the main objectives of the contract was to decrease public sector (ministries, departments and agencies) water consumption through metering. Public sector consumption constitutes some 18–20% of total water produced in the urban water sector (Fichner et al., 2010). AVRL was required to submit a demand management plan within 6 months of commencement to reduce public sector consumption by 3% of a baseline annual consumption.

***Table 1: Selected performance figures from 2006–2011 (Source:** AVRL, 2011; Fichner et al., 2010)*

Performance indicator	Unit	2006	2007	2008	2009	2010	2011
Energy costs							
Electricity cost	M Gh¢		17.1	32.8	22.6	29.8	
Electricity cost/m^3	Gh¢/m^3	0.066	0.080	0.152	0.098	0.12	
Treatment plants energy usage	kWh/m^3	0.83	–	0.71	0.69	0.68	
Technical							
Non-revenue water (NRW)	%	53	52	52	52	50	51
Capacity utilisation	(%)	74	75	75	73	67	
Operating costs							
Collection efficiency	%	96 (95)	90 (89)	91 (93)	79 (97)	(91)	
Collection period	days	376	363	369	372		
Total annual income	M Gh¢	57	69.4	102.3	106.6	146	
Total annual operating cost	M Gh¢	48	57.8	89.6	87.8	109.6	
Net operating surplus	M Gh¢	9	13.4	12.7	18.8	36.4	
Employees							
Staff/1,000 connections	#	7.8	7.9	7.7	7.5	7.2	
Staff as of 31st December	fte	2,840	2,975	3,092	3,156	3,162	

Note: Figures of collection ratio in bracket are from the operator, AVRL. GWCL reported electricity cost/m^3 of Gh¢0.39 for 2009.

The World Bank audit report established that very little was achieved in terms of metering and establishing baselines for public sector institutions. Though water supply to these institutions has improved, billing is mainly based on estimated, rather than actual, consumption. Installation of water meters was held back by slow procurement processes, financial constraints, and other on-site conditions such as installation challenges (AVRL, 2011).

Furthermore, progress on non-revenue water (NRW) reduction, one of the key objectives of the contract, has not been as originally anticipated. The contract required AVRL to submit a comprehensive NRW reduction plan within12 months of commencement that details a systematic reduction by supply area and how to determine NRW levels in the absence of complete metering. The performance target was a 5% reduction per year per service area, with a final target of not more than 25% by the end of the contract. As a percentage of water production, NRW stood at about 53% in 2006 and about 51% in 2011 (Table 1), representing a marginal reduction of 2%. High system losses are expected, given the (a) highly deteriorated distribution network, (b) inadequate pressure management practices; and (c) absence of widespread metering. NRW figures were based on rough estimates due to lack of reliable historic data, inaccurate customer database and billing systems, and lack of bulk and domestic water meters at connections and standpipes. This situation rendered the establishment of baselines and achievement of projected targets impossible.

5.3 Revenue collection efficiency

Revenue collection efficiency, a ratio of cash collections over billings, affects the cashflow of a water utility and measures the efficiency of its commercial management (WASREP &WSP, 2011; Marin, 2009). Figure 2 illustrates the revenue trend and collection efficiency prior to and under private management. Prior to the management contract, GWCL's was collecting 75% of its billings. Under the contract, collection efficiency ranged between 89% and 97%. The 2008–2009 sharp rise in revenue collection level was due to improved collection practices, extensive education campaigns, flexible collection methods for low-income consumers, establishment of more customer pay points, and disconnection of defaulters and (sometimes) court actions (AVRL, 2011). However, maintaining collection levels above 90% was not due to improved service, as irregular supply was widespread, but rather strict collection policies and AVRL's strong commercial incentives.

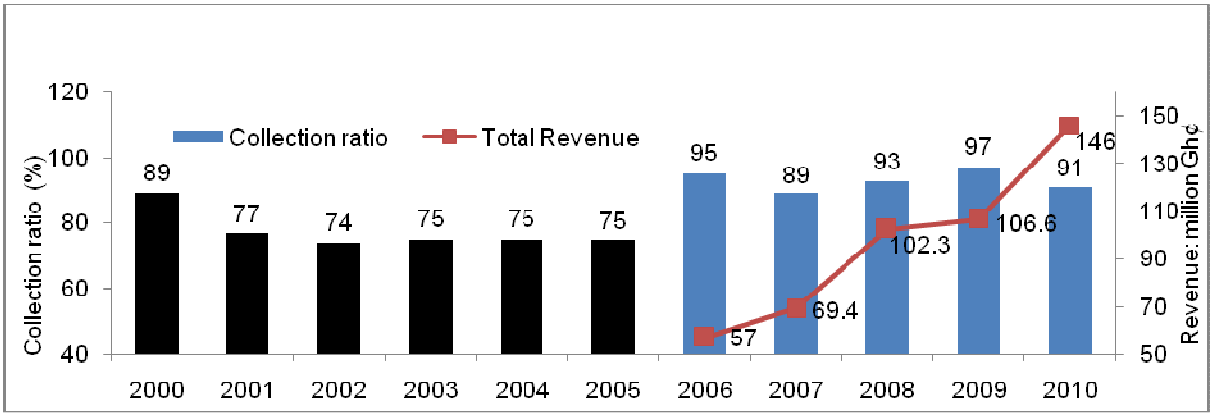

Fig. 2: GWCL revenues and collection efficiency trend before and under private management (Source: Authors)

Moreover, such high collection efficiencies were in part due to collections from accounts receivables – a target of the contract, and also, the starting level was quite good when AVRL took over, for example, a collection rate of 75% for 2003 to 2005. Though data on collection period prior to the management contract is deficient, the number of days for recovering payments under AVRL fell from 376 days in 2006 to 372 days in 2009 (Table 1 indicating a reduction of only 4 days. The data deficit limits our ability to compare with the previous

situation under public management. However, the operator fell short of achieving IBNET's 90-day benchmark. This poor performance in debtor days perhaps reflects the difficulties in recovering payments due to weak consumer confidence in and willingness to pay for services as a result of low quality services and increased tariffs.

5.4 Labour productivity

Labour is the largest fixed cost for water utilities and labour productivity is a relevant measure of operational efficiency (Marin, 2009). Introducing a private operator often results in low staffing levels and improved labour productivity (Gassner et al., 2008). The transition from public to private management entailed major changes in corporate culture, staffing and salary levels and employee qualifications. The need to replace the low-qualified with high-grade employees and ensure higher labour productivity made redundancies inevitable. Though efficiency target of less than 10 employees per 1,000 connections (Table 1) was surpassed (World Bank, 2009), this is largely due to the retrenchment programme executed by the government beforehand. The layoffs were tense and socially sensitive, and therefore AVRL was not involved in the process. During the contract life, the operator further improved staff ratio from 7.8 to 7.2. The retrenchment of 1,600 workers (Fuest and Haffner, 2007) demonstrated how much excess staffing existed under public management before the PPP reform, owing to years of clientelism and political infiltrations. However, staff levels continued to grow gradually from 2,840 in 31st December 2006 to 3,162 in 31st December 2010.

5.5 Cost coverage

Given that the management contract was floated as a panacea to the utility's grave financial distresses, operating cost coverage was a key performance target and expectation of the stakeholders, namely the government, sponsors, GWCL, AVRL, and the civil society. As of 2005, the utility's cash income could not support its operation and maintenance expenditures and only 48% of costs were recovered (AVRL, 2011). From World Bank's perspective, the management contract made significant progress having achieved the target of recovering 100% of the operation and maintenance costs from GWCL's revenues (World Bank, 2009). The annual income increased from Gh¢57 million in 2006 to Gh¢143 million in 2010, with operating surplus rising from Gh¢9 million to Gh¢36.4 million over the same period.

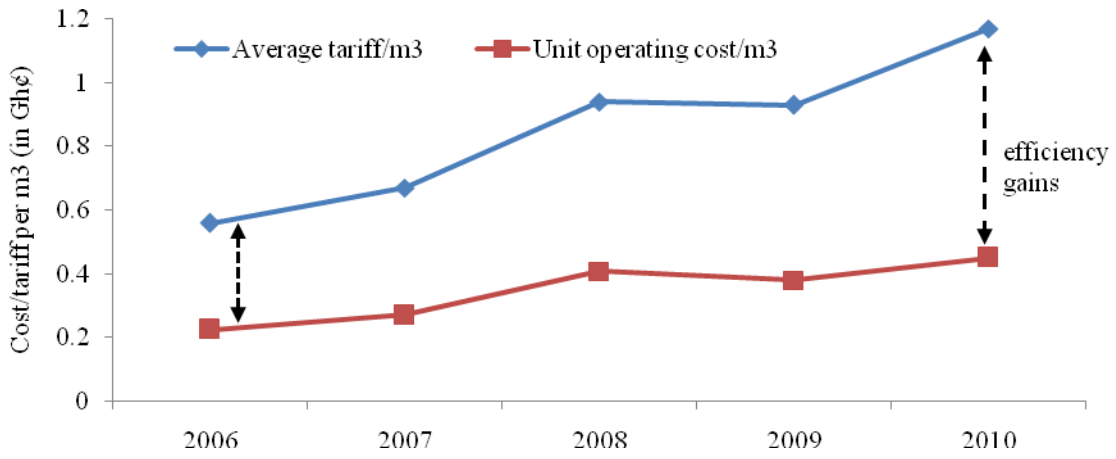

Fig. 3: GWCL's unit operating cost and average tariff under private management (Authors)

Given that tariff increase was subject to PURC's approval, the operator did not have all the factors influencing the financial equilibrium of GWCL under its control, but had the opportunity to strictly control costs. However, the government must be commended for allowing justifiable tariff increases (Ameyaw and Chan, 2012) which largely contributed to operational and maintenance cost coverage. This decent achievement – financial stability and viability of GWCL – is the combined effect of AVRL's effort and the government's commitment. Figure 3 illustrates GWCL's average tariff and unit operating cost under private management – indicating that efficiency gains improved during the 5-year period.

5.6 Policy and institutional development impact

The qualitative evidence suggests that at least the management contract has had wider policy and institutional development impacts beyond the requirements specifically expressed in the contract. Two major policies were promulgated. First, one year into the contract, the National Water Policy was promulgated. The policy provides a framework for sustainable development of water resources in the country. It is targeted at all relevant stakeholders, including water managers and practitioners, investors, water users, and policy- and decision-makers within the central governmental and decentralised structures, international organisations, and non-governmental organisations. Second, a National PPP Policy was enacted in June 2011 to facilitate private sector involvement in infrastructure and services delivery. The policy clearly outlines procedures and models of private sector participation. The adoption of the policy reflects the government's desire to meet the infrastructure needs of the growing population through private sector capital and managerial expertise. These developments reinforced the argument that the presence of a for-profit private operator has the possibility to favourably influence government policies towards water services and their implementation (Mugabi and Marin, 2008).

6. Lessons learnt

The urban water management contract is the first PPP project in Ghana, and there was no prior experience in PPPs. The project, therefore, provides a learning platform for the public and private sectors for future water supply PPPs in the country and elsewhere. Some useful lessons and experiences provided by this case are highlighted:

1. The Ghanaian experience exhibits the indispensable role that government (political) support plays in making management contracts work for water supply services. Despite the widespread water shortages and irregular supply, the government supported increased tariffs and stricter collection policies that in part ensured full O&M cost recovery from the utility revenues. Indeed, a transition from under-pricing to economic-pricing regime requires political backing – a condition for successful management contracts.
2. Private management of water supply services brings new competencies and skills through knowledge transfer, and also promotes policy and institutional transformations.

This brings important service delivery issues to the attention of reformers, water practitioners, and policy- and decision-makers.

3. The public sector should not raise unrealistic high expectations of the performance of the private operator – how fast performance can be improved. The Ghanaian experience indicates that public expectations on fixing the problems of NRW, widespread intermittent service, and chronic water shortages were poorly managed. AVRL had difficulties in reducing NRW, bridging the increasing demand-supply imbalance, and re-establishing continuous service, given the absence of baseline data, destitute network condition, and insufficient funding. It is worthnoting that AVRL's inability to realise these targets hampered the evolution of the management contract into a lease. PPP transaction advisors must carefully set performance targets in future contracts.
4. Management contracts for water supply services must be carefully and properly designed. Ghana's contract exhibited two flaws that must be avoided in future partnerships: (a) unclear objectives and responsibilities. Given the grave sector challenges, a "*catchall with multiple unrealistic targets"* design approach was adopted, seeing the contract as a magic bullet, but leaving the responsibilities of GWCL and AVRL poorly-defined; and (b) difficulties with interpretation of the contract. This prolonged decision making regarding investments, capital budgets, procurement, sales of assets, and outsourcing of services.
5. Access to reliable before-and-after performance data is a significant hindrance to meaningful performance analysis. Poor documentation of and discrepancies in performance data is observed in this case study. There are data inconsistencies depending on source – GWCL, AVRL or independent organisations. This renders practical evaluation of performance difficult, if not impossible. Therefore, there is a need for a proper and common framework for performance monitoring and reporting.

7. Conclusion

The paper has made an attempt to analyse Ghana's experience with its first urban water management contract with a private operator. Prior to the introduction of the private operator, the status of urban water supply was in a terrible condition, characterised by prevalent water losses, chronic water shortages, dissatisfaction among consumers, high operational costs and a debt-ridden public utility that was struggling with high non-payment. To arrest the situation, the Ghanaian government with financial support from the World Bank and Nordic Development Fund engaged the private sector as part of a wider sector reform process. Given Ghana's inexperience with PPPs, the precarious financial condition of GWCL, the unattractiveness of the urban water sector and the fierce public resistance to private sector participation, a 5-year management contract provided many advantages in terms of its flexibility, limited duration and increased government control over tariffs and infrastructure. Before-and-after data showed noticeable improvements in the labour productivity, revenue collections, energy efficiency and cost coverage, but no improvements in demand management and revenue collection period. As this paper has shown, the performance of this management contract is best described as mixed. On one hand, the Ghanaian experience demonstrates that management contracts for water services can potentially activate policy and institutional transformation, paving the way for increased private activity in the water sector.

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The Effect of Construction Demand on Bidders' Mark-up Decision

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Abstract

Construction demand is a core component of the construction market and affects the behavior and decision making of contractors in bid pricing. Much of the investigation performed to date, focus on the extremities of general market conditions such as the peak and trough of a boom or recession but provide little empirical support to describe the effects of the intermediary. That is, the effects of varying levels of construction demand on bidders' mark-up decision. An experimental approach that allows active manipulation of variables for hypothesis testing is adopted for this study. A controlled laboratory environment was used to simulate construction bidding with participation from 55 inexperienced bidders with a construction project management background. Construction demand is modeled as the availability of projects in any instance of time. Over the 20 rounds of the experiment, the bidders were separated into two treatment groups, one with a continually increasing level of construction demand and the other case, a continually decreasing level of construction demand. The results suggest that the level of construction demand does have an effect on the bidders' mark-up level and that periods of greater demand lead to a higher overall mark-up level, whilst lower mark-up levels are characterized by a lower level of construction demand. These findings provide empirical support for describing the effect of varying construction demand on the bid price level and allow for clients to better understand and incorporate this component that may affect their procurement strategy.

Keywords: construction bidding, construction demand, experiment, mark-up

1. Introduction

For the construction industry, descending sealed-bid auctions are the contractors' main method of acquiring work. Part of this process involves formulating a bid that incorporates the cost of construction and a mark-up accounting for risk and profit (Dyer and Kagel, 1996). However, formulating an effective bid is complex and requires an accurate estimate of the cost of construction, in addition to a suitable mark-up with due consideration to the competitors' prices (de Neufville et al., 1977). As de Neufville et al. (1977) summarize the outcome of the process; submitting an uncompetitive bid results in failure to attain the contract as well as forfeiting the time and cost of preparing the bid proposal, and submitting

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a highly competitive bid may result in unrealized profit. Part of this dilemma is due to price forecasting being an inexact science, based on historical data and limited information (Flanagan and Norman, 1983).

Amidst the main factors to be considered in bid price estimation, Runeson and Skitmore (1999) suggest that market conditions have a profound effect on bidder behavior and the price level. The difficulty associated with considering market conditions is due to there being no standardized measure of "market conditions", rather it is necessary to identify a indicator variable that provides an indirect measure for "market conditions" (Flanagan and Norman, 1983). Such is the basis for many empirical works investigating the effects of market conditions on construction bidders, such as; Runeson (1988) in his development of a price-level forecasting model based on a Market Conditions Index reflecting the degree of competition and capacity utilization; Chan et al. (1996) in their analysis of changes in profits of construction firms, considering market conditions as a function of price indexes, GDP and inflation; and Oo et al. (2007, 2010) in their analysis of contractors' mark-up behavior, with market conditions being reflected by the need for work.

When considering possible indicator variables representing market conditions, the neoclassical microeconomic forces of supply and demand have been investigated to be a suitable explanation for changes in the bid price level (Skitmore et al., 2006; Runeson and Skitmore, 1999). Skitmore (1987) defined supply as the availability of contractors and demand was defined by de Neufville et al. (1977) as the level of contractor activity. Much research has been performed to date describing the effect of the number of competitors on the bid price level and all have suggested that the number of competitors has a direct effect on the bid price level, for example; Carr (1983), Brannman et al. (1987); and Kagel et al. (1995). In terms of the effect of construction demand, the need for work and workload have also been shown to be correlated to the bid price level with a focus directly on "good years" and "bad years" or the peak and trough of a boom and recession (de Neufville et al., 1977 and Oo et al., 2007, 2010).

This study focuses on construction demand effects on bidders' mark-up with the number of available projects (the need for construction work to be completed) being the indicator variable for market conditions. Following the work by Oo et al. (2007), an experimental approach is adopted to investigate the effect of varying levels of construction demand on bidders' mark-up levels. Extending on the previous works, a complete observation is made from a boom period (good economic periods) to a recession and vice versa, thus incorporating the intermediate occurrences in the analysis. The paper begins with a literature review on mark-up decisions and construction demand, moving onto the research method adopted for the study and finally the results and conclusions.

2. Bidders' Mark-up Decision

A typical bid mark-up consists of profit, general overheads and contingency (Kerzner, 2005). The decision to balance all three elements is complex, especially when uncertainty is involved (Li and Love, 1999). They suggest that mark-up decisions are based on past experience and unstructured problem solving activities. This is in agreement with Ahmad

and Minkarah (1988) whom also suggest that bid decisions are heuristic in nature and are made on the basis of “experience, judgement and perception”. They also investigated the important factors considered in mark-up decisions through questionnaire surveys received from the top 400 contractors in the United States and found that the top factors affecting such decisions included the degree of difficulty, uncertainty in estimate, historic profit, current workload and need for work. Similarly, in a study by Shash (1993), where the top 300 contractors in the UK were mailed a questionnaire survey, they found that the top five factors that affected the mark-up size decision included: 1) degree of difficulty; 2) risk involved in the work; 3) current workload; 4) need for work; 5) contract conditions. These survey findings are in agreement with the general studies that show mark-up decisions being dominated by a set of key factors related to uncertainty and risk for each unique construction project (McCaffer, 1976; Harris and McCaffer, 1983). These factors can be separated into two categories, i.e., internal and external, where internal factors incorporate design specific issues such as project complexity and external factors related to economic conditions and similar less controllable elements (Skitmore, 1989).

In terms of bidders’ mark-up strategies, Skitmore and Pemberton (1994) summarize that the purpose is to provide a balance between the probability of winning the bid and the potential profit gained if success is achieved. Male (1991) identified that construction bidders operated at three levels: the corporate strategy level; business strategy level; and operational strategy level. At the corporate strategy level, he suggested that contractors define the market domains for which the firm is to operate and compete within. At the business strategy level, contractors determine which contracts to aim and submit bids for (such as project type, size, location). Finally, at the operational strategy level, if the firm decides to bid for a project, a cost estimate is developed which is passed back to the business strategy level where executives apply a mark-up accounting for profit and contingencies. At the corporate and business strategy levels, decisions can be adopted such as random bidding during times of low demand , selective bidding and competitive bidding (characterized by fluctuations in the bid price level) (Fine, 1975) and submission of a cover bid (non-serious bid) (Skitmore, 1989). Three common bidding mark-up strategies were outlined by Boughton (1987) including the “adaptive approach”, “quantitative approach” and “strategic approach”. He describes the adaptive approach being similar to a learning theory model, where the primary goal is to win as many project as possible, with the mark-up percentage being based on the most recent bid and current market conditions. This has the advantage of a competitive bid price, however relies on winning many projects to be effective. The quantitative approach has the primary goal of profit maximization, with the mark-up percentage based on the size of the bid, number of competitors and past performance. The strategic approach has the primary goal of creating long run benefits for the contractor, with the mark-up percentage applied being based on milestones required to achieve the long-term goal. The factors considered in the strategic approach are similar to the adaptive approach and include assessments of competitors and the external environment. Best (1997) identified two pricing strategies similar to Boughton (1987), being cost-based and market based pricing, where cost based pricing is the total cost of service plus an additional mark-up (desired profit) and market based pricing based on competitors’ situation and the client. However, Phillips (2005) suggests that it is not uncommon for firms to use a combination of approaches with the addition of some improvisation.

3. Construction Demand

Construction demand is vital information for contractors as it provides indicators for their current and future workload and can be used to develop effective pricing strategies (Carr and Sandahl, 1978). This is made possible through industry reports and forecasts available (e.g. in Australia, Davis Langdon, 2011a; Davis Langdon 2011b; Australian Industry Group Report, 2011). Akintoye and Skitmore (1994) segregated construction demand into two sectors, public and private, with the construction demand varying differently between the two due to inherent differences in their physical environments and requirements. Runeson and Skitmore (1999) noted that for the industry as a whole, changes in effective demand for building and construction services could be ten percent of more per year, and up to fifty percent or more for individual markets. They suggested that a change in demand lead to a change in bidder behavior and strategy. Many empirical studies have suggested and shown similar relationships. Stone (1983) found a functional relationship suggesting that construction prices increased with increases in demand and prices decreased when demand declined (in line with the law of supply and demand). Runeson and Bennett (1983) considered demand as a function of capacity utilization and found that increases and decreases in the level of activity (demand) resulted in price changes due to the changing number of bidders. De Neufville et al. (1977) in their investigation of 167 building construction and 691 highway projects found that mark-up ratio differed between “good” years and “bad” years (with good years having more projects available for bidding and bad years having less). They concluded that in “good” years, bidders applied high mark-ups in their bidding attempts, whilst in “bad” years, they applied lower mark-ups. Oo et al. (2007) performed an experiment involving senior managers of Hong Kong and Singapore construction firms and found that during booming market condition, the lowest mark-up percentage applied by bidders was higher than that during a recession period. Flanagan and Norman (1985) performed mathematical models on the bid price level and concluded that the current and projected workload affected the bid price, with a higher current workload leading to higher bid prices.

It is interesting to note that that the questionnaire surveys performed by Ahmad and Minkarah (1988) and Shash (1993) both contained indicators of construction demand (such as workload and need for work) as the more important factors considered by contractors in formulating the bid mark-up. In terms of location specific questionnaire surveys performed, Fayek et al. (1999) investigated bidding practices of 58 Canadian civil engineering construction firms and also found that potential profit, need for work, familiarity with market and competitors were the top factors influencing the mark-up size. Shash and Abdul-Hadi (1992) surveyed 71 contractors in Saudi Arabia and found that strength in industry, need for work, competition and the economic situation to be important factors considered in the mark-up size decision. Dulaimi and Shan (2002) investigated 32 medium and large sized contractors in Singapore and discovered that the availability of work was the most important factor considered by the medium sized contractors followed by the need for work and client relations. For large sized contractors they found that the degree of difficulty was most important followed by the availability of work and the competitors in the market. In order to isolate the possible geographic bias from the questionnaire survey results, Ling (2005) performed a meta-analysis on similar surveys performed in Australia, Canada, Saudi Arabia,

Singapore, United Kingdom and the United States. She found that five global (restricted to aforementioned locations) factors included: i) risk; ii) current workload; iii) need for work; iv) reliability of company pricing; and v) competition.

When considering the factors affecting the level of construction demand, Akintoye and Skitmore (1994) suggested that these could be categorized as general and local factors. Local factors include the geographical location of the project, project type (e.g. infrastructure or building) and procurement types (Skitmore, 1987), whereas general factors cover the generic PESTL framework containing political, economic, social, technological and legal factors (Akintoye and Skitmore. 1994). Hillebrandt (2000) identified the key factors affecting construction demand to include: i) population; ii) interest rate; iii) health of the economy; iv) demand for goods; v)renovation demand; vi) government and tax policies; and vii) expectations of demand and profit.

From the literature review, it is clear that mark-up and construction demand work in tandem to directly affect the contractors' profits and survivability. Whilst there have been many studies into the effects and causes of construction demand on bidders' behavior, there are little empirical studies attempting to quantify and observe the specific effects. Although construction demand is often deemed as a factor that cannot be controlled (Skitmore, 1987), its effects on contractors are real and understanding how price levels change with the level of construction demand has clear managerial implications for both construction bidders and clients in formulating their bid pricing and procurement strategies, respectively

4. Research Method

In order to test for the specific construction demand effects on bidder mark-up, an experimental approach was used. As de Vaus (2001) states, using an experimental approach allows us to focus on specific variables (i.e. the dependent and independent variables) that are likely to be the cause and effect of the study. This allows the filtering of external variables such that the effect(s) of the intervention can be clearly observed.

4.1 Experiment Design

There were a total of 55 participants for the experiment. These participants were final year undergraduate students with a construction project management background. The indicator variable representing construction demand is the number of available projects (or number of projects released in each bidding round). Two hypothetical demand curves were generated, one starting off from a recessionary point (low level of construction demand) and continually increasing towards a booming point (high level of construction demand). This curve was called the "booming" scenario. The other demand curve was a direct reflection of the booming scenario curve, starting off from a booming point and continually decreasing to a low point (see Figure 1). This curve was called the "recession scenario". The 55 participants were randomly assigned to both scenarios, with 28 bidders experiencing the booming scenario and 27 bidders experiencing the recession scenario. Nested within these two groups were five subgroups consisting of five to six bidders each. The purpose of these subgroups were to simulate a realistic number of bidders competing for each project as it is

unlikely for 27-28 bidders competing for a single project (see McAfee and McMillan, 1987 and Ngai et al., 2002). The experiment was conducted in a controlled laboratory environment and no communication was allowed between the groups.

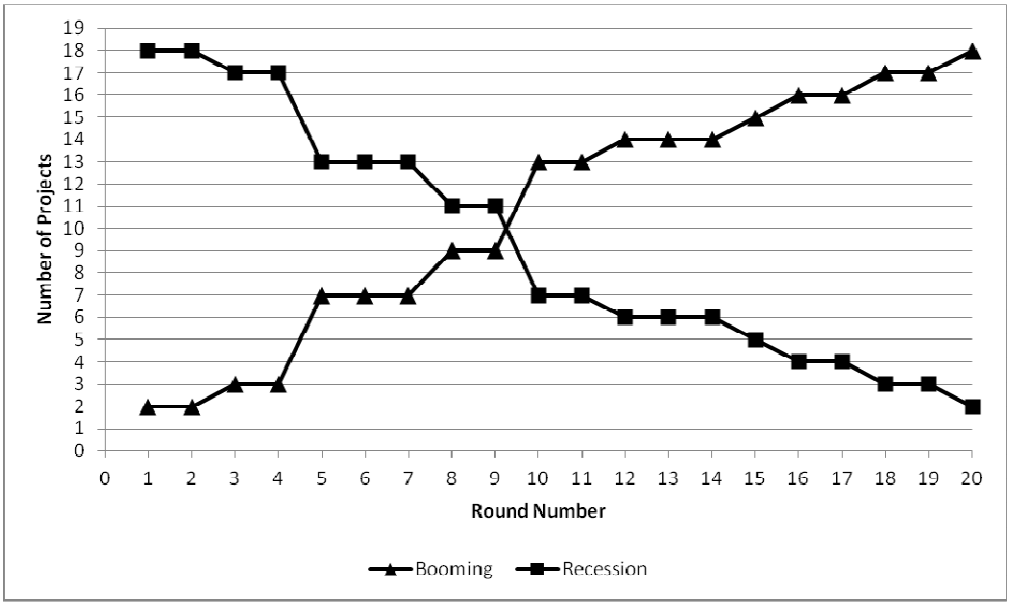

Figure 1: Experimental Treatment Scenarios

The experiment duration was 20 rounds with each round representing a "quarter" of real time (total simulated time is 5 years). Each bidder was provided with a start-up capital of $800,000 and was required to bid for hypothetical building projects. These projects were based on past real projects obtained from the NSW e-tendering website (https://tenders.nsw.gov.au) and project types selected were restricted to general building projects. The construction cost estimate for these projects ranged from approximately AUD 4 - 14 million. Overheads were required to be paid every bidding round and each bidder had a capacity limit of five projects on hand in any one round. If the bidder chose to exceed their capacity, each additional project taken aboard was penalized with a percentage cost representing outsourcing and additional management costs.

In every bidding round, bidders were provided with one hour to decide which projects to bid for and the price to submit for each project. The bid price submitted was expected to include the construction cost in addition for an allowance for profit, overheads and contingency, with due respect for the competition. As the experiment simulates a first price sealed-bid auction, the lowest bidder wins the project, but how this was achieved was left up to them. The general guideline provided to all bidders was that their goal was to prosper and survive.

A market outlook indicator that provided a brief idea of the future construction demand expectation was provided to all bidders at the beginning of each round. From round two onwards, feedback information of preceding rounds was communicated privately to each bidder. These include the winners and the winning bid prices, an up to date statement on the

bidders' current account balance, profit/loss from projects won and their current capacity utilization. An incentives scheme was also implemented in order to promote serious participation and to minimize dropouts, this was in the form of a "mystery prize" not revealed until the conclusion of the experiment.

5. Results and Discussion

The results and discussion begins with an exploratory analysis of the bid dataset obtained, followed by a more detailed statistical correlation test of bidders' mark-up trend. Finally, a between treatments comparison is performed between the booming and recession groups.

5.1 Exploratory Analysis

The sample size for both the booming and recession scenarios is shown in Table 1. In total, 11,598 bid and no-bid observations were collected with 4106 and 3269 bids from the booming and recession groups, respectively. A possible explanation for the higher number of bids received from the booming group is because of the difference in the experiment design. As the recession scenario is a direct reflection of the booming demand curve, less number of projects was released to the recession group (184 vs. 216 projects). For the booming group there were 2156 no-bid decisions and 2067 for the recession group. Although the booming group has a higher number of bids, a simple ratio measure considering the experiment design and difference in the total number of projects released reveals that comparatively, there were more no-bid decisions in the recession group compared to the booming group (2067/2156 vs. 184/216, i.e. 0.96 > 0.85). This can be explained in terms of the need for work, where there was a large number of projects released to the recession group early in the experiment, bidders were likely to win jobs at the early stage of the 20-round experiment and remain occupied for a certain period of time (i.e. operate within their capacity) with more no-bids decisions recorded. A Kolmogorov-Smirnov test on the two sample groups revealed that both distributions were not normally distributed (booming: $Z = 9.658$, $p = 0.000$ & recession: $Z = 7.102$, $p < 0.05$), thus non-parametric were used for subsequent statistical analysis.

Table 1: Experiment Sample Size

	Bid		No-bid		Total	
Scenario	N	Percent	N	Percent	N	Percent
Booming	4106	65.6%	2156	34.4%	6262	100.0%
Recession	3269	61.3%	2067	38.7%	5336	100.0%

Figure 2 shows the scatter plots for the bid dataset obtained from both the booming and recession scenarios. The x-axis represents the time scale and is a function of the bidding round number. The y-axis is the mark-up ratio and is calculated as the contractors' bid divided by the unbiased project cost estimate of a project. A mark-up ratio greater than one represents a mark-up being applied by the bidder (on top of the cost estimate) and a mark-up ratio less than one indicates that the bidder is bidding below cost. A reference line at the

mark-up ratio of one is added on the scatter plots. Fitted to the data-points is a LOWESS curve (locally weighted scatter plot smoothing) and is based on a local polynomial least squares fit to set of data points. The fit is re-smoothed for several iterations to make it more resilient to the effects of noise and marginal outliers (Hardle, 1990).

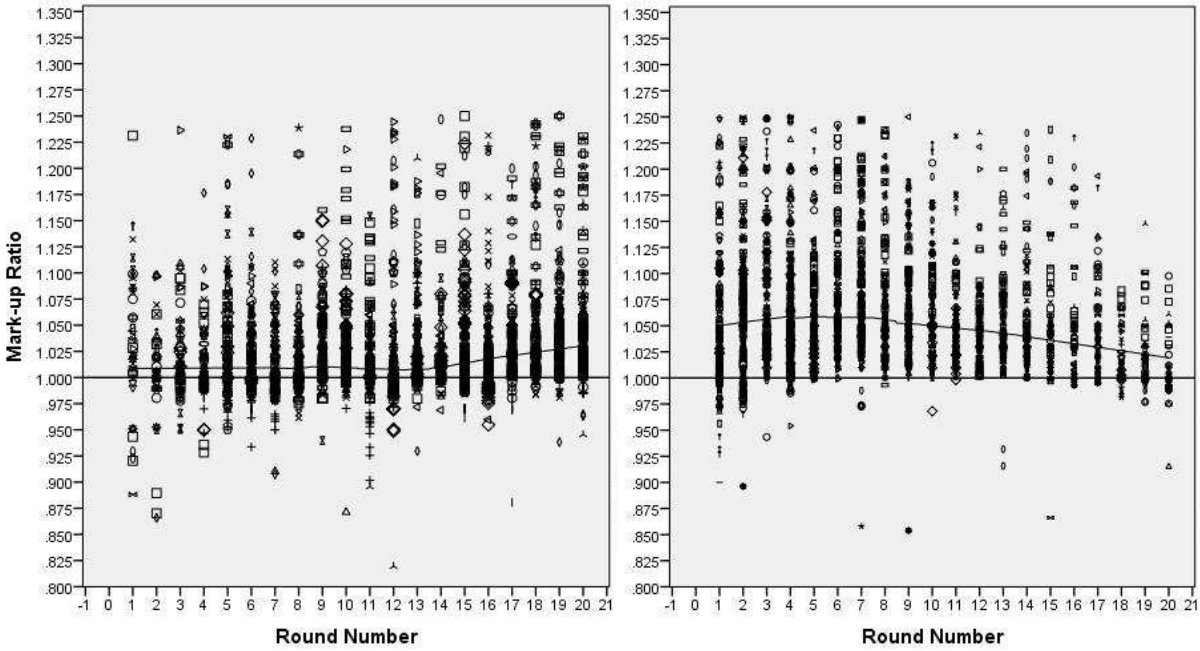

Figure 2: Scatter Plots for Booming (left) and Recession (right) Scenarios

The LOWESS curve for the booming group shows an interesting trend. The mark-up ratio profile appears to be relatively static from rounds one to fourteen. This represents little change in the mark-up trend, most likely stemming from the continual need for work up until round fourteen. Considering that for the first four rounds of the booming scenario only two to three projects were released, the majority of the bidders would have been in high need of work to win job(s) in order to cover overhead costs. From round fourteen and onwards, there is a steady increase in the mark-up ratio being applied by bidders, most likely in response to the increased level of construction demand, and also less competition in the market. That is, at this time, many bidders' would have had enough jobs on hand and less incentive in continuing to bid aggressively. In order to investigate the seemingly static trend from rounds one to fourteen, a Spearman's correlation test was performed in this range in examining the correlation between the mark-up ratio and the number of available projects (see Table 2). Analyzing rounds 1-14 revealed a small overall change in this region (r_s = -0.010) with the correlation between the mark-up ratio and the number of available projects being insignificant (p = 0.604). This indicates an unvarying mark-up trend in this region and a "cut" was needed to explore the trend further. Closer inspection of the LOWESS curve shows a slight "kink" at round 10, indicating changes in the mark-up trend, thus this round was chosen as the cutting point. Performing the same test on rounds 1-10 revealed a positive correlation between the mark-up ratio and the number of available projects at a significant level (r_s = 0.074, p = 0.005). And testing rounds 11-14 reveals a slightly positive correlation between the two variables at a non-significant level (r_s = 0.009, p = 0.762). The results are

interesting in that between rounds 11 and 14 there is an adjustment in the bidders' mark-up behavior before the steady increase in the mark-up ratio observed in Figure 2. A possible conjecture to explain this lies in the bidders' current workload, whereby through learning and assessing their current position and the expected construction demand, they were able to optimize their mark-up in response to the flourishing market conditions.

Table 2: Spearman's Correlation Test for Booming Scenario Rounds 1-14

Mark-up Ratio vs. Number of Projects	Rounds 1-14	Rounds 1-10	Rounds 11-14
N	2484	1440	1044
Spearman's rho	-0.010	0.074	0.009
p-value	0.604	0.005	0.762

As per theoretical expectation, the LOWESS curve for the recession group shows an overall opposite trend compared to the booming group. The trend line shows a steady increase initially from rounds 1 to 4 before steadily decreasing up to round 20. This may indicate a learning curve for the recession group, with the initial four rounds used to learn about the bidding environment and market conditions. With strong construction demand starting from round one for the recession group, there was likely to be enough work to go around thus keeping most bidders with a healthy workload. This is indicated by the initially high level of mark-up being applied in bidding attempts. As the construction demand decreased over the time, the need for work and competition in the market increased, thus bidders would have needed to adjust their bidding strategies accordingly in order to sustain or maximize the efficiency of their workload.

An overall comparison between the scatter plots of the booming and recession groups suggests that the overall mark-up ratio for the recession group is higher than the booming group. This again is the result of the treatment effect of the varying levels of construction demand, where for the booming group, the initial low demand would have likely "starved" many bidders at the early stage of the experiment. Since the need for work was high, the competition was high thus driving the bid prices at an aggressive level. Conversely, for the recession group, initial high demand is likely to have provided many bidders with a healthy workload, with an inherently less competitive market, mark-up levels are able to stay high, until changes in the level of construction demand that forced a change in mark-up strategy (i.e. lower mark-up), a product of learning and adaptation. These findings are consistent with the results from Oo et al. (2007, 2010) and de Neufville et al. (1977) in that during "good" years or booming times (strong market conditions/high demand) the level of mark-up percentage is higher in contrast with the times of poor market conditions or low demand.

5.2 Correlation Tests

To relate the observed mark-up trends from the scatter plots (Figure 2) to the experimental treatment scenarios (Figure 1) , Spearman's correlation test was performed on each dataset obtained from the booming and recession groups. The results show that, for the booming group, the correlation between the mark-up ratio and the number of available projects is

positive and significant (r_s = 0.206, p=0.000) and similarly for the recession group, the correlation coefficient is also positive and significant (r_s = 0.118, p=0.000). The findings show that mark-up applied to projects increases as the level of construction demand increases The results also show that on average, the bidders were behaving in a rational manner. These findings are in line with the study performed by Ball et al. (2000) on the UK construction industry. They examined the performance of 32 medium size public construction firms and found that mark-ups were positively correlated with the construction cycle (in terms of the availability of new work).

5.3 Between Treatments Comparison

Table 3 shows the descriptive statistics for both the booming and recession groups. It can be seen that the mean mark-up ratio is higher overall for bidders subjected to the recession scenario compared to the booming scenario. The standard deviation shows that bidders were more consistent in their bidding attempts in the booming group compared to the recession group. The removal of outliers was based on a criterion set forth by the Hong Kong SAR government, which considers all bids that are 25% above the lowest bid to be non-serious bids (Skitmore, 2002). Due to the nesting of subgroups for this experiment, the criterion was modified such that bids with a mark-up of 25% above the cost estimate were considered as outliers, this explains the maximum mark-up ratio for both the booming and recession groups being identical at 1.250. The Mann-Whitney U test was utilized for comparing the difference in distributions of the mark-up ratio for both the booming and recession groups. The results support the descriptive statistics, and it was found that the mean mark-up ratio for the recession group was higher than the booming group at $p < 0.05$ (U = 3522650 , Z = -35.107, P = 0.000). This provides strong evidence that that both groups come from different distributions (statistically), suggesting that the treatment effects (varying levels of construction demand) did have an effect on bidders' mark-up behavior. In other words, bidders do consider the level of construction demand in their bidding attempts and have formulated their bidding strategies accordingly. This finding is similar to that of King and Mercer (1990) whom applied mathematical analysis to a bidding model and found that bidders adjusted their mark-up in response to changes in the current market and also cost estimate variability.

Table 3: Descriptive Statistics

	Mark-up Ratio				
Scenario Type	N	Mean	Std. Deviation	Minimum	Maximum
Booming	4106	1.02603	0.04464	0.820	1.250
Recession	3269	1.06060	0.05952	0.854	1.250

6. Conclusion

This study investigated the effect of construction demand on bidders' mark-up behavior. Utilizing an experimental approach, 55 inexperienced bidders were placed into two different construction demand scenarios and bid for projects in an environment simulating construction bidding in practice. It was found that bidders did consider the level of

construction demand in their bidding attempts and this was reflected by changes in their mark-up strategy. Correlation tests performed suggest that the mark-up increases as the number of available projects (level of demand) increases. The experiment design allows for intermediary observations between the peak and trough of a typical construction demand cycle. The findings provide empirical support on explaining how varying levels of construction demand affects the bid mark-up level. It is identified that a limitation of this study is the use of student subjects for the experiment, thus limiting the generalization from this study to inexperienced bidders. Suggestions for further studies include repeating the experiment with different demand curves, running the experiment for a longer period of time and use of experienced industry practitioners in similar experiments are all likely to produce useful insights that will further our empirical understanding on how construction demand affects bidder behavior. The results of this study are of importance to contractors and clients, particularly in formulating bidding or procurement strategies to take advantage of or to mitigate the effects of market demand.

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ATTITUDES OF AUSTRALIAN CONSTRUCTION ORGANISATIONS TOWARDS SUSTAINABILITY MANAGEMENT

Fatima Afzal[1*] and Benson T.H. Lim[2]

Abstract

Sustainability management has been touted to be the next strategic weapon for organisational competitiveness. Despite this recognition, very few studies have been done to investigate the sustainability management of construction organisations. The aim of this paper is to investigate the attitudes of construction organisations towards sustainability management. Under this aim, the specific objectives are to: (i) examine the main environmental challenges driving the implementation and management of sustainability practices within construction organisations; (ii) review the organisations' annual and sustainability reports; (iii) identify the types of environmental management initiatives adopted by the construction organisations; and (iv) establish a link between sustainability and competitive advantage. Data were collected via review of relevant organisational documents. Thereafter, content analysis was conducted. The results show that some organisations have embraced a positive attitude to sustainability however there is need for training and change in individual and organisational behaviour to achieve long term sustainability targets. This study provided an evidence of relationship between sustainability management and competitiveness for further sustainability management research and policy making.

Keywords: **Sustainability management, construction organisations, competitiveness.**

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1. Introduction

Construction is the one of the most significant contributor to most economies both in terms of GDP and employment. In Australia it accounted for 6.8% of GDP and employed 9.1% of the Australian workforce, making it Australia's fourth largest industry (ABS, 2010) however; this highly important and value providing sector is underperforming in terms of sustainability (Mill and Glass, 2009). It is generally been accepted in Australia that sustainability needs to be the top priority of businesses; however in practice many organisations struggle to embrace and implement sustainability beyond minimum compliance (Chiveralls, 2011). Shen and Tam (2002) emphasised that a major reason for this low implementation is that environmental and social commitments are seen as an extra expense rather than a benefit.

There is an increased pressure on construction organisations to manage their sustainability performance, especially in the environment of uncertainty in financial markets, increased competition due to globalisation and increased government priorities towards sustainability. However management of organisational sustainability is not an easy process, as it may require organisations to analyse their business environment and change their strategic endeavour and behaviour, towards adopting sustainable ideas and practices for improved competitiveness. In the last decade sustainability management is emerging as a key approach for organisations to remain viable in competitive business environment. It addresses the problem of organisation's contributions to sustainability in an integrative way by presuming that organisations could only contribute to sustainable development if there presents a business case for such contribution (Figge et al., 2001). The concept of sustainability management is well developed in the management literature; however it is relatively new in the domain of construction. This paper is a part of a larger research project which aims to investigate sustainability management of construction organisations. The objectives of this paper are to (i) examine the main environmental challenges driving the implementation and management of sustainability practices within construction organisations; (ii) review the organisations' annual and sustainability reports; (iii) identify the types of environmental management initiatives adopted by the construction organisations; and (iv) establish a link between sustainability and competitive advantage.

The scope of this research is to review the sustainability related documents of top 25 Australian construction organisation listed in Australian Securities Exchange (ASX). Only top organisations were chosen because they represent 68 percent of the total work done within Australia.

2. Sustainability and its implementation in Construction

Sustainability addresses the impact of human development on the existing physical and social structure of society and its natural systems (Khalili, 2011). Sustainability is multi-dimension concept comprising: environment, society and economy. With growing concerns about global warming, climate change and continuous loss of natural resource construction organisations are under an enormous pressure to incorporate sustainability into their business. To be sustainable organisations are required to reduce environmental impacts and provide social equity along with making profitable business. Dyllick and Hockerts (2002,

pg.138) defined corporate sustainability as “meeting the needs of the firm’s direct and indirect stake holders, without compromising its ability to meet future stakeholder needs as well”. In the past decades, there are many initiatives taken globally and on government level to introduce the concept of sustainability in construction**.** There are many frameworks available for example environmental management systems (EMS), corporate social responsibility (CSR) and global reporting initiative (GRI) to integrate sustainability. However, construction organisations are considered as one of the worst in adopting sustainable practices. The motivations for the practitioners to implement EMS are not primarily for achieving sustainability. Ofori et al. (2002) identified that organisations seek certification mainly because of clients or end-purchasers’ demands.

Many researchers have investigated attitudes and behaviour of construction organisations. Petrovic-Lazarevic (2008) examined Australian construction organisations about their attitudes to sustainability via the application of ISO14001 EMS as part of their firms’ CSR. He reported that the majority of the firms interviewed have ISO14001 EMS certification in place, and the reasons for applying EMS include competition, quality improvement, community requirements, increased public awareness and clients’ requirements. Similarly Myers (2005) analysed public disclosures of UK’s construction organisations and outlined that only a few large- sized companies have shown positive commitments for the increased emphasis on sustainable development in their construction activities. This is line with Mills and Glass (2009) that outlined that skill deficit and is one of the reasons of this slow implementation.

Tam et al. (2002) and Shen and Tam (2002) reported that Hong Kong contractors are not adopting sustainability because: (i) cost and time are the main performance criteria; (ii) the clients do not support extra cost of sustainability and (iii) they do not have capacity to implement environmental management systems. Christini et al. (2004) had similar findings and reported that few construction companies have adopted EMS in their business operation due to limited organisational resources and lack of mutual commitment from the industry partners.

Zainul Abidin (2010) investigated the awareness and application of sustainable construction in Malaysia and found that the concept of sustainability is not widely received in the industry as many developers, especially small and medium companies, are still reserving themselves. He also pointed out that sustainability implementation is low because of several factors such as lack of knowledge, poor enforcement of legislation and passive culture of construction organisations. A similar study done by Sakr et al. (2009), discovered that there is low dissemination of information about ISO 14001/EMS among the top contractors due to the absence of the role of local institutions in promoting these systems.

Ofori et al. (2000) surveyed Singaporean construction organisations on their attitudes towards implementing ISO14000 environmental management system (EMS), and found that: (i) most organisations adopted a wait-and-see attitude towards EMS implementation; (ii) there is a lack of knowledge of ISO14001 standards within the industry; and (iii) shortage of qualified personnel and the fragmented nature of the industry are key hurdles faced by construction companies. However a decade later Oo and Lim (2011) studied the attitudes

and behaviour of Singapore contractors towards environmental sustainability, and found that the contractors are increasingly recognising sustainability as a tool for competitive advantage. Also, they ascertained that improved materials efficiency and increased government financial incentives are key drivers for sustainability.

3. Sustainability Management

Sustainability management is emerging as a key strategy for organisations to achieve sustainability and being competitive at the same time. It addresses the problem of organisation's contributions to sustainability in an integrative way, presuming that organisations could only contribute to sustainable development if organisational performance improves in all three dimensions of sustainability simultaneously (Figge et al., 2001). While conflicts between the three performance categories of sustainability (social, ecological and economic goals) may occur, corporate sustainability management identifies and realises opportunities for simultaneous improvements in all three dimensions in order to achieve strong corporate contributions to sustainability (Figge et al., 2002).

According to Figge et al. (2001) the integration of the three pillars of sustainability into general business management by a pragmatic approach offers two advantages. First sustainability practice that is economically sound is not endangered by economic crisis because it is not only carried out as long as the organisation is successful. Usually, if organisations find themselves under financial distress, those costs that are perceived as not contributing to the economic success are cut first. Secondly it could contribute to competitiveness, as the organisation serves as an appropriate role model for other businesses.

Salzmann (2005, p: 30) defined sustainability management as "The strategic and profit-driven corporate response to environmental and social issues that are caused through the organisation's primary and secondary activities". It incorporates organisations willingness to integrate social and environmental issues systematically and persistently into their business strategies. This could be done by providing an economic rationale or business case for sustainability. Bansal and Roth (2000) argued that the business case (e.g. improved processes and reputation) the greater will be the motivation for the sustainability management.

Epstein and Roy (2003) argued that managers can truly integrate social and environmental aspects into their business strategies only by making the business case for social and environmental performance. This view is shared by Schaltegger (2008) who outlined that the business case for sustainability is characterised by creating economic success through (and not just along with) a certain environmental and/ or social activity. He further explained that business case for sustainability is not an automatic relationship with general practices it has to be created actively through an intelligent sustainability management approach.

Afzal and Lim (2012) have provided a conceptual framework for sustainability management of construction organisations. This framework explains that external environmental forces such as legislation, stakeholder pressure and economic opportunities and threats shape up

internal organisational features. If these features (organisational culture; organisational structure; employee skills and attitudes; supply chain capabilities; technological capabilities and business strategies) are managed properly they could improve sustainability performance of organisations and this could in turn provide competitive edge.

4. Linkage between sustainability and competitive advantage

Many researchers have studied the relationship between sustainability and competitive advantage, mainly in manufacturing and IT industry. Madu (2004) argued that environmental management is a key to achieve competitiveness market, he has given examples of Xerox and Kodak; both companies have remained financially successful through re-manufacturing of products. Schaltegger and Synnestvedt (2002) have examined the relationship between sustainability and economic success and outlined that management is the trigger between these two. This view is in line with Salzmann (2006) who asserted that sustainability management is the key for organisations to remain competitive.

Wagner and Schaltegger (2003) conducted a comprehensive review of literature on the link between sustainability performance, business competitiveness and economic success Wagner (2005) studied the relationship between environmental and financial performance across paper industry and manufacturing firms across Europe. He reported environmental performance has no relationship with financial performance for the firms that are not pursuing a value oriented environmental strategy. However firms that make strategic choice seems like to achieve a positive relationship between environmental and economic performance.

Bryson and Lombardi (2009) claimed that evidence from the property development industry suggests that integration of sustainability as a distinctive competency in a firm's strategy results in the identification of profitable market niches. This is in line with Tan et al. (2011) who outlined that sustainability performance can contribute to business competitiveness. However, little research has been done on examining the relationship between sustainability and business competitiveness in the context of the construction industry.

5. Research method

This research adopted a survey research design which involved a systematic review of the contents of annual reports and websites of the major public listed construction organisations. Organisations' attitudes towards sustainability management were analysed by the reporting of organisation's commitments towards environment and society.

Content analysis as a research method is a systematic and objective mean of analysing any written, verbal or visual communication messages (Weber, 1985). Content analysis is widely used in sustainability related research (e.g.: Zeghal and Ahmed (1990); Myers (2005); Gill et al. (2008)) to survey published accounts. According to Krippendorf (1980) the value of content analysis lies in the assumption that the extent of disclosure can be taken as some indication of the importance of an issue to the reporting organisation.

The construction industry in Australia comprises around 320,000 enterprises. Of these enterprises, over 60% are sole traders, with nearly 30% employing between 1 and 4 people. However Housing Industry Association (HIA) indicates that in 2006-07, the largest 100 commercial construction organisations won contracts worth 68% of all work started in the year to March 2007. The 10 largest organisations won 55% of the work won by the largest 100 companies in the sector in 2006-07, while the largest 20 organisations accounted for 71%. Therefore large organisations represent the common trends of the overall industry. Considering this fact a sample of top 25 construction organisations listed on Australian stock exchange (ASX) was selected based on their number of employees and annual turnover.

For each organisation the annual report and any separate sustainability report for the year 2011 were collected and analysed. Furthermore organisation's websites were also researched for any information related to sustainability management. The analysis of disclosure was undertaken to identify whether the organisations included environmental commitments and social responsibility in the annual reports. Furthermore the website information of the sample organisations were analysed to search the following key phrases: sustainability, sustainability management, business case for sustainability; competitive advantage through sustainability.

6. Results and Discussion

Table1 shows that only 36 percent of the organisations publish discrete sustainability reports. The overall percentage of material relating to environmental and social commitments disclosed in annual report is very low ranging from as little as one percent to seven percent. Out of all the organisations 32 percent did not include any material on sustainability in the annual report. Corporate website appears to provide more diverse coverage of sustainability; 96 percent of organisations have reported sustainability commitments on the corporate website.

Table1: Analysis of publicly available information on sustainability

ORGANISATIONS	Annual report no of pages	% pages on Environmental commitments	% pages on Social commitments	Separate sustainability report	Sustainability commitments on website
Abigroup Limited Australia	43	2.56	6.97	▲	▲
AVJENNINGS LIMITED Australia	88	0	2.27	△	▲
Brierty Limited Australia	84	0	2.38	△	▲
Calibre Group Ltd Australia	45	0	8.8	△	▲
Civmec Ltd Australia	N/A			△	▲
Coffey International Limited Australia	116	0	0.86	△	▲
Downer EDI Limited Australia	20	35	25	▲	▲
FKP Property Group Australia	112	0.86	0.86	△	▲
Forge Group Limited Australia	87	0	0	△	▲
Leighton Holdings Limited Australia	136	0	0	△	▲
McConnell Dowell Corporation	24	8.3	4.6	▲	▲

Mirvac Group Australia	105	0	0	▲	▲
Monadelphous Group Limited Australia	22	0	0	△	▲
Multiplex Group Australia	N/A			▲	▲
Norfolk Group Ltd Australia	N/A			△	▲
NRW Holdings Limited Australia	83	1.2	1.2	△	▲
RCR Tomlinson Limited Australia	118	0	3.3	△	▲
Stockland Australia	8	14	28	▲	▲
Structural Systems Limited Australia	68	0	0	△	▲
Transfield Services Limited Australia	143	1.39	2.3	▲	▲
UGL Limited Australia	96	0	0	▲	▲
VDM Group Limited Australia	84	0	0	△	△
Sunland Group Limited Australia	N/A			△	△
Watpac Limited Australia	144	2.08	2.7	△	▲

▲ Organisations with separate sustainability report and sustainability commitments on website
△Organisations without separate sustainability report and sustainability commitments on website

From Table 2 it is interesting to know that among the organisations who published discrete sustainability reports only eight percent indicate the presence of business case for sustainability; furthermore the word sustainability management could be found only once. Six percent of the sample reported to have gained competitive advantage through sustainability. This result indicates that construction organisations within Australia have acknowledge that sustainability needs to be a priority, however only a few exceptionally large organisations are incorporating sustainability into their business values as a profit source. It is also clear that there is a need for educating construction workforce about the potential competitive advantage they can achieve through sustainability management

Table 2: percentage of sample containing key words

Key words	**% of organisations**
Sustainability	96
Sustainability management	4
Business case for corporate sustainability	8
Competitive advantage through sustainability	6

The main environmental challenges driving the implementation and management of sustainability practices, as indicated in the published literature are summarised in Table 3. It is noticed that uncertainty in the global markets is considered as the biggest challenge, as reflected in the annual reports of most organisations (approximately 80 percent). On the other side only 46 percent of the organisations reported that carbon tax will influence future business strategies. High cost associated to sustainability is also recognised as an important issue, this cost include cost of building materials and transportation cost. Furthermore, the findings show that skill deficiency (about 65 percent) is one of the organisational barriers towards implementing sustainability practices, however; it is promising to notice that organisations have shown commitment towards employee skill and training.

Table 3: Challenges for sustainability

Challenges for sustainability	% of organisations
Skill deficiency	67%
High cost associated to sustainability	77%
Carbon Tax	46%
Uncertainty in global market	80%

Table 4 summarises the written commitments of organisations towards different sustainability initiatives. The top initiative adopted by most organisations (80 percent) is employee health and safety. This is followed by employee training and education (78 percent). These high commitments towards employee could be linked to the conceptual framework of Afzal and Lim (2012) which postulates that skills and knowledge of employees can be a source of competitive advantage. Seventy two percent of the organisations are engaged with community through diverse range of activities such as supporting charities, engagement in indigenous well being programs and supporting student scholarships. Material waste is identified the least adopted initiative.

Table 4: Sustainability Initiatives adopted by organisation

Sustainability Initiatives adopted by organisation	% of organisations
Reduce green house gas emissions	64%
Employee Health and Safety	90%
Community engagement	72%
Stakeholder engagement	60%
Employee training on sustainability	78%
Reduce Material waste	56%

In relation to the certification (as shown in Table 5) most organisations (68 percent) reported to hold ISO 14001 certification for environmental management. Sixteen percent have also included the global reporting initiatives (GRI) guide lines in their sustainability reports. A small group (12 percent) followed green building certification. Along with these 20 percent of sample also hold membership for NSW government sustainability advantage programme.

Table 5: Sustainability reporting systems used by organisations

sustainability reporting system	% of organisations
ISO 14001	68%
Global reporting initiative	16%
Green building	12%

The results of this study indicate that the majority of organisations analysed are beginning to acknowledge sustainability (96 percent included sustainability commitments on organisational website). Most of the organisations have separate sections for environmental commitments such as strategies for energy efficiency, water conservation and waste minimisation. Similarly social commitments such as employee well being, health and safety and engagement with community is also well documented. The commitments of construction organisations to adopt different sustainability initiatives seem promising and this could be the beginning of a more sustainable construction future. Most organisations have published these commitments on their website nonetheless only 36 percent of the organisations published separate sustainability report which not only include commitments but also give information on how the sustainability was achieved.

In regards to the attitudes towards sustainability management the results indicate that this concept is exceptionally new in construction domain; only one organisation has reported a framework to manage sustainability. The business case for sustainability is also a novel theme with merely 8 percent of organisations used the term. The results also provided evidence that construction organisations are gaining competitive edge through sustainability, however this relationship is only recognised by few industry leaders and it might take some time to become an industry norm. It is also significant to note that the organisations which claimed to gain competitive advantage are the ones that reported to have business case for sustainability.

7. Conclusion

Sustainability has been an important agenda for construction organisations. This study adopted a survey approach involving content analysis of top public listed Australian construction organisations. On the basis of publicly available information and material, the survey findings suggest that most of the selected construction organisations have acknowledged sustainability. They recognise that economic success only does not add value to an organisation's profile, it is also judged by its social and environmental performance. Sustainability management is emerging as an alternative approach to conventional strategies to achieve sustainability. It is unique in nature because it emphasises on both financial and sustainability performance of organisations. This research showed that the attitudes and behaviour of construction organisations are becoming positive towards sustainability; with an anticipation to gain financial benefit and competitive advantage associated to it.

This study will contribute to knowledge by investigating the potential application of sustainability management within construction organisations. This study appears to be the first empirical research providing link between sustainability and competitive advantage in the domain of construction. The results could be used as a guide by construction organisations to become more sustainable and competitive simultaneously. However it is acknowledged that the survey data is only based on publicly available information on organisational website and annual reports and might not represent the actual practice. Other

limitation of this study belongs to the small sample size and limited indicators used in the analysis thus the results are not definitive but indicative of an apparent trend. Therefore, further and detailed investigations should be conducted for more generalised findings.

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Design Evaluation: Current Practices and a Framework for Future Use

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Abstract

There is significant anecdotal information that good design leads to enhanced quality and higher community outcomes in the built environment. In theory, investing early in design brings better outcomes in regard to whole of life costing and value for money. Evaluating design by considering economic, social, aesthetic and environmental aspects, which includes consideration of objective and subjective attributes, is difficult. For the community a consideration of quality design for new facilities should not be left to chance. Design evaluation should be considered in a structured and consistent manner.

This paper consolidates the findings of how best to evaluate the value of design by forming a comprehensive framework for discussion. The paper analyzes and compares design evaluation tools in terms of functional, social, environmental and economic aspects. It is considered that this framework provides a holistic basis for evaluating design by considering societal benefits and sustainability, design cost, construction cost, operating outcomes and maintenance costs.

Key Words: Design Quality, Design Evaluation, Design Value, Value Quantification, Whole Life Cost

1. Introduction

Design quality is usually subjectively understood or sometimes may be misunderstood. Without an appropriate approach which can help model the outcomes of investing in design it might be perceived that a high quality design may become a luxury. There are several quotes from the government sources promoting the benefits of good design in built environment (Drogee, 1999; Victorian Government Architect, 2011). And also it is been cited in government publications that benchmarking is needed for design assessment (Miles and Chan, 2006; Victorian Government Architect, 2011). A need for design evaluation framework or tool becomes more evident when making procurement decision is aiming among different options. This need becomes more serious when the designers claim that their designs incorporate innovative ideas which may benefit the community and the environment.

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In Australia, at project level there are tools and methods introduced by the government which are used to assess the value for money (VfM) in public and infrastructure projects such as Public Sector Comparator (PSC). But these tools and processes usually tend to focus on financial issues and risk matters associated with projects. Design quality and related metrics are rarely considered in these processes or tools (Duffield 2005; Raisbeck et al. 2010; Sharp&Tinsley 2005). At design level of buildings there are few other tools such as NABERS and Green Star scheme which mainly have been developed to assess buildings or design of buildings with regard to environmental and energy use matters (1200 Buildings, 2012; GBCA 2011). Yet from perspective of building and construction industry there is not a holistic model or framework which considers all design aspects in order to evaluate the real value of good designs.

This study has undertaken a detailed review of approaches and methods used to quantify design value and then develop a consolidated list of quantitative and qualitative attributes of design quality. Of course what is attempted by this study is not unproblematic. One problem is comparing completely different tools which have different sets of attributes. The other problem would be justifying the importance of attributes from different parties' perspectives. Even identifying an appropriate list of attributes is challenging. The list of attributes has to be comprehensive enough to cover whole of life costs, operating revenues, energy expenses and other social and environmental issues. The findings have been used to establish a theoretical framework that can be used for design evaluation by practitioner as thinking tool in procurement and investment decision making process. This study documents a basis for future research in developing more practical evaluation and quantification tools.

2. What is already known about Design Quality Measurement?

A variety of methods may be used to assess design quality including qualitative and quantitative approaches. These methods include but not limited to multi-criteria analysis, opinion survey, expert judgment, benefit realization, cost-benefit analysis and other forms of assessment. In this study current techniques for the review and measurement of design quality have been undertaken by a reviewing the available evaluation tools and techniques related to design. Specific techniques considered include Design Quality Indicators, Housing Quality Indicators, Post Occupancy Review of Buildings, BREEAM, SPeAR, AEDET, NABERS and Green Star. A consolidated comparison of the techniques has then been undertaken and discussed.

DQI (Design Quality Indicator)

DQI is a tool for measuring design quality of buildings. This tool has been used for design as well as a tool for evaluating the value of post occupied building such as hospitals to improve their performance. The DQI's developers have emphasized that it is a tool for thinking not to provide absolute measures and also DQI cannot be used for design process improvement, it is only used for assessing the quality of design as a product (Gann et al., 2003; J. K. Whyte and Gann, 2007).

One of the arguments put forward by Thomas Markus about DQI is that using this tool to measure the quality of occupied building is not sensible due to the fact that it has been developed for measuring the design quality from the beginning. The other critic by Markus is mixing and balancing subjective and objective components of design in DQI (Markus, 2003).

DQI is lacking to integrate economic measures and also there are some problems with the DQI weighting system. The design quality drivers are treated equally. But this issue can be addressed in future work by using modeling techniques to provide more reliable results.

HQI (Housing Quality Indicator)

The Housing Quality Indicator has been developed by Department for Environment, Transfer and Regions (DETR) and The Housing Corporation in UK. HQI has been developed to satisfy the need for a method which directly can assess the housing quality. HQI not only can be used to evaluate different design against a fixed brief but also is applicable to evaluate the quality of existing buildings (Wheeler, 2004). Ten key indicators are considered in this tool including; location, site: visual impact, layout, landscaping, open space, routes and movements, unit size, unit layout, unit noise control, light quality, services, accessibility within the unit, energy, green and sustainable issues, performance in use.

PROBE (The Post-Occupancy Review of Building)

PROBE is a questionnaire based tool to reflect a building occupier view points as well as an energy survey which can be used for comparison and benchmarking. In fact, it is a system to convey feedback to clients and designers rather than a quantification tool. PROBE is usually used for further improvement to the building functionality and performance (Leaman and Bordass, 2001)**.** It is providing clients, designers, developers and occupiers with useful points from the actual users (Gann et al., 2003).

BREEAM (Building Research Establishment Environmental Assessment Method)

BREEAM is basically developed to provide energy consumption measures in building by UK Ecopoints but it fails to integrate sustainability lifecycle issues (J. Whyte et al., 2003). It is a scheme aiming at quantifying environmental impacts of building in order to reduce environmental burdens of buildings by rewarding good designs(BRE, 2012).

SPeAR (Sustainable Project Appraisal Routine)

SPeAR is an alternative to BREEAM developed by ARUP and provides different sustainability indicators to evaluate environmental issues related to the project(J. Whyte et al., 2003). It is a decision making tool which communicates visualized results of several key themes such as transport, biodiversity, culture, employment and skills in a traffic light system diagram(ARUP, 2011).

AEDET (Achieving Excellence Design Evaluation Toolkit)

AEDET is a tool developed by DH Estates and Facilities in UK to assist trust to measure and manage the design quality of new and existing healthcare buildings from initial proposals through to post project evaluation. This tool has 10 evaluation criteria including; Character & innovation, Form & materials, Staff & patient environment, Urban & social integration, Performance, Engineering, Construction, Use, Access and Space which has been categorized in three main sections as Impact, Build Quality and Functionality. It is mainly developed based on DQI's evaluation criteria (NHS, 2008).

NABERS (The National Australian Built Environment Rating Scheme)

NABERS is a set of tools to evaluate the environmental performance of buildings. It is a new developed version of Australian Building Greenhouse Rating (ABGR) scheme. NABERS includes four tools for Energy, Water, Waste and Indoor Environment assessment which rate buildings out of 5 stars scale. Rating is based on building performance data not design of buildings(1200 Buildings, 2012).

A base building rating considers the building's central services such as energy consumption rating including air conditioning, lifts and common area lighting. The environmental impact of certain tenancy is considered in tenancy rating tool. Occupant's light and power consumption is evaluated for energy consumption by this tool. A whole building rating considers both base building and tenancy data (1200 Buildings, 2012).

Green Star

Green Star is a set of tools provided by Green Building Council of Australia to evaluate the design of buildings. Each design receives a rating out of six stars. A four star rating means best practice. Five stars rate signifies Australian excellence and six stars rate introduces world leadership. Compared to NABERS, it considers more environmental criteria and the other difference is that it can be used to rate the design not the building itself. Management, indoor environment quality, energy, transport, water, materials, land use and ecology, emissions and innovation are all taken into account for the development of this tool(1200 Buildings, 2012; GBCA, 2011).

3. Design Quality Attributes

In previously discussed section on tools and techniques different researchers have focused on specific sets of attributes to define design quality measures. The focus of this study was to identify a thorough set of attributes which can lead to an integrated and holistic framework for future use by critical consideration of previous approaches to form a consolidated set of attributes. These attributes are compiled in Table 1. The assessment methods are identification, qualitative and quantitative approaches. Identification means that particular attributes are only identified and described. Quantitative is a kind of objective assessment in physical units or probably in monetary terms. Qualitative is more related to an evaluation based on personal judgment.

Table 1: Design Quality Attributes From Different Tools or Guidelines

Tool/ Guideline	Attributes Measured	Evaluation Method		
		Identification	Quantitative	Qualitative
DQI	Functionality, Built Quality, Impact	√	×	√
HQI	Location, Site (Visual impact, layout, landscaping), Routs and movement, Unit (size, layout, noise), Accessibility, Energy, green and sustainable issues, Performance in use	√	√	√
PROBE	Process (delivery and operational management), Functional Performance (users' needs) and Technical Performance (physical systems)**.**	√	×	√
BREEAM	Management, health and well being, energy, transport, water, materials, waste, pollution, innovation, land use and ecology	√	×	√
SPeAR	Environment, Social, Natural Resources and Economic	√	×	√
AEDET	Functionality, Built Quality, Impact	√	×	√
NABERS	Energy, Water, Waste and Indoor Environment assessment	√	√	×
Green Star	Management, indoor environment quality, energy, transport, water, materials, land use and ecology, emissions and innovation	√	√	×
Communication Tool By: Wong, Lam, & Chan,	Aesthetics, Functionality, Build-ability, Economics	√	×	×
Design Quality Manual By: National Capital Authority Australia	Contextual Analysis, Public Space, Built Form, Land Use and Density Mix, Activation and Vibrancy, Aesthetics, Environmental Performance, Materials, Inclusive, Safe Design, Movement, Urban Art	√	×	×
Principle of good design, Macmillan CABE (UK)	Functionality in use, Build quality, Efficiency and sustainability, Designing in context, Aesthetic quality	√	×	×
What is a well-designed building? Macmillan CABE (UK)	Appearance, Context, Build-ability, Maintenance, Operation	√	×	×
What is a well-designed place? Macmillan CABE (UK)	Character, Continuity and enclosure, Quality of the public realm, Ease of movement legibility, Adaptability, Diversity	√	×	×
√= Used ×=Not used				

Design value drivers have been categorized into four groups: Economic, Environmental, Functional and Impact Value drivers. Each group consists of several features and these have been summarized and presented as Figure 1. Economic and environmental factors are more objective and quantifiable and on the other side functional and impact factors are mainly subjective which are challenging to be quantified however they can be evaluated in other ways. To develop an integrated and thorough framework, all the Economic, Environmental, Functional and Impact factors should be assessed at the same time. Evaluating one or some of the value drivers in isolation would never give a reliable measure. The other important issue is the inter-relationship between factors and combining them together in a proper way based on their importance.

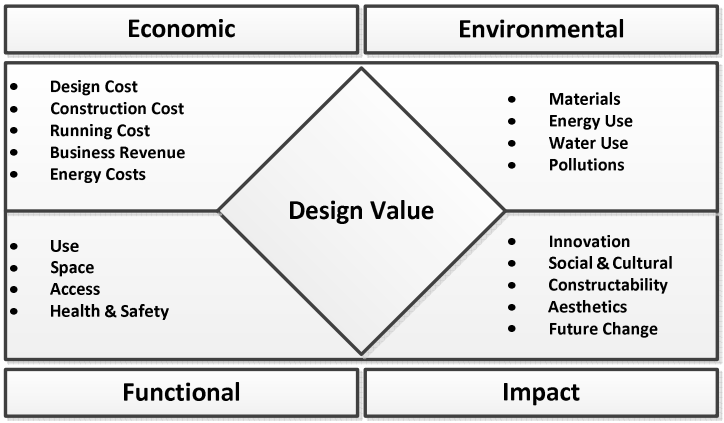

Figure 1: Design Quality Attributes

Current tools and techniques are compared in Table 2 to address which areas might not be studied with regard to the new proposed design attributes grouping.

Table 2: Comparison between Current Tools/Framework

Tool/ Framework	Areas of Consideration				Application		Description
	Functional	Impact	Environmental	Economic	Design	Building	
DQI	√	√	√	×	√	√	A tool for measuring design quality of buildings.
HQI	√	×	√	×	√	√	Mainly used to assess the housing quality.
PROBE	√	×	√	×	√	×	Reflects occupiers' view points by questionnaire.
BREEAM	×	×	√	×	√	√	Basically for energy consumption measure in buildings.
SPeAR	×	×	√	×	√	√	Like BREEAM with different sustainability indicators.
AEDET	√	√	√	×	√	×	Measure the design quality of healthcare buildings.
NABERS	×	×	√	×	×	√	Evaluate the environmental performance of buildings.
Green Star	×	×	√	×	√	×	Evaluate the design of buildings environmentally.
√= Considered ×=Not Considered							

As it can be seen in Table 2, none of the current reviewed methods have a comprehensive and holistic approach for assessment however some of them are really good in their own studied areas such as SPeAR and AEDET. This comparison shows that there is still a gap to bridge in design quality assessment.

4. Design Value from Different Perspectives

Different people have different perceptions about value of design. Everyone tries to satisfy their needs through a specific interpretation of design value. The owner (sometimes financiers play this role) usually considers the economic values more than other ones. Designer on the other side would like to place more emphasize on impact values. But what users are looking for through these wide range of attributes is their convenience through functional values and they are usually concerned with efficiency in use. In this study it is assumed that all the involved parties are concerned about environmental values and accept them as a must (Figure 2).

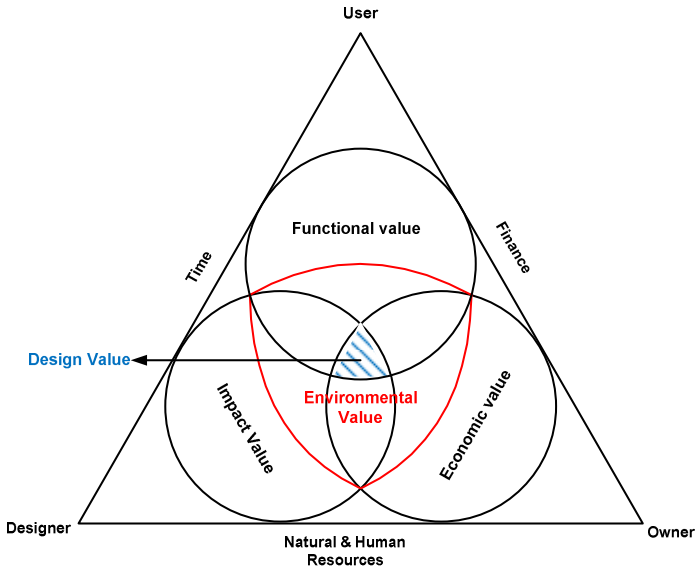

Figure 2: Design Attributes Interaction and Different Perceptions of Value

However, achieving high value design is ideal but defining an optimum balance between this wide range of attributes while considering time, finance and other resources limitations would be crucial as well. Main issue in this context is when quantifying design we need to think from different perspectives but client's view seems to be more important most of the time so there is a need to provide an index as a value indicator which could be realized not only by the client but also by the other involved parties.

As stated before one of the key point in design evaluation would be value for money thinking by applying whole life cost-benefit analysis approach. It means design value especially economic value should be assessed over the project's lifecycle. As it can be seen in Figure 3, different stakeholders are concerned differently about their needs at different stages of projects. For example, in design phase usually designers and the clients are playing the main role while in operation phase users are at the top of the list. Also Figure 3 illustrates that the client always plays a key role over the whole lifecycle of projects.

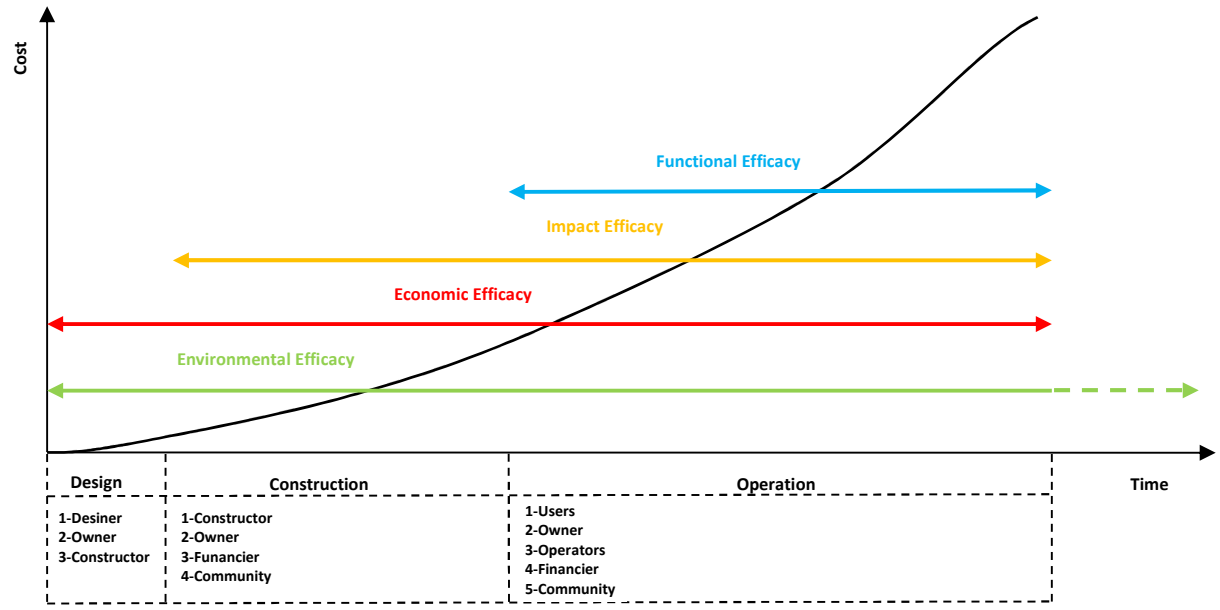

Figure 3: Project Lifecycle and Different Perspectives of Design Value

Figure 3 demonstrates that over the lifecycle of project different drivers are impacting the project differently. For instance, environmental drivers not only affect the whole life cycle but also their impacts may exist for a longer time even after the project. Functional factors are playing the main role in the operation phase but they should be taken into account in design and construction phase as well. Thus it may be assumed that without a whole life costing approach the results of design evaluation would not be reliable.

5. Conceptual Framework for Design Evaluation

This framework could be used in two ways, first as an evaluation framework when to select the best option among different proposals at decision making stage. Secondly, it can be used as a research platform to bring different stakeholders together at the design stage to find an optimal configuration of a design.

If the evaluation is intended tangible and intangible design attributes would be better to be defined into two distinct categories to produce more realistic measures. In other words, finding two distinct indices for objective and subjective factors is really needed. It would be more sensible to evaluate economic and environmental value drivers objectively and functional and impact value drivers subjectively. Figure 4 shows a very basic conceptual framework for design quality evaluation process.

As it is shown in Figure 5, this framework can be used as a process tool if determining the optimal configuration is aiming. This process might be undertaken for example in an interactive workshop environment to capture all the stakeholders' thoughts and viewpoints.

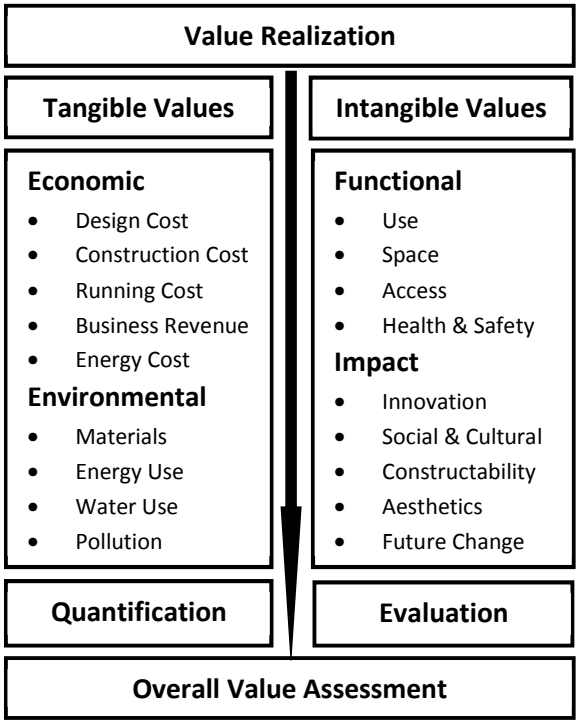

Figure 4: Design Quality Evaluation Framework

The method of quantification for tangible values and evaluation approach for intangibles may be chosen based on the availability of information as well as the intended confident level of assessment. These methods may vary from financial and economic ratios to opinion survey or expert judgements.

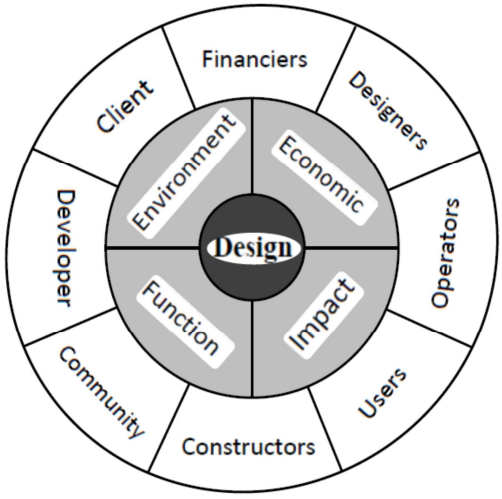

Figure 5: Design Configuration Consideration

When optimal configuration of a quality design is intended the interests of all stakeholders should be taken into account. In the process of design all the stakeholders' view points and thoughts must be captured and justified. There is no doubt that each of these stakeholders tries to satisfy their own needs through the process of design but caution should be exercised to have a balanced approach in this regard.

6. Conclusion

This study undertook a detailed review of approaches and methods used to quantify design value and it then developed a consolidated list of quantitative and qualitative attributes of design quality.

Having reviewed common design tools (e.g. DQI, BREEAM, HQI, PROBE) (often with a sustainability emphasis) through the lenses of economic, environmental, functional and impact value drivers it was found that many of the tools adequately consider functional and environmental attributes but no tool integrates all four attributes encompassing design quality. It is concluded that an integrated design evaluation tool that considers all four attributes would assist in providing a more balanced evaluation of the real value brought to projects by quality design.

Assessing the value of a set of design value drivers primarily focussing on function and the environment may not produce proper measures to make an informed decision. A more holistic design evaluation tool would enable practitioners and researchers to evaluate the design quality at different stages of the project such as business case development, feasibility study or even design. Such an approach would assist clients, developers, investors and project teams to maximize design opportunities when they are making investment decisions.

To commence the process of developing a more holistic evaluation tool both quantitative and qualitative attributes need to be considered. Based on a critical review of the literature a list of important design quality attributes have been identified that embrace economic, environmental, functional and impact value drivers. These design attributes have been developed into a conceptual evaluation framework that specifically considers both tangible and intangible values. It is anticipated that use of this framework may better inform the real value of design quality.

Research is continuing to test the validity of this proposed evaluation framework by testing the benefits of innovative practices and ideas in projects through a whole of life analysis that incorporates value for money (VfM) thinking.

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Application of Relationally Integrated Value Networks in the Implementation of BIM for Better Life Cycle Considerations of Buildings

Aoxiang Ren, Mohan M Kumaraswamy, Kelwin Wong and S. Thomas Ng

Abstract

Emerging as an innovative tool with rapidly increasing usage in the construction industry, Building Information Modeling (BIM) can provide a platform to enable two dimensions of information exchange, namely i) information sharing among relevant participants within a certain project phase; and ii) information exchange between two or more project phases. The latter is of vital importance to help achieve potential life cycle benefits of BIM. However, a significant gap exists in information flows in current BIM implementation in Hong Kong, between 'Design & Construction' (D&C) and 'Operation & Management' (O&M). This paper discusses the potential application of a relational management framework named 'Relationally Integrated Value Networks' (RIVANS) to guide the process of information exchange between 'D&C' and 'O&M' in a BIM system. Possible causes of the above information flow gap are explored and proposals are developed based on RIVANS principles to bridge this gap. Findings and recommendations presented in this paper should pave the way for enhancing information flow in BIM across various phases of a construction project, thereby enabling integrated efforts for improving building life cycle performance.

Keywords: Building Information Modeling (BIM), **relational management**, **integrated teams**, **information exchange**, **life cycle approach**.

1. Introduction

Smooth channels for rapid exchange of relevant knowledge and skills among interacting participants through the project life cycle, in terms of design, construction and operations, are increasingly needed (Kumaraswamy, 2011). BIM is one of the promising channels due to its ability to advance the information exchange through the whole project life cycle. The potential life cycle benefits of BIM are commonly acknowledged by the industry across the world, as evidenced in the various definitions of different institutions. For example, the National Building Information Modeling Standard (NBIMS) defines BIM as a digital representation of physical and functional characteristics of a facility and it serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life cycle from inception onward (NBIMS, 2007). Meanwhile, as one of the major BIM software vendors, Autodesk (2011) defines BIM as 'an intelligent model–based design process that adds value across the entire lifecycle of building and infrastructure projects'. 'Life cycle' is a key word that is emphasised in the above two definitions. In the Hong Kong

industry, the Hong Kong Institute of Building Information Modeling (HKIBIM) adopts a simple definition that BIM is the process of generating and managing building data during its life cycle (HKIBIM, 2011).

Placing BIM firmly within the ‘life cycle’ umbrella indicates that BIM is able to benefit the various stakeholders in different ways in each project phase, from design to operation. Eastman (2011) summarizes a list of benefits that BIM can generate in different projects phases, such as earlier visualizations for the client in the design stage, improved basis for component fabrication in the construction stage and better facility management in the operation stage. One of the key factors to ensure the realization of the life cycle benefits is the consistency of the BIM system in the project’s whole life cycle. Two kinds of supply chains, namely the 'Design & Construction' (D&C) supply chains and the ‘Operation & Management' (O&M) supply chains, are mainly responsible for the presently segregated two principal phases in a building project’s life cycle. Therefore, in order to achieve the potential life cycle benefits of BIM, an efficient information exchange mechanism between these two supply chains needs to be built into the implementation of BIM.

However, in the Hong Kong industry, most projects implement BIM in their ‘D&C’ phase only. Two reasons might explain this situation: 1) not being aware of BIM’s potential benefits in their ‘O&M’ phase, 2) failing to extend the BIM systems into ‘O&M’ phases due to the poor information exchange mechanisms between the two supply chains mentioned above. To address the first reason or barrier, along with the maturing of BIM implementation, the industry should gradually see the benefits in ‘O&M’ phases. Therefore, this paper focuses on the second barrier, discussing the potential application of a relational management framework named 'Relationally Integrated Value Networks' (RIVANS) to guide and smoothen the process of information exchange between the Design and Construction (D&C) and the Operation and Maintenance (O&M) teams in a BIM system, so as to accelerate and improve the two-way flow across this channel in the Hong Kong industry. RIVANS is a conceptualization of ‘aligning and re-aligning divergent or otherwise conflicting values and behaviours towards integrated team working and a confluence of consolidated high performance levels in both project and strategic networks.' (Anvuur and Kumaraswamy, 2011). While RIVANS was first proposed for ‘D&C’ teams (Kumaraswamy, et al., 2009), its conceptualization has been recently extended into Total Asset Management (TAM) (Kumarawamy et al., 2012). One of its main objectives in this extended and holistic context is to identify common goals and values between “D&C” and “O&M” teams, so as to bridge and synergise ‘D&C’ supply chains with ‘O&M’ supply chains efficiently. Later sections will expand on the above while including specifics. The purpose of this paper is to develop relevant outline proposals based on RIVANS principles and the on-going RIVANS for TAM research to inject more focused and valuable life cycle considerations into BIM implementation in the Hong Kong industry.

This reported research is a part of a study which aims to advance BIM implementation through integrated working arrangements and the reported findings in this paper formulate the theoretical foundations for developing long term integrated working arrangements for the whole research project.

2. Research methods overview

This reported research is supported by findings from individual interviews conducted in the Hong Kong industry, a BIM case study in Hong Kong, proposal development based on RIVANS principles and interim findings from an on-going research project entitled 'RIVANS for Total Asset Management (TAM)'. Since most of the data was collected in the Hong Kong industry, the conclusions of this paper are more applicable in Hong Kong, but similar methods may be used to elicit and compare findings from other jurisdictions. To avoid duplication, the research methods are described along with the respective findings in the following sections.

3. Current gaps between D&C and O&M in BIM teams implementation in Hong Kong

The captioned gaps were explored through 18 separate semi-structured interviews and a case study.

All of the 18 interviewees were experienced BIM practitioners or researchers in Hong Kong industry, covering a wide range of stakeholders in terms of clients (private and government), main contractors, BIM consultants, architects and Mechanical-Electrical-Plumbing (MEP) contractors. They provided their opinions on the question about changes and issues in information exchange mechanisms in projects that adopted BIM.

The case study was conducted on a representative BIM project (named Project A in this paper) in Hong Kong. Planned in 2004 and completed in 2008 by a private client, Project A was one of the first projects that implemented BIM in Hong Kong. Since there was very limited previous BIM project experience to refer to, Project A could be regarded as a meaningful pilot project that tried to implement BIM across the whole project life cycle, also providing a benchmark in the context of Hong Kong industry, for later projects to reference in the areas of information exchange mechanisms, operation flow and organizational structure, in the context of Hong Kong industry.

The proposed or 'as expected' life cycle information flow in Project A is illustrated in Figure 1, showing the ideal scenarios of information exchange at each connection point between any pair of project phases. BIM models created in the previous project phase were supposed to be directly enhanced to new BIM models that could be used in the next project phase. In this case study, BIM models created in the design phase could be named as the 'tendering BIM' and BIM models created in the construction phase could be called the 'construction BIM', while BIM models created in the operation phase could be named as the 'operation BIM'. It was expected that 'Tendering BIM' should be able to be enhanced directly into 'construction BIM' and 'construction BIM' should also be able to be enhanced directly into 'operation BIM'.

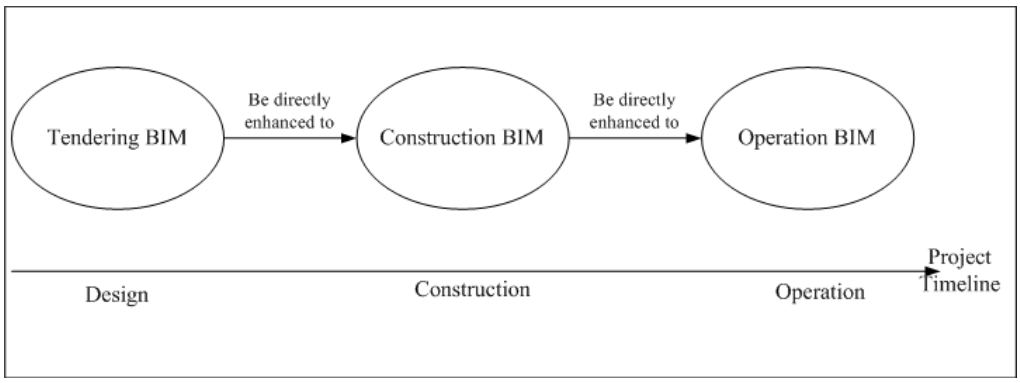

Figure 1：Proposed information flow in Project A

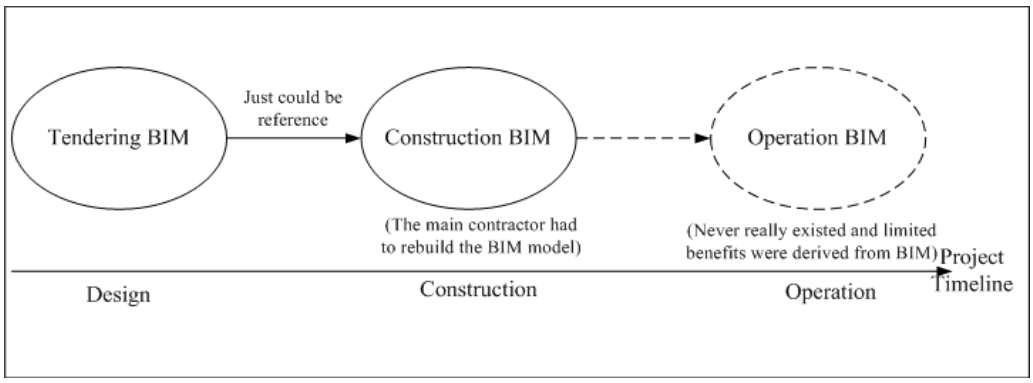

Figure 2: Real information flow in Project A

However, the 'as happened' real BIM implementation process in Project A is illustrated in Figure 2. Huge gaps between 'tendering BIM' and 'construction BIM' made the proposed direct transformation impossible. It was alleged that the main contractor spent almost twice the efforts, as spent on the 'tendering BIM' to create a usable 'construction BIM' that was applicable in the construction phase. Information exchange between the 'D&C' and 'O&M' teams was even more difficult and the expected 'operation BIM' never really materialized.

The main gaps between 'D&C' and 'O&M' teams in BIM implementation were identified and categorized through the individual interviews and case study as follows:

There were no relevant standards in the industry to define an appropriate BIM implementation process which was supposed to include efficient information exchange mechanisms to guide the stakeholders. This confusion was reported by some clients who decided to implement BIM in new projects. Clients needed to set up BIM based information exchange mechanisms by themselves, of course drawing on the services of BIM consultants. Regular coordination meetings were the main approach to ensure timely information exchange within a particular project phase. However, for the information exchange between two project phases, few projects could develop an efficient system for BIM.

Specifications about BIM models were too vague to answer the question of what kind of information should be contained in the 'D&C' team's BIM models so as to benefit the 'O&M' team. The 'D&C' team built BIM models based on their own needs and knowledge. They were unwilling and/or unable to reflect 'O&M' team's needs in their BIM models.

Current project processes restricted the formation of efficient life cycle information exchange mechanisms in the BIM system. BIM is a system that requires the early involvement of key participants, while most projects in the Hong Kong industry are delivered by Design-Bid-Build, leaving little room for this to happen, given the staggered and discontinuous involvement of key team members.

Facility managers were inexperienced in expressing their BIM requirements to upstream stakeholders, such as designers and contractors. Some BIM consultants mentioned that some clients were indeed willing to extend BIM into operation phases, but the facility managers did not know what kind of information should be contained in the earlier BIM models. They did not have the experiences of adopting BIM in the operation stage, suggesting a 'chicken or egg' type 'stale-mate' in this particular learning curve.

Since BIM required extra efforts from stakeholders but benefited the clients most, conflicting value objectives seemed to be generated by individual parties' goals vs the project's whole life cycle goals. Aligning different stakeholders' value objectives is always a critical issue in the industry and BIM implementation requires a higher level of focus on identifying and/or aligning the common value objectives among the participants.

4. Introduction to Relationally Integrated Value Networks (RIVANS)

4.1 Basic concepts of RIVANS

Focusing on the last (but certainly not least) 'gap' as listed in the above section, this is indeed a typical problem in the construction industry in general. Although many high-powered industry improvement reports in different jurisdictions, e.g. Latham (1994), Egan (1998), Construction Industry Review Committee (CIRC) (2001), have urged integrating the teams in 'D&C', this has yet to happen to yield the expected benefits, despite some advances through for example, partnering and alliancing type initiatives. Hypothesizing that such integration would not materialize unless stakeholders identify and focus together on common value objectives, a concept of 'Relationally Integrated Value Networks' (RIVANS) was proposed through the Centre for Infrastructure & Construction Industry Development (CICID) of The University of Hong Kong (CICID, 2007). RIVANS aims to develop a holistic conceptual framework for 'relational' integration of hitherto mutually suspicious project participants into cross-linked 'value networks' '(CICID, 2008). The basic thrusts of RIVANS are shown in Figure 3 (Kumaraswamy *et al*., 2012). Stakeholders in the supply chains form the value networks based on their relational integration, to deliver both one-off projects and a series of projects. There are two basic ideas in RIVANS that can illustrate its core concept:

'Relational Integration' and 'overall value of the network'. Relational integration can be achieved by directing a common focus on the 'overall value' of the 'network', while members of more integrated teams are more likely to be engaged and empowered towards both short term and long term overall 'network value' (Kumaraswamy *et al*., 2009).

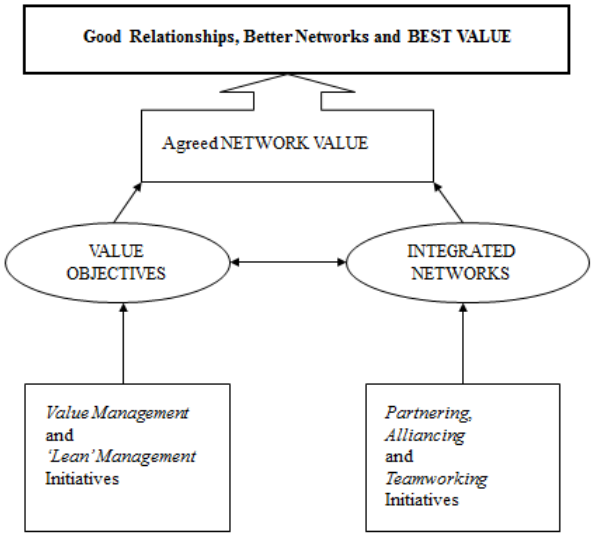

Figure 3: Basic Thrusts in RIVANS

Relational integration implies a higher and deeper level of integration than the structural integration that is expended from organizationally integrating say, the design and construction teams in the Design-Build. It emphasises genuine trust and long term cooperation among the various participants to achieve better project performance. Given its trust and trust-based operational arrangements (Rahman and Kumaraswamy, 2012), higher levels of information exchange efficiency can be expected among diverse participants in the relationally integrated team members.

Overall network value in RIVANS implies that diverse members in the project's supply chains, such as the 'D&C' supply chain and 'O&M' supply chain, should focus on the common best value for the whole project, instead of only on their own benefits. Joint Risk Management (JRM) and 'pain share gain share' mechanisms need to be established in RIVANS through the project life cycle to achieve 'best for project' scenario, of which there are scattered examples as in the case study reported by Kumaraswamy and Rahman (2006).

The above two terms of 'relational integration' and 'overall network value' represent general principles that can be derived from RIVANS to help address the gaps in BIM implementation that were indentified in the previous section. More applicable and directly relevant to the present research would be an exercise to extend RIVANS into the area of Total Asset Management (TAM), so as to encompass the whole life cycle of the built asset. Such a project has commenced as outlined below.

4.2 RIVANS for Total Asset Management (TAM)

RIVANS for TAM is an on-going research project that aims to 1) identify synergies and added value that can be achieved through well-structured and focused collaboration between those engaged in Infrastructure Project Management (IPM) and Infrastructure Asset Management (IAM), and 2) develop concepts and working arrangements for RIVANS for TAM (Kumaraswamy, et al., 2012).

A questionnaire survey has been conducted to collect input from 'D&C' teams and 'O&M' teams in the Hong Kong industry. Participants were invited to indicate their level of agreement on a series of activities (such as the implementation of BIM) that may contribute to better value/synergies by linking the supply chains in the project lifecycle.

In addition, two organizations that were both engaged in 'D&C' and 'O&M' works were selected to conduct case studies to identify the information exchange mechanisms, working arrangements and communications between 'D&C' teams and 'O&M' teams.

Interim findings derived from the case studies while not specific to BIM, are more relevant to help lay the foundations for developing proposals to achieve better life cycle considerations of BIM. Most of these arise from the organizations' current good practices in the areas of information exchange mechanisms, working arrangements and communications between 'D&C' teams and 'O&M' teams. Interim findings about these good practices that are directly relevant to the indentified gaps in this reported BIM research, were recently summarized by Kumaraswamy and Wong (2012):

1) 'O&M' teams get involved in the project quite early and their design input was provided to the 'D&C' teams for consideration;

2) 'O&M' teams conducted design reviews to ensure that their requirements had been sufficiently reflected in the designs;

3) A series of high and mid-level management meetings were held to serve as the platform for information exchange, working arrangements and communication between 'D&C' teams and 'O&M' teams;

4) Monthly Technical Management Steering Committee (TMSC) Meetings served as a bridge between the operation division and project division to share technical issues related to new technologies, technical feasibility and previous experiences.

5. Proposals for applying RIVANS in BIM implementation for better life cycle considerations

Based on the key principles of RIVANS and directly relevant interim findings in the RIVANS for TAM research, a set of proposals are developed in this section to achieve more mutually beneficial BIM implementation from a life cycle consideration.

1) The industry should develop localized BIM guides or specifications to define and/or clearly identify: a) appropriate BIM processes which contain efficient information exchange mechanisms spanning the project life cycle by linking various supply chains, such as 'D&C' teams and 'O&M' teams, and b) the necessary data and information that need to be input into the BIM models so as to benefit all the participants in different project phases. When developing BIM-based life cycle information exchange mechanisms, the industry can refer to findings from the on-going RIVANS for TAM research. Early involvement of the 'O&M' teams, design review rights for 'O&M' teams and the monthly held TMSC meetings are all useful measures to be considered;

2) In order to motivate all the participants, especially the 'D&C' teams, to create and contribute to the BIM models from a life cycle perspective, not only for their own interest, Relational Contracting (RC) which allows for joint risk management and pain/gain share in Target Cost Contracts is suggested to be gradually adopted by projects in the Hong Kong industry (Kumaraswamy, 2012). As a Hong Kong-based RC proposal, RIVANS appears applicable in Hong Kong projects to align the various participants' values in different supply chains to the common best value for the whole project. Once RIVANS are established in the projects, participants, including the current least benefited architects or consultants, may adopt more life cycle concerns while creating BIM models. BIM models created in the early project phase will be more usable for the participants in the next project phase, therefore, a smoother BIM model transferring between the 'D&C' phases and 'O&M' phased can be expected;

3) Large clients (named as 'ongoing clients') who must manage a continuous project flow, i.e., not just on one-off or on-off projects, may be advised to build their own RIVANS. The efficiency of information exchange will be increased among participants in the RIVANS due to the trust-based operational arrangements. Participants in the RIVANS which were established for long-term cooperation would develop strong bonds after the completion of several projects. In such scenarios where various participants understand each others needs and are also willing to consider these needs in the BIM models, BIM can serve as a truly smooth channel to meet the needs of rapid exchange of information, knowledge and skills. Only then can the full potential of BIM be realized. An example of a large client's RIVANS in the project management phase is illustrated in Figure 4 (CICID, 2012).

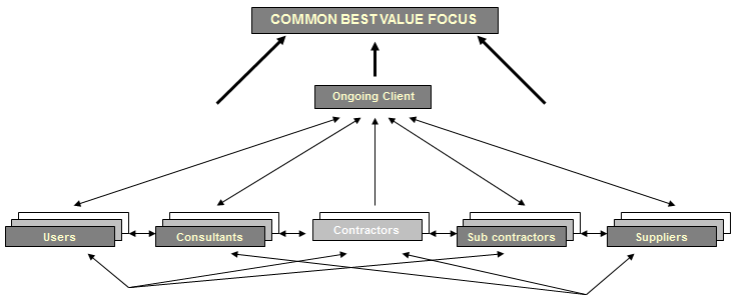

Figure 4: RIVANS of an 'Ongoing Client' in 'D&C' Phase

6. Conclusions

BIM is an innovative tool that has the inherent potential to provide a highly efficient platform for information exchange and knowledge through the whole project life cycle. However, this 'potential' is currently not translated into reality in the Hong Kong industry. Gaps in BIM implementation from a life cycle consideration, especially between 'D&C' supply chains and 'O&M' supply chains, were identified by interviews and a case study in this reported research. Proposals based on RIVANS principles and interim findings from the RIVANS for TAM research are developed from the industry level, projects level and organizational level (particularly for 'on-going' clients) in this paper. The proposals show possible long term measures for the participants to adopt, so that they are able to derive broader potential benefits from BIM through the project lifecycle.

The case study in this reported research was conducted on a project completed in 2008 and the current scenarios have changed in some aspects. Also, RIVANS is a holistic conceptual framework, while RIVANS for TAM is still an on-going R&D initiative and the findings therefrom will need validation before the final outcomes. The above points highlight the main limitations of this paper. Future works will include a BIM case study of a recent project and relevant adjustments to the proposals along with the maturing of RIVANS principles and RIVANS for TAM research.

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Exploring life-cycle-based indicators for integrated sustainability assessment of building structural frames in concrete

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Abstract

Methodologies for indicators selection and benchmarking are paramount to allow quantification of limits and presentation of strategies for achieving sustainability in the construction industry. Life cycle-based studies have consistently shown structural frames and envelopes as major contributors to buildings environmental loads. Despite that, structural frames have not gained enough space in sustainable buildings assessment systems. Given the difficulty to insert life-cycle assessment (LCA) in daily routine of structural design practices, this paper presents a set of LCA- and LCC-based indicators that integrates functional, environmental and economic performance requirements. The goal is to allow proper design decision-making support and a broader, life-cycle, sustainability evaluation of concrete structural frames. Based on a case study approach, the analysis focuses on different concrete building flooring systems. Life-365 software was used to predict service life and estimate LCC for different concrete building typologies. Cradle-to-gate LCAs were performed for reinforcing and prestressing steel, plywood formwork and the concrete mixes. For the conditions studied, prestressed flat slabs showed better functional and economic results than reinforced concrete waffle slabs, which, however, presented the best environmental performance. Results also confirmed the validity to proceed with the analysis of a typical storey *in lieu* of the whole building structure for different residential building typologies, as well as the need to further explore cost and environmentally effective strategies to increase concrete structures service life in marine and industrial environments for compliance with the Brazilian standard ABNT NBR 15575:2012. It is expected that this set of indicators, refined by other case studies, will evolve to a multidimensional framework to support sustainability-oriented structural design decision-making.

Keywords: indicators, structural frame, LCA, LCC, flooring systems.

1. Introduction

Research initiatives for new generations of sustainable buildings assessments state that buildings sustainability level should always be described using indicators. The selection and

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justification of indicators should be based on clear understanding about the issues of concern and the relevance of building sector to these issues (SUPERBUILDINGS, NEWSLETTER-2, 2011, CRISP PeBBu, 2005, LUETZKENDORF et al, 2011). Defined as a parameter or a value derived from parameters, an indicator is used to illustrate the main characteristics of a given object. It should be relevant, measurable and adequate to the analysis (OECD, 2003), whilst remaining objective and providing traceable results. Since indicators main functions are quantification, simplification and communication, they can be used for assessment, diagnosis, comparison and monitoring (ISO/TS 21929-1:2006).

Environmental, economic and social performances should be considered in the sustainability assessment of buildings. Indicators used can be organized to allow the inclusion of a broad representation of sustainability aspects while being relevant to the stakeholders' perspectives (UN ST/ESCAP/2561, 2010).

One of the most comprehensive initiatives for developing indicators for the building sector was the work carried out within the European thematic network *"Construction and City Related Sustainability Indicators"*- CRISP, providing a database of circa 500 indicators. Later, this network carried out studies concerning the application of these indicators to performance-based buildings. It was concluded that considerable additional work was still required to achieve European indicator systems that could be widely used to support and encourage successful adoption of the performance approach to buildings design and construction (CRISP PeBBu, 2005).

The existing sustainable buildings assessment systems offer a number of indicators to be used in different contexts and building life cycle phases (CRISP PeBBu, 2005). Research projects like SUPERBUILDINGS (Sustainability Performance Assessment and Benchmarking of Buildings) and OPENHOUSE currently aim to, among other goals, develop a logical structure for them. While the first focuses on research and development of indicators, their reliability, comparability and validity, the latter develops and tests assessment methodologies through case studies (SUPERBUILDINGS, NEWSLETTER-2, 2011).

The literature review pointed out difficulties on integrating social aspects to environmental LCAs (REAP, 2008), such as *(i)* the lack of consensus on how to integrate and calculate social impacts of products, since social impact methodologies are still in their infancy; and *(ii)* the fact that most impacts on people are independent of the physical processes of manufacturing, increasing complexity on the product-impact relationship.

Another important issue concerning sustainability is durability (LORENZ, 2008), as it decisively influences the service life of buildings and the amount of resources required for maintenance activities. Service life of the structural frame ultimately defines the lifespan and consequently the maintenance intensity of a building. It therefore influences not only the environmental performance of buildings, but its social and economic performances as well.

Life cycle-based studies have shown the structural frame and envelope as major contributors to material environmental loads of a building (DOBBELSTEEN et al, 2005,

DOBBELSTEEN et al, 2007, HAAPIO, VIITANIEMI, 2008, KELLENBERGER, ALTHAUS, 2009, MOON, 2009). However, service life, durability, and role played by structural frames have not gained enough attention in sustainable buildings assessment systems, except perhaps for HQE/AQUA and CASBEE, which include service life extension of the structural frame among their encouraged sustainability strategies.

Structural element reuse can lead to reduction of waste and raw material use for future construction, thus close inspection and accurate qualification of structural members must be completed before that. The advantage of reusing a structural component may result in higher initial project costs and reduce the sustainability of the second structure. Designing for multiple intended uses and possible reuse of a structure may have financial advantages, as the owner can define a new use for the building, which in turn extends the service life of its structure (LAEFER, MANKE, 2008).

A building's design life, as well as the service life of building elements, also defines its environmental performance in terms of material use, once sustainability is given by the ability to fulfil certain (functional) performance requirements, while subjected to degradation factors and necessary maintenance, at the lowest negative impact of that component on the environment (NUNEM, MOOIMAN, 2011).

Considering *(i)* that service life of the structural system ultimately defines the lifespan of a building, *(ii)* that service life is also determinant of the efficiency of resource use for a given function, *(iii)* the role of structural systems in environmental terms, mentioned by studies in other contexts, and *(iv)* the complete absence of data in this regard in Brazil, this work is dedicated to the study of alternative structural systems typically used in Brazilian residential concrete buildings typology. Other relevant building systems as well as the relation with the other parts of the building and the impacts on the technological system as a whole are being targeted by parallel research and are therefore beyond the scope of the present paper.

Life cycle environmental and costs consideration, service life prediction models and functional requirements should be properly balanced and used to support design decision-making. Eco-efficiency indicators are structured to capture resources usage – both in terms of production and consumption – and the consequent environmental impacts (UN ST/ESCAP/2561, 2010).This paper aims at proposing a set of LCA- and LCC-based eco-efficiency indicators to evaluate sustainability aspects of concrete structural frames from a life cycle perspective. A case study approach was adopted to investigate its feasibility to compare sustainability performance of different concrete building flooring systems.

2. Method and approach

The present study was developed in the following steps: *i)* literature review, covering the concept and methodology for developing sustainability and eco-efficiency indicators for the building sector, and the building performance requirements recommended by the Brazilian performance standard (ABNT NBR 15575:2012) as well as ISO 6240:1980 and ISO 6241:1984; *ii)* proposition of a set of indicators for the selection of structural frames, based on functional, environmental and economic performance requirements; *iii)* application of

these indicators for election from a choice of structural flooring systems at the design stage. The final sessions of the paper are dedicated to results presentation and discussion.

2.1 Preliminary set of indicators for structural frames selection

The functional indicators proposed in this paper refer to stability, fire safety and safety in use, flexibility and durability requirements, based on ISO 6240:1980, ISO 6241:1984 and ABNT NBR 15575:2012, the Brazilian standard for buildings performance. The set of environmental performance indicators is based on ISO/TS 21929-1:2006 and mainly associated to resource management. It measures environmental performance of structural frames in accordance with ISO 21931-1:2010 methodological guidelines. Economic indicators describe monetary flows connected to the building. The economic indicators suggested shall provide a balance between its long-and short-term economic aspects. The indicators considered in this study were life cycle costs, payback period and local economy support. Table 1 shows the proposed set of indicators, filtered by predefined criteria (OLIVEIRA et al, 2011).

Table 1 – Set of functional, environmental and economic indicators proposed for selection of buildings structural frames

Indicators for structural frames / elements	
Functional (associated to performance requirements: safety, adaptability / flexibility, constructability)	*Span over height ratio* (ℓ/d) for each direction considered (for beams and slabs), [m/m] *Applied stress over ultimate strength ratio* (for columns) - for reinforced or prestressed concrete elements, it is the compressive design stress over the characteristic compressive (cylinder) strength, fc / fck [kN/m^2 / kN/m^2]; *Column density:* gross floor area over number of columns (m^2/ n^o), [m^2] *Beam over slab height ratio*, [m/m] *Reuse Potential:* % prefabricated with connections for disassembly [% volume]
Environmental (associated to resource management)	*Carbon Footprint* (CF) [$kgCO_{2\text{-}eq}$/functional unit]; *Embodied Energy* (EE) [MJ/ton]; *Blue Water Footprint* (bWF) (surface and groundwater used, except water for turbine use) [m^3/ functional unit]; *Materials resource consumption* (Mc) [kg/ functional unit]: Steel consumption; Concrete consumption; Plywood formwork consumption; and Structural system consumption (steel + concrete+ plywood formwork). *Abiotic Depletion Potential* (ADP) [(kg $_{\text{total material}}$ – kg $_{\text{recycled}}$ – kg $_{\text{reused}}$) / functional unit]
Economic (associated to life cycle monetary flows)	*Life cycle costs, LCC* [$/functional unit]; Initial costs of design and construction = investment cost [$/functional unit]; Maintenance costs [$/functional unit]; Recycling and reuse costs [$/functional unit]; Demolition costs [$/functional unit]; Final disposal costs [$/functional unit]; *Payback period,* investment cost ($) over annual economy provided ($) [years] *Local economy support*, local materials over total materials cost (percentage of material and products extracted or fabricated locally – within a 300 km - radius) [% cost].

2.2 Case studies description

Three case studies on structural flooring systems, used in different residential concrete building typologies in the Brazilian coastal area are presented. They comprise low-and medium-rise concrete-framed residential buildings. Case study 1 has a total built area of 5,829.19 m^2, in 6 floors (24 apartments), with a 27.5cm-thick flooring system comprising reinforced concrete waffle slabs and beams. Case study 2 (8,841.37m^2 in 15 floors; 48 apartments) and Case study 3 (4,943.31m^2 in 6 floors; 32 apartments) have 18cm-thick prestressed concrete flat slabs flooring systems. The structural material/components' usage was quantified for all three buildings from cost estimates spread sheets and structural design drawings provided by the local construction company. For each case study, environmental indicators were calculated for two situations: one typical floor and the total superstructure. Foundations were disregarded to isolate the effects of soil's carrying capacity on sizing, and consequently on material consumption. These case studies were selected to allow *(i)* calculation of functional indicators, some of which specific for structural elements/components; *(ii)* investigation of the representativeness of a typical floor structure on the whole superstructure sustainability performance, for environmental aspects, as occurs in traditional structural design for these typologies; and *(iii)* indicators validation.

2.3 Calculation of multidimensional indicators

Data for computing the functional indicators was extracted from structural design shop drawings and calculation sheets provided by the responsible structural design practices.

Cradle to gate LCA studies for calculation of the environmental indicators were supported by software SimaPro 7.3 and performed following ISO 14040:1997 methodological guidelines. Construction use of materials and disposal stages were therefore disregarded. No impact allocation criterion between steel and ground granulated blast furnace slag (ggbs) was applied. Data for materials/components production cycle modelling were taken from national literature or adapted from processes within SimaPro built-in Ecoinvent database upon switching into the Brazilian energy mix. Table 2 **- Functional unit and inventory data source for materials/components studied**

Construction materials and components	Functional unit	Data source
Concrete (fck 30MPa) [a]	1 m^3	Silva, 2006
Portland cement (CPIII-32) [a]	1 ton	Silva, 2006
Steel rebar (reinforcing steel)	1 ton	ELCD (European life cycle database)
Plywood formwork, Sand, Gravel	1 m^3	Ecoinvent
Wire Rods (prestressing steel)	1 ton	WorldSteel Association
[a] Concrete mix with cement type CPIII-32 (66% of ggbs as clinker replacement in cement)		

Service life is defined as the period between construction and the time to the first repair (tr), which may be determined using quantitative service life models for a particular element in a given environment. In this study, software Life-365 v.2.1 supported the prediction of life-cycle

costs of reinforced concrete structures exposed to chlorides (Life-365 Manual, 2012). Parameters considered are structure type and dimensions; temperature, chloride exposure conditions; concrete mix characteristics, such as water-cementitious materials ratio (w/cm), and replacement of cement (%) by slag, Class F fly ash, or silica fume (SCMs); prestressing steel and steel rebar type, and *steel over concrete cross sectional area ratio* (%).

To enable comparison and level the life span to reach 40 years design life, LCA-based indicators considered the necessary repair schedules: 10 % extra volume of material was therefore added to the overall material consumption of the respective floor for each predicted flooring system repair event projected. shows the functional unit adopted and data sources used for modelling the studied production processes.

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The minimum required service life of a residential building according to the Brazilian performance standard - NBR 15575:2012 - is 40 years (in April 2012). This was considered as the reference period for the LCC studies, being 2012 set as the reference year. LCC indicators have also considered the same repair schedule. Life-cycle cost was calculated as the sum of the initial construction costs and the discounted future repair costs disregarding labour, over the design life of the flooring system. Annual inflation rate of 5.06% and real discount rate of 9.75% were adopted. These figures respectively represented (in April 2012) the Price index to consumer rate (IPCA), defined by the Brazilian Institute of Applied Economic Research (IPEA), and the special system of liquidation and custody rate (SELIC)

established by the Brazilian Monetary Policy Committee. A 10-year interval between repairs was adopted, being the date of the first repair based on the service life predicted for each case study. The payback period shall be calculated based on such assumptions as well.

Important savings may however lie on the structural frame itself at any stage of its life cycle, or given by optimization of other building systems triggered by decisions regarding the structural frame. Levelling slab and beam heights, or adopting flat slabs, for instance, brings savings to energy and materials resources consumption due to optimized storey heights, reducing sealing / closing walls, and coating, heating and cooling, besides facilitating adaptability. Also, optimized columns layout provides less column density, enhancing net floor area, facilitating adaptability, improving parking spaces, which brings value to a building investment. Another example is designing for disassembly, which facilitates reuse and brings savings to demolition, recycling and materials resources consumption as well. Finally, the *local economy support indicator* was calculated based on availability of material suppliers within a 300 km-radius.

3. Results and discussion

Concerning the functional performance, Case study 2 (prestressed flat slab) presented the best performance for *span over slab ratio* and *column density indicators.* As to the *reuse potential indicator*, all three slabs were cast *in situ* and not designed for disassembly. Case study 1 (reinforced concrete waffle slab with beams) has better end-of-life performance, due to smaller spans and existence of beams, which make demolition easier and safer, resulting in lower demolition costs than the prestressed flat slabs used in Case studies 2 and 3. Furthermore, reinforcing steel has higher recycling market value than prestressing steel. Notwithstanding, the flooring system with no beams and longer spans (Case study 2) provides increased flexibility. Table 3 shows functional indicators results for all three case studies. The highlighted values are the best among alternatives.

Table 3 – Results of application of functional indicators to the three case studies

Functional Requirements	***Indicators***	***A typical floor***		
		Case 1	***Case 2***	***Case 3***
Structural safety	*span over height ratio (ℓ/d) [m/m]*	*24.3*	***39.7***	*32.8*
	applied stress over ultimate strength ratio (fc/fck) [kN/m^2/ kN/m^2]	*N/A*	*N/A*	*N/A*
Maintenance and constructability	*Reuse Potential (% volume prefabricated with connections for disassembly) [% volume]*	*0*	*0*	*0*
Flexibility / adaptability	*Column density: gross floor area over number of columns (m^2/ n^o), [m^2]*	*17.8*	***30.6***	*19.8*
	Beam over slab height ratio, [m/m]	*1*	*1*	*1*

The results of service life prediction for the studied conditions (Table 4) confirm the need of a repair schedule for each alternative to ensure service lives of 40 years, which means that, under those conditions, designing by the Brazilian standard NBR 6118:2007 does not assure compliance to NBR 15575:2012. The environmental indicators per functional unit were multiplied by consumption of each material in mass or volume, including the material added

by predicted repair events, and then divided by m^2 of structural area, in order to obtain each indicator per m^2. At typical floor scale, Case study 2 (15-storey building with no beams and prestressed concrete flat slabs) presented the best results for CF and EE, while Case study 1 (6-storey building with reinforced concrete waffle slabs) showed best results for bWF, ADP and Mc (Figure 1). Results for the whole superstructure showed a similar trend, except for CF, whose best result pointed to Case study 1 (Figure 2).

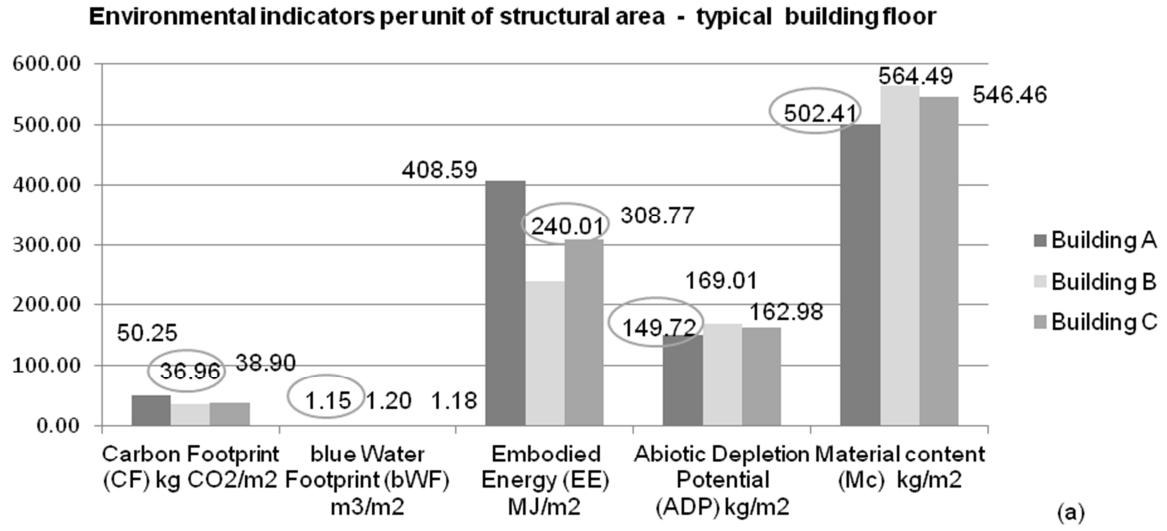

Figure 1 - Results of environmental indicators application to Case studies 1 (Building A), 2 (Building B) and 3 (Building C), for a typical floor.

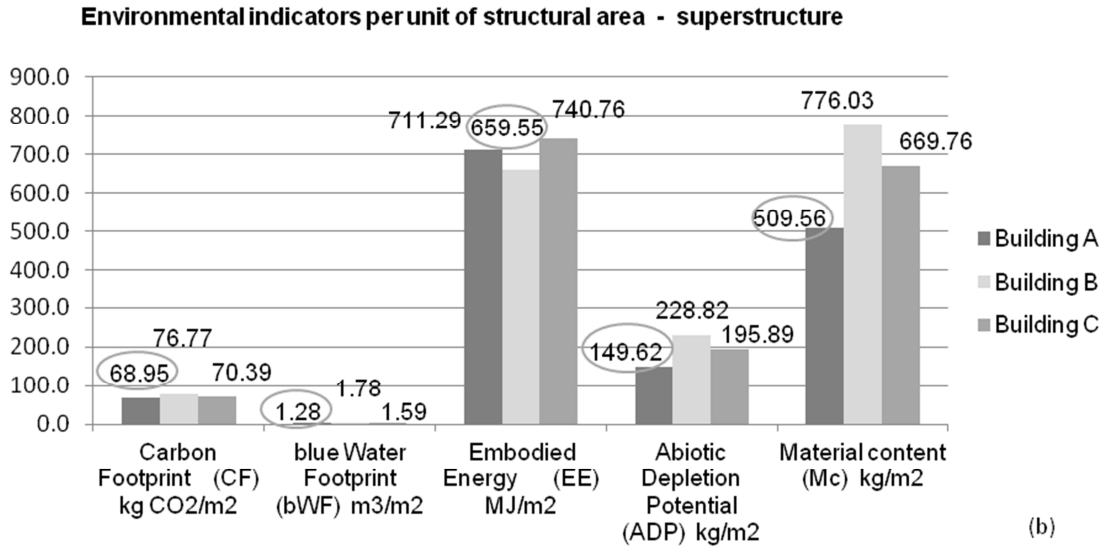

Figure 2 - Results of environmental indicators application to Case studies 1* (Building A), *2* (Building B) and *3* (Building C), *for the whole superstructure.

The service life estimated for the three case studies was similar because they had identical characteristic strength, mix composition and nominal concrete cover. The same applies to the repair costs/m^2, obtained through a simplified default estimate despite having taken into account different costs of reinforcing and prestressing steel, and different steel percentages in the cross section of reinforced and prestressed concrete slabs. Table 4 presents values of *LCC indicators* for the three case studies, showing the best results for Case study 3.

Table 4 - Service life and life cycle costs estimated for the three case studies

Case studies	Typical floor description	Estimated Service life [years]	Life cycle costs (LCC) US $ /$m^2_{\text{structural floor area}}$						
			Initial costs					Maintenance / Repair costs	Total life cycle costs
			Plywood formwork	Concrete	Rebar	Prestressing steel	Total initial costs		
1	RC waffle slab	11.7	2.93	17.48	20.07	0.00	40.47	57.85	98.32
2	PC flat slab	11.2	2.94	20.00	9.44	6.73	39.10	57.85	96.95
3	PC flat slab	11.2	2.79	19.33	8.53	5.35	36.00	57.85	93.85

A complete *payback* indicator calculation shall address the savings provided by *(i)* the lowest column density of Case study 2 (Table 3) concerning parking spaces and typical floors flexibility, *(ii)* the 9.5cm reduction from a 27.5cm-thick waffle slab (Case study 1) to 18cm-thick prestressed flat slabs of case studies 2 and 3 to envelope plaster and coating consumption, and *(iii)* the smallest dead weight of Case study 1 waffle slab (equivalent to a 14.7cm-thick flat slab) to whole superstructure sizing and foundations. Monetary figures and flows related to such additional data are usually not readily available at the structural design offices, and therefore were not provided for the studied cases. Implementation of continuous value engineering techniques during design would enable reasonably accurate estimation and allow the recommended integrative approach.

For *local economy support indicator*, the flooring system of a typical floor in Case study 3 presented the best result, with local materials responding for 59% of total material costs, followed by Case studies 2 (56%) and 1 (48%), respectively (Table 5).

Table 5 – Results of application of local economy support indicator to the three case studies

Indicator	**Typical floor**		
	Case study 1	**Case study 2**	**Case study 3**
Local economy support [% in costs]	48	56	**59**

4. Concluding remarks

Discrepancies or deficiency of national and international reference data for insertion in LCA platforms demand the use of different databases for modelling the materials /components production cycle. Reinforcing steel, plywood formwork (processes adapted within different databases by switching into the Brazilian energy mix), and prestressing steel (production cycle taken from WorldSteel database with no possibility of energy mix adaptation) are examples. This may compromise accuracy and reliability of LCA-based indicators application.

Other strategies for increasing concrete structures service life than to predict a repair schedule were perceived during Life-365 software modelling, such as enhancing cover of reinforcement; using chemical corrosion inhibitors, membranes or sealers; specifying stainless steel; or using silica fume as mineral admixture. Considering the current Brazilian construction practice, only the use of chemical corrosion inhibitors and silica fume seem reasonable.

At whole superstructure scale, the EE indicator pointed to Case study 2 (prestressed concrete flat slab) as the best solution from the environmental viewpoint, while ADP, Mc, bWF and CF indicators pointed to Case study 1 (reinforced concrete waffle slab and beams) as best performing flooring system. Concerning the economic and functional indicators, prestressed concrete flat slabs performed best. Therefore, next research steps include adoption of a multi-attribute analysis method to define relative importance of indicators in each dimension structuring them in a decision matrix assembling different weighting scenarios, to streamline choice of a single solution, whenever indicators show contrasting trends.

Proceeding with the analysis of a typical structural floor *in lieu* of the whole building structure – analogously to structural design common practice - seems to be potentially valid. Amongst the five environmental indicators, four of them showed similar trends at both typical floor and whole superstructure scales. CF indicator shifted trend when zooming into typical floor scale. *The local economy support indicator* provided useful information when applied to a typical floor. Due to the limited number of case studies, these findings are promising but still exploratory. Enlargement of case study library in future studies will provide robustness to analysis and allow in-depth statistical treatment and more assertive conclusions.

Exploring the most cost-and environmentally-effective strategies for increasing concrete structures service life exposed to a marine environment is also of interest. It is expected that this set evolve to a framework of functional, environmental and economic indicators as a tool to support design decision-making regarding important sustainability aspects in concrete structural frames selection.

Acknowledgements

The authors would like to thank the Brazilian Coordination of Improvement of Higher Education Personnel (CAPES), the National Council of Technological and Scientific

Development (CNPq) and CPFL Energy / ANEEL R&D Funding line for their financial support.

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The impact of mega events on construction planning, processes and performance – Auckland's experience of the Rugby World Cup 2011

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Abstract

Internationally, mega events have been used by cities to enhance their image and improve urban spaces. Cities may be viewed as commodities, particularly when local or national governments are making the pitch for hosting rights of such events. As a commodity, they need to sell themselves, often requiring some change in the way they look and perform. New Zealand's hosting of the Rugby World Cup (RWC) in 2011 created an opportunity for New Zealand to carry out much-needed improvements to the image of the country, the main cities, and Auckland in particular. Of the 48 World Cup games, 15 were held in Auckland, including the semi-finals and the final, as well as the opening and closing ceremonies for the event. The city required significant changes and improvements to local infrastructure, as well as expansion and upgrade of a number of venues, all within a relatively short space of time. This paper looks at some of the transformations that took place in Auckland in the lead up to the Rugby World Cup 2011, and explores the impacts of the event on planning processes and performance in the city.

The paper first identifies the range of projects undertaken as part of the RWC upgrade in Auckland, and then focuses on the perceptions of seven industry representatives who were involved with key projects in the RWC development in Auckland. These individuals all participated closely in the planning and development processes of their respective projects. They have provided their reflections on how the RWC affected their projects, and lessons learnt in delivering within the context of such a mega event. The paper also briefly considers their perceptions of the social and economic impacts resulting from the RWC developments, and the opportunities lost and gained in the process.

Keywords: mega events, urban planning, urban development.

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1. Introduction

Mega events are large scale one-off events, most commonly sports-focused (eg. Commonwealth or Olympic Games or FIFA World Cup) but also extending to large trade or cultural festivals (e.g. World's Fairs or Expos) which attract significant numbers of international participants and spectators, have a profile internationally beyond the region in which they are run, and generate significant global media coverage. Countries or cities bid to host mega events in an attempt to promote their locations and attract investors (Chalkley & Essex 1999). Mega events typically draw a large number of tourists to the host region and generate extensive publicity through media coverage of events, so bidding cities or countries are willing to make huge investments in hosting the event itself, and also make substantial investment to infrastructure related to the event.

1.1 Mega events and urban development

The use of mega events as a catalyst for urban development is an idea that has been adopted by many cities and nations in recent bids for hosting rights. Whereas in the past the focus for mega events has been on the perceived economic benefits from media involvement and resulting tourism and investment opportunities, many studies have found these difficult to quantify, and claimed returns have often been challenged (Dwyer, 2005). Where economic effects have been calculated, their impact has been shown to be small and short-term in most cases, and for a number of events the net economic outcome has been negative. Mega events have however been useful to stimulate urban development, and promoters increasingly frame their pitch in terms of the legacy of improvement and expansion that hosting such an event will deliver (Mills, 2013). Cities which may have found it difficult to justify spending money on 'aspirational' projects as part of their normal operations may use the guise of a mega event to support large capital expenditure. Internationally iconic buildings have resulted from various sporting events or festivals in some locations: the Eiffel tower in Paris, built for the 1889 World's Fair; the original Wembley stadium in London, built for the British Empire Exhibition in 1924; the Maracana Stadium, built in Río de Janeiro for the 1950 FIFA World Cup; the Calatrava Tower in Barcelona, built for the 1992 Olympics; and more recently the 'Birds Nest' or Beijing National Stadium, built for the 2008 Olympics.

Apart from creating opportunities for constructing new sports facilities, mega sporting events can create an opportunity to improve the environment of the wider urban environment (Malfas et al., 2004). The number of participants, officials, media and tourists that are associated with mega events require an efficient transport network, sophisticated media broadcast facilities, hotels, commercial centres and public spaces (Malfas et al 2004, Greene 2003, Hiller 2006). Beyond the development needs of an event, significant urban regeneration has also been hailed as a product of mega events, for example the inner city renewal of Atlanta, USA (1992 Olympics), social integration and infrastructure development in South Africa (FIFA World Cup 2010) and redevelopment of East London (2012 Olympics) Whether these regeneration projects have actually achieved their aims is far more controversial, however.

1.2 The Rugby World Cup 2011

The Rugby World Cup (RWC) is the third largest sporting event in the world, after the Olympic Games and the FIFA World Cup (IRB, n.d.). New Zealand's hosting of the RWC in 2011 began in November 2005 when the NZ Rugby Union won their bid to host the event, allowing less than six years to prepare the country to host an event of an unprecedented scale. This required significant changes and improvements to local infrastructure (transport networks, leisure centres, roads and stadiums) and expansion and upgrade of a number of venues, all within a relatively short space of time. Auckland was particularly affected; although games were held in 12 venues around the country, two of these venues were in the Auckland region, and the opening and closing ceremonies, the semi-finals and the finals were all held in Auckland.

2. Planning and processes

Large scale developments brought about as part of a mega event are subject to strict deadlines, usually entailing "fast track decision making and implementation processes in order to ensure completion of projects on time" (Varrel & Kennedy 2001, p. 3). Because of this over-riding need for on-time completion, there is an increased risk that planning and processes leading to project delivery may infringe on existing legislation (planning regulations), environmental sustainability and democracy (lack of public consultation). Burbank (2002) argues that for a mega event to be successful it will need support from local government, local residents and the private sector. However, because of the scale of mega events and their influence on urban development, even when there is resistance to an event or to its associated projects, the public often ends up having very little input into the planning process. For example, some of the developments that took place prior to the FIFA World Cup 2010 in South Africa were deemed to be of national importance and the public were completely excluded from the decision making (Benit-Gbaffou, 2009).

Mega events present a definite deadline for construction projects (venues and supporting infrastructure) and central and local government may use this as an excuse to forgo the usual application processes (public hearings, consents, environmental and social assessments) and fast track preferred projects to meet up with the deadlines (Malfas et al 2004). Hiller (2006) adds that the process of using public funds or even private sector funding differs in comparison with the normal processes so deadlines can be met and that an event becomes a mega event for the city hosting it when it intervenes in the normal functioning of a city to mobilise resources for the event.

In Auckland, various levels of local and central government became involved in the delivery process for the RWC at different stages of the lead-up, which included involvement in the development of the built environment. Table 1 sets out the timeline of relevant milestones leading up to the RWC 2011.

Table 1 RWC 2011 planning timeline

Date	Event
November 2005	NZRU wins bid to host RWC 2011
June 2006	Rugby New Zealand 2011 Limited (RNZ 2011) established as a joint venture, limited liability company, based on a partnership between the Government and the NZRU.
February 2007	RWC Co-ordination Office established as part of the Ministry of Economic Development (MED) to co-ordinate core Government services to support the tournament, including border control, security, transport and infrastructure.
June 2007	Wynyard Quarter development began
October 2007	Minister for Rugby World Cup appointed by NZ Government.
May 2008	Eden Park upgrade began
September 2009.	"2011 Group" established by Government (a panel of advisers designated to work with RWC Ministers and the New Zealand 2011 Office)
November 2010	Rugby World Cup 2011 Empowering Act passed to allow government intervention in standard planning processes.
August 2011	Rugby World Cup 2011 opening ceremony

2.1 The research

In order to understand the impact of the RWC on the infrastructure of Auckland, and the associated planning and processes leading to its delivery, an exploration of the experiences, attitudes and perceptions of selected participants was carried out. Seven senior industry representatives were interviewed about the projects they were involved in that were linked to the RWC, and about the experiences of the industry more generally. Projects that were highlighted by participants were within the urban zone of Auckland, mainly the central business district or city fringe.

2.2 Participants

Participants were sought to represent the perspectives of architects and design consultants, project managers, construction companies, and project alliances. These roles were chosen because they represent key stake holders in the industry in relation to the projects developed within the RWC context. Seven of the individuals approached agreed to take part, as follows: two directors of architectural firms, two project managers, a director of a construction company, a public relations/environment manager for a construction alliance, and an engineer.

3. Projects and impacts

Projects in Auckland that were undertaken for the RWC can be divided into two categories. Core projects are those which were essential to the tournament, including work which was contractually required as part of the hosting agreement. These included:

- Eden Park stadium redevelopment
- Eden Park precinct - upgrades to rail network, stations, pedestrian access.

Catalyst projects are projects which were either initiated or brought forward to improve the city's image or amenities to take advantage of the increased publicity of the RWC. These included:

- Queens Wharf – structural upgrade to the wharf, redevelopment of Shed 10 and construction of 'The Cloud' events
- Wynyard Quarter – waterfront developments to create a large public park
- Central Business District streetscape upgrades
- Central rail upgrades
- Newmarket overpass – motorway upgrade.

3.1 Schedules and timeframes

Participants were questioned on the extent to which projects they were involved with were influenced by the hosting of the RWC. Participants believed that most of the projects carried out under the auspices of the RWC were within the plans for Auckland's development, but considered that if it were not for the RWC these projects would not have been initiated within the projected timeframes. Participants agreed that "the RWC provided a definite deadline" and considered that overall it was a good thing for the projects.

Table 2 provides a summary of some of the projects that were affected by the RWC. The start date of the majority of projects was brought forward, but the physical design was not changed to suit the event. Most projects were upgrades of existing facilities as opposed to being new construction.

There was some disagreement between participants about whether projects were "fast tracked", with most preferring the term "brought forward", stating that it was only the start dates of projects that were changed and not the process of construction that was sped up. This however was contradicted by their own descriptions of the impacts of the RWC on the planning and construction process. Many used the term "fast track" to talk about the expedited consents process, and again to describe parallel execution of construction tasks adopted to meet the deadline, as opposed to the more usual sequential progression.

Table 2 Impact of RWC on identified projects

Project	New project/ event based	Fast tracked/ brought forward	Upgraded existing project/ facility	Existing plans
Eden Park and precinct	✓		✓	
Queens Wharf (incl. The Cloud)	✓			
Newmarket (SH1) Overpass		✓		✓
Wynyard Quarter		✓		✓
Transport system		✓	✓	
Kiwi Rail		✓	✓	
Streetscape projects		✓	✓	

Several of the projects that were discussed were seen to have "come to a stop at kickoff", meaning that only some phases of the project had been completed prior to the opening of the RWC. Most of these projects were part of the long term plan for the city's development initiated by local government, but the start dates were brought forward. The ongoing development and completion of the further project phases has not been carried out but is still projected. Some of these projects may take a further 10-20 years to complete, as stated by one of the architects interviewed, and dates for the commencement of future work are still undefined.

Mega events are frequently seen by their supporters as a means to bringing forward long term projects that would otherwise have taken a long time to initiate (Malfas et al., 2004). This was clearly the case with the RWC in Auckland. All of the participants considered this to be an advantage for both the city and the construction industry, "Those projects would have happened anyway but just the timing of them may have been slightly different. So the RWC has been positive in that respect in that it has pushed or created an end point for which projects have to be delivered" (Architect).

3.2 Consents and approvals processes

The key benefit identified by all participants was the significant reduction in the time taken by planning authorities to process consents and planning applications. It was evident from the responses from all the participants that processes did alter and help fast track projects. "One of the main things that was changed was the consents and processing time lines. So we basically got a dedicated team in council to help fast track any consent issues. Got rid of the long processing time lines, if you said this was RWC project it got special emphasis on it" (Project Manager).

Several participants identified that other projects that were planned for construction but were not expected to complete before the start of the RWC were either not given consent or were put on hold even after consents were issued. This was done so that no major works would be carried out around the city, both for safety reasons and so that it would not appear as if Auckland was unprepared to host the RWC. Auckland Council imposed a construction

moratorium from mid–August 2011, meaning that all construction work in the city had to be completed by that date, and no work was to take place during the RWC. This impacted many projects and meant companies had to work long hours in order to meet the deadline. Main contractors worked in a more integrated fashion with sub-contractors to reach targets, and a lot of weekend work and overtime was done on some projects.

Specific legislation (Rugby World Cup 2011 Empowering Act 2010) was implemented by the Government to expedite planning and approvals for the event. “Time-critical RWC activities and facilities will require a wide range of consents, licences, regulatory approvals, and temporary waivers (“approvals”) that existing approval processes are not suited to address. This is because of the long timeframes needed for some approval processes; the risk of capacity constraints arising within some consenting authorities, given the substantial increase in consent applications that is anticipated; and the likelihood that urgent approvals may be needed to resolve unforeseen circumstances.” (Rendle, 2010). Under the requirements of this legislation, the affected territorial authorities were required to provide additional administrative support for processing applications. In addition to this there was provision for the RWC Authority to override normal planning processes to grant approvals where required.

None of the participants were aware of the relevance of this legislation to their roles. However, they had all recognised the unusually fast turnaround period for getting consents on both their major projects and other minor projects and upgrades which would have normally not been approved so quickly, and on reflection considered that the legislation could have been the reason why Council acted so quickly on the consents. All participants agreed that “any project that had the RWC tag on it” was given priority in terms of consents issued over other projects, and the conclusion was that the legislation had been taken advantage of without the knowledge of most stakeholders. “I am not aware of any particular changes to the planning process. Apart from the fact the Government stepped in and took over Queens Wharf and they managed that process. I suppose there was more high level Government influence on the planning processes for parts of the RWC infrastructure” (Architect).

3.3 Planning processes

Because most of the projects involved in the RWC were previously part of the city’s development plans or based on existing facilities, there was little controversy around the appropriateness of the urban development that was undertaken. The exception to this was around the redevelopment of Eden Park as opposed to a new stadium development, and the subsequent debate about the rehabilitation of Queens Wharf. The original plan was for an upgraded Eden Park to become the foundation of the RWC match schedule. This was disrupted in 2006 when the Government proposed a new showcase stadium on Auckland’s waterfront. Following a brief but intense period of public debate this idea was put aside in favour of the Eden Park upgrade.

Discussion was reignited with the decision to promote a new development of Queens Wharf as “Party Central” for the RWC. The site was bought by the Government and Auckland

Regional Council in 2009 to form a centrepiece for RWC celebrations A public design competition was held, which resulted in the selection of eight finalists. A winner was never chosen, however, because of intervention from central and local government and the decision that the proposed designs were not sufficiently "iconic" to represent the city and country in the RWC events. A redevelopment of one of the heritage buildings on the wharf was then proposed, along with the creation of "a multi-purpose temporary facility named The Cloud" (Key, 2010).

The government intervention in this development was the main cause of negative feeling around the RWC from any of the participants. The possibility of the Government stepping in and taking over was perceived to be a risk not just for this situation but in any of the RWC projects, and was considered to be damaging to the construction industry as it prevented a company from making money as well as showcasing their work, and to the build-up to the RWC as it interfered with the proper scheduling and development processes. "The Shed 10 and the Cloud is a compromise and that is middle thinking and to be honest with you for a city like Auckland it probably shows a dysfunctional relationship between Government and council but at the end of the day every city is faced with difficult decisions, it's just having the leadership to have the confidence to actually make those decisions and be confident that they have made the right decisions and I don't think we have the leadership either at local government or council" (Architect). Decision making was seen to be ad hoc and with no co-ordinated planning process.

Hiller (2006) suggests that the process of using high profile events and public funds to drive development in this way can create a breach with the normal planning processes, as occurred in this particular RWC project. Many participants considered this project to be a missed opportunity with the wrong processes followed for the underlying planning of the development, "If we were pitching to go for the international events, whether it be RWC or Commonwealth games or that kind of scenario, we should have had a lot more forethought" (Construction director).

3.4 Design and construction processes

All participants recognised the impact that the tight deadlines had had on design and construction processes. Consultants had to work quickly to complete designs, and in many cases design and construction processes were done in parallel instead of the more usual sequential approach. Participants considered it to be inevitable that this time pressure had a negative effect on design and construction innovation. One architect identified that most of the projects he was involved with had to be procured quickly and methods of construction had to be ones that had been proved efficient because of the definite finish dates. "There were absolute fixed times for the work to be done so that affected the contractors in terms of organising their labour and materials to be delivered absolutely on time". The potential risk involved in adopting novel approaches, sourcing new materials or even in appointing unfamiliar contractor or sub-contractor organisations was considered too great in the majority of projects. 'The Cloud' development on Queens Wharf was one notable exception

to this conservatism, where the innovative design and construction were made possible through “months of detailed planning and consultation” once the project got underway.

The transport and roading projects had the longest time frames of all the RWC projects, having been in progress for over three years prior to the start of the RWC. Despite the long lead time, the project alliance representative stated that they had to factor all of their planning processes around the RWC dates. To be sure of outcomes, they spent the last two and a half years (prior to the games) having conversations with all stakeholders, to make sure that stakeholder expectations and Alliance plans were in tandem. “We had to make sure that we were totally aware of what was being planned for the Rugby World Cup and that we could terminate our work around those days. Black days, gray days, rainy days, snow days. Nothing could be left to the last minute so all processes were streamlined and ran a tight schedule.” (Alliance representative).

3.5 Urban environment

The land selected for development as a result of mega events is often obsolete or deteriorating, and such events have been seen as a potential to aid in the transformation or regeneration of the urban environment (Hiller 2006). Central city locations are preferred over distant suburbs because hosting such events requires visitor infrastructure to be put in central areas or maybe refurbished (Hiller 2006). Again, this point was illustrated in Auckland with the development of the waterfront in particular. The “tank farm” that was part of the Ports of Auckland prior to the development of Wynyard Quarter was considered an eyesore, whereas “now with the restaurants and playground it has given Auckland a new life. I think it’s all come together and I think it’s all a critical mass and I think Auckland has greatly benefitted from that.” (Architect).

D’Arcy (2006) suggests that developments resulting from mega events are likely to alter the advantages of certain areas in the city, with rezoning resulting in land values and property prices shifting. He goes on to say that is vital that investment in infrastructure is done in a way that does not hinder the progress of established areas. Malfas et al. (2004) also points out that development undertaken in order to host a mega event may hinder other projects, because so much of the available funds or resources are channelled into one city or a limited focus of development. This concept was touched on by one of the participants in relation to the size of the investment into Eden Park stadium and precinct, noting that, “I still don’t think it’s a good idea, having a stadium in suburbia was never a good idea…the entire infrastructure was downtown.” (Construction director). However, in general the participants were positive about the resulting development of Auckland. The investment was seen as sufficiently diverse that there were benefits to many parts of the city, particularly in relation to transport improvements, “Transport systems were improved and in the long term they will be still used. The trains have been upgraded and soon will all be electrified. The motorways were upgraded again, something that will beneficial in the short to long term.” (Engineer).

As claimed by Essex and Chalkley (1999), mega events may help to strengthen regional traditions and values whilst increasing local pride and community spirit. This was certainly

the over-riding opinion of the development undertaken in Auckland for the RWC. “I overheard somebody saying “this is great, it’s just like being abroad, like being in a proper world class city.” (Architect).

4. Conclusions

All of the development projects that took place in Auckland during the time between the RFU winning the bid to host the RWC and the start of the tournament were in some way affected by the RWC. The majority of projects highlighted as RWC developments were already part of the city’s long term development plans, and the hosting of the RWC brought forward their timelines. Projects were completed in a much shorter timeframe than would otherwise have been the case, and several of the projects would have taken another 10 years or more to come to fruition.

In order to meet tight deadlines, planning, design and construction work was carried out in parallel rather than sequentially. Procurement processes had to happen more quickly and consultants were on the jobs sooner. Council improved the turnaround time of planning and consenting processes significantly, and project participants also improved their performance. In most cases, projects stayed with well-established design concepts, methods of construction and known construction contractors and sub-contractors. A lot of overtime and weekend work was required in order to deliver projects as required.

Few negative impacts were identified, but most were focused on the development process of the Queens Wharf regeneration, the only project which was not already part of the city’s plan or based on an upgrade of existing facilities. All of the interviewees were critical of the Government’s intervention in this project, which they considered to have complicated the planning process unnecessarily and to have had a detrimental impact on the time and choices available to Auckland in making choices around use of the waterfront. This project was seen as a missed opportunity. It is interesting to note that the only other negative point made, that the tight timeframe imposed by the RWC deadline reduced creativity and opportunities to explore innovative design or construction solutions, did not apply to the Cloud development which was seen as original and inventive.

On the whole, the impact of the RWC on Auckland’s performance while hosting the tournament and on its contribution to the city’s future was seen as extremely positive. The resulting urban development was regarded to be “world class”. The planning and associated processes were also considered to have been very successful and operated well within the time constraints imposed.

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Realigning Practices in UK Built Environment Higher Education toward Sustainable Communities

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Abstract

Learning has been considered essential in understanding and addressing pressing sustainability challenges, whilst higher education has been considered vital in shaping the way which future generations learn to cope with the complexities of sustainable development. Therefore, contemporary higher education practices in different disciplines around the world have been striving to adopt sustainability features in their courses. Following his defining Egan Report (1998), Sir John Egan was leading another government initiative championing the concept of "Sustainable Communities" in the UK. Many of the aspects of the sustainable communities can be considered relevant to the built environment discipline. However, many of them can be difficult to quantify and measuring their achievement may be harder to demonstrate. Relevant events, including UK Government involvement in the Kyoto Protocol to reduce greenhouse gases emission, have driven the UK construction industry into environmental sustainability focus. Attempting to respond to various reports and articles depicting gaps between higher education academic practices and the needs in the construction industry, built environment higher education in the UK are trying to integrate sustainability in their curriculum. This ranges from simply including add-on knowledge of relevant tools such as BREEAM into their modules to developing new modules with the word 'sustainability' explicitly showcased in the titles. Many of these attempts are focused on environmental sustainability with the bigger agenda for sustainable communities quietly disappearing in the background. This paper aims to provide a review of potential ways to refocus practices back to the achievement of sustainable communities. Comparative analysis of two case studies involving practices in the UK and Australia was conducted to bring together lessons learned and recommend the way forward for the UK higher education in built environment.

Keywords: Built environment, construction management, higher education, sustainable communities.

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1. Introduction

Learning has been considered important and even imperative in understanding and addressing the pressing sustainability challenges that we are facing today (Dunphy, *et al*., 2007; Ballard, 2005). Thus the higher education sector is deemed to play a vital role in shaping the way which future generations appreciate and learn to cope with complexities of sustainability related issues and sustainable development (UNESCO, 2005). This is largely manifested in the establishment of the United Nation Decade of Education for Sustainable Development (UN DESD) aiming to reorient traditional educational approaches towards interdisciplinary and holistic learning values-based learning, critically reflective thinking, multi-method approaches, participatory decision-making and locally relevant information. Naturally, the role of the education sector in championing the creation of a sustainable community is focused at the knowledge, skills, values, capacity and motivation needed for individuals and organisations to be able to respond to the complex sustainability issues they may encounter. Motivated by the UN declaration (UN, 2002) of the period 2005 to 2014 as the decade of education for sustainability, higher education institutions have been working hard trying to integrate sustainability into their curriculum and to somehow include sustainability in their practices. Different disciplines have been taking different approaches in doing so with varying results (Sutrisna and Rowe, 2012).

Whilst designing curriculum in general has been regarded core but not without its problems by many higher education scholars (e.g. Lea, 2004; Jarvis, 2002; Biggs, 1999; Wiklund and Wiklund, 1999), embedding sustainability into the curriculum has naturally increased the degree of difficulties. Added complexity into curriculum design may come from the need to embrace the potential of interdisciplinary and holistic learning, the dynamic need to create innovative teaching formats to foster student enthusiasm and inquiry (Letterman and Dugan, 2004) or the existence of 'discipline allegiances' that may vary the degree of acceptance of the benefits of adding something that may be perceived non-traditional in certain disciplines (Clifford, 2009; Becher and Trowler, 2001). Thus, even though sustainability comes as a universal theme, its actual embedment into curriculum is a delicate matter. Specific to the built environment and other construction related disciplines in the UK, the existence of the sustainable community agenda (this is discussed in the subsequent section) has added another dimension to the sustainability discourse.

In light of the on-going discussion, this paper intends to present a comparative analysis of two case studies from the UK and Australia, identifying similarities, differences and context, as well as lessons learned and recommend the way forward for UK higher education in the built environment to refocus practices toward the achievement of sustainable communities.

2. Sustainability in the Built Environment and Sustainable Communities in the UK

The Higher Education Funding Council for England (HEFCE) recognise the important role of Higher Education in championing sustainability and set an inspirational vision that within the next 10 years, the higher education sector (in England) should be recognised as a major contributor to society's efforts to achieve sustainability – through the skills and knowledge

that its graduates learn and put into practice, and through its own strategies and operations (HEFCE, 2005). However, this appears to be easier said than done. The Consultation on Sustainable Development in Prague in 2003 acknowledged the failure of the higher education sector to produce graduates with the skills, motivation and knowledge to address the problems emerging in the work towards sustainability (IAU, 2006). Sibbel (2009) reported various potential sources of this 'failure', highlighting redesigning curricula to incorporate sustainability as one of the most prevalent ones. It appears that a certain focus point may be required for different disciplines to better align their industry practitioners and academics in incorporating sustainability in the curriculum.

In the UK construction industry, there have been many government and industry initiatives to review and put together reports aiming to improve the industry. These started as early as 1944. These reports were prepared with the view to evaluate current practices and propose improvements in a more collective manner. Following the defining Egan Report (1998) that unveiled deficiencies in the industry and set targets for improvement for the UK construction industry in order to retain its competitiveness in the world, Sir John Egan was tasked to lead another government initiative and produced another report championing the "Sustainable Communities" concept. The key features of sustainable communities described in the report includes the creation of flourishing local economy to provide jobs and wealth; effective engagement and participation by local people, groups and businesses and an active voluntary and community sector; good public transport and other transport infrastructure both within the community and linking it to urban, rural and regional centres; building – both individually and collectively – that can meet different needs over time, and that minimise the use of resources; good quality local public services, including education and training opportunities, healthcare and community facilities; a diverse, vibrant and creative local culture, encouraging pride in the community and cohesion within it; a "sense of place"; and the right links with the wider regional, national and international community. Thus, the report defined sustainability in a more holistic way and aimed to build the community rather than focusing at environmental alone with special emphasis on the further development of skills of people in achieving sustainable communities (Egan, 2004).

Many of the aspects of the sustainable communities are relevant to the built environment discipline. The wide spectrum of the built environment manifests in its definition as an abstract concept used to describe the products of human building activity and it refers to the broadest sense to any physical alteration of the natural environment, from hearths to cities, through construction by humans (Lawrence and Low, 1990). Thus, the concept of sustainable communities appears to be a suitable focus point to better align industry practitioners and academics in incorporating sustainability in curriculum. However, many of the aspects are not really straightforward to quantify and measuring their achievement may need to be discussed and in some cases debated. Relevant events, including UK Government sign up to the Kyoto Protocol to reduce greenhouse gases emission (UN, 1998), has driven the UK construction industry into a low carbon emission focus. The UK based environmental assessment and certification system, BREEAM, has rapidly becoming the standard in the UK construction industry. Attempting to respond to various reports and articles depicting gaps between higher education academic practices and the needs in the construction industry (e.g. Langlands Report, 2005; Roberts Report, 2002; Gann, 2001), built

environment higher education in the UK have been striving to integrate sustainability in their curriculum. This is ranging from simply including add-on knowledge of relevant tools such as BREEAM into their modules to devising new modules explicitly labelled with the word ‘sustainability’ in its titles. Most of these attempts are focused on environmental sustainability with the bigger agenda for sustainable communities quietly fading in the background (Sutrisna and Rowe, 2012).

3. Research Methodology

Research methodology refers to the principles and procedures of logical thought processes applied to a scientific study (Fellows and Liu, 1997). Thus, research methodology mainly concerns with the discussion of how a particular research should be undertaken and can be understood as the critical study of research methods and their use (Grix, 2001). Research methodology includes justification of the choice of research strategy taken by a particular researcher in tackling a specific set of research aim and objectives. The research strategy actually applied is usually a compromise between options, and the choices are frequently determined by the, the nature of the problem itself as well as availability of resources (Gill and Johnson, 1997).

Case study has been used to develop and test research hypothesis in formal settings as early as the 1800s (Naumes and Naumes, 2006). Case study has been regarded as a strategy, a stance, or an approach rather than a method in research (Robson, 2002). The case study approach, as a research strategy, has been perceived as an empirical inquiry that allows researchers to investigate phenomena in their natural settings (Yin, 2003). Case study strategy includes both single and multiple case studies. In many studies, it has been found more appropriate to study more than a single case. Multiple case study can improve the potential to better generalise the results of the study (Naumes and Naumes, 2006). The use of multiple case studies, however, is not intended to gather a ‘sample’ of cases to make a generalisation to some population in the same manner as in a statistical generalisation, but rather to have an ‘analytic or theoretical generalisation’ (Robson, 2002). Analytical or theoretical generalisation in this matter differ in the use the data gained from a particular study to provide theoretical insights containing a sufficient degree of generality/universality to allow their projection to other contexts or situations (Sim, 1998). The multiple case study strategy aims to identify patterns using replication logic within and among cases, which can be either similar (literal replication) or contrary but for predictable reasons (theoretical replication). Another strategy known as pattern matching compares findings across cases or to a theoretical proposition to reveal patterns (Yin, 2003). In a multiple case study strategy, the cases are studied in their real-life contexts with reliance on multiple sources of evidence (Groat and Wang, 2002).

Case studies, including the data gathering and analysis, can be designed and conducted in various ways (Platt, 1992; Stake, 1995). In this particular study, two cases have been selected for comparative analysis. The analysis was conducted adapting a structured procedure for designing integrated learning environments proposed by Lewis and Merton (1996). The original model takes into account students' needs and learning styles as the starting point of the process of embedding Communication and Information Technology

(ICT) into higher education curriculum. This has been adapted to suit the purpose of this analysis, i.e. sustainability instead of ITC. The steps adapted from this model includes the following steps: identification of students' learning needs, identification of student ability, consideration of the organisation and presentation of the curriculum (including: learning outcomes, learning methods, sequence of methods and media, assessment methods, learning hours and access to learning materials).

4. The Case Study

The case study involves two UG construction management courses, one in the UK and one in Australia. Both cases are within the Construction Management domain in the Built Environment. Construction Management courses are selected for further discussion here due to some identified issues (particularly the UK). In the UK, scholars have long acknowledged the difficulty in defining the field of construction management (Hughes, 1997). Construction management have been considered falls short of being a profession in the traditional sense despite its steady gain in status and recognition in the eyes of clients and other Built Environment profession (Fryer *et al*., 2004). Research suggest most large employers in the UK thought that level 4 qualifications were a good proxy of skills, however in some sectors there is a mismatch between the needs of business and the courses provided by higher education institutions (DIUS, 2008). A survey conducted by the Chartered Institution of Buildings (2011), the professional institution in the UK that accredits construction management courses, revealed that despite the recession and downturn in demand, construction industry is still suffering a skill shortage.

As discussed above, the comparative analysis is conducted using the Lewis and Merton (1996) procedures. Below is an overview of each case study.

4.1 Case Study 1

The case study 1 is a Bachelor with Honours in Construction Management course in the UK. The course was originally introduced in 1988 and has enjoyed construction industry support in the form of sponsorship to its students, thin sandwich industrial placement opportunities (the thin sandwich arrangement has made the course duration into 4 years instead of the typical 3 years Bachelor Honours in the UK) and direct input towards further development of the curriculum via a formal industry consortium attached to the course. In addition to that, practitioners from the construction industry have helped delivering guest lecture and involved in project based modules. The student body in this course is mostly made from local UK students mainly due to the thin sandwich arrangement that may require working permits for international students to work during the placement period. The mode of attendance offered is full time only, again mainly due to the thin sandwich arrangement.

Sustainability related matters and principles have been embedded informally through various modules, mainly through project based modules. For the first time since its inception, a module called “Sustainable Design and Construction” has been included in the course structure (core for final year students) in 2012/2013 academic year. The module is an existing one and has been included in other courses in the school as an elective module in

last few years but has been made a core module for final years (level 6) in this particular course. This inclusion is done taking the momentum from the recent requirement from the university to review courses and modules to comply with certain criteria and principles.

4.2 Case Study 2

The case study 2 is a Bachelor ordinary/with Honours in Construction Management and Economics course in Australia. The course was originally introduced in early 1990s and has enjoyed construction industry support in the form of teaching delivery from many sessional staff who are working full time as practitioners in the construction industry. The course duration is typical for Australian UG degrees in similar field which is 4 years. The student body in this course is made of roughly equal proportion of local and international students. Both full time and part time modes of study are offered, but international students will have to take the full time mode mainly due their visa requirement.

Sustainability related matters are covered in a module taught in year 3 which is a part of the Building Technology stream. Currently a proposal has been approved to use this module as a basis for a new module called “Sustainable Construction” upgraded to make it suitable for year 4 from 2014 academic year. This is a part of a regular cycle of reviewing and modifying courses in the university. The course title will also be changed into Construction Management (leaving out “Economics”) to better represent the modification to be applied to the course.

Whilst looking into both courses holistically, a special attention is drawn towards the two modules addressing sustainability as discussed in 4.1 and 4.2 above in conducting the comparative analysis. The main intention here is to use the case study from Australia as a benchmark to the UK case study.

5. The Analytical Framework

The comparative analysis using the above mentioned framework is shown in the table 1 as follows.

Table 1. Comparative Analysis of the 2 case studies

Implementation factors	Case study 1	Case study 2
Identification of student learning needs	• There is no official guidance on the level of need for UG student in the Built Environment in the UK on sustainability • The module leader and tutors jointly determined what level and scope needed for each module guided by the module specification • Input of industry consortium available	• There is no official guidance on the level of need for UG student in the Built Environment in Australia on sustainability • The module leader and tutors jointly determined what level and scope needed for each module guided by the module outline

Identification of student ability	• Aimed at UG level and assuming that students do not possess any prior knowledge on sustainability • Students in this particular course would have some knowledge about the implementation of sustainability on project site • Industry involvement in selection process	• Aimed at UG level and assuming that students do not possess any prior knowledge on sustainability • Some students in this course may have some knowledge about the implementation of sustainability on project site
Consideration of the organisation	• Staff involved in the development and delivery of the module mainly come from design and architecture domain • The expertise of sustainability in the school is mainly including urban design and regeneration	• Staff involved in the development and delivery of the module mainly come from construction and commercial management domain • The expertise of sustainability in the school is including architecture, urban design and construction management
Presentation of curriculum:		
• learning outcomes	• The learning outcomes are clearly prescribed including knowledge and understanding as well as transferable key skills and other attributes • Learning outcome and syllabus are leaning towards regulatory framework as well as design and construction (mainly environmental/ecological)	• The learning outcomes are described in the module outline but not in a detailed manner • Learning outcomes and syllabus are prescribing roughly equal proportion of economic, social and environmental sustainability with the regulatory framework as a background
• learning methods	• Formal lecture, group works, tutorial, and independent study • Specialist project modules	• Formal lecture, group works, tutorial and independent study
• sequence of methods and media	• Syllabus is covered in lectures followed by team work activities/assignments supported by studio design tutorials	• Syllabus is covered in lectures followed by group activities and tutorials
• assessment methods	• Portfolio of individual assessments and group works	• 40% group exercises and 60% examination
• learning hours	• 36 hours of contact time in 1 semester	• 36 hours of contact time in 1 semester
• access to learning materials	• All lecture materials and supplements are made available via online system and students are given access to library including print out copies, online database of journals/e-books.	• All lecture materials and supplements are made available via online system and students are given access to library including print out copies, online database of journals/e-books.

6. Discussion and Conclusion

This is not a crisis, but merely a part of the continued evolution of the global political landscape and hence our society's understanding of what constitutes a "sustainable community". As such, we are in a dynamic, fluid situation and understanding the contribution that the built environment sector can make is an on-going process, rather than a finite target.

Within the built environment discipline, if we consider the construction management discipline studied here, there is a need to look at a number of performance parameters for that industry, before considering how these might be optimised for the future by modifying the HE learning environment. Traditionally, the construction industry has been trade skill based, indicating that "knowledge" is centred on the technology and engineering of the building product. Allied to this and equally prized by the industry are "application skills", both at trade level and, as project complexity increases, at organisation and management level. In the HE sector, this has lead to responses such as the construction management programmes considered here, where the knowledge content has been extended to include management processes, alongside product technology and some attention has been paid to building application skills for this management knowledge.

It can be argued that these developments are in parallel with development in the industry with reports coming forward on the importance of the team (constructing the team, Latham 1994), the way that the industry performs and interacts with others (rethinking construction, Egan 1998), and the emerging environment of "sustainable communities" (skills for sustainable communities, Egan 2004). Clearly, these are addressing the process skills required by the industry, but are also widening the environment in which these skills might be called to operate. Examples of how this environment has been extended to embrace the wider community and its sustainability include the widespread adoption of Corporate Social Responsibility (CSR) policies by many construction companies, with initiatives such as the Considerate Constructors Scheme (CCS) in the UK arising from that. In its best form, this initiative does much to involve the local community in the construction of part of their environment. (e.g. Brunswick Health Centre, MastLift programme).

Part of the problem for HE curriculum designers is understanding the potential contribution of the built environment sector to sustainable communities and hence, where to apply development and in what form. If it is acknowledged that learning will be based around the acquisition of a blend of knowledge and application skills (which might be translated as product and process), then our product knowledge can already be shown to have given some contribution via measurable environmental improvements (e.g. improved insulations).

If we consider how process learning might contribute, those knowledge and skills need to be focused toward a sustainable community agenda. As such, it might be useful to extend our model of the industry thus:

Product – Process – Purpose

Where Purpose can be interpreted as the dynamic project environment within which construction takes place, part of this will include knowledge and awareness and part will be application skills within that environment.

As an interesting sub-plot, it can be argued that the higher education sector has sustainability issues of its own, needing to balance the advancement of knowledge with attracting sufficient students to study. Clearly it is important to students that they can find jobs at graduation, so a balance needs to be engineered between knowledge and skills appropriate for industry employers now and into the future.

When we consider the case studies here, it is possible to make a number of interesting observations:

1. They are remarkably similar in structure and overall approach, suggesting a maturity of development, as both programmes are well established

2. There appears to be a similar pedagogical approach, suggesting that understanding of the concept of "knowledge and skills" is broadly similar.

3. There appears to be a similar direction in better articulating the inclusion of sustainability explicitly into the module title. This is despite the fact that the module in case study 1 was originally developed from the design side which can be argued demonstrating convergence of the sub disciplines in the built environment, at least in terms of sustainability.

4. Case study 1 appears to have a slightly stronger emphasis on "skills" as evidenced by more project working.

5. Case study 2 appears to value individual knowledge, as evidenced by a stronger emphasis on individual examination based assessment.

6. Strongly informed by the 2 modules in sustainability in both cases, it is evidence that there are attempts in addressing knowledge acquisition in a new area, as evidenced by learning methods employed

In conclusion, these would both seem to be appropriate responses at this point in time, as understanding of the sustainability of communities and how the built environment sector can contribute to this is still developing. As a sector, the built environment already has some confidence in the improving technology of its products and its processes are evolving alongside the increasing complexity of the projects undertaken. It is reasonable to assume that its processes can evolve in similar manner in the future and that what is missing at this point in time is knowledge and awareness of the purpose – Sustainable Communities. Whilst the achievement of this 'purpose' will be hard if not impossible to measure (due to its dynamic nature), analysis such as the one conducted in this paper can be considered useful in continuously benchmarking practice in UK Built Environment Higher Education with its purpose taking into account practices elsewhere. Thus, such analysis may not be able to

directly inform higher education practitioners on how to 'successfully implement sustainability', but it may help higher education practitioners to continuously realigning their practices with the dynamics of the sustainable communities concepts.

One further consideration is that other sub-disciplines in the built environment sector may be more influential in addressing the sustainable communities agenda e.g. design. In the long run, the higher education may well have to consider the balance of its discipline products, but this should not distract from the construction discipline objective of delivering a sustainable built environment production process for the community within which it operates.

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Change Management Research in Construction: A Critical Review

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Abstract

Change creates opportunities for businesses and change management has therefore been touted to be the next strategic weapon for organisations to remain competitive in a business environment. Over the past decades, many studies have been conducted to investigate change management in construction. However, it appears that the concept of change management is not well-understood and that there is a lack of systematic review of existing research efforts and achievements. A comprehensive review and analysis of past research in change management indicates that previous studies have mainly focused on two perspectives of change management: (1) organisational perspective; and (2) project perspective. It is also identified that between these two perspectives, little emphasis has been placed to investigate the dimensionality of changes in construction and how different factors collectively shape the implementation of change management.

Keyword: Change management, Construction, Competitive business environment

1. INTRODUCTION

In today's business environment, changes are increasing at a rapid pace taking the form of different types, scales and quantities. According to Burnes (1992), effective change management is a critical process for firms' continued existence. However, managing changes is not an easy task. The status quo of change management implementation is not as successful as people expected; especially in construction due to its multi-layered contracting nature.

The objectives of this paper are to critically review past studies done in construction change management and then identify knowledge gaps for further explorations. This paper attempts to inform researchers about the current state of the arts on construction change management.

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2. METHODOLOGY

This research adopted a literature survey design and categorised discussions along three themes: 1) the concept of change management; 2) research methodologies and analytical techniques; and 3) research contexts and variables. These endeavours attempt to identify the keywords towards defining change management, and the types of research methodologies, techniques and variables adopted by previous studies. Information was sourced from several electronic databases via the online library gateway. These databases include Science Direct, Emerald, Ecospecifier, Compendex, etc. Also, hardcopies (such as books, journals and proceedings), stored in libraries were used.

3. CONCEPT OF CHANGE MANAGEMENT

The review of literature reveals that change management has been widely defined by researchers. Table 1 summarizes a list of definitions found in previous studies. It is however acknowledged that this list of definitions is not exhaustive given the vast number of existing definition of change management. The definitions have been categorised along three contexts: (i) general business; (ii) organisational level; and (iii) project level.

Table 1 Summary of definitions

Author	Location	Research context	Definition
Abbs (2012) p.2	Pakistan	General business	A whole organized procedure of planning, initiating, realizing, controlling, stabilizing and sustaining new and altered work activities at the corporate, group and individual level.
Blake and Bush (2009) p.3	Global	General business	The process, tools and techniques to manage the people side of business change to achieve the most successful business outcome.
Filicetti (2007)	Global	Project level	A structured approach to shifting/transitioning individuals, teams, and organizations from a current state to a desired future state.
Yarberry (2005) p.12	USA	General business	A control system that ensures programs, systems, and infrastructure modifications are authorized, tested, documented, and monitored on its most basic level.
Hiatt and Creasey (2003)	Global	Project level	A process used by project teams to manage the people side of system, process and organizational changes to achieve the desired business results. A competency applied by managers and supervisors to help employees through the transition from the current state to the future state, and A strategic capability to increase the organizational change capacity and to accelerate changes within an organization.
Mitchell et al.	Australia	Organizati	A strategic activity which aimed to get the best

(2002)p.6		onal level	outcomes from the change process. It is about managing the changes that are part of or a consequence of that strategy in such a way to suit the particular organization's context and the type of change required. It is a sub-set of strategy making.
Moran and Brightman (2001)	USA	Organizati onal level	The process of continually renewing an organization's direction, structure, and capabilities to serve the ever-changing needs of external and internal customers.
Voropajev (1998) p.17	Global	Project level	An integral process related to: all project internal and external factors, influencing project changes; possible change forecast, to identification of already occurred changes; planning preventive impacts; and to coordination of changes across the entire project.
Kudray and Kleiner (1997) p.18	USA	Organizati onal level	Continuous process of aligning an organization with its marketplace and doing so more responsively and effectively than competitors
(Whelehan, 1995) p.1	Global	Organizati onal level	A holistic approach to implementing large-scale change that integrates an organization's strategy and processes with its people and culture.
Kramer and Magee (1990) p.1294	Global	General business	It provides facilities for controlling change such that application consistency is preserved both while the change is applied and subsequent to the change.

From Table 1, several keywords have been identified, as shown below:

- D1: planning, initiating, realizing, controlling, stabilizing and sustaining
- D2: process, tools and techniques, and outcomes
- D3: shifting/transitioning and desired future state
- D4: control system, authorized, tested, documented and monitored
- D5: desired business results, competency, transition, strategic capability, increase change capacity, and accelerate changes
- D6: strategic activity and best outcome
- D7: renewing direction, structure, capabilities, and serve customers
- D8: integral process, forecast, identification, preventive, and coordination
- D9: continuous process, aligning, responsively, effectively, and competitor
- D10: holistic approach, implementing, large-scale change, integration, strategy, people, and culture

- D11: facilities, controlling, change, consistency, and preserving

From the review, it is noted that the terms ‘integrative’, ‘process’ and ‘system’ are often used by researchers to describing change management. This may imply that an integrative and systemic process is the key factors driving people and other organisational resources for effective change management. Thus, in this study, a definition of change management has been proposed as follows:

> ‘An integrative and systematic process that involves continuously managing and aligning the needs of an organisation and its employees for effective transition and hence better performance’.

4. RESEARCH METHODOLOGIES

Many studies had attempted to identify the current state of the arts on change management research in the general business management domain. For example, Todnem (2005) provided a comprehensive review on a global context in an attempt to critically analyse the current research and implement situations of organizational change management and found the urgency for a new and pragmatic framework for change management. Apart from reviewing the literature, Oakland and Tanner (2007) adopted a survey design and conducted questionnaire survey via face-to-face interview with 34 senior management to ascertain the key factors driving successful change management. Similarly, Raineri (2011) conducted a survey in 90 organizations in Chile with the attempts to (i) investigate the perceptions of change strategists and change receptors on the implementation of change management practices between change strategists and receptors, and (ii) determine the influence of different practices on the change management implementation process and hence, the organisational performance. Gareis (2010), however, pointed out that the solitary use of a data collection approach is no longer sufficient to capture the multi-dimensionality of change management and thus had used multiple approaches to globally investigate cultural and structural clarity for the management of changes. The methods used include documentation analysis, interviews, workshops and focus groups, communities of practice.

In construction, Bröchner and Badenfelt (2011) face to face interviewed 32 practitioners and surveyed four construction contractors in Sweden in an attempt to explore the relationships between construction change management and information technology. They found that errors in original documentation is the main reason of changes in construction, which is followed by understanding of client needs, technology change, and understanding of original state. Using a questionnaire survey approach, Hwang and Low (2011) have attempted to explore the implementation of project change management process in Singapore’s construction industry and found that the implementation of change management is relatively low in the industry. Park (2002) recognised the dynamics of change management process and thus adopted a case study approach to examine ways to address changes in fast-tracking construction projects. Similarly, through an exploratory case study design, Price and Chahal (2006) interviewed

managers from British Telecom, Aluminium Company of America, and Crown House Engineering, and thereafter developed a strategic framework for change management aligning organizational culture. Through the review of literature, Motawa et al. (2007) classified different dimensions of changes and thereafter developed a change management model, which is underpinned by the fuzzy logic-based theory and Dynamic Planning and Control Methodology (DPM) approaches. Likewise, Sun et al. (2005) and Ibbs et al. (2001) have provided a comprehensive literature review on change management in UK and the US respectively. The former developed a toolkit which captures both soft and hard issues relevant to construction projects, and the latter introduced a systematic change management system. Table 2 summarized the methodologies adopted by precedent studies.

Table 2 research methodologies

Research methodologies	authors	Research field
Literature review	Todnem (2005), Oakland and Tanner (2007), Gareis (2010)	General business
Questionnaire	Oakland and Tanner (2007), Gareis (2010)	
Interview	Raineri (2011), Gareis (2010)	
Questionnaire	Bröchner and Badenfelt (2011), Hwang and Low (2011)	Construction industry
Interview	Bröchner and Badenfelt (2011), Price and Chahal (2006)	
Case study	Park (2002), Price and Chahal (2006)	
Literature review	Hwang and Low (2011), Sun et al. (2005), Ibbs et al. (2001)	
Dynamic Planning and control Methodology	Motawa et al. (2007)	

5. RESEARCH CONTEXTS AND VARIABLES

This section discusses the plausible enablers of and implementation process of change management from: (i) the project perspective; (ii) organisational perspectives; and (iii) change management models.

5.1 Organizational perspective of change management

In US, Porras and Hoffer (1986) surveyed 42 leading organizational development and change management scholars and practitioners, and identified several critical factors for successful change management. These include: open communication, information flow, teamwork and collaboration, shared vision and responsibility, leadership, effective solutions, respect, support and developing other team members, participation and strategic management. Similarly, in an attempt to explore the implementation and forces of changes, Oakland and Tanner (2007)

surveyed senior managers from 28 organizations including public sectors and a variety of industries, and found that the alignment of strategic objectives and operational improvement is the key for effective change management. They reinforced that, in order to gain employees' behaviour commitment to changes, the employees should be clearly informed of their organisational needs and directions, and be involved in the decision-making process. This is consistent with the findings of Kotter (1996) and Duck (1993), who identified the open communication and learning cultures are the key enablers of effective change management. Similarly, Hirschfield (1999) and Hardy (1997) shared the view that, for effective communication, management should clearly set out, articulate and contextualise a clear purpose to the 'right' group of audience. If not, employees will become anxious and resistance to changes (Bruegman 1994; Haas and Chris 1999).

According to Kosson (1994), offering logical reasons is a means of managing employees' resistance to changes. This could take the forms of: (i) discussion and negotiation (DuBrin 1996; White and Chapman 1997); (ii) education (Kotter and Schlesinger 2008); (iii) participation (Lines 2004); (iv) facilitation (Kotter and Schlesinger 2008); and (v) coercion (Dent and Goldberg 1999). Reinforcing these, Myers (1998) and Benziger (2000) pointed out that stable procedures only are not enough to address resistance, it is important for managers to consider the different personality types of employees.

In construction, Price and Chahal (2006) emphasised that aligning the organisational culture with change management is a critical factor. Walker and Loosemore (2003) and Lim e t al. (2011) shared the view that fostering learning culture and creating an open communication environment could enhance employees' responsiveness to unexpected changes.

5.2 Change management in project perspectives

Ibbs et al. (2001) introduced some systematic approaches to manage project change, which have five principles: a balanced change culture, recognition, evaluation, implementation, and continual improvement from experiences. Love et al. (2002) analysed how changes affected the project management system. Hao et al. (2008) suggested that changes are common and inevitable in construction projects due to incomplete information, assumptions and personal experiences and proposed a change process model that contains five stages: identify, evaluate & propose, approve, implement and review. Different change iteration cycles are involved in fast-tracking construction and their characteristics and behaviour patterns were identified by Park (2002).

Hwang and Low (2011) conducted a status, importance and impact assessment on 384 projects from 32 construction companies in Singapore. They found that the implementation status in the Singapore construction industry is relatively low, and that those contractors who have implemented change management in their business strategy are better performers than their counterparts, in terms of project cost, time and quality. In the context of Saudi Arabia, Al-Sedairy (2001) highlighted the fall of oil price had created a huge turmoil in the country. Due to

the decrease of the oil price, the government shifted its dependence on the private sector to pursue economic objectives, thus the financial pressure had been transferred into industries including construction. He then developed an exclusive model of managing changes for the Saudi construction industry which including four different change actions (crisis management; efficiency drives; strategic planning; and corporate re-structuring) for changes in different depth.

5.3 Models of change management

A great number of change management models, procedures and frameworks have emerged over the past decade in an attempt to help organisations towards improving their responsiveness to sudden disturbances. Figure 1 summarizes the evolution of change management models from 1952 to 2010.

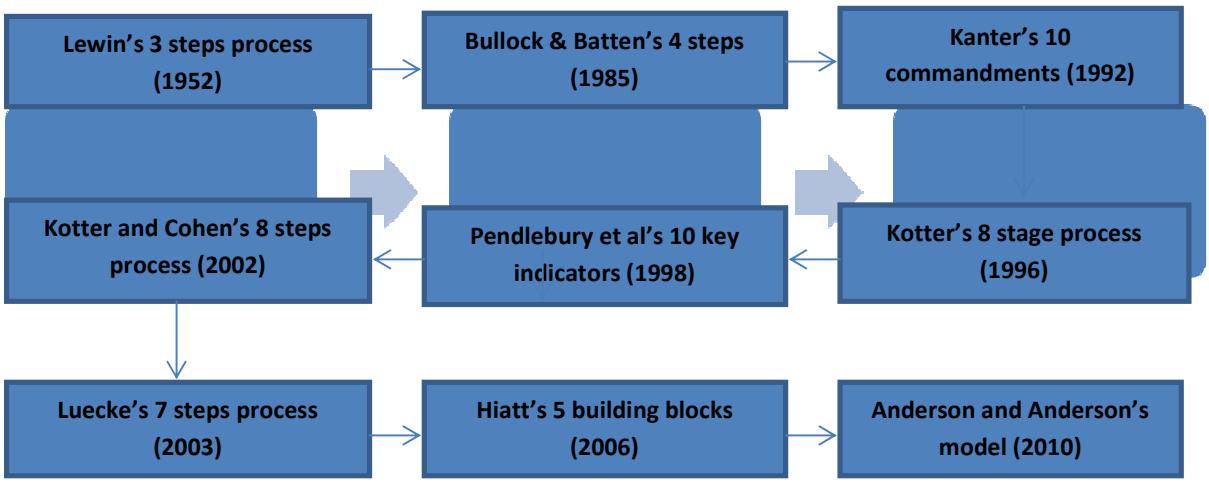

Figure 1 Change management models

Lewin's (1952) three-step model has been recognised as one of the most influential approaches in change management discipline, and has been used by many other researchers such as Todnem (2005) and Holbeche (2006). The model comprises three steps: (i) unfreezing the current state; (ii) moving towards the expected state by evolving and engaging employees and groups; and (iii) refreezing and stabilising the new state by new rules, standards and reward systems. This three-step process has been extended by Bullock and Batten (1985), who included the 4th step, i.e., exploration planning, action and integration.

Kanter et al. (1992) proposed ten commandments for change execution. These are: i) analyse the organization and its need for change; ii) create a vision and common direction; iii) separate from the past; iv) create a sense of urgency; v) support a strong leadership role; vi) line up

political sponsorship; vii) craft an implementation plan; viii) develop enabling structures; ix) communicate; and x) involve people and be honest, and reinforce and institutionalise change.

As shown in Figure 1, Kotter's (1996) eight-stage process is the fourth generation of change management model. The processes include: i) projecting a vision and strategy; ii) inducing a sense of urgency; iii) creating a guiding coalition; iv) empowering broad-based action; v) communicating the change vision; vi) anchor new approaches in the culture; vii) generating short-term wins; and viii) consolidating gains and producing more change.

Pendlebury et al. (1998) identified ten key indicators for successful change management: i) defining the vision; ii) mobilising; iii) catalysing; iv) steering; v) delivering; vi) obtaining participation; vii) handing the emotional dimension; viii) handing the power issues; ix) training and coaching; and x) communicating actively are included in the ten indicators.

Kotter and Cohen (2002) identified eight steps for successful large-scale change management, which includes: i) increasing urgency; ii) building the guiding team; iii) getting the right vision; iv) communicating; v) empowering people; vi) creating short term wins; vii) not to letting up; and viii) making change stick.

Luecke (2003) argued that change management should be a seven-step process in managing changes and transitions. The seven steps are: i) systematize energy and commitment through joint identification of business problems and their resolutions; ii) develop a shared vision on organizing and managing for competitiveness; iii) identify the leadership; iv) institutionalise success through formal policies, systems, and structures; v) put focuses on outcomes but activities; vi) change at the periphery at the beginning, then let it spread to other units without pushing it from the top; and vii) monitor and adjust strategies from feedbacks of problems in the change process.

Hiatt (2006) investigated the change patterns of more than 700 companies and developed the ADKAR model, which originally intended to understand change on individual level. It has five building blocks or objectives: i) awareness of the need to change; ii) desire to participate and support change; iii) knowledge on how to change; iv) ability to implement required skills and behaviours; and v) reinforcement to sustain the change. He then proposed the Prosci's change process, which has three main parts: i) preparing for change; ii) managing change and iii) reinforcing change. The first part contains defining change management strategy, preparing a change management team, and developing a sponsorship model. Developing change management plans, taking actions and implementing plans constitute the 'managing change' part. The third so called 'reinforcing change' part contains three subparts: collect and analyse feedback, diagnose gaps, manage resistance and implement corrective actions and celebrate successes.

Lastly, Anderson and Anderson (2010) structured a change process model, which consists of nine phases of activity. There are: i) preparing to lead the change; ii) Creating organizational

vision; iii) commitment and capacity follows behind; iv) assessing the situation to determine design requirements; v) design the desired state, analyse the impact; vi) plan and organize for implementation; vii) implement the change; viii) celebrate and integrate the new state; ix) and learn and course correct.

6. LIMITATIONS AND DILEMMAS

The review of literature reveals that there are limitations in the previous research, which are discussed below.

6.1 Regional limitation

From Table 1, it can be noted that only one out of the 11 definitions are proposed in the context of a developing country, i.e. Pakistan. Also, the literature review shows that most studies have been conducted by researchers from the developed western countries. Evidence also could be found in the research on project change management. (e.g. the studies of Al-Sedairy (2001)). These findings revealed that the quantity and quality of change management implementation and research in developing countries are falling behind US, Europe and Australasian countries in developing countries.

6.2 Industrial limitation

It appears that most of those definitions of change management have been proposed in the general business context. Instead of analysing the different characters among different fields, studies on organizational change management focused on developing a general and universal solution which could cover most of the industries. Kotter (1996) developed his model and focused on general business change management, while Haas and Chris (1999) and Bruegman (1994) investigated change management in the fire-fighting industry. Hitherto, it appears that little has been done on organisational change management in construction; apart from Price and Chahal's (2006) work.

6.3 Lack of alignments between project management and organizational management

The literature reviews reveal the knowledge gap between organisational and project contexts of change management in construction Researchers from these two fields have different perspectives and focused on various research objectives. Most researchers focusing on project change management were trying to optimize workflow and process of management strategies and developing prediction toolkits. (e.g. Love et al (2002) and Hao et al (2008)). On the other hand, studies that focuses on organizational context attempted to identify the plausible resource-based factors driving effective change management.

6.4 Lack of flexibility

The frequently changing pace of the world keeps introducing a great amount of new technologies, strategies and frameworks to industries. Thus, there will be no 'best' ways of managing changes except a more flexible manner. Instead of those existing frameworks (identified in 5.3), a more flexible framework needs to be structured to facilitate the management process and improve the organizational culture and structure.

6.5 Lack of implementation

As discussed in Section 5.3, there exists many change management models but there is no adequate evidence to suggest if they are practical. There are two main reasons for this: 1) change management has been in existence for less than thirty years, the time span is not adequate for identifying whether a model or framework is effective or not; and 2) the feedback system is under-researched; previous studies had placed less emphasis on validating and improving their models.

7. CONCLUSION

In this prevailing business environment, characterised by fast pace of changes and increased level of uncertainty, the ability for organisations to manage changes effectively is the key for their continued existence. However, the performance of these change management practices did not meet the expectation. In order to find out the reasons underlying in this phenomenon and then improve the overall quality of change management implementation, the authors conducted a critical literature review on change management along three dimensions: concepts of change management; research methodologies; research contexts and variables. Under the first dimension, the definitions of change management, definition context, definition location, and key words had been highlighted and thereafter an exclusive definition of change management for the construction industry had been imposed.

The methodologies which adopted by change management researchers were also reviewed and classified. The review demonstrated that literature review, interview and questionnaire are the most common measures to explore change management issues.

Research contexts and variables were reviewed on three perspectives: organizational perspective; project perspective; and change management models. The research location, variables, and findings of these researches were marked to analysis the research limitations and dilemmas.

Five limitations of existing researches were identified in this paper, they are: regional limitation; industrial limitation; lack of alignments between project management and organizational management; lack of flexibility; and lack of implementation. This paper attempts to inform researchers about the further research directions in change management.

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Social Governance Mechanisms in Construction Projects

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Abstract

Inter-organisational Relationships (IORs) governance literature is by now quite extensive and has been studied in different contexts (e.g. economics, strategy, organisation, and management). Due to the complex nature of IORs in construction projects in terms of inter-firm exchanges (e.g. engineering, procurement, finance, construction, and operation), many academics and practitioners have studied possible outcomes of applying different governance mechanisms in these projects to control the behavior of different project parties. One of the identified governance mechanisms is the social mechanism that has been broadly examined through conducting empirical studies. However, its definition and indicators are highly dispersed that may lead to contradictory results or misinterpretation of outcomes. This paper aims at making contribution to the IORs governance literature through explaining and clarifying the meaning of social governance and identifying, synthesising, and categorising different instruments that have been used for measuring the existence of different modes of social governance mechanism in previous studies. As a result, we will provide a useful framework to have a better understanding of social governance mechanism and its application in construction projects.

Keywords: Clan Control, Input Control, Inter-organisational Socialisation, Inter-personal Socialisation, Social Governance Mechanisms.

1. Introduction

Organisations are increasingly relying on each other for achieving their business objectives as work becomes more complex, non-routine, and knowledge intensive, which demands the expertise from multiple partners for problem solving and risk sharing. The construction industry is fragmented with many specialised trades (Chen & Chen 2007). Collaboration across various organisations is essential for undertaking complex civil infrastructure projects. Historically, the business relationships for collaborations in these projects are governed predominantly by formal contracts. Over time, the adverse effects from the adversarial nature of formal contracts have been recognised as contributing to a culture of dispute and non-cooperation, thus hampering

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the efficiency and effectiveness of the construction project delivery (Chan et al. 2006; Eriksson & Westerberg 2011). Subsequently, attention has shifted to examine the use of alternative governance mechanisms to contract-- social governance mechanisms (Tuuli et al. 2010).

Inter-organisational relationships (IORs) literature examines governance mechanisms for inter-organisational collaboration. IORs governance refers to the arrangements used to regulate the relationships among two or more cooperative parties with the main focus on mitigating opportunistic behavior and promoting cooperation. The governance mechanisms can be categorised into two types: formal and social governance mechanisms. Social governance mechanisms, also referred to as relational governance, relational control, social control, informal control, informal contracts, or social embeddedness, focus mostly on deploying informal means to regulate the IORs. Although there is an extensive literature on social governance mechanisms, the definition is varied, often vague and the instruments used for measuring this construct vary a great deal from study to study making it difficult to build knowledge based on past studies.

This paper attempts to clarify the meaning of social governance mechanism through literature review as well as identifying and synthesising different instruments that have been used for measuring the construct in previous studies. The contribution of this paper is to clarify of a key construct in the IORs literature and to synthesise diverse range of instruments used for measuring the construct, which facilitates the further development of a common language and building block for the advancement of IORs literature.

In the following sections, the concept of social governance mechanism is reviewed with focus on the underpinning theories, levels of socialisation and the whole spectrum of social control modes. Then, various social governance mechanisms are typologised through developing a two by two matrix. Finally, conclusions are drawn and implications are discussed.

2. The Concept of Social Governance

For having more comprehensive understanding of social governance concept, we conceptualise it through three different viewpoints. At first, we recognise various theoretical foundations of social governance arrangement. Then, we identify two typological categorisations for social governance mechanism and try to describe each perspective.

2.1. Theoretical Background

According to the IORs literature, inter-organisational exchanges are subject to two main problems: safeguarding and coordination (Hoetker & Mellewigt 2009; Jones et al. 1997). Safeguarding has to do with mitigating opportunistic behavior of engaged parties in a collaborative project whereas coordination is about integrating dispersed activities and resources which are critical to the value creation in the project (Hoetker & Mellewigt 2009).

Part of the IORs governance literature mostly focuses on safeguarding role of social governance mechanism seeing it as an arrangement for controlling the behavior of exchange parties and arguing how this informal apparatus safeguards the exchange parties against risks of opportunistic behavior as well as reducing the environmental uncertainty by utilising trust and fostering embedded relationships in the project network (Li et al. 2010; Mellewigt et al. 2007; Smyth & Edkins 2007; Yang et al. 2011; Yu et al. 2006; Zhao & G. Wang 2011). However, there are several studies addressing both safeguarding and cooperation remedies in form of social governance mechanism in inter-organisational exchanges (Aulakh & Gencturk 2000; Boulay 2010; Carson et al. 2006; Chen et al. 2009; Claro et al. 2003; Deeds & Hill 1998; Dekker 2004; Dong et al. 2008; Ferguson et al. 2005; Fryxell et al. 2002; Hoetker & Mellewigt 2009; Kohtamäki et al. 2006; Luo et al. 2011; Patzelt & Shepherd 2008; Poppo & Zenger 2002; Poppo et al. 2008; Sengun & Wasti 2009; Wang & Wei 2007). Theory of trust, relational contracting, and social exchange theory are underpinning theories for describing the advantages of social governance mechanism in regulating the behavior of exchange parties (Macneil 1980; Das & Teng 2002; Das & Teng 1998; Dyer & Singh 1998).

According to the trust perspective, the literature categorises trust into two general types of calculative trust and benevolent trust (Doney & Cannon 1997) whereas the former is much affected by reputation of exchange parties as well as the chance of future inter-relationships among partners and the latter is more related to the history of relationships among parties (Carson et al. 2006). Calculative trust is more rational-based and can remove incentives for opportunistic behavior by ensuring parties about their capabilities and introducing sanctions in the form of the loss of future business (Heide & Miner 1992; Carson et al. 2006). On the other hand, benevolent trust refers to the degree to which one party is confident of the other party's goodwill and reliability in an uncertain exchange situation (Smith & Van De Ven 1994; Nooteboom et al. 1997; Yang et al. 2011; Das & Teng 1998) and consequently the longer the duration of successful relationships among parties, the greater and deeper the benevolent trust (Dyer & Chu 2000; Yu et al. 2006).

Relational contracting, in the same way, argues that working together through long term interactions along with deploying different social means may help partners to create shared culture and shared norms and subsequently, to reduce goal and preference incongruence while increasing commitment, mutuality, solidarity and flexibility (Carson et al. 2006; Kohtamäki et al. 2006; Patzelt & Shepherd 2008; Poppo et al. 2008; Wang & Wei 2007). Development of these relational norms may provide the parties with a degree of confidence enhancing the cooperative atmosphere in the project (Hatten et al. 2012; Macneil 1974; Macneil 1978).

Originating from sociology, social exchange theory views people's behavior in terms of exchanges of resources and claims that the lack of resources encourages parties to engage each other for obtaining valuable inputs (Levine & White 1961; Das & Teng 2002). Researchers argue that this dependency may promote commitment among exchange parties, thereby increasing the probability of future collaboration (Young-Ybarra & Wiersema 1999; Parkhe 1993).

2.2. Different Levels of Socialisation

Despite the importance of understanding the nature of socialisation in IORs, there is noticeable ambiguity in the literature about the role of social mechanism as it operates at different levels of analysis (Dekker 2004; Gulati 1995; Ring & Van de Ven 1992; Zaheer et al. 1998). The main challenge in conceptualising the role of social arrangements in economic exchange is extending an inherently individual-level phenomenon to the organisational level of analysis, because socialisation is taking place among members of organizations, rather than the organisations themselves (Zaheer et al. 1998). Zaheer et al. (1998) argue that theories of IORs are committing a "cross-level fallacy" by viewing the social exchanges as inter-orgainsational properties without differentiating micro (individual) and macro (organizational) levels of exchanges. In other words, these theories do not state the mechanisms by which individual-level action affects organisational-level outcomes. They argue that in an actual exchange relationship, individual boundary spanners that are representatives of their organisations in inter-firm relationships, have an important role in exchange performance. On the other hand, institutionalised practices and routines at the organizational level for governing IORs, provide a stable environment within which inter-organisational and inter-personal norms develop. That is, these two micro and macro levels of analysis, have a reciprocal relationship among each other. Hence, neither alone is enough for realising the performance of exchange relationships. Similarly, Luo et al. (2011) categorise social mechanisms into relational norms (macro-level) and inter-personal socialization (micro-level). They point out that relational norms reflect the shared expectations about behavior among engaged organisations whereas inter-personal socialisation refers to personal ties between senior executives of exchange partners. Supporting Zaheer et al. argument about reciprocity among these two levels, they assert that inter-personal socialisation may strengthen the bonds among people leading to group norms that increases the commitment of the parties to a cooperative relationship (Luo et al. 2011).

2.3. Different Modes of Social Governance

Generally, in terms of the target of control mechanisms for regulating the inter-firm relationships, the IORs governance literature has identified four types of control modes, namely, output control, behavior control, clan control, and input control (Kirsch et al. 2010; Tuuli et al. 2010; Cardinal 2001). Typically, the former two control modes are categorised as formal control modes while the latter two are referred to as informal or social control modes. Since the focus of this paper is on the social governance mechanisms, the discussions below concentrate on social control modes.

Under ambiguous and uncertain conditions, reliability and accuracy of measurement declines and consequently formal control mechanisms are not dependable individually (Ouchi 1979). In these situations, clan control via social interactions and shared norms and values, provides a supportive environment for partner firms to have a better understanding of the process and objective of their collaboration (Das & Teng 1998). Having established norms of performance, any violent behavior would be rejected by the other members through subtle reminders like

humor, kidding or hinting to modify the faults, and if the violent member continues to ignore the common norms, the collective sanction may be imposed (Jaworski 1988; Kirsch et al. 2002). That is, clan control only encourages desirable behavior through soft measures and there is no formal constraint on member's behavior (Cardinal et al. 2004; Das & Teng 1998). As a result, this type of control is manifested in a certain level of trust among firms (Das & Teng 1998). However, repeated ties between partners may lead to overembedded relationship in a way that impedes innovation, leaves out new links, and impairs the organizational structure (Lin et al. 2012).

Table 1- Social Governance Definition

Perspective	Definition	Representative research
Theoretical background	**Control:** Utilizes trust to encourage desirable behavior, mitigate opportunism, lower monitoring cost, and facilitate dispute resolution	Carson et al. (2006); Li et al. (2010); Kohtamäki et al. (2006); Mellewigt et al. (2007); Patzelt & Shepherd (2008); Poppo et al. (2008); Smyth & Edkins (2007); Wang & Wei (2007); Yang et al. (2011); Yu et al. (2006); Zhao & Wang (2011)
	Cooperation: Employs joint actions and information sharing and creates shared culture and shared values, norms, beliefs and goals to reduce goal and preference incongruence and increase parties' cooperation, commitment, mutuality, solidarity and flexibility	Aulakh & Gencturk (2000); Badenfelt (2010); Boulay (2010); Carson et al. (2006); Chen et al. (2009); Claro et al. (2003); Deeds & Hill (1998); Dekker (2004); Dong et al. (2008); Ferguson et al.(2005); Ferguson et al. (2005); Fryxell et al. (2002); Hatten et al. (2012); Hoetker & Mellewigt (2009); Kohtamäki et al. (2006); Luo et al. (2011); Patzelt & Shepherd (2008); Poppo & Zenger (2002); Poppo et al. (2008); Sengun & Wasti (2009); Wang & Wei (2007);
Level of Socialisation	**Inter-organisational:** Refers to the extent of inter-organisational ties among parties in the project network	Luo et al. (2011); Zaheer et al. (1998)
	Inter-personal: Refers to the personal ties among boundary spanners and project team members in different parties' organisations	Luo et al. (2011); Zaheer et al. (1998)
Type of control	**Input control:** Focuses on providing the desired environment in the project by manipulating the degree and variety of knowledge, skills, experiences, and attitudes displayed on the job	Cardinal (2001); Khodyakov (2007); Snell (1992)
	Clan control: Focuses on shared values and shared norms and common vision	Kirsch et al. (2010); Ouchi (1979); Tuuli et al. (2010)

Input control, also referred to as "skill standardisation" (Mintzberg 1979) or "ex-ante control" (Flamholtz 1979), can be considered a form of resource allocation referring to the selection and training processes that can be deployed by the exchange parties to regulate the antecedent conditions of exchange performance i.e. the required knowledge, skills, abilities, values, and motives of partners and their personnel (Snell 1992; Cardinal 2001). Through wise partner

selection as well as careful staffing and training practices, Input control may mitigate deficiencies that might be unfeasible to remedy later (Snell 1992; Kirsch et al. 2010).

3. Operationalisation of Social Governance

The operationalisation of social governance in the empirical literature is rich but diverse which could lead to inconsistent interpretation or even misinterpretation of the research results. In the discussions below, we review the empirical literature and categorise extant instrument used to operationalise social governance into a 2 by 2 matrix (Figure 1). The matrix serves as a framework for identifying various social arrangements under different contexts.

	Inter-organisational	**Inter-personal**
Input control	Indicators for inter-organisational socialisation focusing on input control	Indicators for inter-personal socialisation focusing on input control
Clan control	Indicators for inter-organisational socialisation focusing on clan control	Indicators for inter-personal socialisation focusing on clan control

Figure 1- Social governance matrix

3.1. Inter-organisational Socialisation for Input Control

As mentioned previously, the main purpose of utilizing input control is to prevent later performance problems through proper selection and appropriate training in the front-end stage of the project. Based on abovementioned literature, some scholars argued that individual level and organisational level of interaction among exchange partners should be distinguished. Consequently, those input control arrangements that are related to the selection of project partners or the collaboration approach and dependent skills can be classified as inter-organisational socialisation mechanisms (Table 2). Applying these mechanisms can foster the sense of trustworthiness in the project and facilitate cooperation among parties leading to better project performance.

3.2. Inter-personal Socialization for Input Control

As shown in table 3, input control arrangements can be in the form of personal characteristics of project team members and the extent to which they have shared culture and values and are able to count on each other in terms of competence and reputation trust or benevolent trust. The partners should be careful about appointing right personnel as their organisation's representatives or team members, because even if the engaged parties have a good history of relationship with each other, the project team members may not be able to match their counterparts in other parties' project teams and consequently it may raise considerable problems in the project.

Table 2- Indicators for inter-organisational socialisation focusing on input control

	Inter-organisational socialisation	Representative research
Input control	• Utilising partnering arrangements; Partnering training and seminars • Joint governance design; • Joint alliance board; Rotation of alliance board members • Good reputation of parties • To be able to rely on each other to keep promises • To be able to count on each other to be sincere in dealings • To be able to rely on each other when face with adversity • To be able to rely on each other when the specifications are vague • Feeling like part of one family • Having successful experience of collaboration in the past • Having shared history and culture • Having shared processes and procedures for doing the work • Having well established routines between partners • Having shared long- and short-term goals and plans • Having some attractive ideas or resources for each other • Expecting the relationship to last in the future • Preferring maintaining the relationship other than seeking individual benefits	Aulakh & Gencturk (2000); Boulay (2010); Chen et al. (2009); Dekker (2004); Ferguson et al. (2005); Fryxell et al. (2002); Hatten et al. (2012); Jap & Ganesan (2000); Li et al. (2010); Li et al. (2010); Lui (2009); Mellewigt et al. (2007); Patzelt & Shepherd (2008); Poppo & Zenger (2002); Poppo et al. (2008); Sengun & Wasti (2009); Smyth & Edkins (2007); Wang & Wei (2007); Yang et al. (2011); Yu et al. (2006); Zaheer et al. (1998); Zhao & Wang (2011).

Table 3- Indicators for inter-personal socialization focusing on input control

	Inter-personal socialization	Representative research
Input control	• People of both parties can work together properly and efficiently • People of both parties can count on each other to keep promises • People of both parties have fair perspective towards each other • People of both parties have faith in each other to look out for each other's interests even when it is costly to do so • Project team members have shared norms and values • Project team members have common vision of the project	Kirsch et al. (2010); Wang & Wei (2007); Zaheer et al. (1998)

3.3. Inter-organisational Socialisation for Clan Control

Like input control, clan control mechanisms can be considered in both individual and organisational levels. Previous studies utilised different instruments for measuring the extent to which clan control arrangements are applied at inter-organisational level (Table 4). Proper use of clan control mechanisms may reduce the behavior uncertainty and the risk of opportunism in inter-firm relationships by providing a common understanding of the project objectives and sharing organisational norms and values so that alleviate potential disputes and deal with unexpected situations in a more cooperative environment.

3.4. Inter-personal Socialisation for Clan control

Alongside those clan control mechanisms used at inter-organisational level, some studies identified other clan-type arrangements that are related to the individual level. As illustrated in table 5, these types of control arrangements are used to facilitate social interaction among

project team members in order that clarify the code of conduct for expected behavior and provide a collaborative environment leading to cooperation satisfaction.

Table 4- Indicators for inter-organisational socialisation focusing on clan control

	Inter-organisational socialization	Representative research
Clan control	• Having participatory decision-making and/or Joint planning • Working together to resolve the problems caused by whichever party • Solving disagreements by cooperation and working together • Frequent fine-grained information exchange • Providing proprietary information if it can help the other party • Frequent interaction and informal socialization • Communicating with each other about events and changes that will affect collaboration • Welcoming each other's improving ideas • Committing to improvements that may benefit the relationship as a whole, and not only individual parties • Not using pressure tactics to influence each other • Having fair perspective towards the relationship • Trying to adapt themselves to other parties' needs • Accessing new networks and resources through each other	Boulay (2010); Claro et al. (2003); Dekker (2004); Ferguson et al.(2005); Ferguson et al. (2005); Fryxell et al. (2002); Hatten et al. (2012); Jap & Ganesan (2000); Li et al. (2010); Li et al. (2010); Luo et al. (2011); Patzelt & Shepherd (2008); Poppo & Zenger (2002); Poppo et al. (2008); Sengun & Wasti (2009); Wang & Wei (2007); Yu et al. (2006); Zaheer et al. (1998); Zhang et al. (2009); Zhao & Wang (2011).

Table 5- Indicators for inter-personal socialization focusing on clan control

	Inter-personal socialization	Representative research
Clan control	• Partners' top managers invite each other to attend important occasions and social activities • Partners' top managers often visit each other's company • Partners' top managers are very familiar with each other via frequent meetings and discussions • All project team members attempt to be "regular" members of the project team • Project team members have face-to-face contacts at the operational level	Aulakh & Gencturk (2000); Chen et al. (2009); Deeds & Hill (1998); Ferguson et al. (2005); Fryxell et al. (2002); Hoetker & Mellewigt (2009); Kirsch et al. (2010); Luo et al. (2011); Zaheer et al. (1998);

4. Conclusion

Large construction projects typically involve multiple partners and, as a result, effective governance of inter-organisational relationships (IORs) is essential to the successful delivery of these projects. The literature on IORs governance is relatively recent and there are overlapping and sometimes inconsistent definitions of similar constructs. One of such constructs is social governance mechanism. This paper develops a framework for classifying the various social governance mechanisms along two dimensions. Further, various instruments used for measuring social control mechanisms have been classified and synthesized.

The main contribution of this paper to the IORs governance literature is the typology framework for classifying various social control mechanisms and the synthesis of various instruments for

measuring the construct. The framework will facilitate the advancement of knowledge of IORs governance at clarifying the construct in various contexts and thus a common platform and language enabling the accumulation of knowledge.

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Innovation through Alliancing in a No-Blame Culture

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Abstract

Innovation occurs within the safety of a no-blame culture yet we see surprisingly scant literature on how this is facilitated within a construction project management context. The purpose of this paper is to demonstrate how innovation and promotion of innovative thinking in action is enabled through a no-blame culture in project alliances in Australia. We argue that innovation is dependent upon collaboration and true collaboration is inextricable linked to behavioural drivers. Foremost of these is a culture of openness and willingness to share the pain and gain from experimentation. Further, this culture requires that collaborators be protected from the threat of being blamed and held accountable for experimental failure.

We draw upon theory and data gathered over several recent research studies on the experience of project alliances in Australia. The project alliance procurement form has a unique 'no-blame' behavioural contract clause that is crucial in developing a collaborative culture where innovation can evolve through a process of trial and error.

Keywords: Collaborative Procurement, No-blame, Project Alliancing, Culture

1. Introduction

The project management (PM) literature has been evolving since the 1940s to a highly deterministic sub-discipline concerned with planning and control (Morris 2011). It had been dominated by tools and techniques (such as the Gantt chart) within a Scientific movement world view of PM (Geraldi and Lechler 2012). In a special issue of *The International Journal of Managing Projects in Business* tracing the role of PM literature classics on current PM trends and practices (Söderlund and Geraldi 2012) we see that recognition of the complexity of organising projects has been reaffirmed and that collaboration and PM integration has been a continuing challenge to project managers and clients engaged in project work.

One paper in particular (Brady, Davies and Nightingale 2012) draws upon classical work by Klein & Meckling (1958) and the way that innovation is perceived and applied within projects. A key point they made is the worldview of the innovator. One view (they called this Mr Optimizer) is focused on detailed planning and an expectation that plans are real and can be made and followed 'correctly' to achieve an optimum result while the other (Mr Skeptic) seeing plans as evolving and fluid with an holistic objective that may be delivered in a range of ways, all equally effective in the end. Brady et al. (2012) argue that an intuitive approach opens up greater possibilities for innovation in complex projects than does a highly analytical

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one where the analysis and deliverers are wedded to a particular deterministic view that plans are real and that not following them constitutes some form of failure or blame.

Brady *et al.* (Brady *et al.* 2012) fits neatly with this paper about the practice of delivering construction projects via a project alliance (PA) between the client, design consultants and contractors and major subcontractors. This procurement form has become widely used in Australia. Wood and Duffield report that the total value of alliance projects between 2004 and 2009 in Australia was $32 billion (2009, p7). Similar forms of PAs are used elsewhere for example in the USA the term integrated project delivery is used (Cohen 2010) and in the Heathrow Terminal five (T5) project a sophisticated integrated supply chain was adopted (Brady, Davies, Gann and Rush 2007; Doherty 2008). In the Netherlands and in other parts of Europe an approach called the competitive dialogue is used (Hoezen, Voordijk and Dewulf 2012) as well as PAs as used in Australia (Laan, Voordijk and Dewulf 2011). While some nuances illustrate differences in the degree to which alliance partners collectively share pain and gain from the arrangements a common world view prevails that projects present many challenges requiring collaborative decision making and action, and that plans are never perfect. Uncertainty is certainly a characteristic, and innovation to seek pathways through adverse situations is a key need in complex construction projects. In this paper we will restrict ourselves to PAs because they specifically demand that alliance parties 'sink or swim together' (Walker 2002) and this explicitly demands a no-blame culture.

The research question to be addressed in this paper is:

How may a project team's safe, no-blame culture facilitate innovation through collaboration in construction project alliances?

The paper is structured as follows. First we briefly describe the paper's context in terms of fundamental constructs, what a no-blame culture may look like, what a construction project alliance means, what we mean by innovation and how the concept of 'trust' is relevant to our argument. We provide an explanatory model to answer the research question. We then discuss the results together with some illustrations from practice and explore their implications and finally conclude the paper.

2. Fundamental Constructs

We introduce several constructs that we explain. These are innovation, PAs, trust and blame and we first explain our ontological stance because this is fundamental to our argument.

2.1 Our Ontological Stance

A traditional design and construction project management (PM) approach could be seen as falling within the paradigm of *product thinking*. The project delivers the specified end product with performance dominated by highly positivist ontological stance of achieving time and cost targets together with strict specification of quality and fitness for purpose. There is an objective product 'out there' in terms of a tangible design for its realisation. All plans, budgets, forecasts and projections are 'real' artefacts and are based on facts about the

optimum and ‘best’ delivery method. While it is generally conceded that these plans and projections are subject to some level of imprecision they are nevertheless relatively fixed and reliable. There is limited acknowledgment of uncertainty and its impact can be assumed to be contained and allowed for by establishing a contingency estimate.

Koskinen (2012) argues that much of PM entails *process thinking* and he sees projects as learning episodes. Both Cavaleri (2008) and Steinfort and Walker (2011) demonstrate that PM as a form of action learning. Koskinen (2012) notes that PM standards guide meta-processes such as design, planning, monitoring, controlling but that sensemaking and negotiating of meaning sub-process lies at the heart of PM. Sensemaking is the construction, interpretation, recognition and creation of meaning. Project organisations consist of people, all of whom have had different experiences have a range of knowledge about salient matters and have different interpretations of what they experience. People construct meaning and they negotiate what they collectively perceive as ‘truth’ or ‘reality’ during the course of interacting with other people, systems and even technology. This view places PM in an *interpretivist* rather than traditional *positivist* paradigm because both inputs and outputs are contestable and their meaning is negotiated. Effective communication to negotiate meaning is considerable once we accept that sensemaking is vital for interpreting a construction project design brief, design details and the validity of plans, forecasts and various future projections. Process thinking undermines the primacy of a command and control approach because of the need to ‘negotiate meaning’ so there is a responsibility to facilitate joint commitment to decisions and this changes the dynamics from simply following fixed plans towards the construction of what Pitsis, Clegg, Marosszeky and Rura-Polley (2003) call a *future perfect* strategy. Establishing a compelling vision (Christensen and Kreiner 1997; Christenson and Walker 2004) forms the boundaries within which negotiation about methods, specific processes and value can take place. Interpreting and mutually constructing the ‘reality’ of budgets, plans and design solutions opens up possibilities for innovation and creative thinking for two reasons:

First, viewing plans, budgets and forecasts as constructed realities framed by a vision of the project’s end state makes it not only permissible but necessary to deviate from plans that are not achieving the desired outcome. There is recognition that unforeseen circumstances and factors intervene that must be compensated for by recalibrating plans by adopting a pragmatic best-for project (B4P) approach. Energy can then be directed towards adjusting and adapting action rather than developing claims and counterclaims for changes to a rigid contract. Plans can be considered as guides and not mandates so that energy is positively rather than defensively deployed to counter potential consequences of being blamed.

Second, challenging assumptions made about how budgets and plans can be recalibrated and adjusted becomes a learning opportunity. Thus a processual *interpretivist* paradigm requires a very different culture to a traditional construction *positivist* PM paradigm and this requires a culture of embracing innovation, critically questioning assumptions and a high level of perspective taking so that meaning can be negotiated through sensemaking within a consensus and no-blame culture. Parker, Atkins and Axtell (2008) argue that this requires a person motivated to understand the other person’s view, rather than one assumes an

automatic shared understanding. Perception taking requires shifting from a culture of blame to one of reflecting upon contextual structural, team and individual level influences.

2.2 What do we mean by Innovation?

According to Walker and Hampson (2003c, p. 238), innovation is 'an idea, practice, or object that is perceived as new by an individual or other unit of adoption' or 'a decision-making process to enact change in technology, processes, services rendered or other management approaches'. Slaughter (1998) presents innovation categories based on exploiting existing knowledge skills and experience. Innovation can range from small incremental change to radical re-conceptualisation and occur at the component, module, system or architecture level. It may involve reconfiguring a component or re-designing it; re-designing a configuration of components within a system, or re-designing and reconfiguring links between systems. All innovation can lead to unintended consequences and uncertain outcomes. It is easy to blame those that innovate when an expected positive outcome fails to occur or when an unforeseen hazard is encountered. The decision whether or not to innovate fuels the knowledge exploitation versus exploration debate. Should construction delivery teams harvest knowledge from past projects and past patterns of project delivery or should they be continually alert to possibilities of continually 'tweaking' or radically reconceptualising what they deliver? Should they follow a well trodden path or experiment with new approaches and ways to re-interpret the outcome of what they were asked to deliver?

2.3 What do we mean by Project Alliances (PAs)?

A project alliance agreement (PAA) is made between two or more entities—the project owner or its representative (PO) and consultants and contractors who are non-owners of the project (NOPs). All entities commit to working cooperatively in good faith, sharing the risk and rewards of the project in order to achieve the stated outcomes (Jefferies *et al.* 2006). A definition of project alliancing that begins to describe the culture and ambience is

"… a method of procuring … [where] All parties are required to work together in good faith, acting with integrity and making best-for-project decisions. Working as an integrated, collaborative team, they make unanimous decisions on all key project delivery issues.

Alliance agreements are premised on joint management of risk for project delivery. All parties jointly manage that risk within the terms of an 'alliance agreement', and share the outcomes of the project" (Department of Finance and Treasury Victoria 2010, p9)

The above statements suggest a no-blame culture where the immediate response of project team members is to fix a problem rather than apportion blame and take defensive action to protect their individual home-base organisation's interests.

The commitment to acting in good faith by alliance parties and to sink or swim together sets the tone of the alliance culture linking powerful contractual incentives to contractual behaviour. This contractual arrangement provides a defining difference with other voluntary

collaboration project delivery approaches. The commercial contract element is established to be fair and to balance the right of NOPs to make a fair profit with the right and obligation of the project owner (PO) to ensure that value for money is competitively achieved. The concept of reasonable profit return and value for money is enshrined in the PA agreement as are expectations of collaboration. A no-litigation PA clause (unless there has been illegal acts or gross incompetence) replacing the normal rights to sue parties that do not perform to expectations with a collaborative, proactive, integrated and more responsive whole-project team approach to achieving key performance indicators (KPIs) and key results areas (KRAs) through linking incentives to behaviours. The behavioural contract element requires signatories to work together in good faith, acting with integrity and making best-for-project decisions. The incentivisation contract element ensures that the financial reward and penalty provisions drive motivation so that it is in the interest of all parties to work closely to achieve best value. The PA also pools its insurances with an alliance insurance agreement being negotiated rather than separate insurance requirements. This reinforces unity of purpose. A turn-out-cost (TOC) is established early in the alliance selection phase of the project to represent a fair and reasonable expected end costs and the details of budgets and all design and delivery assumptions are openly and transparently discussed and understood during initial post alliance TOC agreement workshops so that risk can be more effectively shared and apportioned to be managed by the most appropriate alliance partner. The TOC represents a best-practice cost target because of the shared knowledge and collaboration involved in its articulation and externally validated referencing. Potential gainsharing from the incentivisation contract leg is mainly achieved by innovation and so this arrangement encourages and facilitates innovation. Most innovation emerge throughout the project delivery phase as clearer understanding of the unfolding events of the project offer opportunities for refining best practice methods and for creative out-of-the-box thinking.

2.4 What do we mean by Trust?

The PM contextual literature on trust as it applies to the relationship of parties within the construction industry is well developed (Kadefors 2004; Smyth 2005;2006; Smyth and Pryke 2008; Smyth, Gustafsson and Ganskau 2010) This brings us to a discussion about PA behavioural drivers. Much of the theory stems from the concept of trust as being calculative by parties involved and this is based on self interest.

Trust is a function of a trustor's propensity to trust and their level of understanding of the context. This is mediated by their perception of the ability (individually and organisationally constrained), benevolence and integrity of those being trusted together with the type of experienced (in terms of want-to, ought-to or must-do) commitment and the depth of that commitment. The trustor takes a risk on something and the outcome of that is tested so this means that the trustor requires experience in testing a trust-risk outcome as well as be clear on what the outcome actually is and the context in which the test occurs. Perceived conclusions lead to re-calibration of trust.

Smyth (2006, p102-103) makes the point that the models derived from Mayer's work are predicated on calculative trust. This particular world view refers overwhelmingly to *self-interested trust* where there is minimal evidence of trust but estimated high levels of mutual

self-interest in obtaining a win-win outcome from the relationship. This requires the parties to trust each other and the systems in place to enforce that trust. Smyth contrasts that with *socially oriented trust* in which the enforcement mechanisms are social and potentially more powerful. He includes such things as social networks, peer-values, brand/reputation and the need for collaboration in these. Trust is realised at "a deeper level, generated through obligations in a social network and comes through reputation, advocacy and especially supportive relationships, where the motive is, ''What can I do for the other party?" (Smyth and Edkins 2007, p234). Social trust is potentially more effective because calculating self-interest and motivation is fraught with hazards of under/over estimation and short term perspectives while social trust is much more attuned to long term assessment and being intrinsic and thus more in line with affective, rather than normative or continuance, commitment. He illustrates a model in which conditions of trust lead from calculative self-interested trust towards socially oriented trust through mechanisms of faith (unseen capabilities of others parties to perform), hope (that they will perform to that expected) and confidence (based on experience of past performance, reputation etc. and as an indicator of future performance) building within a socially driven (rather than governance and hierarchy driven) context. The model's building blocks are stated as characteristics of trust, components of trust and conditions of trust (Smyth 2006, p114-115).

Trust may be linked to formal control but not necessarily directly. From a transaction cost economics (TCE) perspective the 'cost' or 'value' of trust is a related to governance burden the effort and cost of ensuring that parties do not take advantage of each other. Bijlsma-Frankema and Costa (2005) present a model of trust and control co-existing as long as there are shared accepted rules and positive exchanges and in terms of PAs there is an acceptance of transparency, open-book monitoring and commitment to fairness, honesty and each party's right to clarify motives, advantages and other aspects that represent social rather than rule-based forms of control. This is likely to better encourage collaboration.

2.5 What do we mean by a No-blame culture?

The National Alliance Contracting Guidelines Guide to Alliance Contracting (Department of Infrastructure and Transport 2011, p19) highlights several no-blame features including: good faith in acting with integrity in making best-for-project decisions; peer relationships; respect for others and their expertise: and "… *where each Participant has an equal say in decisions for the project. It is expected that all joint decisions made by the Participants will be best-for-project […] The establishment of a 'no fault – no blame' culture underpins the alliance delivery method. It involves a commitment from each of the Participants that, where there is an error, mistake or poor performance under the alliance contract, the Participants will not attempt to assign blame but will rather accept joint responsibility and its consequences and agree a remedy or solution which is best-for-project. If the Participants disagree, they must work together to resolve issues in a best-for-project manner"* (p19-20).

Contractual drivers specifically detail requirements referenced to a project brief that specifies deliverables and applicable performance measures to verify delivery within an acceptable boundary. The brief and contractual obligations become artefacts that are sensed as 'real'.

These measures contribute control artefacts that provide a boundary to delivery expectations as well as rewards and incentives.

Figure 1 illustrates the dynamics at work. The no-blame culture is predicated by both contractual and behavioural drivers that deliver a platform for performance that has at its core a paradigm or theory about the best way for the PO and NOPs to interact and conduct business. Their world view is shaped by their values and potential perceived rewards.

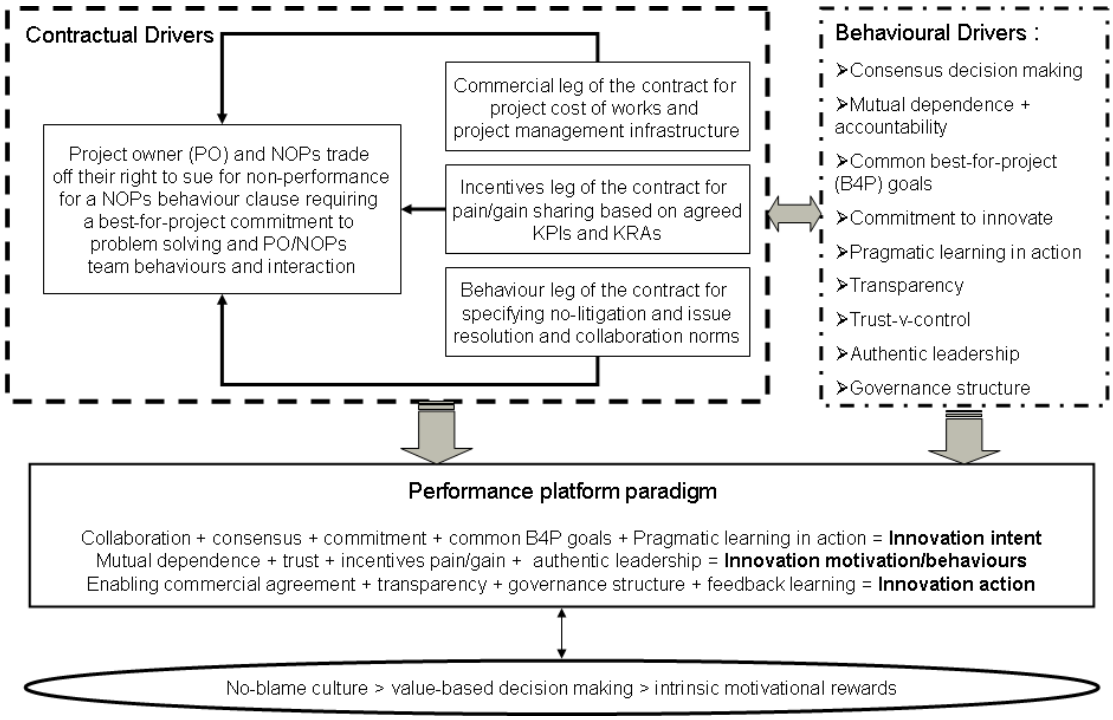

Figure 1: Characteristics and Impact of the no-Blame Culture

Behavioural drivers of PAs are interesting because they are reliant upon process thinking and an interpretivist paradigm. Consensus decision making for example can only effectively be achieved if egos are set aside and participant who traditionally would be 'in charge' take the time and effort to genuinely engage in dialogue where they try to understand, re-interpret their own assumptions and judgements toward a mutually negotiated outcome. This more closely resembles an interpretivist *becoming* paradigm than a *positivist* being paradigm. True consensus requires skills in being empathic and being able to accept the perception of others as a valid negotiating point. Consensus behaviours turn power and communication imbalances to symmetrical input mechanisms that allow consensus about a solution to emerge that has greater intellectual and experiential input that leads to greater commitment by all parties to the decision. The sink-or-swim contract condition in PAAs, along with the practical need for consensus building, means that accountability, transparency and mutual dependence are necessary. Trust and control dimensions provide an interesting backdrop to alliances. PAs closely resemble joint ventures in their shared goal and requirements for integration and collaboration with features of high trust and high control (Das and Teng 2001) this is similar to the high trust and simultaneous distrust described by Lewicki, McAllister and Bies (1998). The high control aspect in PAs is generally monitored through adherence to KPIs and an open-book approach to probity and auditing. This provides both trust and what may be perceived as distrust. Alliance members trust the governance

arrangements, and integrity of probity of those that audit them through open-book access to their financial and business records.

A no-blame culture develops from these features because consensus means that if all agree to a course of action then individuals can hardly opt out when they feel it inconvenient. The transparency and open-book approach lowers fears that any party can 'cheat' the system. Mutual dependency binds participants more closely together because the incentive contract rewards project, not individual, performance. The signing off on agreement to strive for best-for-project decisions triggers an important behavioural mindset to aim for pragmatic action. All strive for best-for project with an understanding that this involves trying new approaches and recalibrating efforts pragmatically when better understanding of the context require plans to be changed.

Authentic leadership is an important PA behavioural trait in which leadership action is aligned with rhetoric and is consistent with liberating team members to maximise their contribution and a best-for-project attitude is demonstrated. Leadership may be officially vested in the PA manager but in reality it is distributed because individual project team members take the initiative when and as required based on their expertise, contribution and input into best-for-project decision and action outcomes.

Finally, the PA governance structure supports the behavioural contract. Governance aspects that are absent from many other collaborative procurement forms include the enforcement of a mutual respect clause in the PAA through a dispute and issues escalation policy that clearly identifies escalation steps when issues can be resolved at any one level. This is an important measure which is shared by partnering but when combined with the sink-and-swim-together culture it adds another important layer to the effectiveness of consensus decision making. PAA governance is design to reinforce the links between incentivisation, contractual performance and behavioural performance measures so that it becomes a unique procurement design to achieve consensus, create a no-blame culture and therefore redirect resources away from defensive routines to more constructive action.

We suggest in Figure 1 that the no-blame culture is the key to making value-based decision making that in turn generates intrinsic rewards.

This section has helped to answer how a project team's no-blame culture facilitates innovation in construction PAs. In the next section we provide a model of no-blame culture to frame evidence that supports this assertion.

3. Explanatory Model Based on a Case Study

This section draws upon data gathered on a recently completed PA in Melbourne that is indicative of the process of no-blame that generally occurs across all project alliances that we have studied. These include a longitudinal study of the National Museum of Australia reported upon in a book (Walker and Hampson 2003) and a 2010 study of ten alliance managers (AMs), three managers of AMs plus two validation workshops with two additional Alliance Leadership team members and seven other alliance team members (Walker and

Lloyd-Walker 2011). The following figures were provided by the AM from the recently completed Hamer Hall project.

Figure 2 illustrates the business as usual case in traditional projects where each participant looks after their own interest as the first priority.

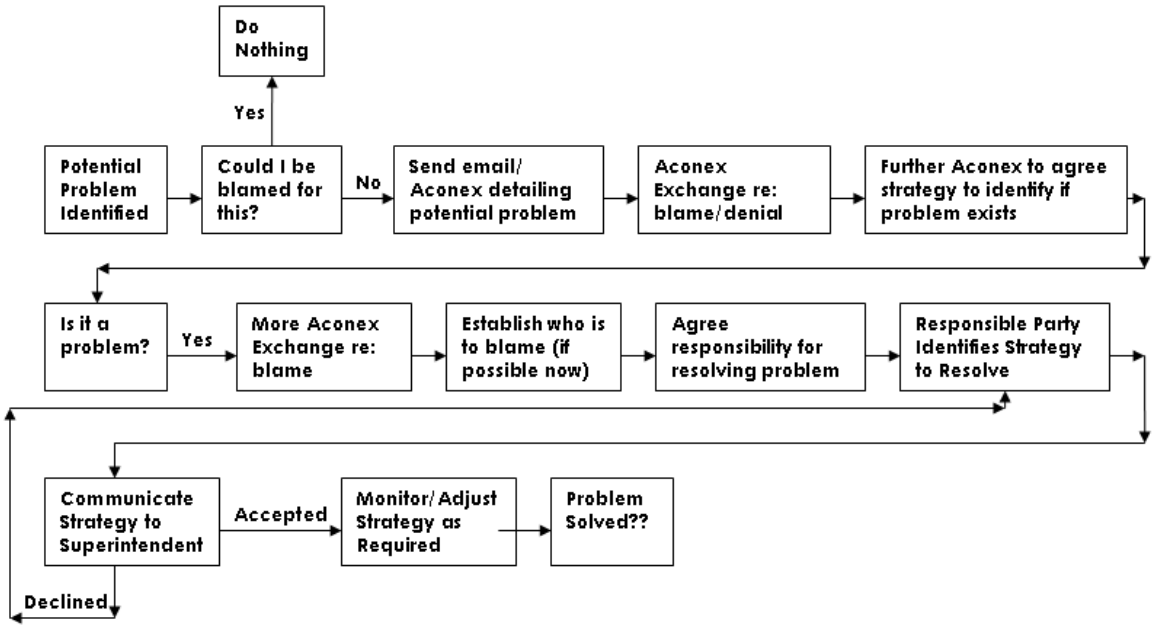

Figure 2: Typical Business-as-usual Problem Solving Model (Pitman 2012)

Aconex is the electronic groupware communication platform used on the project. Figure 2 begins with a problem being identified, typically an interface problem where there is no guidance on which project participant was responsible for temporary work that is clearly needed to maintain schedule. It is clear who is best placed to undertake this interface work but contract documents are ambiguous about who is responsible and somebody should be instructed to proceed with that action. Other typical examples may pertain to conformance to conflicting standards, legal requirements, local authority interpretations and an array of ambiguous resolution of coordination and compliance issues. Many other situations trigger such an event. Figure 2 clearly illustrates a trail of potential blame-shifting and inaction. This can be contrasted with Figure 3 which illustrates the same process following a potential problem being identified in a PA.

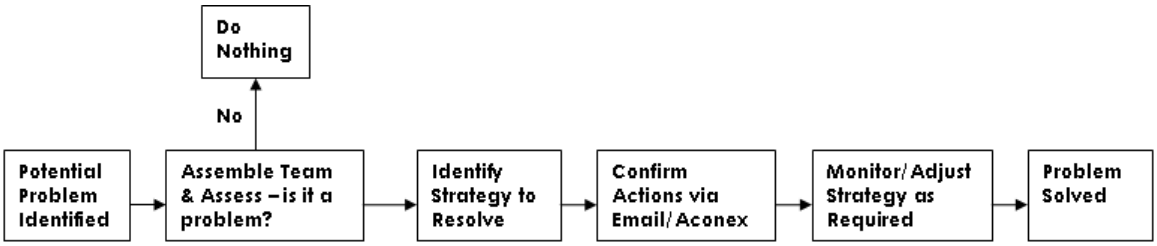

Figure 3: Typical Project Alliance Problem Solving Model (Pitman 2012)

Figure 3 begins in the same way as Figure 2 except that the relevant team members are assembled to assess and make a judgement about the identified problem. This *ad hoc* team would comprise those that the governance system would require to take action so that

authority to proceed and conversations about liability, accountability and responsibility can be dealt with together against the backdrop of the “incentivisation” and behavioural leg of the PAA. Because it is in the interest of all parties to resolve the issue quickly and pragmatically, and because the best-for-project behaviour is linked to potential pain/gain sharing a totally different dynamic is enacted to that portrayed in Figure 2. Additionally, the *ad hoc* team can thus create new knowledge about the context that triggered the problem through a more thorough and wide reaching investigation of potential cause and effect loops and other symptoms and causes. This is achieved by looking at the ‘problem’ with the broad expertise of the *ad hoc* team and considering potential opportunities triggered by the crisis event. The focus that is applied because of the governance system (the way that teams are designed to behave towards each other, the contractual arrangements and the ambience of the PA) dismisses issues of blame from the conversation and instead introduces an action learning process to both resolve the issue and to imbibe and absorb learning from this learning event exercise.

In this way a strategy to resolve the problem is developed, this is confirmed and documented through the document sharing system for later access as a potential ‘lesson learned’ and the action is processed with monitoring, adjustment and further documenting of the action and how the process worked. The problem is thus resolved. More importantly perhaps is the intangible value created through this illustration of the process. This can be summarised for successful problem solving as:

1. The problem is more effectively and efficiently resolved;

2. Relationships are generally enhanced and reinforced through collaborative problem-solving that increases absorptive capacity and generates new knowledge about the project context;

3. The value of collaboration and knowledge sharing is enhanced and so the perceived value of each participant in the *ad hoc* team and what they offer in terms of knowledge, skills, experience and social capital is enhanced;

4. The project context becomes better understood and appreciated and so it becomes a richer context in terms of knowledge transfer, often team members learn something new from exposure to solving the problem;

5. The process is documented to make explicit previous tacit knowledge and to embed that through productive socialisation, theories are tested by experimentation; and

6. A potential innovation may have resulted out of this process to be leveraged throughout the project.

4. Discussion and Conclusions

The PA agreement is critical in that stipulates the way in which the PO and NOPs will interaction collaboratively in addressing the frequent and inevitable problems that arise from

uncertainty in planning and delivery of projects. It specifically ***requires*** collaboration and consensus and it establishes a governance framework through the PAA for fair payment of work undertaken, collaborative engagement on problem solving and a pain/gain sharing formulae to incentivise the world view and actions of participants based upon the overall project performance as stipulated by agreed and clear KPis. Trust is designed into the approach through self-interested trust and PAA terms as well as through socially oriented trust embedded in both the PAA and the PA work practices. This socially constructed approach that uses a 'real' PAA artefact effectively negates the tendency to blame so that a full repertoire of options to solve problems as they arise and this leads to innovation in process, ways that work may be undertaken and even re-design of product elements. We illustrated how a typical problem arising out of project work is handled in Figure 2 and 3.

Figure 1 illustrates the characteristics of the no-blame culture that is designed and delivered through the PAA commercial, behavioural and incentivisation elements. In this way we answer the research question posed and demonstrate the elements of safety that constitutes the no-blame culture, how it is configured and how it is enacted.

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Prefabrication within the Electrical Construction Industry – a Survey of Electrical Contractors

Lonny Simonian[1] and Thomas Korman[2]

Abstract

Prefabrication has been defined as "a manufacturing process that generally takes place at a specialized facility, where materials are joined to form a component part of a final installation" (Construction Industry Institute). Also, Preassembly may be defined as "a process where materials, prefabricated components, and/or equipment are joined together at a remote location for subsequent installation as a sub-unit; generally focused on a system" (Construction Industry Institute). The use of prefabrication and preassembly have the potential to significantly reduce project duration, improve productivity, reduce labor needs and costs, and improve safety (National Electrical Contractors Association 2009). Projects with prefabricated assemblies also may result in cleaner construction sites due to the fact that many MEP systems are prefabricated offsite and brought on the site in assemblies, resulting in less fabrication equipment needed onsite (Khanzode 2008).

This paper presents the results of a survey of electrical contractors on their use of prefabricated electrical assemblies. The survey topics include: how the use of Building Information Modeling (BIM) enhances the prefabrication approach, systems and assemblies that are candidates for prefabrication, cost and/or time savings associated with prefabrication, scheduling improvements achieved through prefabrication, coordination of prefabricated assembly installation with other contractors, and size, type, and composite crew utilized for prefabrication. The results are correlated to the size of the construction company, size and cost of projects, types of construction market sectors, and type of project delivery.

Keywords: Building Information Modeling (BIM), Prefabrication, Preassembly

1. INTRODUCTION

This paper presents the results of a survey to determine the best management practices (BMP's) and outlining the benefits of using prefabrication for Electrical Contractors. The project had the following objectives:

- Increase awareness of technology available for use by Electrical Contractors in MEP coordination, pre-fabrication, and pre-planning processes

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- Provide recommendations for Electrical Contractors when performing MEP coordination that will incorporate pre-fabrication, field assembly methods, and pre-planning.

- Guidelines for MEP coordination, which incorporate standard field installation methods and encourage pre-fabrication practices

2. METHODOLOGY

Survey questions were formed with input from ELECTRI-International (EI) council members; EI is the research foundation for the National Electrical Contractors Association. The survey was designed in two parts; the first obtained information regarding individual company background while the second focused upon the use of Prefabrication.

2.1 Company Background

1. What is the dollar value of your company's business?

2. What is the range of your projects, in square footage?

3. What is the range of your projects in constructed cost?

4. What is the percentage of each of your company's market sectors?

5. What is the percentage (of your company's total) for each type of project delivery?

2.2 Prefabrication

1. How has the use of BIM enhanced your prefabrication approach?

2. Does your company utilize any prefabricated assemblies?

3. Do you prefabricate the assemblies yourself?

4. How has the use of BIM enhanced your prefabrication approach?

5. What are your most frequently used prefabricated assemblies?

6. What other systems/assemblies are you considering for prefabrication?

7. What time savings do you attribute to using prefabricated assemblies?

8. What cost savings do you attribute to using prefabricated assemblies?

9. Does prefabrication allow you to perform work out-of-sequence (earlier) than conventional fab-in-place?

10. When/How do you coordinate the prefab installation schedule with the General Contractor (GC) and Mech. Contractor (MC)?

11. How large is your prefabrication shop? (e.g., number of workers, square-footage, etc.)

12. What special equipment/tools do you use in your prefab shop?

13. What is the difference between your composite crew rate for field fabrication and shop prefabrication?

3. SURVEY RESPONSES

Initially, one hundred and fifty (150) companies were selected for the survey. Selection was based on National Electrical Contractors Association (NECA) membership and geographic location. In order to be able to obtain a representative sample, companies were selected from NECA member lists from chapters located throughout the United States. The companies were selected based on annual dollar volume of work completed during the last year. Three ranges were selected: small, medium, and large. Small companies included companies with an annual dollar volume of less than $100M USD per year. Medium companies included companies with an annual dollar volume of between $100M and $250M USD per year. Large companies included companies with an annual dollar volume greater than $250M USD per year. Following the initial survey, an additional one hundred and fifty (150) companies were added in order to gain more responses. For the second round of companies, the selection process focused on companies located in major metropolitan areas throughout the United States where there has been historically a high volume of electrical construction. In total, 259 electrical contractors were contacted, 147 had the survey emailed to them, 100 were contacted by phone, and 55 returned a completed survey. A flow diagram is shown in Figure 1 for clarity.

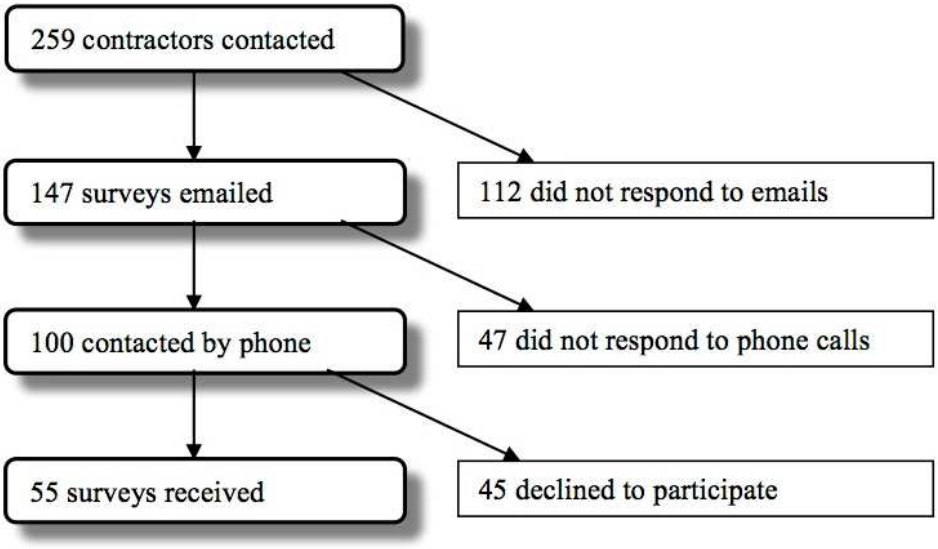

Figure 1 – Flow Diagram of Survey Solicitations

4. SURVEY RESULTS

4.1 Company Background Responses

4.1.1 What was the $ USD volume of your company's work last year?

Responses ranged from $8 USD to $455M USD. The median was $116M USD.

4.1.2 What is the range of your projects, in square footage?

Responses ranged from less than 1,000 square feet (93 square meters) up to 3 million square feet (278,710 square meters).

4.1.3 What is the range of your projects in constructed cost?

Responses ranged from less than $1,000 USD up to $350M USD.

4.1.4 What is the percentage of each of your company's market sectors?

Market Sector	Low (%)	High (%)	Median (%)
Residential	0	100	5
Commercial	0	90	39
Institutional	0	80	20
Industrial	0	100	21
Process	0	55	5

A composite breakdown of all market sectors is shown in Figure 2.

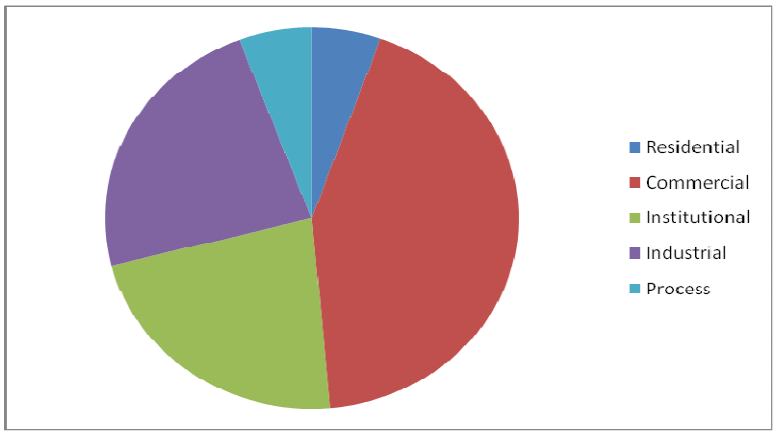

Figure 2 – Composite breakdown of company market sectors

4.1.5 What is the percentage (of your company's total) for each type of project delivery?

Project Delivery Method	Low (%)	High (%)	Median (%)
Design Only	0	80	5
Design-Bid-Build	0	100	14
Pure Design-Build	0	70	40
DB w/Bridging*	0	70	13

* Also referred to as DB assist

A composite breakdown of all project delivery methods is shown in Figure 3.

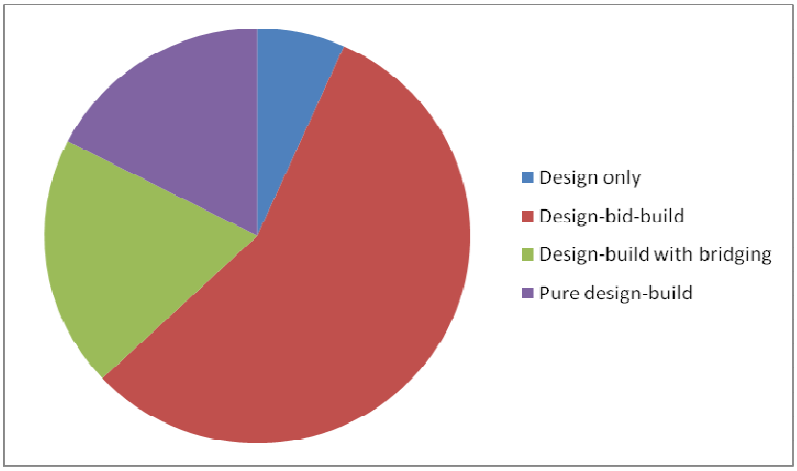

Figure 3 – Composite breakdown of project delivery methods

4.2 Prefabrication Responses

4.2.1. How has the use of BIM enhanced your prefabrication approach?

All survey respondents indicated that the use of BIM has enhanced their ability to prefabricate electrical assemblies for installation. Most survey respondents indicated that the greatest value from the BIM model was the ability to visualize the system in 3-D. Using the visualization capabilities of the BIM model allows detailers to group electrical components and determine appropriate assemblies for prefabrication. This process is more beneficial than using traditional hand or 2-D CAD drawings because when using the BIM model in the selection process, systems of the other specialty contractors can be taken into consideration due to BIM's visualization capabilities. In addition, using the electronic BIM model documents dimensions that can be validated much easier and results in increased confidence and accuracy, allowing for more prefabrication than in the past.

4.2.2. Does your company utilize any prefabricated assemblies?

The vast majority (44) of the respondents use prefabricated assemblies, as shown in Figure 4. All contractors with a volume of work greater than $90M USD reported that they used prefabrication on their projects. Thus, there is a 100% correlation between the use of prefabrication and the contractors whose volume of work exceeded $90M USD. 23 contractors reported that they use BIM to construct their projects; of these, 14 report that they prefabricate assemblies. There also is a good (61%) correlation amongst those contractors who both use BIM and prefabricate their assemblies.

Only eight of the 55 responders reported that they did not use prefabricated assemblies. This pool consisted of those contractors whose volume of work ranged from $7.0M USD to $90M USD; the median for this group was $32M USD. All eight contractors in this group reported that they did not use BIM for construction. Thus there is a 100% correlation between those contractors who do not prefabricate assemblies and who do not also use BIM.

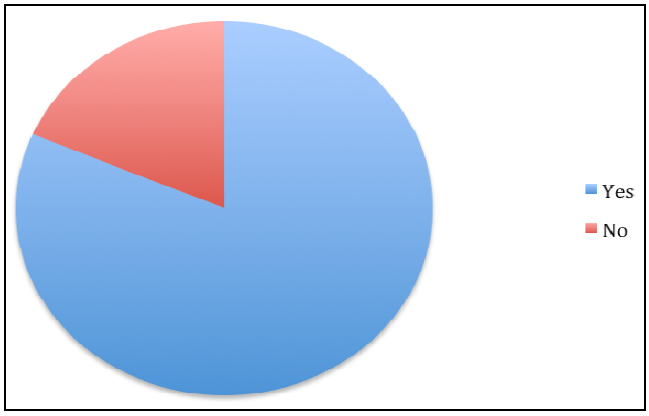

Figure 4 – Use of prefabricated assemblies

4.2.3. Do you prefabricate the assemblies yourself?

More than one half (30) of electrical contractors prefabricate their own assemblies, as shown in Figure 5.

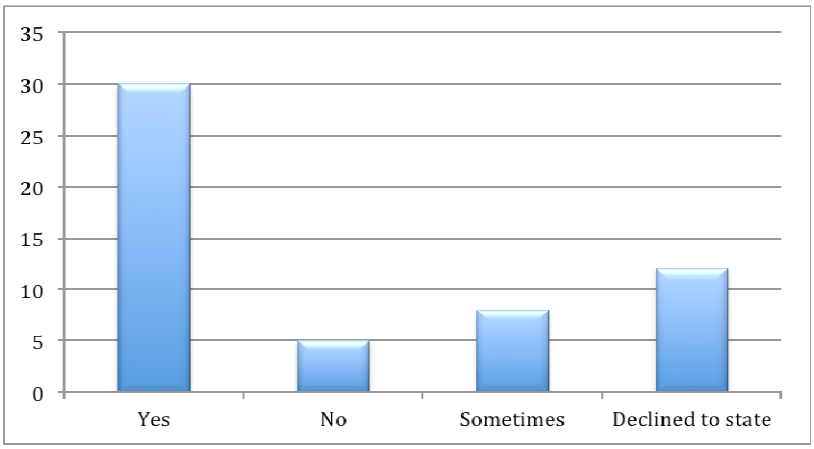

Figure 5 – Number of contractors who prefabricate their own assemblies

4.2.4. How has the use of BIM enhanced your prefabrication approach?

Several contractors reported that prefabrication was closely aligned with the use of BIM or a 3D model. Some of the most cited benefits included:

- Earlier information for prefabrication
- Fabrication directly from BIM model
- Assists and helps the installation process
- Validates dimensional concerns
- Increased accuracy allows more prefabrication opportunities

4.2.5. What are your most frequently used prefabricated assemblies?

The two most frequently prefabricated assemblies were device boxes and lighting fixture whips, as shown in Figure 6.

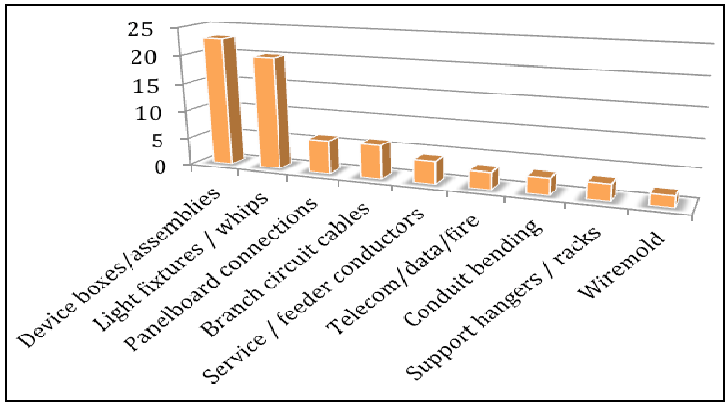

Figure 6 – Types of prefabricated assemblies (by # of contractors responding)

4.2.6. What other systems/assemblies are you considering for prefabrication?

The three most cited systems/assemblies considered for prefabrication were branch circuit cables, lighting fixture whips, and panel board connections, as shown in Figure 7. This is consistent with the results from the previous question.

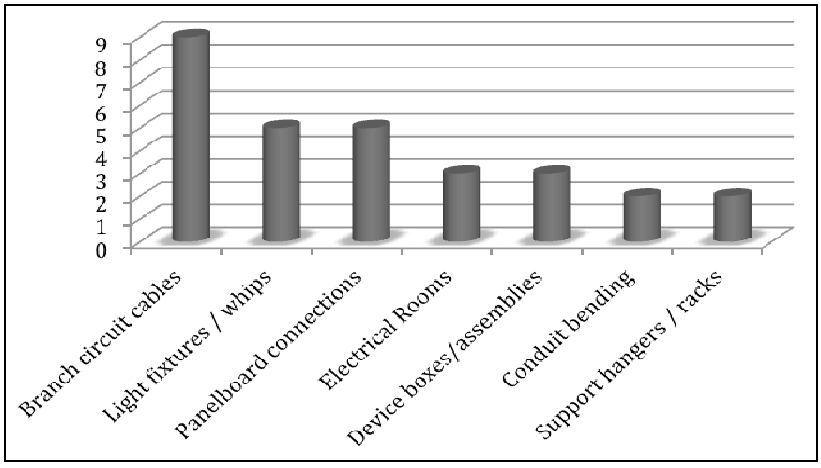

Figure 7 – Assembly candidates for prefabrication (by # of contractors responding)

4.2.7. What time savings do you attribute to using prefabricated assemblies?

The average time savings was 11-20% as shown in Figure 8.

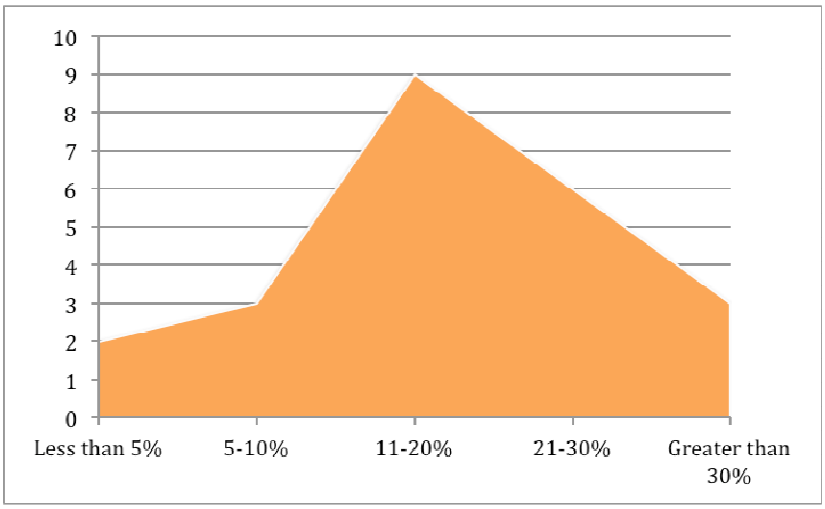

Figure 8 – Time savings using prefabricated assemblies (by contractors responding)

4.2.8. What cost savings do you attribute to using prefabricated assemblies?

The average cost savings was 21-30% as shown in Figure 9.

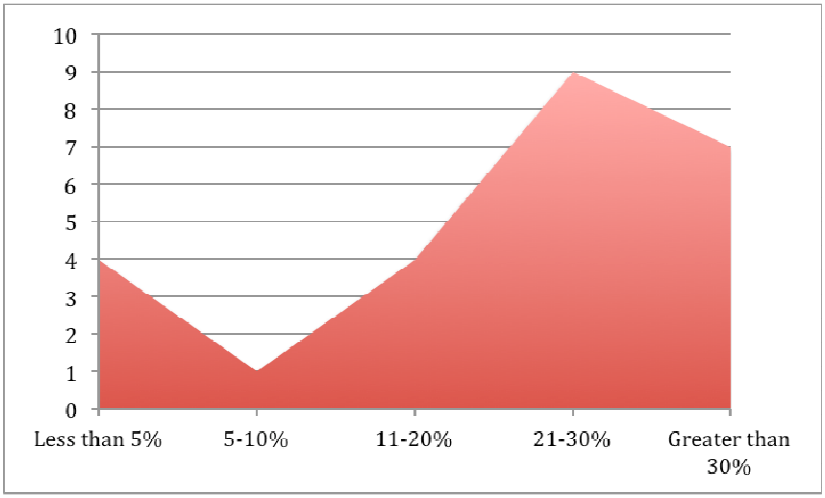

Figure 9 – Cost savings using prefabricated assemblies (by contractors responding)

4.2.9. Does prefabrication allow you to perform work out-of-sequence (earlier) than conventional fab-in-place?

One half (28) of the respondents reported that prefabrication allowed them to perform work out-of-sequence as shown in Figure 10.

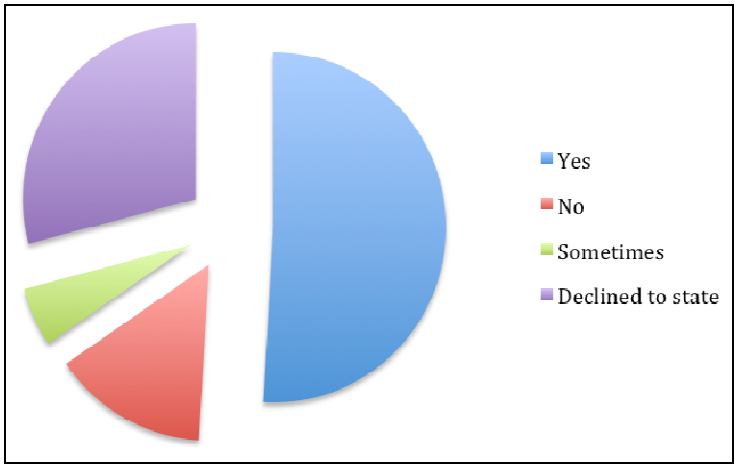

Figure 10 – Ability to perform work out-of-sequence due to prefabrication

4.2.10. When/How do you coordinate the prefab installation schedule with the General Contractor (GC) and Mechanical Contractor (MC)?

While some respondents stated that they did not coordinate prefabrication with the GC or MC, the majority of respondents coordinated their prefabrication installation as early as possible; this usually occurred at the bid and initial coordination meeting. They also coordinated their work throughout construction via BIM or 2D/3D meetings and information sharing. Some also engaged in wall mock-ups at the submittal stage.

4.2.11. How large is your prefabrication shop? (e.g., number of workers, square-footage, etc.)

Responses ranged from 2 to 10 employees and 1,000 to 50,000 square footage of shop space. The average was 4 to 6 workers in a 3,000 to 6,000 square foot shop.

4.2.12. What special equip/tools do you use in your prefab shop?

Special tools included:

- Plasma cutting machines
- Pipe cutting machines
- Computerized welding machines
- Specially equipped band saw
- Hydraulic benders
- Power cable stripper
- Power crimp tools
- MC cut/stripper machine
- Pneumatic tools
- Press Punch
- Welders
- Chop saw

4.2.13. What is the difference between your composite crew rate for field fabrication and shop prefabrication?

Respondents stated that they were able to have a consistently lower composite crew rate in their prefabrication shops due to the nature of the work and the skill level needed. This included a composite rate reduction of from 15-30% by using more apprenticed labor.

5. CONCLUSIONS AND RECOMMENDATIONS

All contractors responding to the survey who had an annual volume of work greater than $90M USD reported that they used prefabrication on their projects. Conversely, only eight of the 55 responders reported that they did not use prefabricated assemblies. Electrical contractors who use BIM indicate that an additional benefit in cost and time savings was the ability to prefabricate assemblies for direct installation.

There was a 100% correlation between those contractors who do not prefabricate assemblies and who do not also use BIM. Therefore, we concluded that if a design model was not provided, electrical contractors were not inclined to produce their own system model unless it was beneficial for their fabrication process.

6. ACKNOWLEDGEMENTS

The researchers would like to acknowledge the contributions of the ELECTRI Council members and staff who contributed to this project. The researchers wish to thank the ELECTRI Council for providing the financial support and the project Taskforce members for providing their comments.

The data collection for the preparation of this report would not have been possible without the hard work and efforts of numerous student research assistants, who obtained the data needed to complete the project.

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Capacity Building to achieve Sustainable Water Management System in Arid and Semi-Arid Lands (ASALs)

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Abstract

Arid and Semi-Arid Lands (ASALs) comprise of more than 40% of the earth's land surface and supports 20% of the total human population. Droughts, or periods of unusually low rainfall, are part of the expected pattern of precipitation in these regions. Over the past decade, the effects of climate change have become more pronounced, leading to reoccurring cycles of drought in ASALs. The 2011 drought in the Horn of Africa was considered to be the worst in past 60 years which affected 13.5 million people. Such events had far reaching adverse impacts on human health, food security, economic activity, physical infrastructure, natural resources, environment, and national and global security. In order to improve the situation and mitigate the effects, government and NGOs continue their efforts for capacity building through water interventions and training programs. But these initiatives are often short term and uncoordinated. Therefore, there is a need for a holistic framework for capacity building to achieve a sustainable water management system in ASALs. This paper outlines a framework for capacity building that aims to integrate indigenous water management systems with strategies required to overcome current issues. Main focus of this paper is to illustrate three types of capacities (economic, social and environmental) at three levels (individual, organizational and system) to achieve a sustainable water management system and to present a framework that involves five defined phases of capacity building. These five phases are preparation, assessment, planning, implementation and evaluation. This framework would assist in achieving reliability of long-term water availability and enhance self-reliance over time.

Keyword: Capacity, Capacity building, Water management, Arid and Semi-Arid Lands, Indigenous knowledge.

1. Introduction

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Arid and Semi-Arid Lands (ASALs) are characterized by low and erratic precipitation which results in low and unpredictable crop and livestock production. Typically, arid areas are defined as those receiving less than 200 mm of winter rainfall or less than 400 mm of summer rainfall annually (UN Economic and Social Council 2007). Conversely, semi-arid areas are defined as those receiving between 200–500 mm of winter rainfall or between 400–600 mm of summer rainfall (UN Economic and Social Council 2007).The annual rainfall varies between 50-100% in the arid zones of the world with averages of up to 350 mm. In the semi-arid zones, annual rainfall varies between 20- 50% with averages of up to 700 mm (UN Economic and Social Council 2007). In Africa, ASALs (excluding deserts or hyper-arid lands) comprise of more than 40% of the land surface (UN Economic and Social Council 2007). Figure-1 shows a large portion of land area in Africa is currently under water stress and water scarcity (FAO 2008). According to the Falkenmark Water Stress Indicator, a country or region is said to experience "water stress" when annual water supplies drop below 1,700 m^3 per person per year. At levels between 1,700 and 1,000 m^3 per person per year, periodic or limited water shortages can be expected. When water supplies drop below 1,000 m^3 per person per year, the country faces "water scarcity".

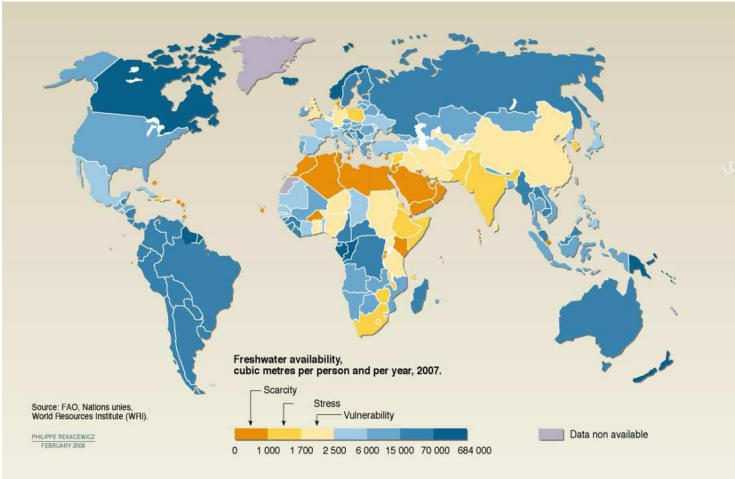

Figure 1. Freshwater availability around the globe (FAO 2008)

Most of the countries in Figure-1 which are under water stress and scarcity have “traditional‟ or “indigenous‟ approaches that have been used for managing water scarcity. They are based on lifestyle adaptations that minimized consumption and maximized beneficial local use (Arab Water Council 2008).The natives of these regions have several indigenous coping mechanisms to overcome the effects of drought in these areas. But studies conducted by UNEP in 2008 mentioned a steep decline in use of such knowledge in past few decades. A 2008 report by Arab Water Council also mentioned the dominance of indigenous knowledge up to the 1970s and increase in usage of modern water management practices after 1970. Though these technological innovations help for a short period of time, they significantly alter water management behaviors and create social, economic and environmental disruptions in these ASALs. Deep tube wells allow continual, unsustainable drawdown of aquifers as well as access to fossil water, wherever available. Pumps allow faster abstraction from canals and rivers than

previously possible, disrupting historical patterns of consumption. Some of the challenges causing these disruptions are short term planning and lack of a framework to build capacity (UNESCO-IICBA 2006). This paper aims towards identifying methods for building capacity to achieve sustainable water management system in ASALs of Africa.

2. Background

There are various definitions of "capacity" and "capacity building". Sometimes the terms are used in an ambiguous manner or without being defined (UNDP 2008, UNEP 2002). Hence, it is necessary to have a common and clear understanding of basic concepts. UNISDR (2009) defines capacity as, combination of all the strengths, attributes and resources available within a community, society or organization that can be used to achieve agreed goals. UNDP (2005) defines capacity building as sustainable creation, retention, and utilization of capacity in order to reduce poverty, enhance self-reliance, and improve people's lives. The term capacity building evolved from past terms such as institutional building and organizational development lead within UN systems for action and thinking (UNDP 2008). In the 1950s and 1960‟s these terms referred to community development that focused on enhancing the technological and self-help capacities of individuals in rural areas (UNDP 2008). In the 1970s, following a series of reports on international development, an emphasis was put on building capacity for technical skills in rural areas, and also in the administrative sectors of developing countries where training was the most important activity (UNDP 2008). For a long period of time capacity building was referred to training individuals. In the 1980s the concept of institutional development started expanding even more. In the year 2000, UNDP with its partner strategic GEF Secretariat, launched the Capacity Development Initiative (CDI), which involved extensive process to identify countries' priority issues in capacity development needs on global environmental issues. Then the three levels of capacity building were developed by UNDP as individual level, organizational level and system level (UNDP 2008). Individual level focused on attitudes and behaviors-imparting knowledge and developing skills of an individual entity while maximizing the benefits of participation, knowledge exchange and ownership (UNDP 2008). Organizational level focused on the overall organizational performance and functioning capabilities, as well as the ability of an organization to adapt to change (UNDP 2008). System level emphasized on the overall policy framework in which individuals and organizations operate and interact with the external environment (UNDP 2008).

In 2005, a German Donor Agency GTZ (Deutsche Gesellschaftfür Technische Zusammenarbeit) introduced the concept of five phases of capacity building cycle. These five phases were: preparation, analysis, planning, implementation and evaluation. Phase I is the preparatory phase of the capacity building cycle which addresses the agreement on objectives, the establishment of the work process at the individual, organizational and system levels. Phase II identifies existing capacity gaps in view of particular goal which has to be achieved. It determines capacities which need to be built, acquired or utilized. Phase III transforms identified capacity needs into time dependent capacity building strategies. Phase IV is implementation of activities that requires sound planning of measures and identification of capacity building service

providers to deliver specific services. Phase V is the final phase that evaluates the impact of capacity building (GTZ 2005).

Capacity building has evolved a lot in past decades but the 2005 report by World Bank Operations Evaluation Department, mentioned that capacity building was still not a well-defined practice in ASALs of Africa. Herold's 2009 report on water crisis in Africa mentioned that capacity building for water management has several challenges in almost all the ASALs in Africa. Various challenges mentioned in his report were:

- Immediate needs are addressed instead of long term planning. Capacity building caters to immediate water needs that creates mismatch between water supply and water demand grows in few years. Also as mentioned in the UNEP 2002 report, water demand calculations conducted in past took care of the immediate needs of water demand or need in near future thus if there is a drastic change in the future demand, the availability of water is not enough to cater the community.
- Absence of a capacity building framework. Different policies related to water securities and usage are not defined in usual water management programs and absence of these capacities lead to theft of water and over exploitation of water resources (UNESCO-IICBA 2006. Most of the communities in ASALs of Africa are poor and live a nomadic life, traveling with their livestock in search of water and pasture (FAO 2008). There is no legal administration regarding water security policies in those regions (UNEP 2002). Thus water theft arises purely from failure to define water rights, enforce monitoring, lack of interpretation of readily available information that is collected at great cost and enforce compliance.
- Several agencies understand capacity building as a post disaster need assessment programs whereas some believe that capacity building is limited to training people and organizations living in different communities (World Bank OED 2005).
- Decline in indigenous knowledge and its application is one of the biggest capacity building challenges in rural areas of ASALs of Africa (UNEP 2008, Arab Water Council 2008). Capacity building needs a lot of community interaction and involvement, indigenous skills, customs and social norms help the better involvement of pastoral communities in ASALs.
- Capacity building is always performed to achieve agreed goals but often the goals are not clearly defined.
- Unavailability of local authority and legal framework. Capacity building is a long term process and thus it is important to understand the different capacities which need to be developed in order to achieve the goal.

Thus these challenges clearly define the necessity of a capacity building framework for an agreed goal, i.e., to achieve sustainable water management system in ASALs of Africa. There is a need to revive indigenous water management practices with strategies to overcome these challenges. This can be done by using the capacity building framework and understanding the underlying importance of indigenous knowledge for efficient use of resources and the ability to deliver social, cultural and economic needs of the community. This would increase reliability of

long-term water availability in ASALs of Africa and have a potential impact on social, economic and environmental condition of such regions. This paper presents a capacity building framework to achieve sustainable water management system in ASALs of Africa.

3. Research Methodology

Research methodology can be divided in three tasks. (i) Various indigenous water management practices in ASALs around the globe were identified from existing literature as well as the evolution of capacity building was identified. (ii) Second task focused on developing the entire capacity building framework which includes feasibility study of the various indigenous water management practices, selection of a practice to define the goal of capacity building, five phases of capacity building and development of a system dynamic model for a long term projection and sustainable retention of water. (iii) Third task included application of the framework, results and analysis. This paper illustrates the development of the framework whereas application of this framework is subject of another paper.

4. Development of the framework

A generic flowchart of the framework is shown in Figure-2.

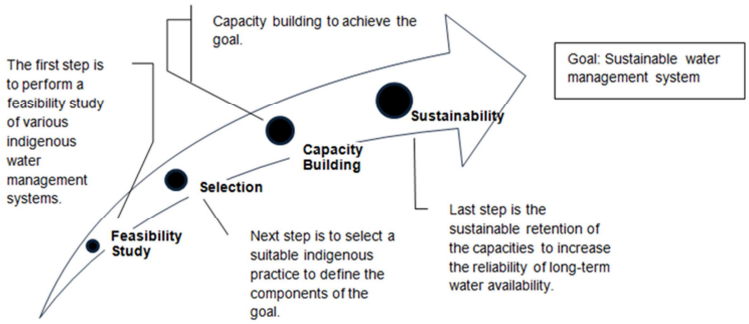

Figure 2. A generic flowchart of the capacity building framework (Sinha 2012)

4.1. Goal: Sustainable water management system

A Sustainable water management system in this research is defined as a system that utilizes rain water harvesting technique to store water using a selected indigenous water management practice. This system addresses the current issues of water management in ASALs of Africa in terms of water security and water usage policies, financial constraints related to construction and maintenance of the system, and legal framework to implement those policies. A capacity matrix is proposed in this research to be utilized during the first four phases of capacity building.

4.2. Feasibility study

Table 1 shows feasibility study of some of the indigenous water management practices selected to be studied for this research based on their cost of construction, water contamination and loss of water due to evaporation. 2004 SASOL report mentions that these three parameters are important technical criteria before selecting any water intervention in ASALs.

Table 1. Feasibility Study of various indigenous water management practices

	Definition	**Cost (USD/m^3)**	**Contamination**	**Evaporation loss**
Roof catchment Systems (UNEP/SEI 2009)	Rooftop catchment systems collect rainwater from the roofs of houses, schools, etc., using gutters and downpipes and then store it in containers that range from simple pots to large ferrocement tanks. It is practiced around the globe.	7-15 depending on the type of construction material for container	Low contamination. Very close to portable drinking water	Evaporation loss of water is low in a covered container
Ponds and Pans (Gomes 2006)	Ponds and pans are like a hole dug in the ground, which can be square, rectangular or round. Very common practice in ASALs of Africa and Asia	30-130 depending on the type of construction material and design of pond	In absence of a silt trap, water in ponds and pans have high contamination	Evaporation loss of water is high
Underground Tanks (UNEP/SE 2009, Gomes 2006)	Some communities in ASAls of Africa, Asia and Middle East also direct runoff water into an underground tank or cisterns dug into the ground.	10-150 depending on the type of construction material and design of tank	Contamination is low in a covered underground tank	Evaporation loss is low in covered underground tank
Johad (Hemispheres 2007)	Johads are simple mud and rubble barriers built across the contour of a slope to arrest rainwater. It is primarily used in ASALs of India.	1-4 depending on the design	Relatively high water contamination	Evaporation loss is high
Sand dam (www.sandam.org, last visited Nov 2012)	A sand storage dam(Or sand dam) is a small dam build on and into the riverbed of a seasonal sand river. Practiced primarily in Ethiopia and Kenya	0.8- 2 depending on construction material	Low water contamination due to sand that acts as a filter	Evaporation loss is almost negligible

4.3. Selection

As evident from table 1, among all the practices, sand dam is the least expensive water management practice which stores water within the sandy riverbed causing low contamination as well as almost negligible water loss due to evaporation. Thus in this research, sand dam is selected as the water storage component of the sustainable water management system.

4.4. Capacity Building

It is understood from the evolution of capacity building that it occurs at three different levels (individual, organization and system). But capacity building initiatives still lack a framework that differentiates in various types of capacities such as social capacity, economic capacity and environmental capacity. Hence a capacity matrix is proposed in this paper which includes not only the levels of capacity but segregates them as social, economic and environmental capacity. UNISDR (2009) defines capacity as, combination of all the strengths, attributes and resources available within a community, society or organization that can be used to achieve the agreed goals. Following the same definition in this research; social capacities are defined as those strengths, attributes and resources which are defined under social parameters related to health, education, resource management, population etc. Economic capacities are those strengths, attributes and resources related to funds and financing and Environmental capacities are those strengths, attributes and resources available within a community, related to environment e.g. river, topography, environment protection policy, environment protection activity etc.

Capacity building is a five phase (preparation, analysis, planning, implementation and evaluation) cyclic activity. In this research the proposed matrix is utilized in the first four phases of capacity building and for the last phase which is the evaluation phase a system dynamic model is proposed to show the water projection as a result of this sustainable water management system.

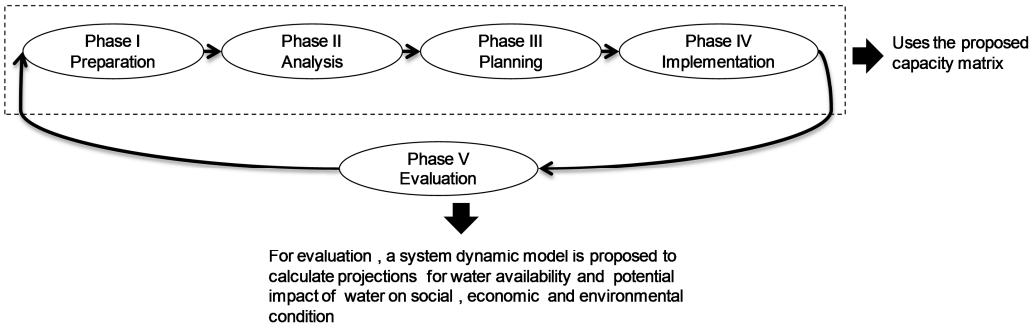

Figure 3. Capacity building phases

4.4.1. Phase I Preparation

The preparatory phase of the capacity building cycle addresses the agreement on objectives and the establishment of the capacities required to achieve the objective at the individual, organizational and system levels depending on different capacity types. The objective of this

phase is to prepare for and set in motion a structured process of discussing each capacity required at each level to achieve the goal. In this research, the agreed objective of capacity building is sustainable water management system which includes construction of sand dam and other capacities including policies and resources. Table 2 demonstrates the preparation of the capacities using the proposed capacity matrix.

Table 2. Preparation phase capacity matrix

	Social Capacity	**Economic Capacity**	**Environmental Capacity**
System level	Water security policies	Government funds	Topography Sandy Riverbed
Organizational level	Local committee, NGOs, Materials	Committee funds	Environment protection agencies
Individual level	Labors, Skill	Livelihood	Environment protection activities

4.4.2. Phase II Analysis

Second phase of the capacity building cycle is the analysis phase which identifies capacity needs of a community based on a simple scale developed in this research. It identifies the capacities which are available, unavailable or have a limited availability. Unavailability shows that the respective capacity is not available and needs to be created or acquired in order to achieve the goal. Limited availability shows that the capacity is available but needs improvement to achieve the goal. Availability shows that these capacities are available within a community to achieve the goal. Thus for all the capacities mentioned in preparation phase to achieve the goal, capacity need assessment is conducted in analysis phase, using the mentioned scale.

4.4.3. Phase III Planning

The planning phase transforms the identified capacity building needs into time dependent capacity development strategies. Short term and long term capacity building action plan is accompanied by a list of activities in implementation phase to provide strategic direction for capacity building process in the future. Short term action plan focuses on those capacities in each capacity type which need to be either improved or acquired or created in a few months before or during the construction of sand dam, e.g., improvement of individual skill (social capacity at individual level) and selection of a riverbed (an environmental capacity at system level) are some of the capacity building activities which fall under a short term action plan. Long term action plan includes the rest of the limited available and not available capacities, which

cannot be developed immediately and needs to be developed over a year or more to achieve the goal, e.g., water security, financing opportunities and environmental protection policies (all three capacity types at system level).

4.4.4. Phase IV Implementation

Once the capacities are divided under short term and long term action plan, implementation schemas are prepared accordingly. The implementation of capacity building activities requires sound planning of measures and the identification of capacity building service providers to deliver specific services. The implementation of capacity building hence includes several types of activities geared towards each type of capacity at different levels. A continuous monitoring of accomplishments ensures that the capacity building process stays on track and that improved governance related products and services are made available to regional beneficiaries.

4.4.5. Phase V Evaluation

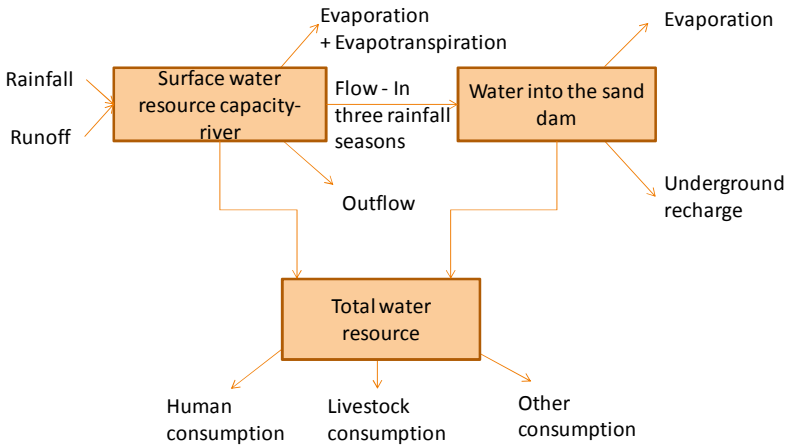

Figure 4. Schematic diagram to show causal relationship for part 1

The final phase of the capacity building process deals with the evaluation of overall outcomes and impacts obtained from capacity building and the goal achieved for the community. Following the implementation of planned capacity building measures, the outcomes and impacts need to be evaluated pertaining to the achieved goal and the impact on social, economic and environmental condition from a sustainable water management system. Thus a system dynamics model is proposed in this research. A system dynamics model helps in understanding the behavior of a complex system over time. Since water management in this research comprises of a complex set of physical and social systems hence system dynamics is used to develop a model to understand water demand and supply after the construction of sand dam. The model also helps in understanding the potential impact of water on social, economic and environmental conditions in ASALs of Africa. The model has two parts:

First part calculates the total water accumulated from surface water of the river bed and the water that is stored in sand dams after its construction. Before developing the model, present

water yield, water demand and total number of sand dams required to be built in a community needs to be calculated.

Three main parameters of the first part are surface water capacity of river, water into sand dam and total water available. The schematic diagram shown in Figure-4 depicts the inflows and the outflows of the three main parameters. Total water resource is the water consumed from surface of the river and from water in the sand dam. This water is consumed by humans, livestock and other facilities like hospitals, schools etc. Water on the surface of the river bed is received directly from rainfall and indirectly from runoffs and this water is lost through evaporation, evapotranspiration, overflow and a portion that goes into the sand dam. Similarly water into the sand dam comes from river surface and the outflow is either for underground recharge or a minimal evaporation loss.

Second part calculates the growth in human and livestock population due to direct impact of water availability. The causal loop for human population and livestock population is shown in Figure-5.

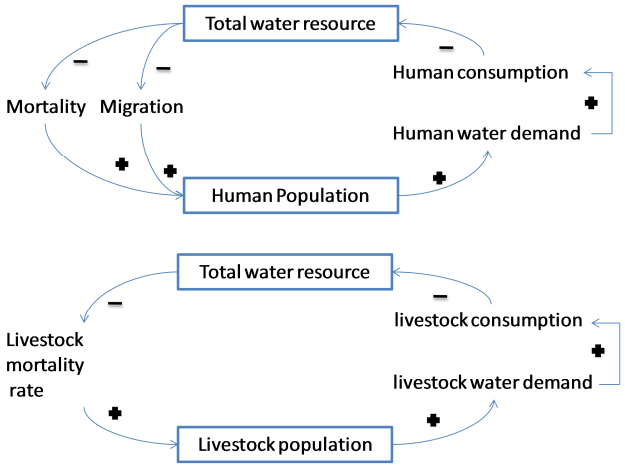

Figure 5. Schematic diagram to show causal relationship for part 2

In Figure-5, first two loops show that increase in total water resource decreases mortality rate and migration rate of human which increases the population which in turn increases the water demand, further increasing the water consumption which reduces the total water resource. The lower loop shows that increase in total water resource decreases livestock mortality rate which increases the livestock population which in turn increases the livestock water demand, increasing their water consumption which reduces the total water resource.

5. Results

The model was run to show a projection for 10 years for a hypothetical case where the total water demand from livestock, human and other facilities for a community was assumed to be 30,000 m^3/month (based on the literature review of ASALs in Africa) with an annual rainfall of 200 mm, mean annual rainfall of 2240 mm, evaporation runoff coefficient 70%. For the sand dam, available data saturation of sand dam is 45% of the volume of sand and total extracted water from sand dam was 35% (www.sanddam.org, last visited Nov 2012). The initial water in the riverbed was assumed to be zero as sand dams are built on perennial rivers and total number of sand dam was assumed to be 34.

The result (Figure-6) for this hypothetical case initially shows a decrease in total water resource (as the sand dam becomes fully functional in 20 months (Nissen-Petersen, 2006)), but after that it shows an increase in water availability which starts declining after end of 5th year, primarily because of the growth in water demand but even after 10 years with growth in population and other consumption, water is available; whereas during the past decade several regions in ASALs of Africa got water only during the rainy seasons.

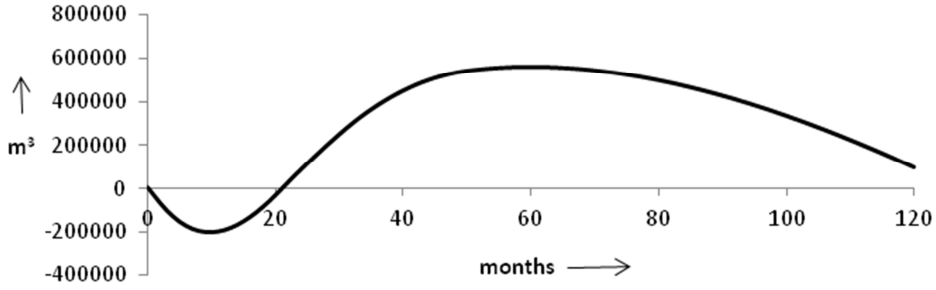

Figure 6. Results for total water resource (m^3) for next 10 years

6. Discussions and Conclusion

Indigenous knowledge for disaster management has helped various communities in Africa to survive in harmony with their environment but a decline in such knowledge is making these communities vulnerable to events like drought. The main aim of this paper was to develop a framework for capacity building to achieve sustainable water management system in ASALs of Africa. This sustainable water management system includes reviving an indigenous water management practice of ASALs of Africa such as sand dams and developing planned strategies for using the water efficiently for long term through capacity building framework. Capacity matrix proposed in this paper highlights different types of capacity along with the three levels of capacity which helps in understanding the importance of social, economic and environmental capacities. This matrix is used in preparation phase, analysis phase, planning phase and implementation phase of capacity building. For the evaluation phase of capacity building cycle a system dynamics model is developed that shows increase in reliability of water availability, using a hypothetical case for the base run of the model.

This framework would mainly assist government agencies and NGOs in their water management interventions in Kenya, Ethiopia and other ASALs in Africa with similar kind of disaster events and climatic conditions. This research helps in understanding capacities in form

of a complex matrix which can be used for achieving agreed goals of a community and is not limited to water management. The system dynamics model proposed in this research helps in understanding the continuous relationship between the demand and supply of water in any region and potential impacts of water availability.

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Community Directed School Infrastructure Development in Vanuatu

Lawther, Peter[1]

Abstract

The demand for primary level education in Vanuatu continues to rise driven by strong population growth and the introduction of fee-free schooling. This in turn places pressure on supply side educational requirements, of which school infrastructure is a significant one, and more broadly places achievement of relevant Millennium Development Goals at risk. School infrastructure includes classrooms, toilets, staff houses, dormitories, furniture etc.

The commonly used method for the provision of school infrastructure in Vanuatu is through a centralised (inside out) model implemented by the Ministry of Education, with international donor support. However, geographical and institutional constraints has resulted in an under supply of school infrastructure which is unable to meet increased demand for education.

As a result, a community directed school infrastructure pilot program was implemented in 2011/12, with the objective being to trial an alternative (outside in) delivery mechanism. In addition, a refined building design, which more aptly captures local knowledge, skill and maintenance requirements was developed, whilst retaining some deference to “imported” disaster risk reduction engineering principles. With support from the Ministry of Education and Donors, the new “hybrid” classroom building was constructed by “the community” of Takara, on Efate Island, Vanuatu and opened in May 2012.

This paper documents the rationale and implementation of the project, concluding that it represents a realistic methodology to address required school classroom provision in Vanuatu.

Keywords: Vanuatu, School Infrastructure, Community Directed Development, Hybrid

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1 Introduction

Increasing demand for primary level education in Vanuatu is being driven by strong population growth and the introduction of fee-free schooling. This demand is placing pressure on supply side educational requirements, including infrastructure. It estimated that some 200 school classrooms per year are required to be either refurbished or reconstructed to keep pace with enrolment demand. Whilst this figure has not been verified, it is clear that the current output of classrooms (approximately 30 – 40 per year) will not cater for this demand. Further, the current double classroom block design reinforced concrete is comparatively slow and expensive to build.

2 Current Method of Education Infrastructure Delivery

The design and delivery of school infrastructure in Vanuatu is the responsibility of the Ministry of Education (MoE). A standard double classroom design is used throughout the country. This design comprises a reinforced concrete frame with solid concrete block infill walls, and a timber framed metal deck roof. The MoE utilises a centralized approach to school infrastructure delivery throughout Vanuatu. Historically, this has operated with the MoE procuring materials centrally and distributing them to school sites on an "as needed" basis. Installation of the materials is in turn done by local contractors whom are sourced through competitive local bidding. This is essentially an "inside-out" control paradigm of infrastructure delivery which broadly places the Authorities at the centre of delivery, and communities at the periphery as per Figure 1 below.

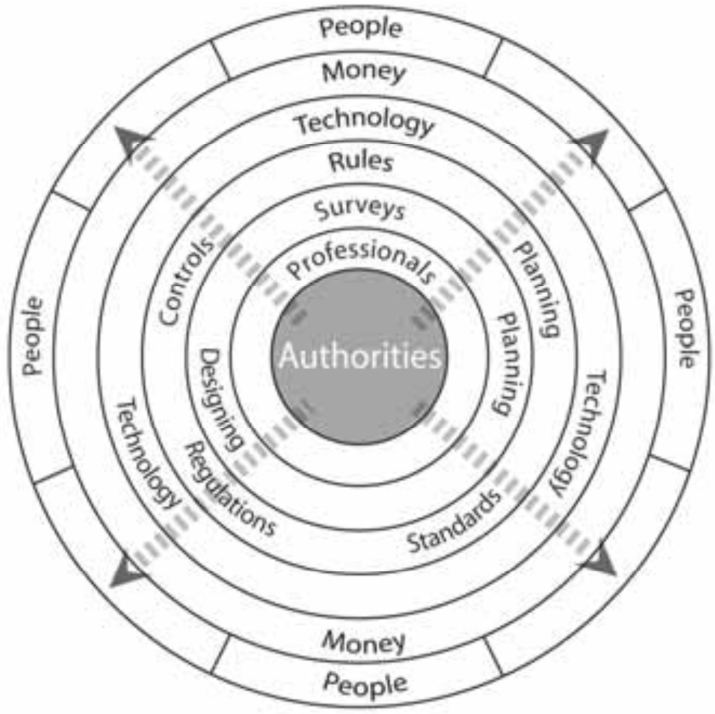

Figure 1: The Control Paradigm of Infrastructure Delivery (Lankatilleke 2010)

However, institutional capacity constraints (predominantly in the form of human resourcing) associated with this method of delivery currently result in an undersupply of classrooms

(approximately 30-40 per year), which clearly will not deliver the identified required output of 200 classrooms per year as stated above. As such, an alternative approach to school infrastructure procurement is required.

3 A Community Driven Development Approach

A Community Driven Development approach (CDD) is an alternative procurement option which has been used successfully in the Pacific (Lawther 2009), South Asia (Edstrom 2002, World Bank 2003), as well as a number of African countries (Theunynck 2009) to deliver school infrastructure on a large volume basis.

CDD essentially decentralizes the provision of school infrastructure from the MoE to the communities. The emphasis shifts from the current government provision of infrastructure to the community, to the community provision of infrastructure. In practice, the community is paid a stage based grant to deliver a facility that they identify as necessary for their local school, within an holistic school development plan. CDD leverages off existing capacities within communities and provides the necessary resources (usually money and technical expertise) to augment these capacities. In addition, communities are encouraged to think strategically about the immediate and longer term infrastructure requirements for their schools. Such an approach is commensurate with accepted development theory (Chambers 1997) which seeks to empower communities to identify and achieve their own development objectives, and thus delivery infrastructure through an outside in, or support paradigm, as shown in Figure 2 below.

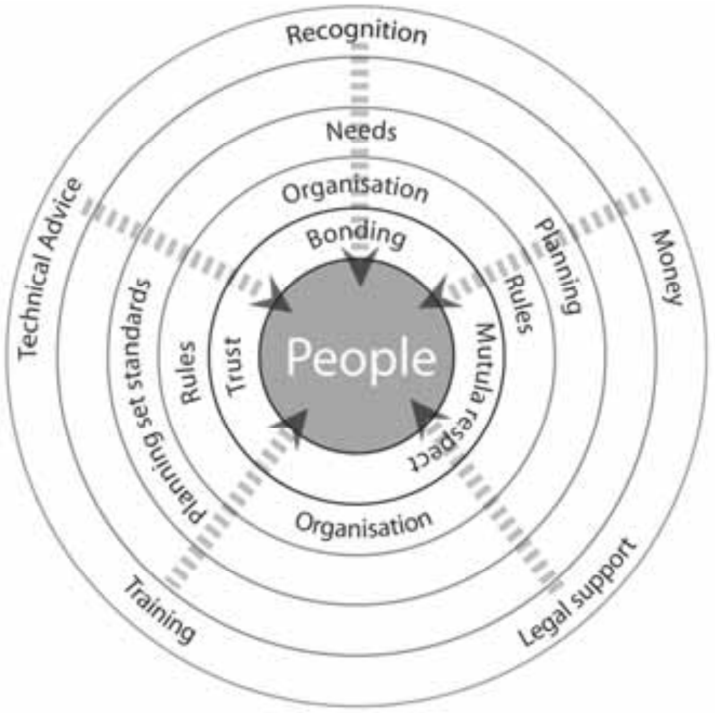

Figure 2: The Support Paradigm of Infrastructure Delivery (Lankatilleke 2010)

International experience (World Bank 2003) has shown that the transfer of responsibility from government to community for the delivery of small scale infrastructure, such as school buildings;

- leads to substantial cost-savings, community empowerment and ownership, increased speed of the execution of large programs of scattered small facilities, and in the case of school construction, increased participation of the community in the school life.
- community-based contracting is feasible and particularly desirable in remote areas.
- Governments consistently underestimate the capability of rural communities to mobilize and manage projects. Nonetheless communities need properly targeted mobilization and support, in order to succeed.

In addition, a CDD approach to school construction typically delivers the following benefits (Lawther 2009):

- reduced costs, through the increased use of lower cost rural labor, material and
- management capacities.
- greater maintainability, as the skills and materials needed to maintain the building are both sourced and developed locally.
- greater ownership, as the community sees the finished building as something they created rather something belonging to the Government.
- greater empowerment, as Villages successfully undertake the task of producing quality school buildings.
- better dialogue and relationships between Government and Village, through the process of working together.
- great economic benefits, as more of the work and money associated with school infrastructure investment flows through the Village, rather than directly to urban contractors and suppliers.

Success of CDD (World Bank 2003) depends upon the following principles:

- Investment in an awareness program to socialize the concept of CDD within communities.
- Use of local knowledge and having the local community participate in the design and ongoing review of the program.
- Working within existing community governance structures.
- Paying the community properly for the service they render the Nation through managing the construction of schools.
- Proper investment in the planning and management of the program.
- Use of financial incentives so that producing school buildings that are well built, and built quickly, delivers the greatest rewards for the community.
- Use of pro-active Quality Assurance systems that prevent mistakes before they happen, and help the communities to succeed, rather than identifying mistakes after the fact.

- Develop designs that are appropriate and attuned to the local skills and materials base, for ease of local production.
- Delegation of responsibility. It is better to give the community too much responsibility, and later pull back, than to be timid, and never know how much they are capable of.
- Maintaining simplicity by using minimum paperwork and procedures at the community level.
- Ensuring transparency and accountability by all members of the community being aware of where and how the finances are being spent.

Thus a CDD approach to the delivery of school infrastructure was piloted. This pilot required the design and construction of a “hybrid” classroom building. This is now considered.

4 The Hybrid Design

The overarching design philosophy of the project was to involve the local community as much as possible. This required the use of local materials to the full extent possible, coupled with the integration of discreet specific “western” seismic and anchoring details. This fusion of local and external technologies gave rise to the “hybrid” nomenclature”. The spatial layout of the classroom building was based upon the MoE’s existing double classroom layout, but with scalable flexibility as shown in Figure 3 below. In this sense the floor plan replicated the existing classroom facility.

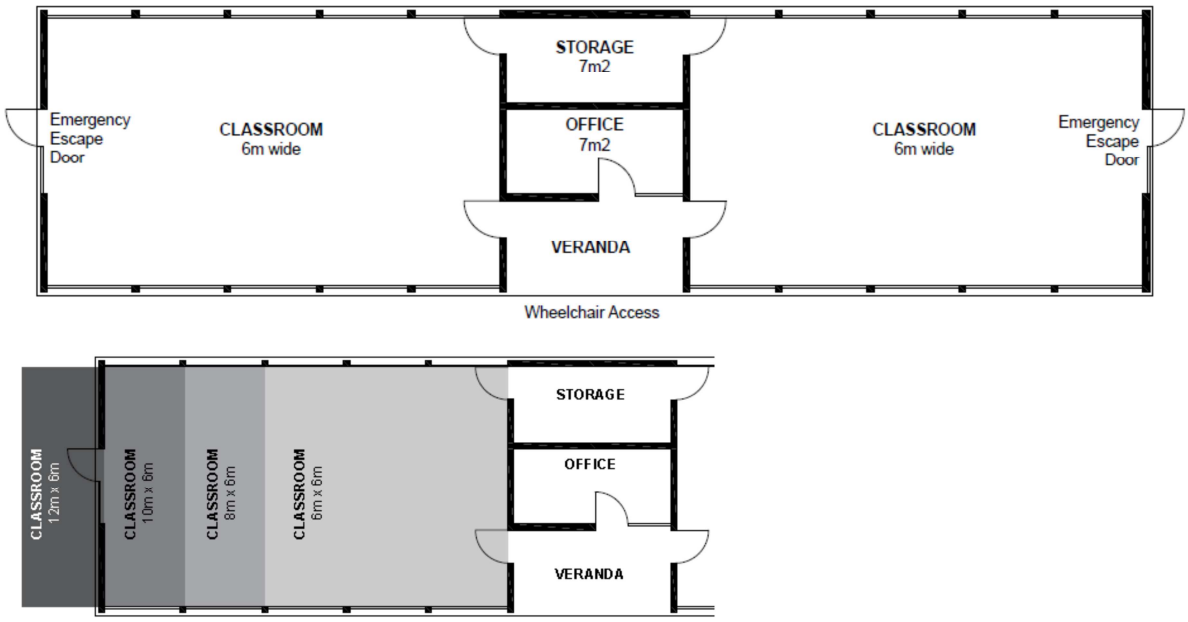

Figure 3: Hybrid Building Floor Plan (Source: Kaunitz 2011)

However, the reinforced concrete frame was replaced with a timber frame to facilitate the use of local materials in construction. Structural connection and tie downs were included for

earthquake and cyclone resilience (hence the term “hybrid). Design options considered and chosen by the community included:

- the type of flooring being either reinforced concrete slab, or traditional crushed coral. The community chose reinforced concrete.
- the type of walling infill panels, such as timber or stone. The community chose local stone.
- the type of roofing, typically either metal deck roof sheeting, or traditional thatch. The community chose thatch on the basis of its deference to traditional local building design. This was interesting as metal sheeting is often considered as having lower maintenance requirements (Lawther 2009).

Additional consideration was also given to lighting and ventilation to facilitate user comfort as shown in figure 4 below.

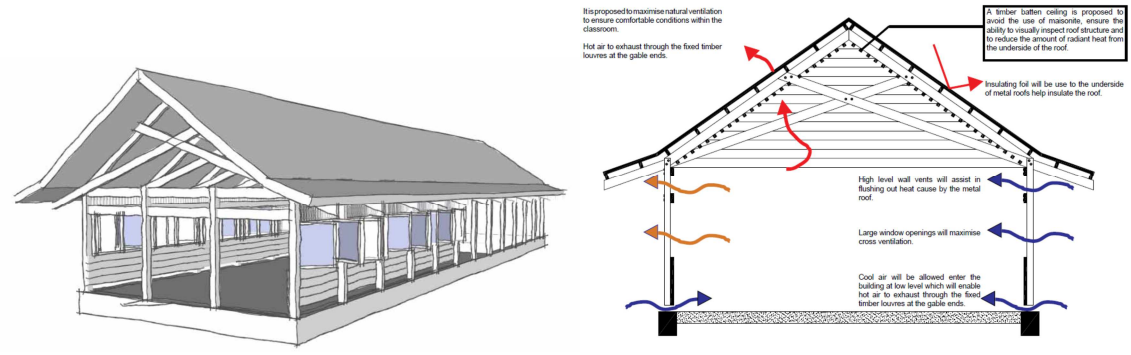

Figure 4: Lighting and Ventilation considerations (Source: Kaunitz 2011)

A comparison of salient design features between the pre-existing reinforced concrete frame and the hybrid design is shown in table 1 below:

Table 1 – Comparative Design Features (Source: Lawther 2011)

Design Parameter	Reinforced Concrete	Hybrid
		
Internal Floor Area	144 m2	151 m2
Internal Classroom Floor Area	121 m2	116 m2
Internal Office / Verandah / Storage Floor Area	21 m2	33 m2
Classroom Ventilation Area	30 m2	97 m2
Classroom Lighting (window) area	30 m2	35 m2
Ventilation to Classroom Floor Area Ratio	0.25	0.84
Lighting to Classroom Floor Area Ratio	0.25	0.30
Floor to Truss Chord Height	2.6 m	2.4 m

From Table 1 above, the following can be gleaned:

- The hybrid design is approximately 5% larger than the reinforced concrete design in terms of internal floor area.
- The hybrid design has approximately 4% less classroom area than the reinforced concrete design. However, the hybrid has a separate common classroom storage area, which should assist user efficiency of classroom space utilization, as items will be capable of being stored adjacent to, rather than within, the classroom.
- The hybrid design is approximately 50% larger in terms of the office, storage, verandah area.
- The ventilation area provision of the hybrid design is approximately 3 times that of the reinforced concrete building, and should provide greater thermal comfort for users.
- The lighting area provision of the hybrid is approximately 20% greater than the reinforced concrete building, and should provide enhanced visual comfort for users.

- The floor to truss height of the hybrid design (at the external wall) is 200mm lower than the reinforced concrete building. Whilst the hybrid design roof is therefore effectively 200mm closer to users, and some impact upon thermal comfort might be expected, it is considered that this will be compensated for by the significant increase in ventilation provision, as above. In addition, a thatch roof covering (if chosen) will also assist in defraying any adverse thermal impact.

5 Construction

The construction of the hybrid building was undertaken by the community of Takara, Efate island. This community was chosen as they expressed interest in undertaking the project, and were within proximity of MoE and donors (approximately 1 hour from Port Vila). In order to simplify the piloting process, it was decided to use milled timber sourced from Port Vila, rather than milled on site, which is the ultimate objective of the CDD, particularly given the importance of timber to the building. As stated, however, the Takara community opted for a concrete slab flooring, stone wall infills and a thatched roof in accordance with traditional local design principles.

A pictorial record of the construction is presented in Figure 5 below:





Figure 5: Construction (Kaunitz 2012a)

The final construction report (Kaunitz 2012b), highlighted the following key issues from the construction component of the project:

- The project took eight months to construct, which is longer than that experienced for the reinforced concrete design (3-5 months generally). However, a substantial component of these delays resulted from procurement delays in the MoE. When these (and holiday periods) are removed, the construction period is 5 months, which is comparable with the reinforced concrete design However, future local milling of timber would add to this timeframe.
- A group of twelve local men predominantly undertook the majority of the construction work on the project. The Takara and surrounding communities also supplied the necessary sand, gravel, thatch and woven bamboo window hatches. Local timber species were used in construction.
- The cost of the hybrid was 5.45 million Vatu. This represents an approximate 50% saving of the reinforced concrete designed classroom building. If locally milled timber were be used, it is estimated the cost of the hybrid would decrease to approximately 30% of the reinforced concrete design meaning that school classroom production could theoretically be increased threefold – clearly a significant achievement in addressing demand for education in Vanuatu.
- Additional MoE support to the community is required, particularly in terms of procurement and on-site supervision. This could be achieved through outsourcing to the private sector and thus overcoming inherent capacity constraints.

The overall success of the community directed development approach is summarised in the following communiqué from the MoE supervisor of the project to the designer.

> *“Thank you very much everything.*
>
> *It's been a very big pleasure been working with you to put all our theories into PRACTICAL so now people of Takara , Efate, Shefa and all Vanuatu have witnessed and enjoyed so much the complete product.*
>
> *It has help me a lot too in my building capacity or carrier in hybrid construction and also shows me more creative ideas & techniques of mixtures of natural to artificial materials to develop schools and communities around all Vanuatu.*
>
> *This MODEL will grow so fast in the other island I can tell you, as now I am already having problems in working on the designs of the staff houses, classrooms, libraries and schools halls and all at one go, by using parts of our takara models for EPI ISLAND and EFATE ISLANDS following so many requests, and soon or later you will see some of them built.”*

6 Conclusion

The increasing demand for primary level education in Vanuatu has placed pressure upon school infrastructure delivery mechanisms. The existing inside-out government controlled procurement paradigm of school infrastructure has proved incapable of catering for such demand.

This has resulted in the trialling of a community directed development (outside in) procurement paradigm comprising the design and construction of a “hybrid” double classroom building. The hybrid label is derived from a predominantly local based technological solution laced with some discreet deference to Western style engineering principles vis a viz earthquake and cyclone resistant principles.

The hybrid building was successfully piloted in the community of Takara on Efate island, Vanuatu in 2011/12. The project was constructed in comparable time to the mainstream reinforced concrete design, although at half the cost. Further economies could be expected as the process is refined through further implementation.

Subject to a detailed evaluation of user satisfaction which is yet to be undertaken, the hybrid pilot project provides a workable model of a community driven development approach that can be implemented on a broader scale to address current infrastructure supply constraints that potentially restrict access to primary education in Vanuatu.

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Social and cultural drivers of incentive effectiveness in infrastructure projects

Timothy M. Rose[1], Leentje Volker[2]

Abstract

Formal incentives systems aim to encourage improved performance by offering a reward for the achievement of project-specific goals. Despite argued benefits of incentive systems on project delivery outcomes, there remains debate over how incentive systems can be designed to encourage the formation of strong project relationships within a complex social system such as an infrastructure project. This challenge is compounded by the increasing emphasis in construction management research on the important mediating influence of technical and organisational context on project performance. In light of this challenge, the research presented in this paper focuses on the design of incentive systems in four infrastructure projects: two road reconstructions in the Netherlands and two building constructions in Australia. Based on a motivational theory frame, a cross case analysis is conducted to examine differences and similarities across social and cultural drivers impacting on the effectiveness of the incentive systems in light of infrastructure project context.

Despite significant differences in case project characteristics, results indicate the projects' experience similar social drivers impacting on incentive effectiveness. Significant value across the projects was placed on: varied performance goals and multiple opportunities to across the project team to pursue incentive rewards; fair risk allocation across contract parties; value-driven tender selection; improved design-build integration; and promotion of future work opportunities. However, differences across the contexts were identified. Results suggest future work opportunities were a more powerful social driver in upholding reputation and establishing strong project relationships in the Australian context. On the other hand, the relationship initiatives in the Dutch context seemed to be more broadly embraced resulting in a greater willingness to collaboratively manage project risk. Although there are limitations with this research in drawing generalizations across two sets of case projects, the results provide a strong base to explore the social and cultural influences on incentive effectiveness across different geographical and contextual boundaries in future research.

Keywords: incentives, collaboration, infrastructure project, Australia, the Netherlands

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1. Introduction

Internationally, construction industries are faced with rapid globalisation requiring new governance structures to bridge the gap between social, legal and cultural work practices, to efficiently manage global supply chains. A major emerging issue in the procurement of infrastructure internationally is the need for greater emphasis on integrated delivery incorporating vertically and horizontally integrated construction organisations (Levitt 2007; Renier, Volker et al. 2009). This has led to the recent developments in integrated governance mechanisms including alternative financing and delivery arrangements such as Alliancing and Public-Private Partnerships. Advances in the areas of integrated design/construction and asset management systems (e.g. Building Information Modelling), vertically integrated supply chain networks (e.g. strategic alliancing) and alternative project procurement and financing arrangements offer opportunities to improve construction sector productivity (Roehrich and Lewis 2010).

Similarly, increased global competition across industry firms has seen greater emphasis placed on innovation offering more effective ways to compete and achieve greater value for money. However, there remain major challenges in enhancing infrastructure project performance within a highly complex (and unique) multi-firm production model. This model is characterised by fragmented supply chains, typically resulting in disjointed relationships across project networks (Rose and Manley 2012). However, it is also characterised by highly interdependent project outputs. Under these conditions, a key challenge faced by project leaders is how to effectively align formal and informal governance arrangements in a complimentary way (Hinze 1994; Gann and Salter 2000; London 2001). According to Miozzo and Dewick (2002), the strength and capacity of project-based organisations to increase competitive advantage and encourage innovation is driven by: 1) the management and structure of ownership of the contractor; 2) the creation of inter-firm institutions to facilitate innovation diffusion, while maximising firm-specific competencies; and 3) established relationships and collaboration between organisations and external knowledge sources. Thus, project performance and innovation is argued to be governed partly by the nature of the project delivery approach and more specifically, by how the delivery approach may encourage or discourage the formation of a coherent and coordinated ‘project organisation’.

In light of the argument that incentive systems need to be carefully applied to suit specific project context, this paper explores the nature of attitudes and motivations of contracted parties towards incentive goal achievement across culturally and organisationally varied environments. The authors compare the effectiveness of incentive systems to motivate contracted parties towards incentive goals across four broadly different infrastructure projects: two road reconstructions in the Netherlands and two building constructions in Australia. This comparative analysis aims to provide guidance for improving the effectiveness of incentive systems to promote project performance by deriving similarities and differences across the Australian and Dutch contexts. Secondly, the paper explores the nature of shared social drivers that influence the effectiveness of incentive systems. The paper now presents our theoretical constructs that underpin incentive motivation and the drivers of financial incentive motivation in construction projects to be explored in the case studies that follow.

2. Theoretical Background

2.1 Motivation

Incentives offered in construction projects aim to increase motivation and commitment of project stakeholder towards above 'business as usual' performance. Broadly, their effectiveness to induce motivation is founded on principles of work motivation theories. Work motivation can be defined as a set of external and internal energetic forces that initiate work-related behaviour and determine its form, intensity, direction and duration. Reward systems such incentives impact on motivation, which in turn determines effort and ultimately performance (Van Herpen, Van Praag et al. 2002). Although there are a wide range of motivation theories, three key theoretical constructs are argued to usefully inform the nature of incentive systems on construction projects. They comprise Justice, Goal Commitment and Social Preferences/Reciprocity Theory.

The perception of *fairness (or justice)* regarding how and what decisions are made about reward systems can significantly affect motivation toward reward goals. Justice theories (Colquitt 2004) identify three different aspects: fairness of decision outcomes or distributive justice, justice of the decision-making processes that lead to decision outcomes (procedural justice), and interactional justice relating to aspects of the communication process between reward providers and recipients, such as honesty and respect. As an extension to goal-setting, *goal commitment* (Hollenbeck and Klein 1987) refers to the sustained determination and motivation to try for an incentive goal – suggesting the way the goals of an incentive are managed over time will impact motivation and commitment. Key antecedents of goal commitment are those that impact on the attractiveness of goal attainment and those that impact on the expectancy of goal attainment (Hollenbeck and Klein 1987). Similar to interaction justice, economic *reciprocity* theory states contract agents prefer a condition of fairness in their exchange relationship. Depending on shared behaviour, the value of a financial reward can be perceived to be positive or negative. Thus, if the incentive's intention is perceived to be as 'calculative' or hostile, parties may view the incentive negatively, which can lead to a hostile response (Fehr and Falk 2002).

2.2 Incentive contracting

As a part of procurement, conditions of contract allocate the responsibilities and liabilities of each contracting party, and define contractual risk and reward. Although the clear definition of responsibilities in the conditions of contract encourage efficient management of risks during construction, the attitudes and motivations of contracted parties towards risk, facilitated through strong relationships and co-operative teamwork, are important for high project performance (Rahman and Kumaraswamy 2002). A common approach in to aligning the attitudes and motivations of contracted parties and improve the balance between project risk and reward for performance is through incentive contracting. Simply, incentive contracting provides the opportunity for contract parties to earn additional profit for higher performance (Bower, Ashby et al. 2002), and focus on client gain-sharing by providing a share in the client's success from a project.

Financial incentives can be combined with any type of base construction contract and can be designed to reward the achievement of a wide range of project objectives depending on the specific project. Generally, incentives are structured through: 1) the method of payment of the contract price, 2) a profit sharing (cost-plus) incentive arrangement, and 3) a performance bonus (Rose and Manley, 2011),. The use of incentives aligns the contractor's objective with the client's expectations and ensures that contracted parties pay attention to the issues that are important for the client. Commonly, positive project performance incentives are used along with disincentives (penalties). However, to ensure that an adversarial relationship does not occur between the contracting parties, the incentive systems should focus on positive incentives, rather than penalties (Lahdenpera and Koppinen 2003).

2.3 Social and cultural contextual drivers

The effectiveness of incentive systems to promote effort towards client goals is highly sensitive to the context in which it is applied (Bresnen and Marshall 2000), making them highly challenging to design and implement. Effective design and implementation require a clear understanding of not only the incentive mechanism, but also the context in which it is implemented. Thus, if a financial incentive is not carefully designed to suit its context, it may induce undesired behaviour, inhibiting the formation of the trust and cooperation (Rose and Manley 2011). As incentive systems are inherently formal in nature, a key challenge faced by incentive designers is to align the formal incentive systems with informal governance arrangements in a complimentary way.

The effectiveness of incentive systems to encourage high performance is also influenced by social and cultural organisational drivers, establishing 'behavioural' norms in response to governance arrangements. Broadly, social and cultural norms are expected to influence the strength of inter-organisational relationships in the context of an infrastructure project. Cultural attitudes of interrelated project organizations are also seen to significantly influence the diffusion and uptake of innovative ideas in construction (Hartmann 2006). Broadly, cultural and social norms define perceptions of behaviour and altitudes of project parties about each other's intentions, including their trustworthiness. In the case of financial incentives, this can influence how project participants perceive the intention behind a formal incentive system.

Cultural norms can be defined at both an industry and project level and are closely interrelated. For example, cultural norms can define contract parties' independence, orientation towards rationality, willingness to communicate openly, and risk and conflict adverseness. Similarly, differences in national cultures defined by geographical boundaries can influence perceived intentions and expectations of behaviour. Thus, from an individual perspective, cognition, emotion, and motivation can be widely influenced by cultural norms, for example, the strikingly different construal's between western and non-western self-perception. Although there are clearly incremental levels across countries, the western culture perception of self is defined by individuals who are independent, self-contained and autonomous, while non-western normative imperative is for individuals to maintain a fundamental *connectedness* and interdependence (Markus and Kitayama 1991). Without

going into the highly detailed description of the differences across international cultures, these types of behavioural norms can heavily influence self-perceptions, and thus, impact on the effectiveness of organisational systems. This is certainly the case in construction, where the indirect influence of cultural norms can cause difficulties with institutional mismatching across international organisational boundaries resulting in high transaction costs and conflict (Levitt 2007). Further, business cultures that place greater emphasis on connectedness and interdependence may generally have a greater tenancy towards teamwork and are less antagonistic and adversarial.

3. Methods

Case studies were seen as the best method given the complexity of project environments, and the need for in-depth understanding of the dynamics surrounding project-based motivation in order to effectively scope and identify the social and cultural drivers (Edmondson and McManus 2007; Easton 2010). In this paper, a comparison is made of the social and cultural drivers seen to promote or inhibit motivation towards incentive goals of four integrated Design and Build cases in public infrastructure: two road reconstructions in the Netherlands and two building constructions in Australia. For this study each of the authors selected two cases that were collected in their country of origin in the context of independent research projects. The selection of the cases can be considered as revelatory since they originate from a different research context and types of infrastructure. Yet, all four cases share the same innovative and incentive based character. This provided a rich data set to compare and contrast the differences in project types and the nature of project delivery (including the cultural and social differences) across the cases, while maintaining the character of the incentive system relatively constant.

In each case study, the client and head contractor involved in the procurement and design stages of the case projects were interviewed. Two people from each of party were interviewed on each project, ranging from 60 to 90 minutes duration and based on semi-structured questioning. The semi-structured interviews involved general questions about the project characteristics and the stage outcomes (e.g. *Where there any constraints in the design stage that effected performance towards incentivised goals?*), followed by questions relating to distributive and procedural justice, goal commitment and social preferences as important motivation constructs. Example questions relating to the motivation constructs included *'Did you see value in pursuing the incentive goal? Where you involved in the goal setting process?* (Goal Commitment); *What influenced your perception that the incentive reward on offer was fair/ unfair in relation to pursuing project goals?* (Justice); *Did you feel the underlying intention of the incentive was honourable and fair?* (Social Preferences). Apart from a comparison of the contractual agreements and case details, the cases were compared based on *incentive characteristics* seen to impact on the effectiveness of the design and implementation of incentive systems based on Rose (2008). This paper focuses on aspects that relate to the selection and design phase of the projects. These *incentive characteristics* were unpacked across each case to identify differences and similarities in how the incentives were designed and applied; and the nature of the social and cultural drivers perceived to influence incentive goal effectiveness. The *incentive characteristics* explored in this paper are as follows:

1. Incentive goal and reward opportunities: the range of goals covering key project priorities and the nature of the incentive reward on offer across project stakeholders.
2. Design and build integration: the involvement of project parties, particularly the contractor, in the design process and integration with construction.
3. Risk allocation: how design and construction risk is allocated under the base contract.
4. Value-driven tender: the nature of the tender selection process in promoting 'value' selection.
5. Future work: project stakeholder opportunities for future work.

Each case project was treated as an independent study which was subsequently subjected to cross-case analysis under the previous headings. Throughout data analysis and reporting the authors were frequently cross referenced between the interpretation and the original data. They regularly contacted each other to discuss the framework and share a common understanding about the cases and its context. This process can be characterised as ex ante use of theory in qualitative research. The general aim of this approach is 'not to build consensus aiming diverging theoretical perspectives but rather to use their divergences as vantage points for creating new insights' (Andersen and Kragh 2010, p. 53). This approach suited the study since the research focused on the commonalities and differences between the four cases and two countries.

The four cases comprised: Brisbane Magistrates Courts project (A1) and the Lyell McEwin Health Redevelopment project (A2) where social infrastructure (building) projects delivered in Australia, while Highway package F (D1) and Highway A12 (D2) were civil infrastructure projects delivered in the Netherlands. Further case project details and the incentive characteristics can be found in Volker and Rose (2012).

4. Findings on Incentive Drivers

The incentive characteristics identified from the case studies are now compared to identify social and cultural organisational drivers seen to impact on incentive effectiveness across the case contexts in the selection and design phase of the projects. The five incentive characteristics are: incentive goal and reward opportunities, design and build integration, risk allocation, value driven tender, and future work.

4.1 Incentive goal and reward opportunities

4.1.1 Multiple goal opportunities

Case A2, D1 and D2 had a wide range of performance goals and multiple opportunities to secure the financial incentive, resulting in improved level of motivation. This also was seen to encourage teamwork as goal achievement required effort from a wider range of project participants across multiple goals. This induced a team mentality towards goal achievement (high interdependency and a social expectation for achievement) in the Dutch cases and A2, which was not present in A1. These research findings indicate the importance to clearly define the project goals at the early stages of the project, and 'balance' incentive goal parameters to prevent overemphasis on particular goals. The client in the Dutch situation

applied several innovative procurement methods (e.g. best value procurement, listing the risks and key performance indicators), which enabled both the client and the contractor to better define the project goals in a relatively early phase of the project and improved the sensemaking processes between the client and the contractor. The bidders also made a more explicit choice to aim for the financial bonuses. In all projects, communication about common goals stimulated the development of a collaborative culture from the beginning of a project. During the interviews, examples were mentioned of situations in which both parties were willing to take the blame in situations where unexpected events threatened the achievement of an incentivised goal.

4.1.2 Incentive distribution equality

The research findings indicate the importance in offering the incentive reward to those parties expected to contribute to overall performance in key project priority areas. Equality in how incentive rewards are distributed based on performance contribution was perceived to be an important social driver and such expectations were defined at the early project stages in A2 and the Dutch cases. In the case of A2, the project participants valued the client's decision to allow the project team to decide how the incentive amount would be distributed. Project parties jointly agreed during the design development stage that the bonus pool would be distributed according to fee proportions, an equitable offer for those parties involved. This was also part of the best value procurement approach, which is a specific dialogue-based tender procedure. This tender was less formalised and more open than the competitive dialogue procedure, yet both leading to a commonly accepted risk perception and consensus on the assignment and related rewards. The payment structure and the level of bonuses and penalties were primarily determined by the client in D1 and D2. On the other hand, A1 only offered the incentive reward to the managing contractor to the disappointment of consultants and key subcontractors who were seen to contribute to pursuing stretched scope incentive goals. By setting multiple goals and levels of reward across the project, clients can ensure goals remain achievable, teamwork is fostered through joint commitment, and credit is given for partial success.

4.2 Design and build integration

4.2.1 Early involvement of key stakeholders in design

The results of project A2 and D2 indicate a strong emphasis on integrated design build contracts contributes significantly to timely and cost efficient project delivery. According to the A2 project client, the early involvement of contractors assisted the team to "find building smarts that would improve the value of the project" - and gave "a good indication of what [the team] were aiming for in terms of cost reduction". This was also seen to improve the level of collaboration. Project A2 also uniquely involved key subcontractors in the design stage, which was seen to improve the managing contractor's effectiveness in identifying value-added design options. The tender dialogue in D2 encouraging the discussion of concept designs with the client and award based on the expected traffic flows, sustainability and level of stakeholder inconvenience. This introduced discussion about innovative construction methods to increase the construction speed. The client contract manager indicated that

“most of the questions related to the qualitative elements instead of the bolt and nuts” which shows a different focus by the bidders.

4.2.2 Emphasis on design-build collaboration

A difference between the Netherlands civil and Australian building case projects was the increased emphasis on the design quality in building projects in comparison to road infrastructure. As such, participants involved in the building projects placed greater emphasis on the involvement of the contractor and key subcontractors in the design stage, as design discrepancy risks can be potentially higher in building projects in comparison to civil road projects. However, this did not discount the impact of design integration on improving project collaboration. In fact, improved definition of project objectives and constraints through input from multi-disciplinary experts in design commonly assisted with value and risk management. This led to more stable cost calculations and satisfying incentive goals. It also provided the opportunity to build project relationships earlier, improving motivation towards incentive goals. Greater emphasis on design build integration created significant change in the regular operating environment for the contractor of D2. According to the D2 project leader “it seems as if the time has finally come to accept the benefits of integrated design deliveries”.

4.3 Risk allocation

4.3.1 Willingness to share cost overrun risk

In all cases the allocation of risk under contract arrangements impacted on the implementation of the incentives. In case A1, the managing contractor took on a greater share of construction cost risk in comparison to A2 under different contract forms. According to the participants involved in project A2, the client’s willingness to share construction cost risk was seen to improve the managing contractors’ ability to achieve the incentive goals, as they were less likely to be focused on their own financial liabilities, and more likely to perceive the client behaviour as fair. For example, the managing contractor perceived the client’s willingness to share construction risk “broke down the ‘us versus them’ attitude which is prevalent in [traditional] contracts and focused our joint attention on achieving the project goals.” This perception of justice was an important social driver for developing the project relationship and thus, promoting motivation towards the project goals. On the other hand, the A1 project participants acknowledged that the contractor resorted to a self-protective position due to their high risk liability, partly resulting in an unwillingness to pursue the stretched scope incentive goals.

4.3.2 Perception of risk assurance and project culture

In the tender phase of D2, a list of previously identified risks and opportunities were made available. According to the project leader, the contractor tenderers could decide which of these risks were to be included in their job description. After submission of the final bids, it appeared most of the contractors accepted the majority of the items. This was probably due to the level of competition in the market and the expectation that other contractors would

also accept the majority of the risk. Project D1 included a shared risk fund. In case of unexpected events, the contractor was allowed to solve the problems based on actual costs +5% cost mark-up. The contractor was entitled to 25% of the remainder of this fund after delivery of the project. In this way, the contractor was stimulated to create preventive measures in the early phase of the project that would leave the risk fund untouched, which occurred. The results indicate that this risk fund contributed to the project culture in which not every detail and possible additional costs were discussed. Yet, in D2 the client project leader indicated that hardly any unforeseen costs were filed: “apparently you don’t need a shared risk fund if the arrangements are just”. This was an interesting finding in comparison to the Australian cases, as the bidders was offered the opportunity to define the level of risk to be taken as part of their job description during tender, thus encouraging a level of fairness (justice) in their initial dealings. Also, the shared risk fund promoted a positive project culture through the perception that if difficulties arose funds were available, despite most of the risk taken on by the appointed contractor. In contrast, the Australian cases indicated contractors took a protectionist view of risk. This may be due to cultural differences across the two industries, however, likely related to how conducive the project environment was towards defining and managing risk across the two sets of case projects.

4.4 Value-driven tender

4.4.1 Non-price selection criteria

All case projects involved some form of non-price criteria that encouraged selection based on value in comparison to price alone. Both A1 and A2 had relatively high non-price proponents, with project A1 affording a 30% price and 70% non-price split, and project A2 with a two-stage 40% price and 60% non-price split. Non price criteria included proven past performance and ability; resource strategy; project methodology; commitment to relationship management; and community consultation. In D1 the price/quality ratio was 30/70, in which the quality included the allocated risks, offered opportunities, planning, and capabilities key project personnel - tested during an interview. This resulted in a selection process with a high level of information exchange between client and bidder. Although the bidders were nervous about the qualitative aspects of tender judgements in D2, they placed importance on information exchange during the tender to build a successful project relationship. This was similar to the Australian cases where the currency of accurate informal information during the tender stage was also seen as an important social driver to building project relationships.

4.4.2 Alignment of ambitions

The results of all cases indicate that the selection of project participants based on their ability to add value to the project (rather than the traditional price-focused tender selection) increased the project participants’ expectations that incentive goals could be achieved, promoting commitment. This was also seen to encourage a willingness to align with the team objectives and meet the client expectations by which they were selected. In the Australian cases this was seen as an important social driver as the contractor and consultants felt “an obligation to prove [they had been] rightly appointed” to deliver this important and highly

visible social infrastructure project. The Dutch projects were part of publicly announced improvement trajectories in the road network as part of an economic stimulation measure. This commitment to high performance was reflected through all project team leaders, who had a personal stake in achieving the higher order project goals. In some cases the project leaders were specifically selected to match the value-based culture of the project. This showed that the drivers of the project organisation were strongly embedded in the organisational and social context of the organisations involved.

4.5 Future work

4.5.1 Long-term business relationships

Future work is a powerful performance driver that seems to be becoming increasingly important in the global construction industry. The results from the Australian cases identified that due to a highly competitive local building construction market the desire to uphold and improve reputation, so as to increase future commercial opportunities, was a strong social motivator to maintain business relationships with the client and pursue incentive goals. This was particularly relevant to public infrastructure projects, where state governments are major repeat clients. It is likely that the desire to strengthen reputation with these clients would be stronger than with clients who are less likely to provide further work opportunities. The was particularly evident in the project outcomes for project A2, where the key project participants were offered the opportunity to be reappointed to on-going stages of the hospital redevelopment program if they achieved high performance. This strongly intensified the desire to achieve the incentive targets outside the financial reward on offer where the contractor was “driven to maintain the good relationship with the government client so [they] would be looked on favourably in future projects…as valued reward outside the [financial] incentives.”

4.5.2 Need for transparency and integrity

In the Dutch context, D1 and D2 were part of a strategic governmental program to support the construction industry surviving the recent credit crunch. For these relatively large projects, there are a small number of competent players in the field. Therefore, the client decided not to exclude any party in the bidding process. However, the market situation has changed dramatically over the last few years. This has resulted in construction companies placing great importance on future work opportunities to remain buoyant, even accepting lower profit margins to do so. Additionally, the procurement obligations have increased the urge for transparency and objectivity. This had led to a greater need for quality and service assurance within running contracts and a strong preference for long term integrated contracts which include performance based maintenance agreements, such as 25-year Design Build Finance and Maintain (DBFM) contracts and regional asset management responsibilities for 5 to 10 years. These long term commitments stretch the evaluation period of projects, but also increase the size of projects while limiting the amount of new projects. This caused an increase of activities and accompanying responsibilities that are outsourced to market parties. In a sense, long term contracts can be considered as future work

assurance as well. These arrangements require greater transparency in collaboration and performance measurement, relating to improved reciprocity among both parties.

In the Australian cases, future work opportunity was a highly influential organisational driver, seen to increase the effectiveness of the incentive system. This response was driven by increased levels of distributive justice, where contractors' could clearly see if they achieved high performance (achievement of incentive goals) it was likely to translate into future work opportunities. The contractor on A2 was also driven by reciprocity reflected in commitment to their client through the client's offer to re-appoint them for on-going construction stages. This direct link was not a prevalent in the Dutch cases. This may have been due to the localised nature of the construction industry in Australia, where future work is strongly driven by informal relationships. This may reinforce the need to maintain strong client-contractor relationships and uphold reputation as a social driver embedded in industry culture. Currently in the Netherlands, informal relationships in the construction industry are publicly condemned since a major fraud case was revealed in 2001, badly damaging the reputation of the construction industry. The need for strong client-contractor relationship in the Netherlands originates from the character of the long-term integrated contracts. Moreover, the Dutch road, rail and governmental building agencies have recently focused on developing a joint past performance assessment system with the aim to further develop this as a performance driver, as well as a quality assurance mechanism.

5. Conclusions and discussion

Incentive reward systems should be fairly applied so that rewards and measurement processes illicit their desired behaviours in light of the project environment. These shared behaviours can heavily influence the establishment of collaboration and trustworthiness in on-going project relationships, acknowledging that project participants will be more likely to cooperate voluntarily and reciprocate positive behaviour if they jointly perceive an incentive intention is fair, honourable and recognise high performance. As such, the use of incentives introduces complex social and cultural organisational dynamics that impact on effectiveness i.e. their ability to promote motivation towards higher order project goals. These complex dynamics result in challenges for infrastructure project leaders, particularly due to the highly sensitive of incentives to the context in which it is applied.

Effective incentive design thus requires a clear understanding of the impact of different delivery strategies and social and cultural contexts on incentive goal motivation. Drawing on the results of two Australian social infrastructure (building) case projects and two civil (road) infrastructure projects from the Netherlands, differences and similarities in key social and cultural drivers were explored. This research focused on the selection and design phase of these projects, with particular emphasis on aspects of the incentive design and broader procurement approach that drive motivation and commitment towards incentivised goals early in a project. Despite significant differences in the project characteristics across the two countries, results indicate they experience similar social drivers impacting on the incentive effectiveness. Case results identified that contract parties saw the incentive as a commercial opportunity to increase their profit margins, but also acknowledged the influence project and relationship management processes had on their commitment to the project and pride in the

achievement of project goals in light of the social environment. This was consistent across the two countries and across the two types of projects. This suggests these processes, particularly the value driven procurement initiatives, enhanced the collaborative environment between client and contractor and increased the predictability of the risks, intensifying the motivational effect of the incentives on offer.

Despite these common themes, there were two notable differences across the Australian and Dutch contexts. They related to differences in how contract parties perceived future work as a driver to forge on-going project relationships; and differences in how risk in pursing project goals was perceived and managed. Firstly, future work opportunities were identified to be a more prevalent social driver in the Australian building context due to a highly competitive building construction market in comparison to the Dutch market, who have limited amount of players in road construction. This has induced an Australian industry culture driven by local relationships, reinforcing the need to maintain a strong reputation in the market to maintain competitiveness. Although this was not as prevalent in the Dutch cases, several Dutch agencies have recently focused on developing assessment systems based on previous performance with the aim to further develop this as a performance driver and act as quality insurance measure. Secondly, case results indicate there were differences in how contract parties responded to project risk. Contractors in the Dutch context seemed to more broadly pursue an open book approach in fairly defining and managing risk, while in the Australian context contractors took a 'hard-line' protectionist view of risk. Although difficult to generalise across a small sample, this may be due to greater willingness of Dutch project participants to embrace an innovative collaborative project culture with clear tasks and responsibilities. On the other hand, this also may be due to how conducive the project environment was towards defining and managing risk across the two sets of case projects.

In summary, findings suggest multi-levelled incentives systems, value-driven procurement, improved design-build integration, equitable risk management and promotion of future work opportunities are important ingredients for developing strong project relationships, leading to improved project performance. Early evidence indicates these shared drivers may fundamentally apply across different social and cultural organisational settings. Although there are limitations with this research in drawing generalisations across two sets of diverse case projects, the results provide a strong base to explore incentive systems across a wider range of project types and across social and cultural boundaries in future research. As an early contribution to this knowledge, the research suggests if incentives are designed such that participants genuinely value the financial reward on offer, the incentive goals are perceived as achievable and the incentive is positioned within a complementary set of procurement initiatives that promote recognition and reward for high performance, in light of project context.

Acknowledgements

This work was supported by the Cooperative Research Centre for Construction Innovation in Australia, the Next Generation Infrastructures Foundation in the Netherlands and the Dutch Forum of Public Clients in Construction.

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Probabilistic time-specific risk load for PPP

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Abstract

Risk allocation is crucial for the success of a Public Private Partnership project. When looking for the optimal risk allocation, the risk-bearing capacity of the private party needs to be considered. The risk-bearing capacity is ensured if the risk coverage exceeds the risk load at all times during the contract phase. This paper presents a probabilistic approach that refines a simulation for the aggregation of a project's risk load using time-related information from subjective expert estimations. In the process, the concept of time-specific risk impact and risk periodicity is integrated in a Monte Carlo simulation model. In the simulation, the impact of single risk events is allocated to time units according to the underlying time-related random variables. The result is an "empirical" distribution function of the project's risk load resulting from the simulated artificial statistical data base for either just one specific point in time or the cumulative project's risk load until that specific point in time. The time-specific project risk load can be used to assess, if the private party is able to provide risk-bearing capacity and to determine the necessary financial risk coverage at this point in time.

Keywords: Monte Carlo simulation, Public Private Partnership, risk-bearing capacity, risk cost, risk load.

1. Introduction

Many national economies are confronted with infrastructure investment needs. To meet the needs, Public Private Partnership (PPP) has become an alternative to traditional public procurement. Finding the optimal risk allocation is of high importance for a PPP projects' success (Andersen and Enterprise LSE (2000)). Today's risk allocation (RA) takes place mainly in a qualitative way according to intuitive, habitual, opportunistic criteria or bargaining strength (Delmon (2009), Girmscheid and Pohle (2010)). A current research project at ETH Zurich aims for an implemented tool that determines the "optimal" RA quantitatively and consequently according to rational and traceable decision-making with clear criteria. Aside from being cost minimal, the RA is considered optimal in the present work, if the resulting private party's risk load does not exceed the according private party's risk coverage and thus risk-bearing capacity is ensured at all times. The presented work is based on the RA model developed by Girmscheid (2013) and related (see state of research).

The overall research project is presented in Fig. 1. The first part of the RA model covers rational information acquisition for a quantitative RA model (see Firmenich and Girmscheid

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(2013)). The modules of the RA model's first part follow the usual steps of the risk management process: risk identification, risk assessment and risk classification. The second part of the RA model contains the quantifiable and thus implementable decision-making: risk allocation / risk handling, risk load, risk coverage and risk-bearing capacity. The paper's subject and contribution to the overall research project is the quantitative time-specific calculation of the PPP project's risk load.

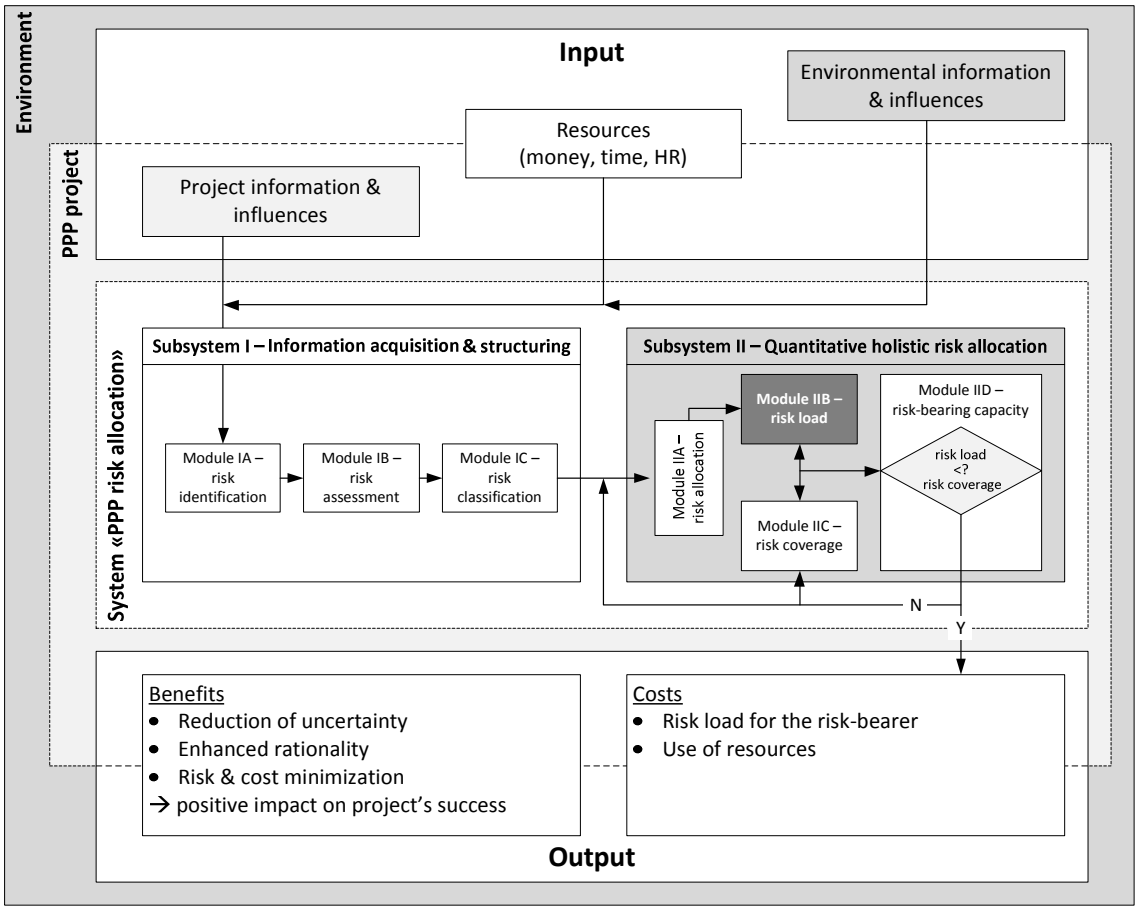

Figure 1: Concept of a quantitative holistic risk allocation model under consideration of the private party's risk-bearing capacity with focus on risk load calculation

The chosen approach is characterized by being probabilistic (i.e. input and output are random variables with an according distribution function), using a Monte Carlo simulation (MCS) for risk aggregation from single to project risk and including time-specific information into MCS. Because of the consistent quantitative modelling, this RA model part is readily implementable and complex causalities can be processed electronically. This is demonstrated with an example. Based on and in the frame of the relevant previous work (see state of research) this paper's objective is to integrate time-related risk modelling concepts like risk periodicity and time-specific single risk impact consistently into an established Monte Carlo simulation for risk aggregation (see Girmscheid (2013) and related). That's how a time-specific project risk load is derived for comparison with project risk coverage to ensure risk-bearing capacity.

2. State of research regarding risk assessment and risk load calculation in the context of risk allocation for PPP projects

The institutional PPP guidelines on the one hand often promote simple practice friendly deterministic approaches for risk management (e.g. European Commission (2003)). The research literature on the other hand often covers more sophisticated probabilistic methodologies using random variables, MCS and/or stochastic processes (e.g. Boussabaine and Kirkham (2004), Schöbener, et al. (2007), Alfen, et al. (2010)). The concept of analysing risk-bearing capacity with risk coverage exceeding the risk load was used in Girmscheid and Busch (2008) for risk aggregation on project and company level of the construction industry. Furthermore, the concept was integrated in a holistic probabilistc RA model for PPP developed by Girmscheid (2011) and Girmscheid (2013). In the following, Girmscheid (2013) is used as main reference, which implies the consideration of the other publications mentioned above. Firmenich (2011) as well as Firmenich and Girmscheid (2013) cover further hitherto results of the underlying research project. Girmscheid (2013) in particular, contains a probabilistic MCS approach for the aggregation of identified and assessed single risks to a cumulated probabilistic project's risk load over the contract phase. Furthermore, the concept of risk periodicity is introduced in that publication. This is taken as a basis to integrate time-specific information and MCS for risk aggregation in a probabilistic and implementable way to enhance the given state of research, as is presented in this paper. So far, time development of PPP project risks was either covered with stochastic processes (e.g. Irwin (2007), Schöbener, et al. (2007), Alfen, et al. (2010)) or two-dimensional random variables (Elbing (2006)).

3. General research methodology

The presented overall research is based on the research methodology according to Girmscheid (2007). Construction management science relates to the Third World of Popper's three worlds (Popper (1987)). The construction management's processes and models design the socio-technical environment of Popper's Third World according to the hermeneutic research paradigm. The presented research follows the radical constructivism science paradigm according to Von Glasersfeld (1997). In that context, the objectives to the corresponding problem and the target-means-relationship to solve the problem and achieve the objectives are developed. The actional decision model's structure is developed according to cybernetic systems theory and the methodological focus lies on the application of quantitative methods. Research quality will be ensured by viability, validity and reliability based on triangulation according to Yin (2009).

4. Concept of an enhanced Monte Carlo simulation for a time-specific probabilistic project's risk load determination

4.1 Preliminary work for the simulation

In the context of this research, risk load means the cost resulting from risk events, called risk cost. Single risk cost result from a single risk event whereas the project risk cost are the

result from all risk events of the project. The determination of the project's risk load requires, firstly, the cause oriented identification of single risks. These single risks need to be assessed for risk load determination in a second step. As no statistical historical data is available, this is done by subjective expert estimation. It is suggested to use a combination of established methods like brainstorming and the Delphi method to conduct the required subjective expert estimations (see Firmenich and Girmscheid (2013)).

For risk load aggregation and thus determination under absence of statistical historical data the Monte Carlo simulation (MCS), as probabilistic approach, is common. It requires wider expert estimations than a deterministic approach that lead to distribution functions for all simulated random variables of every single risk entering the MCS. The simulation determines scenario values out of the inverse distribution functions by means of random numbers and then aggregates these values according to the underlying simulation model. The result of one iteration or scenario is stored and the process is repeated as often as specified. This leads to the generation of an artificial statistical data base from which an "empirical" distribution function of project risk can be derived and further processed. For further reading in that matter see Girmscheid (2013) and related. However, special care needs to be taken that the MCS result contains time-specific information.

A simulation purely aiming for aggregation, as described above, results in project risk cost that reflect the cumulative value at the end of the simulated period. Consequently, such MCS results would not show the risk load at a certain point in time during the simulation period. This, however, is relevant to ensure risk coverage and risk-bearing capacity at every point in time during the contract phase. The following sections present a MCS approach that is based upon a probabilistic simulation of risk impact (using "probability of occurrence" $P(O_i = 1)$ and "impact of occurrence" I_i) as shown in Girmscheid (2013). The integration of several combined random variables into MCS allows modelling of more complex and realistic causalities. This enhancement integrates, therefore, not only the idea of risk periodicity into MCS, but also the idea of single risks occurring probabilistically over time as random variables (new random variable "frequency of occurrence" F_i and "time of occurrence" T_i). The concept of risk periodicity is described by Girmscheid (2013), meaning single risks that represent potential multiple risks. The risk periodicity implemented as F_i characterizes a single risk i as one-time or multiple risk and allows the derivation of how often one risk will occur in the simulation. The risk periodicity has a strong influence on the project's risk cost because of a potential multiplier effect.

Depending on the cause, a single risk's impact usually cannot occur during all the PPP's contract phase. It is relatively easy to let the experts specify in what project phases single risks actually could occur (single risk impact phases). For example, construction risks usually cannot occur in the operation phase anymore. After comparing several PPP project phase classifications of relevant literature in a thorough review, the main phases after contract signing (altogether "contract phase") are outlined as follows: "construction phase", "operation phase" and "termination phase". The construction phase is divided into "excavation phase", "structure phase" and "finishing phase".

4.2 MCS model for time-specific project risk load aggregation

Any modelling of the input parameters should aim for a realistic possible solution space of the project. The simulation model includes expert estimations, derived density or distribution functions of the simulation model's random variables ($P(O_i = 1)$, I_i, F_i, T_i) and single risk impact phases. The MCS produces a certain number of iterations. The higher the total number of iterations, the more reliable the probabilistic result is. Each iteration leads to a scenario of how the modelled risk situation could have taken place according to the underlying governing simulation model. Random numbers $Z \in [0,1]$ are used as input for the single risk's random variables' inverse distribution function G to generate a scenario value. For each random variable of each single risk, a random number is needed that will be generated newly for each iteration.

The following section describes the risk scenario derivation for every simulation's iteration. The risk assessment provides a probability of occurrence $P(O_i = 1)$ for every single risk i, which can be translated into a Binomial distribution for the risk occurrence O_i (1)(2). With the according random number of the random variable O_i of the single risk i for the iteration k ($Z_{O,i,k}$) as input for the inverse distribution function $G(F(O_i))$, the single risk occurrence is determined (3). $O^*_{i,k} = 1$ means that the single risk i occurs in scenario k and $O^*_{i,k} = 0$ means that the single risk i does not occur in scenario k. The process mentioned before is described in Girmscheid (2013) and related. In a next step, this result is used to determine the frequency of occurrence in case the single risk is assessed as multiple single risk ($F_i^{max} > 1$). The according subjective three-point-estimation (min a, mode b, max c) of the experts for every single risk is used to derive a fitting distribution function (4). Again a random number $Z_{F,i,k}$ is generated for every single risk i for every iteration k as input for the inverse distribution function $G(F(F_i))$ of random variable F_i (5). The result depends on $O^*_{i,k}$ and on whether the single risk i is a one-time or multiple risk. The same procedure applies for the random variable I_i (6)(7). Neglecting a specific time of occurrence and that multiple occurrences $F^*_{i,k} > 1$ could have a different $I_{i,k}$ every time, the single risk's impact of occurrence for the whole simulation period calculates according to $(8)\ I^{**}_{i,k} = I^{*}_{i,k} \cdot F^{*}_{i,k} \cdot O^{*}_{i,k} \text{ for } \forall t \in [t_0, t_{end}]$ as a simple alternative.

As described before, the single risk's specific risk impact phases are estimated subjectively by experts. Assuming these phases are always sequential, the result is a single risk impact period with a beginning â and end ĉ of possible impact within the simulation period. Depending on whether a single risk i could have a constant, a decreasing or an increasing probability of occurrence over time in that single risk impact period between â and ĉ, the random variable T_i is modelled as a continuous uniform distribution or BetaPERT distribution (9). In both cases the density and distribution function are scaled to fit the specific single risk impact period within â and ĉ (10). The actual time of occurrence $T^*_{i,k}$ for the impact $I^*_{i,k}$ of the single risk i in scenario k is determined as before with a random number and the inverse distribution function $G(F(T_i))$ (11)(12). The interim result (see Fig. 3) after one iteration is a scenario k that probabilistically determines for all project's single risks i, whether the risk occurred or not ($P(O_i = 1) \rightarrow O^*_{i,k} = 0$ or $O^*_{i,k} = 1$), how often the risk occurred, if it occurred at all ($O^*_{i,k} \rightarrow F^*_{i,k}$), with what impact the risk occurred ($I^*_{i,k}$), and when the risk occurred ($T^*_{i,k} \rightarrow I^*_{i,k,t}$).

for all single risks $i \in I \in \mathbb{N}$ and every iteration $k \in \mathbb{N}$

using values from subjective expert estimations: $p_i = P(O_i = 1) \in [0,1]$,

$\underline{a_i} = F_i^{min}$, $\overline{b_i} = F_i^{mode}$, $\underline{c_i} = F_i^{max}$, $\underline{\underline{a_i}} = I_i^{min}$, $\underline{\underline{b_i}} = I_i^{mode}$, $\underline{\underline{c_i}} = \max I_i^{max}$

– – –

Probabilistic Single Risk Impact of Occurence Determination

$$(1)\ f_{O_i}(x) = \begin{cases} 1-p_i & x=0 \\ p_i & x=1 \end{cases} \quad F_{O_i}(x) = \begin{cases} 1-p_i & x=0 \\ 1 & x=1 \end{cases}$$

$$(2)\ O_i \sim \text{Binomial}(1, p_i)$$

$$\mathbf{(3)\ O_{i,k}^* = G(F_{O_i}(x)) = F_{O_i}^{-1}(Z_{O_{i,k}}) = O_{i,k}(Z_{O_{i,k}}) \in \{0;1\}}$$

$$(4)\ F_i \sim \text{DUniform}(\underline{a_i}, \underline{c_i}) \text{ or } F_i \sim \text{BetaPERT}(\underline{a_i}, \underline{b_i}, \underline{c_i})$$

$$\mathbf{(5)\ F_{i,k}^* = G(F_{F_i}(x)) = F_{F_i}^{-1}(Z_{F_{i,k}}) = \begin{cases} 0 & O_{i,k}^* = 0 \\ 1 & O_{i,k}^* = 1 \wedge F_i^{max} = 1 \\ F_{F_i}^{-1}(Z_{F_{i,k}}) & O_{i,k}^* = 1 \wedge F_i^{max} > 1 \end{cases}}$$

$$(6)\ I_i \sim \text{PERT}(\underline{\underline{a_i}}, \underline{\underline{b_i}}, \underline{\underline{c_i}}) \text{ or } I_i \sim \text{Triangle}(\underline{\underline{a_i}}, \underline{\underline{b_i}}, \underline{\underline{c_i}}) \text{ or } I_i \sim \text{CUniform}(\underline{\underline{a_i}}, \underline{\underline{c_i}})$$

$$\mathbf{(7)\ I_{i,k}^* = G(F_{I_i}(x)) = F_{I_i}^{-1}(Z_{I_{i,k}})}$$

Probabilistic Single Risk Time of Occurence

$$(9)\ T_i \sim \text{BetaPERT}(\hat{a}, \hat{b}, \hat{c}) \text{ or } T_i \sim \text{CUniform}(\hat{a}, \hat{c}) \text{ with}$$

$$(10a)\ F_{T_i}(t = \hat{a}) = 0;\ \hat{a} = T_i^{min} \in (t_0; t_{end}) \in \mathbb{N} \text{ beginning of single risk impact period}$$

$$(10b)\ F_{T_i}(t = \hat{c}) = 1;\ \hat{c} = T_i^{max} \in (t_0; t_{end}] \in \mathbb{N} \text{ end of single risk impact period}$$

$$(10c)\ \hat{b} = T_i^{mode} = \begin{cases} \hat{a} & T_i \text{ decreasing over time} \\ \hat{c} & T_i \text{ increasing over time} \end{cases}$$

$$\mathbf{(11)\ T_{i,k}^* = t_{i,k}^{I^*} = G(F_{T_i}(t)) = F_{T_i}^{-1}(Z_{T_{i,k}})}$$

$$\mathbf{(12)\ I_{i,k,t}^* = I_{i,k}^*(t = t_{i,k}^{I^*})}$$

After k iterations the result is k simulated scenarios as described above representing artificial statistical data that can be aggregated probabilistically. The three aggregation dimensions are the single risks i, the time t and the iterations k. The aggregation over i and t is a simple summation within the data set of a scenario k. The aggregation over all scenarios k is the building of an “empirical” distribution function. If only the single risks’ impact is summed up at a certain point in time t, the aggregation over all scenarios k leads to an “empirical” distribution function of the project’s risk load for the simulated year t of the project (13). This result is exemplified in Fig. 4. If the single risks’ impact is summed up itself and over certain time units of the simulation period as well (14a), the result after aggregation of this value over all scenarios k is an “empirical” **cumulative** distribution function (14b). For $t = t_{end}$ this equals the original MCS result of a probabilistic project’s risk load at the end of the simulated period as described in section 4.1. This result is exemplified in Fig. 5. Because of applying a more time-specific MCS approach, the project’s risk load accumulation can be derived in form of an “empirical” cumulative distribution function now for every point in time t between t_0

and t_{end} of the simulation period (see Fig. 6 and 7). This result can be used to check the risk coverage and risk-bearing capacity at every point in time t.

Probabilistic Aggregation

(13a) $I_{k,t}^{tot} = \sum_{\forall i} I_{i,k,t} \quad \forall t \in [t_0, t_{end}]$ and (13b) $F_{I_t^{tot}}(x) \; \forall k \; \forall t \in [t_0, t_{end}]$

(14a) $I_{k,t}^{tot,cum} = \sum_{t=t_0=0}^{t} I_{k,t}^{tot} = \sum_{t=t_0=0}^{t} \sum_{\forall i} I_{i,k,t} \quad \forall t \in [t_0, t_{end}]$ and

(14b) $F_{I_t^{tot,cum}}(x) \; \forall k \; \forall t \in [t_0, t_{end}]$

4.3 Implemented example

As demonstration, a generic example of the MCS model presented above was implemented with 9 exemplary single risks i over a 10 year contract phase in MS-Excel using VBA and "ModelRisk" from "Vose Software". The results after 1'000 simulation runs are shown in the following Figures. The demonstration considers specific I^*_i and T^*_i for $F^*_{i,k} > 1$. Reference for the input estimations of the single risks' impact is a project volume of 100m$. The simulation period covers t_0 to t_{end} and corresponds to the contract phase.

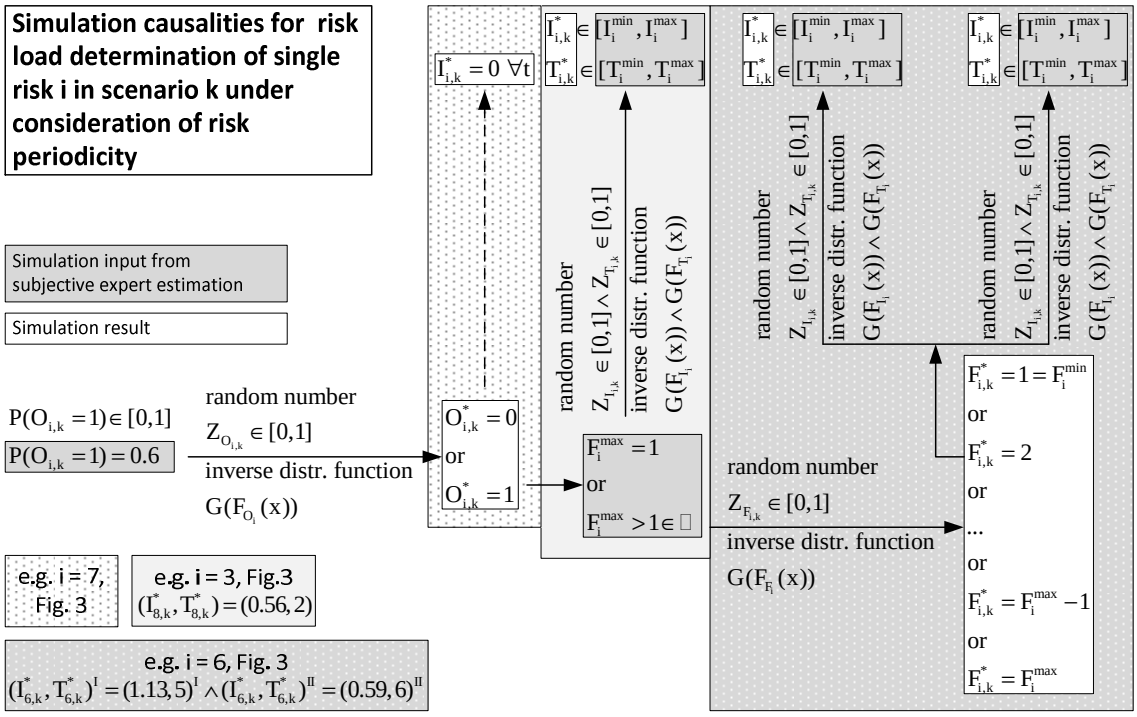

Figure 2: Simulation causalities for risk load determination

Fig. 3 presents the scenario after one MCS iteration k as interim result of the simulation causalities shown in Fig. 2. The single risks did not occur (e.g. i = 7), occurred once (e.g. i = 3) or occurred multiple times (e.g. i = 6) in the simulation. The event occurrences have a specific impact and are assigned to different points of time t. After the probabilistic allocation of all risk events to points of time in the simulation period, all single risk occurrences can be summed up for one point in time t, resulting in a time-specific risk scenario of one iteration k.

For example, in the first year (t = 1) of the scenario displayed in Fig. 3, the ground risk (i = 1) occurred with I_1 = 0.25m$ and the technical risk of construction (i = 2) occurred with I_2 = 0.40m$. Consequently, the project's risk load of this scenario in year one sums up to 0.64m$ (rounding error). The single risks occur only in possible single risk impact phases considered. For example, the technical risk of operation (i = 4) occurred only in the operation phase between t = 4 and t = 9. The row sum of this paper's Fig. 3 at the bottom was simulated already in Girmscheid (2013) and related. The column sum in Fig. 3 at the right represents the contribution of this paper in the form of additional time-specific information of a project's risk load. The risk costs in t_end sum up to 0.28m$, while the **cumulated** risk cost of all periods ($t \in [1,10]$) is 5.78m$ for the scenario shown in Fig. 3.

	ground risk	*techhnical risks construction*	*logistical risk cosntruction*	*technical risks operation*	*termination risk*	*refinancing risk*	*inflation risk*	*change of political conditions*	*insolvency risk*		
Single risks i →	1	2	3	4	5	6	7	8	9	∑	
Time t [year] ↓											
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	t0
1	0.25	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.64	t_exc
2	0.00	1.26	0.56	0.00	0.00	0.00	0.00	0.00	0.00	1.82	t_str
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	t_fin
4	0.00	0.64	0.00	0.31	0.00	0.00	0.00	0.00	0.00	0.95	-
5	0.00	0.00	0.00	0.00	0.00	1.13	0.00	0.00	0.00	1.13	-
6	0.00	0.00	0.00	0.22	0.00	0.59	0.00	0.00	0.00	0.82	-
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-
8	0.00	0.00	0.00	0.15	0.00	0.00	0.00	0.00	0.00	0.15	-
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	t_ope
10	0.00	0.00	0.00	0.00	0.28	0.00	0.00	0.00	0.00	0.28	t_end
∑	0.25	2.30	0.56	0.68	0.28	1.72	0.00	0.00	0.00	OK	5.78
Project's cumulated risk load after t_end in run k [monetary units]→										5.78	

Figure 3: Interim result after one MCS iteration (time-specific risk scenario)

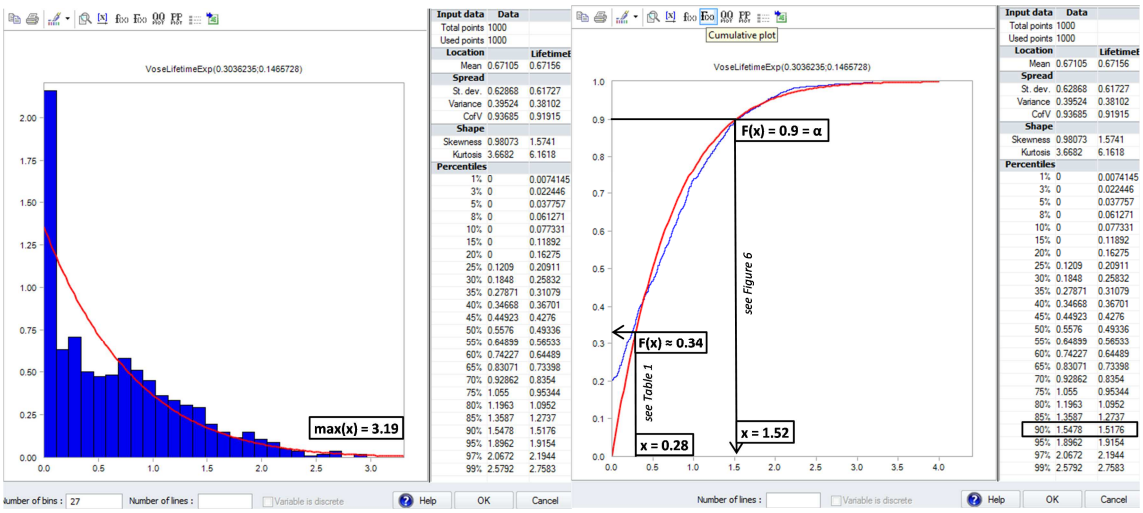

Figure 4: Density and distribution function of project risk load in period t_end only

After k iterations, the “empirical” distribution function can be derived for the project risk load that just has occurred at a point in time t (see Fig. 4) or for the **cumulated** risk load that has occurred until a point in time t (see Fig. 5). The difference of the risk load at one point in time and the accumulated risk load until this point in time becomes apparent, when comparing the maximum value of Fig. 4 being 3.19m$ to the maximum value of Fig. 5 being 39.28m$. This means that the maximum risk load of all simulation scenarios in the last time unit of the simulation was 3.19m$ and that the maximal simulated risk load cumulated over all time units was 39.28m$. If the 90%-quantile (α = 0.9) of the according “empirical” distribution function is chosen, the project’s cumulated risk load until t_{end} is 18.84m$ as shown in Fig. 5 and Fig. 7.

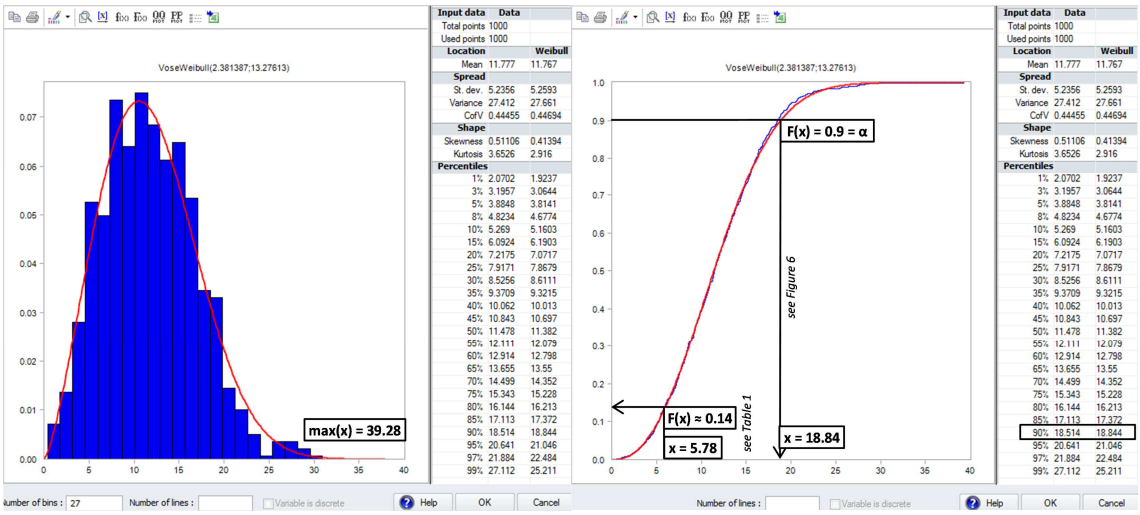

Figure 5: Density and distribution function of cumulated project risk load until t_end

Fig. 6 shows the expected MCS results in the three dimensions time t, impact of occurrence I and probability of impact P(I). The concept displayed on top of Fig. 6 is based on Girmscheid (2011), part 2, Fig. 2 and was now integrated in a MCS for the determination of the project specific risk load results, not only retrospectively a the end of the project, but also for the points in time inbetween. Over time, the maximum value of the according density function increases because the cumulated project load increases because the longer the project run’s, the more risk could have occurred and caused an impact and thus cost. The bottom of Fig. 6 shows the accumulation of the project risk load after applying a confidence level α to the MCS results, which makes the results of different points in time comparable. Fig. 7 represents basically the same illustration as the bottom of Fig. 6 with the results of the implemented example for a confidence level α = 0.9 applied to the project risk load distribution as MCS result. The **accumulating** project risk load is shown for every simulated time unit t (I_tot_cum_α) as well as the decreasing project risk load of each time unit t (I_tot_α).

5. Discussion and outlook

The MCS accumulation curve “I_tot_cum_α” is concave as shown in Fig. 7. This relates to “I_tot_α” decreasing over time. Thus, a modelling based on linear trends or convex functions (e.g. Brownian bridge) would tend to underestimate the risk load development. However, the simulation result depends strongly on the form of the distribution functions chosen for T_i.

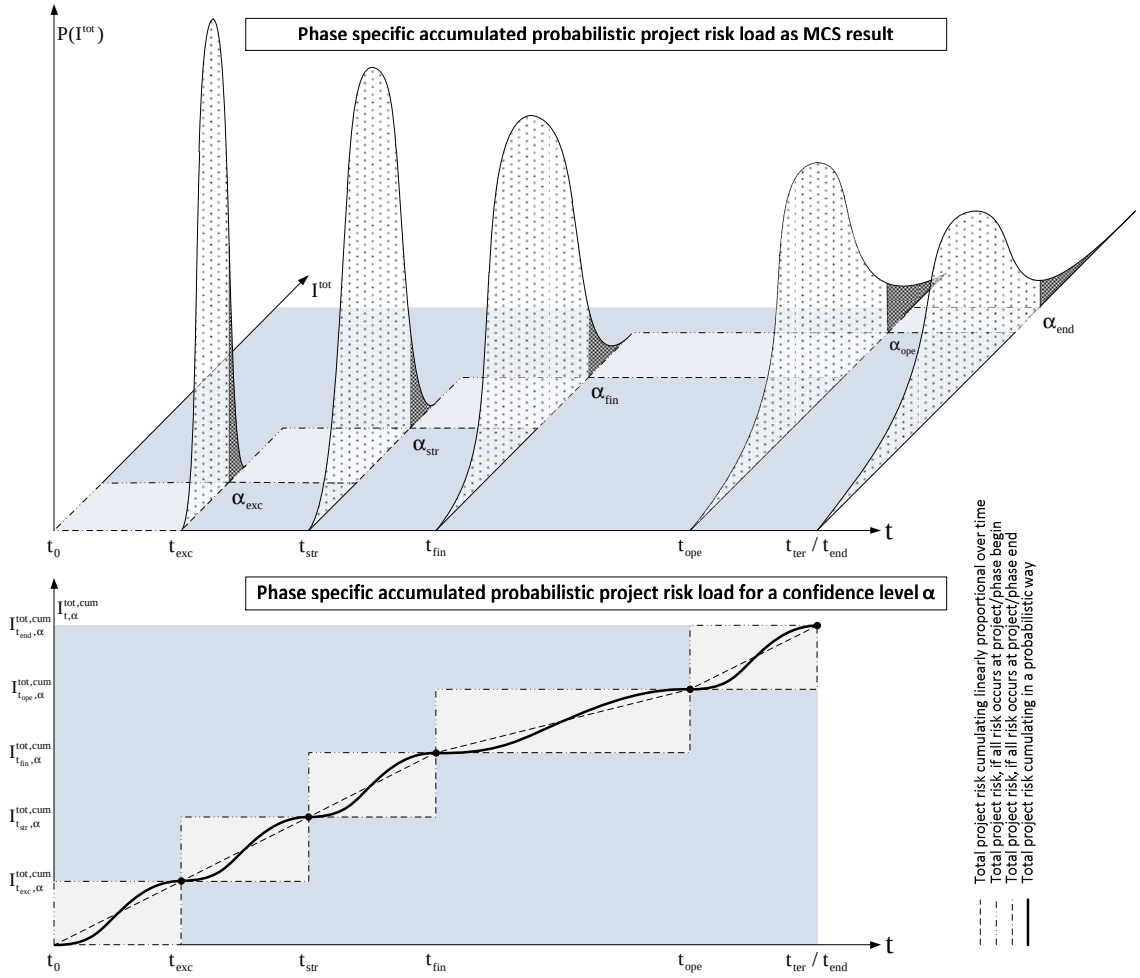

Figure 6: Concept of phase specific accumulated project risk after MCS

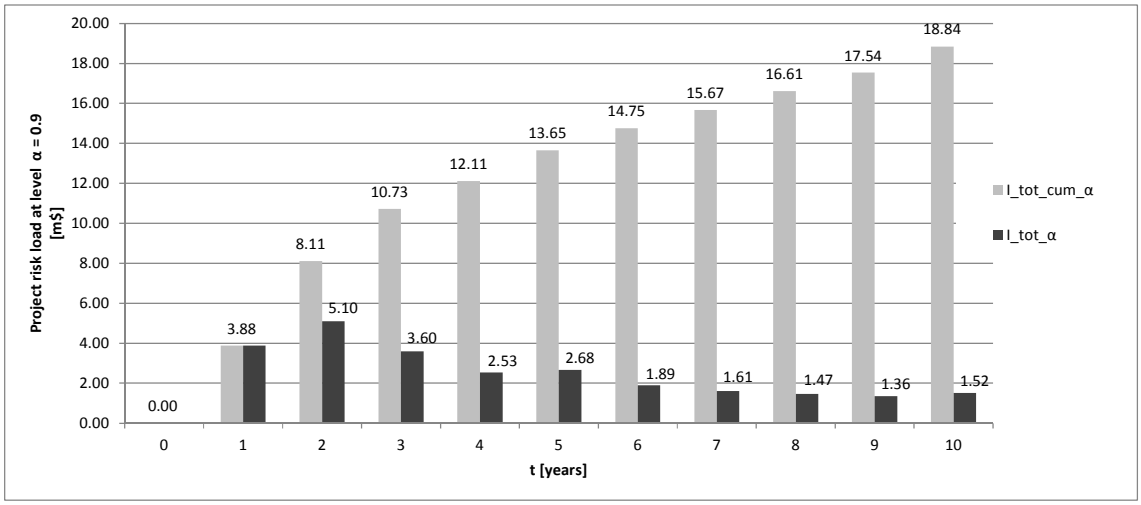

Figure 7: Accumulation development of project risk load for confidence level α = 0.9

Fig. 7 assumes the resulting cumulative distribution functions are normally distributed, according to the central limit theorem. However, the MCS results tend to be positively skewed distributions (see Fig. 4 and 5). Consequently, the general assumption of the normal distribution would lead to an approximation error in the tails, which can be important to the RA model user, depending on the interest in extreme events. This raises the question how the explicit interest in extreme events can be integrated in the present approach. Further

development of the risk load calculation will include differentiation of single risks into periodic and non-periodic occurrence of these risks, e.g. to model risk like HVAC replacement in a better way (see Girmscheid (2013)), and consideration of correlations. The principle of prudence requires that the positive correlations must be considered at least in order to avoid underestimation of the project's risk load. Furthermore, the algorithm will be adapted to run a Latin Hypercube sampling. The implementation will be expanded to other modules as shown in Fig. 1, with the aim of an implemented prototype tool that calculates the quantitative RA automatically, under consideration of the private party's risk-bearing capacity. After completion of this task, the RA model will be tested with real project data. While the overall research project is tailored to PPP projects, the presented concept can be applied to any life-cycle oriented construction project for probabilistic quantitative determination of the risk load. Of course, the results will only be as good as the according input data from subjective expert estimations.

6. Conclusion

Within the limitations described above, the aim of probabilistically determining a time-specific project risk load for PPP building projects was achieved. Time-related random variables were integrated into a given MCS approach for project risk aggregation to enhance the methodology accordingly. Rational and traceable decision-making next to the use of clear and unambiguous criteria allows for the implementation of a generic example, which underpins the theoretical ideas. Because of the implementation, more complex and realistic causalities can be processed easily with reduced resource use, as long as sound input data is available. The main benefit is the availability of a PPP project risk load at every point in time over the contract phase. The project's risk load is determined to check the private party's risk-bearing capacity and the risk coverage for the PPP project. With the concept presented above, the project's risk load can be simulated not only for the end of the contract phase but for every point in time in between. As a consequence, the financial resources for risk coverage can be derived more time specifically, which might lead to reduced financing cost. Furthermore, the presented approach leads to more transparency in the calculation of risk costs and might help to avoid bounded rationality, opportunism and alike. The given time specificity of the project's risk load allows for the proper consideration of price increases, interest, etc. The presented research was co-financed by the Swiss Commission for Technology and Innovation (CTI).

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Hypothesis Analysis of Building Information Modelling Penetration in Malaysian Construction Industry

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Abstract

The demand pull for a more effective construction process within architecture, engineering and construction (AEC) industry continuous to transform design techniques from 2D, 3D and building information modelling (BIM). Leverage on IT pivotal for construction industry development has been earmarked by the Malaysian construction industry master plan (CIMP). BIM uptake by stakeholders in Malaysia construction industry is on a gradual increase. BIM generates and manage building data during its life cycle via three-dimensional, real-time, dynamic building modelling. The model is dependent on collaborative contribution by project teams input at various stages. However, challenges such as people, process and technology impede an effective penetration rate in Malaysia. This paper presents a continuation of the theoretical framework developed, to further investigate the relationship for BIM penetration from perspectives of people, process and technology to strategic IT in construction and collaborative construction. The theorised hypotheses argue that strategic IT planning will invariably aid BIM penetration in the industry. The hypothesis will undergo structural equation modelling (SEM) to analyse the desired statistical power, test for close versus exact fit and complexity of the model. The findings will delineate the variables with predominant impact on BIM penetration and serves as a guide to policy making on BIM implementation in Malaysia.

Keywords: Building Information Modelling, Information Technology, Penetration, Malaysia Construction Industry.

1. Introduction

Malaysian construction industry is continually adapting to meet competitive challenges around the globe market. Thus, the need to imbibe change reaction and modernism from capacity and knowledge acquired, tapping from similar initiatives by the UK construction industry stipulated in 1998 Latham report. Hamid and Kamar (2010) recommended the construction best practice programme (CBPP) model for Malaysia construction industry involving rethinking IT programs and tools. The UK National Building Specification (NBS) National BIM 2012 Report expressed a competitive disadvantage syndrome for organisation lagging behind in BIM adoption (Malleson, 2012). The Malaysian-German Chambers of Commerce projected a 5.2% expansion in the construction industry as a result of civil

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engineering works from government stimulus package. The analysis also hinged a successful growth rate on technological investments in Information Technology (IT), similar to growth in other sectors spawn by IT. Malaysian construction industry should take a cue for a more sustainable construction growth performance. Under the 10th Malaysian plan an estimated growth of 3.7% per annum is expected compared to the nations' 6% per annum GDP (Brandt & Yong, 2011). The revolutionary BIM tool in the Architecture, Engineering, and Construction (AEC) industry presents great advantages towards the vision on Construction Industry Development Board (CIDB) master plan and the nations' 2020 vision through increase in key performance indicators (KPIs) and productivity. BIM provides sustainable assessment tool for life cycle simulations, efficient costing, improvement in engineering quality and promising a new crop of graduates (Nguyen et al, 2010; CRC, 2007; Russell et al, 2009; Ibrahim et al, 2004; Kaner et al, 2008; Smith et al, 2005; Sun & Zhou, 2010). However, every new IT tool is without inherent challenges such as inherent interoperability issues, legal and contractual aspects management BIM pedagogy, BIM training and high cost of purchasing software (Rezgui & Zarli, 2006; Taylor et al, 2007; Enegbuma et al, 2010; Tse et al, 2005; Rosenberg, 2006; PSDC, 2010). The first part of the paper introduces the current scenario in the industry, usefulness and challenges of BIM. Subsequent sections delineate the model construct and hypothesis extending previous study by Enegbuma and Ali (2012).

2. Building Information Modelling

Models seek better perfection in creation of forms and buildings (Teran, 2008). Building Information Modelling is collaboration by different stakeholders at different phases of the life-cycle of a facility to insert, extract, update or modify information in the model to support and reflect the roles of that stakeholder. The model is a shared digital representation with open standards for interoperability (Smith & Edgar, 2008; McCuen, 2008). The process generates and manages building data during its life cycle using three-dimensional, real-time, dynamic building modelling software to increase productivity in building design and construction which encompasses building geometry, spatial relationships, geographic information, and quantities and properties of building components (Lee et al., 2006). BDS (Building Design Systems) and RUCAPS (Really Universal Computer Aided Production System) formed the early parts of BIM development which were sold across UK and US, followed by SONATA in 1986 though limited to central work stationing, personalized computer CAD systems such as ArchiCAD were in developmental stages while, GLIDE (Graphical Language for Interactive Design), GLIDE-II, and CAEADS (Computer Aided Engineering and Architectural Design System) (See, 2007). Industry Foundation Classes (IFC) is open and neutral data format for openBIM borne by the increased pressure to integrate various BIM formats and software to smoothen the collaborative platform. IFC is registered with the International Standardization Organization ISO as ISO16739 and specification are developed and maintained by buildingSMART International (IFC 2002; IFC, 2012). Information Delivery Manuals (IDM) in ISO 29481-1:2010 is an initiative by BuildingSMART geared towards the capture of real life construction documentation, with several challenging test carried out to capture real life construction data which is universally accepted by the BIM support software. Timely update and quality information dissemination forms a key part and strict guideline from initiation of the process, development, application for official status with buildingSMART, approval and

publishing (Karlshoj, 2011). International Framework for Dictionaries (IFD) was hatched to control vocabulary of construction terminology inevitably essential to support data exchange (Bell et al., 2008). Model view definition (MVD) defines a subset of the IFC schema needed to satisfy one or many exchange requirements of the AEC industry using IDM exchange requirement in its definition (Liebich et al., 2011).

2.1 People

BIM offers an unsettling precedence to an already defragmented construction industry which offers less surety. New processes to enhance the construction process, electronic designs and construction professionals must acknowledge the individual risk associated with such a new technology. Boundaries of professional responsibility and work product are not clearly defined creating uncertainty for liability in a BIM model. The trend of older professionals still lagging behind while younger professionals lack experience in legal matters with a need for flexible legal form of agreement between construction teams to meet the rapid growth (Jordani, 2008; Rosenberg, 2006; Salmon, 2009). The emergence of local user Groups in various localities to discuss BIM concepts, softwares and products including information sharing on achievements has shown an adaptive response by people for BIM improvements (Lega, 2008). Owner awareness is lacking in terms of information regarding successes of BIM by other competitive companies in operation, maintenance, repair and remodeling. While, other seminar authors proposed a future expansion of current pedagogy in education of building professionals due to current challenges of constructing sustainable life cycle buildings (Edgar, 2008; Henderson & Jordan, 2009).

2.2 Process

Construction industry reports such as Simon 1944, Banwell 1964 and British Property Federation 1983 except the Latham 1994 report, have ignored IT as an integral process in construction. However, emphasis on technology development alone places less attention to organisational and human issues. Furthermore, fewer staffs to regularly update BIM models and inadequate human resource training exist in the construction industry (Aouad et al., 1999; Rezgui & Zarli, 2006; Damain & Yan, 2008; Liu, 2010). For smooth BIM implementation within an organisation strict consideration must be given to the long term goals of the organisation and requirement. Similarly, managing the cost of ownership can be actualised through BIM, with diligent improvement in BIM practices owners' BIM metamorphoses into a Business Intelligence Model placing it right within corporate mission and objectives. Similar to the CAD migration from manual drawings, BIM is faced with an ever challenging bureaucracy by top management due to new risk and liability fears consummating into a lengthy list of disclaimers during model sharing (Smith, 2007; Jordani, 2008). BIM implementation in the US coast guard on subsequent Charleston Regional Strategic Plan (RSP) achieved partial success. Full success was eventually marred by people's culture and senior leadership resistance to new methodologies; workflow changes; and technological innovation (Hammond, 2008).

2.3 Technology

Owner push for faster product delivery improvement, safer construction environment, reduced construction cost, lean adoption to eliminate waste and proactive drive by industry professionals to assimilate new technology such as BIM (Jordani, 2008). Malaysian construction industry grapples in advanced IT and project management techniques which forms an essential part to high-tech and capital intensive construction in line with American Institutes of Architects (AIA) push for advancement and open standards (Ibrahim et al, 2010). McGraw-Hill construction report suggests that for BIM to strive and meet the challenges of the future, model objects needs to be readily available for smooth information extraction. Although, product library were created by software companies to represent generic components they lack enough data to represent the specifications of Building Product Manufacturers (BPMs). Knowledge of BIM software, inadequate reference material and component database provide challenges in BIM education in tertiary institutions. Inherent deficiencies in BIM specification provide inadequate differentiation between requirement for BIM deliverables and technology to deliver such information. Similarly, during hyper collaborative platforms such as BIM Storm, participants had to revert to do some manual communication (Jones & Lien, 2008; East, 2009; Onuma, 2008).

2.4 Strategic IT Planning

As industries transform, from adversarial to cooperative thinking with more emphasis on business process, the construction industry in transforming into long term strategic planning to cope with the dynamic nature of economic, technological and social factors. Strategic IT usage though perceived with a degree of reluctance by the construction industry is currently transforming, as most business process were never designed but formed by ad hoc means. Research in labour and cost saving by Adam Smith and Fredrick Taylor provided an initiating argument towards a re-think of business process (Davenport & Short, 1990; Johansson et al., 1993; Betts, 1999). Sustainable competitive advantage is maintained though innovative process improvement and management reliant on IT to provide enabling environment (Kangas, 1999; Moingeon et al., 1998; Alshawi, 2007). ICT showed a positive and significant impact on the Malaysian economy from 1982 – 2004 which established a change from the norm of investments on agrarian economy to one of manufacturing and industrialisation (Kappusamy & Shanmugam, 2007). Technology acceptance and usage has been studied extensively, expanding Fishbein and Ajzen Model of 1975, Fred Davies formulated the technology acceptance model (TAM). Fishbein and Ajzen Model explained the theory of reasoned action, which Davies conceptualised the existence of a response predicted by user motivation and influenced by external stimulus consisting of the system features and capabilities which triggered the use of a system. Davenport (1993) perceived change to be structured and measured sets of activities designed for a specific product for various markets and clientele. In construction, process change from inception, project completion and FM stages provide benefits to clients in Malaysian construction industry. Business Process Re-engineering (BPR) drives organization to change their career paths, training, recruitment and policies (Anthony, 1965; Porte & Millar, 1985; Liang & Cohen, 1994). Factors highlighted in driving BPR are organisational training, reward, communication, research and development (Kohar et al., 2012).

2.5 Collaborative Construction

Collaboration in construction is defined as an agreement among specialist to share their abilities in a particular process, to achieve the larger adjectives of the project as a whole, as defined by a client, a community, or a society at large. Collaboration can further be seen a working together in a seamless team for common objectives that deliver benefit to all. Collaboration is more effective when undertaken at the project inception stage (Hobbs, 1996; be 2004; Anumba & Newnham, 2000). The construction industry presents a rather unique approach to collaborating which when done ineffectively creates islands of automation (Kalay, 2001; Yeomans, 2005; Sun & Aouad, 2000). Major challenges to effective collaboration exist in the construction industry due to independent working and taking decisions which affects the project team (Anumba et al, 1997, 2001 & 2002; Yeomans, 2005). Issues bordering around undefined boundary between teamwork and collaboration including, unsolved issues of shared-understanding, alignment of purpose and shared meaning. Different educational upbringing, terminologies and adversarial contractual agreement further provides barriers to collaboration (Lang et al., 2002; Yeomans, 2005; Anumba et al, 2000; Kalay, 2001; Yeomans, 2005).

2.6 BIM Penetration

The communication of innovation over time amongst members of the same social systems over a period of time is often referred to as a product of complex social interaction. The social system acts as a determinant of socio-psychological processes within the social system (Rogers, 2003; Bain et al, 2001; Dackert et al, 2004; Kanter, 1988; West, 1990; Panuwatwanich et al, 2009). Diffusion describes the acceptance and usage of new technology while innovation denotes a new product or process technology, or administrative. This research targets the penetration of BIM within the Malaysian construction industry to foster prompt attention and improvement of grey areas within the industry. Seminar authors in innovation diffusion proposed new models of diffusion of new technologies with complimentary implications for increasing the rate of innovation in the industry. Furthermore, investigations identified four forces that drive innovation: competitive advantage, process problems, technological opportunity, and institutional requirements (Rogers & Shoemaker, 1971; Damanpour, 1991; Tatum & Mitropoulos, 2000). Rogers (1983) argued that relative advantage, compatibility, complexity, observability and triability are determining factors for technology diffusion. The structural equation modelling path study towards improving innovation diffusion level within the architectural and engineering design (AED), delineated definitive pathways and practical strategies harnessed by the construction industry to derive outcomes from innovation via diagnosing and improving their existing innovation capability which invariably strengthen their business performance (Panuwatwanich et al, 2009).

3. The Research Model

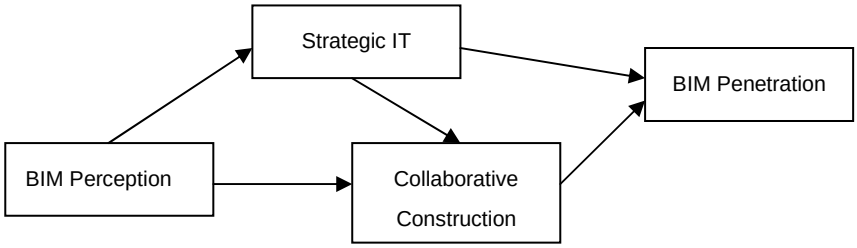

Figure 1: Overview of Research Model (Enegbuma and Ali, 2012)

The research model encompasses research gaps on BIM perceptions and the effects on penetration for construction industries adopting building information modelling. Existing literature an underlining need for adequate strategic IT planning which drew from IT acceptance models, business process re-engineering and collaborative construction. The model shown in figure 1, builds on BIM perception in the construction industry towards effective BIM penetration incorporating strategic IT implementation (Betts, 1999), technology acceptance model (Davis, 1985; Chuttur, 2009), business process re-engineering (Anthony, 1965; Porte & Millar, 1985; Liang & Cohen, 1994) and collaborative construction.

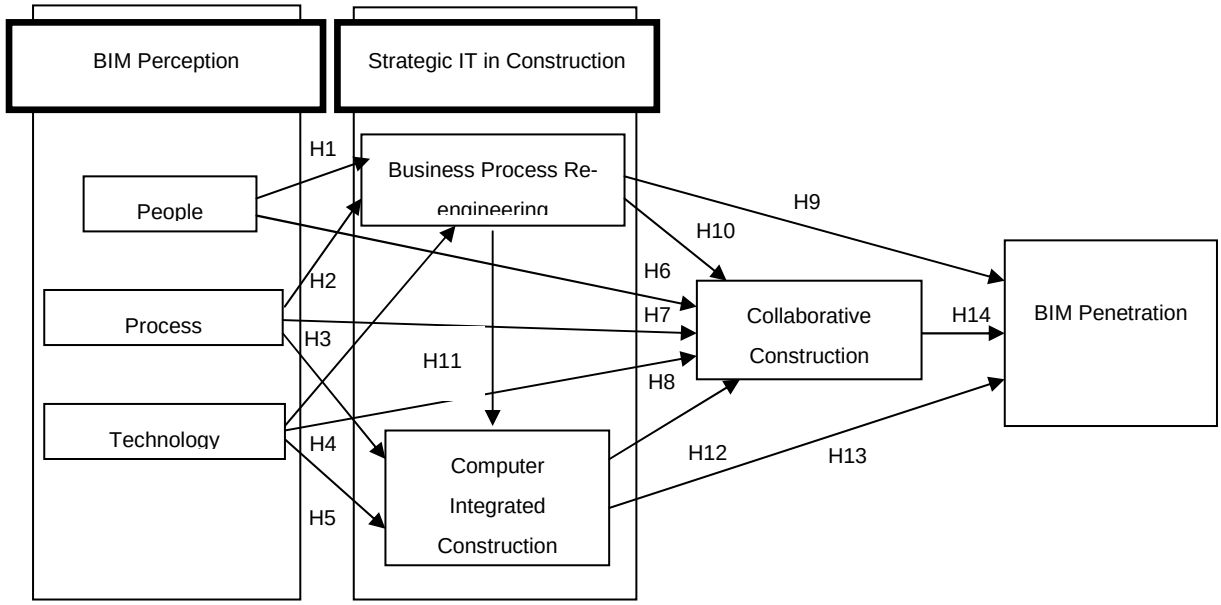

Figure 2: Research Model and Hypothesis (Enegbuma and Ali, 2012)

3.1 BIM Perception and Strategic IT in Construction

In the research model shown in fig 2, the causative linkage between BIM Perception and strategic IT in construction as posit in literature will be discussed. IT implementation relies on the perception from people, process and technological knowhow due to inadequate artificial intelligence in software and devices (Sommerville & Craig, 2006). Human interaction with a new system influences the rate of implementation in an organisation. Drivers such as communication, human activity, system processing, design, specification and tradeoffs are

necessary considerations (Fidelman, 2002; AELR, 1995; Sommerville and Craig, 2006). The phenomenon known as people managers translates the importance of people in organisations adapting to new IT technologies. Hence, understanding ways to tap into individual creative energy, intelligence, initiative, managing change, alley fears to change is critical to implementation success (Towers, 1996, Cooper &Markus, 1995; Kennedy, 1994; Arendt et al, 1995; Alshawi, 2007). Although fears arise from the perceived reduction in professional fees with BIM, cost savings from energy savings, maintenance, informed decisions, purchasing, clash detection, reduced request for information adds value to the project for clients, hence the onus to demonstrate the level of value added to clients (Hamil, 2012). Alshawi (2007) argued that technological push generated more awareness on the need for improvement in business process and re-engineering. Also, incompatibility in IT applications creates island of automation challenging the normal business processes and computer integrated construction. Hence, it is hypothesized that:

- H1: There is a positive relationship between People and Business Process Re-engineering
- H2: There is a positive relationship between Process and Business Process Re-engineering
- H3: There is a positive relationship between Technology and Business Process Re-engineering
- H4: There is a positive relationship between Process and Computer Integrated Construction
- H5: There is a positive relationship between Technology and Computer Integrated Construction

3.2 BIM Perception and Collaborative Construction

Collaboration is a unified platform that enables interaction between various individuals or groups of individuals in the project team. This triggers a creative process and enables sharing of ideas within openness, honesty, trust and mutual respect towards achieving a common goal. Certain philosophies argues that irrespective of the manner of communication, either synchronised or asynchronised collaboration, the basic premise lies in the communication between one or more individuals. This view point was further stressed when collaboration is referred to as an activity. Emphasis is laid on technology as an enabler providing an atmosphere for various technologies to interact (Burtler Group, 2003; Wilkinson, 2005). BIM utilisation stimulated a downward trend in variation orders geared towards a zero variation order for projects. Early collaboration provide the opportunity for practical solutions for constructability complexities, owner awareness and government push also further increases BIM usage (Cannistraro, 2010) thus leading lead to hypothesis:

- H6: There is a positive relationship between People and Collaborative Construction
- H7: There is a positive relationship between Process and Collaborative Construction
- H8: There is a positive relationship between Technology and Collaborative Construction

3.3 Strategic IT in Construction, Collaborative Construction and BIM Penetration

Integrating IT systems with business processes reshapes and facilitates the organisational culture, performed task, coordinated activities (Davenport and Short, 1990; Hinterhuber, 1995; Hammer, 1990; Willcocks & Smith, 1994; Tapscott & Caston, 1993; Klenke, 1994; Alter, 1993; Davenport, 1993; Alshawi, 2007). However, to achieve a greater business re-engineering prompt attention is given to modelling new business processes around the implemented IT systems (Koch et al., 1999; Alshawi, 2007). Yeomans et al., (2006) expressed the need for certain project teams to provide extra effort towards achieving collaboration, however, in Malaysia current literature is void of which project team members should with the advent of BIM engage more for a push towards effective collaboration. Yeomans et al. (2006) also argues that there is no resulting disadvantage from adopting collaboration practices in the industry, dependent on the commitment of the project team, merger of collaborative ideals with procurement systems and developing a means to capture and report the benefits. Sommerville and Craig (2006) argued that the increase usage of IT in business processes resulted from the increased awareness of the benefits of open collaborative efforts by project teams in the construction industry. The push for effective collaborative will inadvertently provide higher productivity and returns on investments for clients increased demands which led to further hypothesis of:

- H9: There is a positive relationship between Business Process Re-engineering and BIM Penetration
- H10: There is a positive relationship between Business Process Re-engineering and Collaborative Construction
- H11: There is a positive relationship between Business Process Re-engineering and Computer Integrated Construction
- H12: There is a positive relationship between Computer Integrated Construction and Collaborative Construction
- H13: There is a positive relationship between Computer Integrated Construction and BIM Penetration
- H14: There is a positive relationship between Collaborative Construction and BIM Penetration

4. Conclusion

As Malaysia moves towards its target vision of high income economy, BIM provides adequate IT leverage in the construction sector. This paper has presented an argument and hypothetical background of BIM penetration model formation. The model hypothesises variables of people, process, technology, strategic IT planning and collaborative construction to further enhance BIM acceptance in Malaysia construction industry. Overcoming the challenge of increasing BIM adoption and usage promises a more sustainable construction process in all ramifications. The hypothesis will undergo Structural Equation Modelling (SEM) to analyse the desired statistical power, test for close versus exact fit and complexity of the model after data collection. The structural equation modelling analyses the relationships to pin point the perception factors with higher effect on collaborative working, denoting grey area for investment and research focus in the industry.

Acknowledgements

The authors will like to appreciate the International Doctorial Fellowship (IDF) initiated by Universiti Teknologi Malaysia and supported by the Ministry of Higher Education (MOHE).

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Feasible Energy Saving Potentials in Renovations for Residential and Service Building Stock

Jaakko Vihola[1], Juhani Heljo[2], Antti Kurvinen[3]

The aim of the study behind this paper was to define feasible energy saving potentials of renovations in the 2010 Finnish residential and service building stock by 2050. This paper includes descriptions of the Finnish building stock and bottom-up calculation model called EKOREM, which was used to calculate different energy saving scenarios. Three different research methods that were used to determine the volume of potential renovations in the Finnish building stock are also described. Furthermore various reasons behind decisions to omit optional energy saving measures are discussed.

Finnish building stock consumes almost 40% of the total energy use in Finland. Thus it should be one of the main focus areas when trying to achieve energy efficiency goals set by the European Union. The study showed that the feasible energy saving potential in renovations for the residential and service building stock in Finland is quite low compared to the rest of Europe. Feasible annual savings in heating energy from renovations varies from 0.2-0.7%. That means that cumulative savings in 2050 would be between 8-28 %. In theory, it is possible to save more energy than is considered feasible. Calculations were completed where the whole building stock was set to correspond to the 2010 Building Regulations of Finland. That resulted to about 40% of savings in the 2010 building stock by 2050.

Low feasible saving potential is mainly due the fact that it usually pays to implement structural energy-saving measures only when the targeted elements are in a need of repair because of their physical condition. Attempts to achieve greater energy savings than can be reached with measures connected to scheduled renovations may multiply costs. Thus, the savings in energy costs will not necessarily cover the investments needed. In Finland, about 70% of the residential buildings are owner occupied. Owners cannot be forced to implement any energy saving measures that they don't see reasonable or cannot afford. This comes to play especially in areas facing an uncertain future, and therefore financial possibilities to carry out expensive renovations are low. These are only few of the various reasons why energy-based renovations cannot be speeded up very much.

Keywords: Energy consumption, Energy saving, Renovations, Residential and service buildings, Building stock

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1. Introduction

At the end of 2006, the European Union pledged to cut its annual consumption of primary energy and greenhouse gas emissions by 20% compared to 1990 levels by 2020. Finland, as a part of the European Union, is required to fulfill these energy saving requirements as well. Building stock is a major contributor to energy consumption in Finland. In the year 2007 end usage of the energy in Finland was 307 TWh. Building stock's share from this was 38% (Vehviläinen et al. 2010, p.13). Because of the high share, building stock should be one of the main areas of focus when considering how required energy savings and greenhouse gas reductions could be reached.

This study focuses on feasible energy saving potentials of renovations in the 2010 Finnish residential and service building stock by 2050. In this case, feasible energy saving potential means savings achieved by energy saving measures which are carried out within scheduled renovations and are considered technically approved and economic. Plenty of earlier research has focused on the economics of energy efficiency investments. It seems that even at the present level of energy prices and without implementation of large scale policy instruments, many of energy saving measures are profitable to carry out (Amstalden et al. 2006). Profitability of different measures can increase even more if different kinds of co-benefits are considered in addition to energy-related benefits (Jakob 2004). Co-benefits include, for instance, improved indoor air quality and protection against external noise.

The energy saving potential calculations were made using EKOREM-calculation model (Heljo 2005). Four different scenarios were studied and the results show that feasible energy saving potential in renovations is smaller than expected and might cause some serious challenges when considering the goals set by the European Union. In the UK, similar results have been achieved regarding of CO_2 emission reductions (Johnston et al. 2004). Because of complex nature of the building stock and its energy consumption, this study focuses only on energy saving measures that consider buildings' envelope, ventilation system and hot water usage. Electricity consumption is only observed as a part of ventilation renovations. Heating system changes, new production saving potentials and energy consumption affected by user behavior are excluded from this study.

Globally thinking results might vary greatly depending on which country is studied. Savings potential in energy consumption and greenhouse gas emissions are highly dependent on characteristics of the studied building stock and climate conditions. For example, distribution of building types and age as well as heating/cooling systems used are all factors when trying to estimate feasible saving potentials. In Finland, where the climate is cold, most of the energy saving in old buildings is achieved by increasing isolation layers of building envelope within scheduled renovations or by less expensive HVAC adjustment measures. In hot climate conditions, completely different problem field must be considered. There main focus should be directed to how to minimize cooling demand of buildings. This study has been made using Finnish climate data and building stock information, and thus the results are not to be generalized globally without further examination.

Finland is situated in northern hemisphere between the latitudes 60° and 70°. The average temperature in Helsinki (capital of Finland) on the southern coast of Finland is approximately 6°C. Difference in climate conditions between seasons is remarkable changing from hot summers to cold snowy winters.

The Finnish residential and service building stock is one of the youngest in Europe. Almost 70% of the stock has been built between 1970-2010 (Figure 1). 72% of the stock consists of residential buildings where single family houses form the largest group (40% of the stock). The age distribution of the building stock is the reason why big part of the building stock is in a need of renovation.

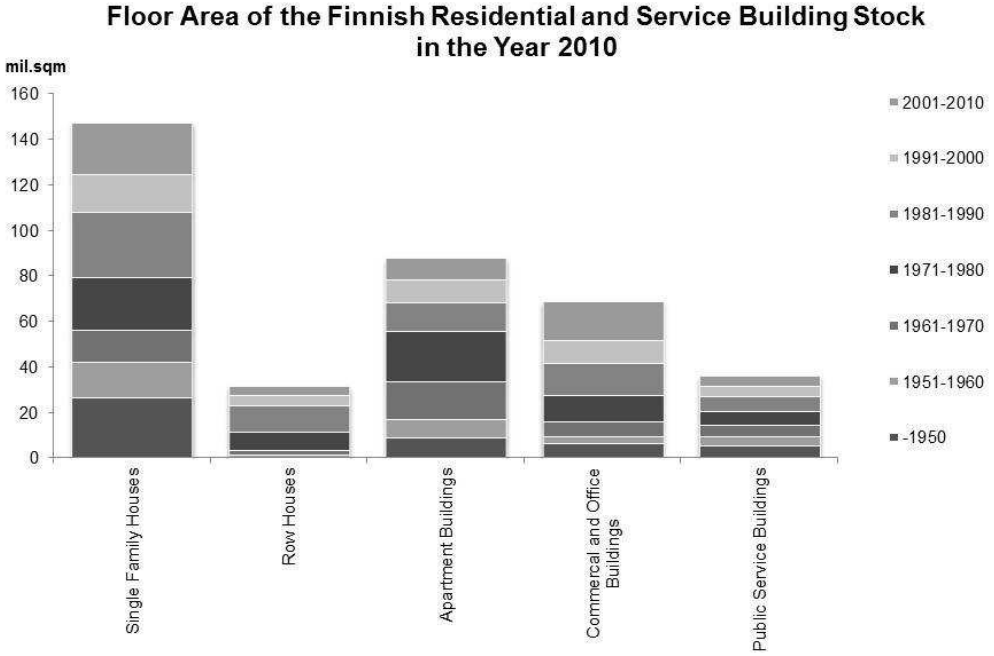

Figure 1. The Finnish residential and service building stock in the year 2010. Data is categorized into five different groups which represent different building types. Inside each of these five groups data is further divided to show when buildings have been constructed. (Statistics Finland)

Heating system distribution, especially in single family houses, is highly diversified. Most of the heating energy demand in single family houses is met either by wood/pellet, oil or electricity. Because of the new building regulations in the new production, focus will move strongly towards ground source heat pumps and other systems that utilize renewable energy resources. Rest of the residential and service building stock is almost exclusively connected to district heating except in the rural areas where service is not available.

In 2010 the Finnish residential and service building stock was using energy about 91 TWh. Residential buildings' share of this was approximately 64% and the rest 36% was consumed in different kind of service buildings. In residential buildings, most of the total energy consumption goes to heating of spaces and hot water. In service buildings, proportion of electricity consumption is noticeably higher because of the lightning requirements and demand of effective cooling caused by large amount of electric devices and people using the spaces.

The objective of this paper is to give a scientific estimation of feasible energy saving potentials in the Finnish residential and service building stock. Whenever saving potentials are referred to, for example by the politicians or the press, usually the magnitudes are way off. Statements are often based on sophisticated guesses rather than data produced by scientific methods. That is because of challenging nature of the building stock as a research object and the lack of statistical data considering renovations in the building stock.

2. Research Methods

Analysis of energy saving potentials was made by using bottom-up calculation model called EKOREM developed in Tampere University of Technology (Heljo et al. 2005). EKOREM is a building stock calculation model which can be used to determine energy consumption and greenhouse gas emission of the building stock in different cross-section years. Calculation method of the model is based on the part D5 (2007) of the National Building Code of Finland called “Calculation of Power and Energy Needs for heating of Buildings” (Finnish Ministry of Environment 2007).

In the model, building stock is divided in building type categories similar to used by Statistics Finland so that official statistical data can be easily used in calculations. Inside each building type buildings are further divided to age groups so that different groups can be given different kind of describing technical base values (for example U-values of different structural elements), which represent the methods of construction in each era as an average.

The main purpose of the EKOREM-model has been to create data for the EU-reporting needs to show how development of the National Building Code of Finland has reduced building stock’s energy consumption and greenhouse gas emissions. Besides this, many regional studies have also been made.

2.1 Studied Energy Saving Measures

In this study, the following energy saving measures were included: adding insulation to external walls, adding insulation to roofs, improving energy effectiveness of windows, improving air tightness of building envelope, improving/adding heat recovery unit to ventilation systems and installing flow meters to decrease consumption of hot water.

When trying to estimate energy saving potential in renovations of the building stock, studies must be based on an assumption that different building elements are only renovated when they are in need of a repair because of their physical state. Carrying out renovations, considering only energy saving aspect and without real technical or physical needs will lead to significant additional costs (Heljo & Vihola 2012). In figure 2 is simplified linear presentation which shows how energy saving measure’s share of total costs increases if trying to implement it before there is a need of renovation because of the physical state of the structure. From the economic point of view, energy renovations are most profitable when carried out within scheduled renovations.

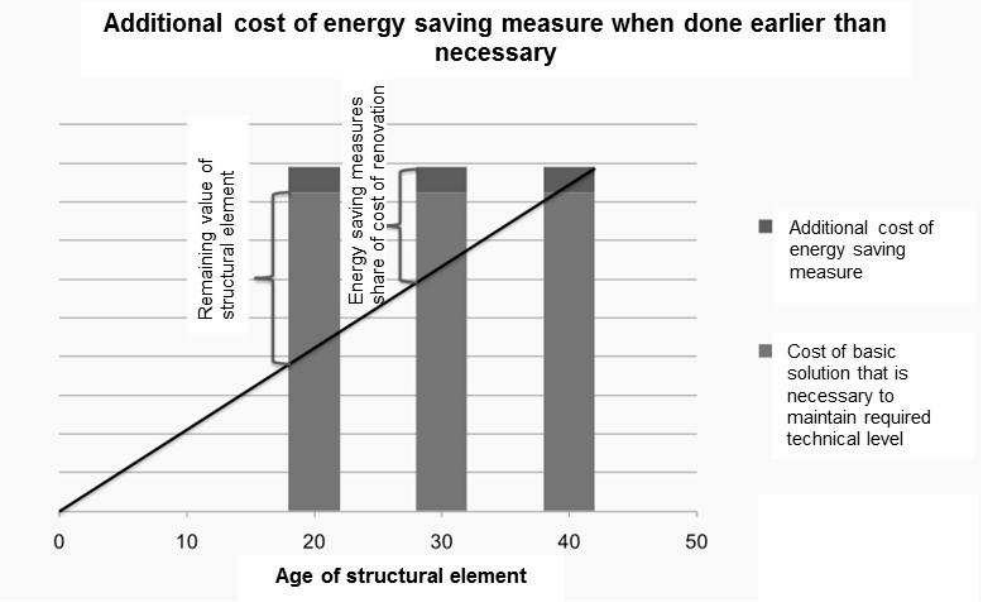

Figure 2. Simplified presentation of how additional cost of energy saving measure grows when trying to implement a measure earlier than is required from the technical and physical point of view. (Heljo & Vihola 2012)

2.2 Volume of Renovations

To know the volume of different kind of completed renovations is essential for estimating building stock's energy saving potentials. Within this study, three different estimations were created about the volume of renovation projects in the complete national building stock. First estimate is based on the very comprehensive research made by Technical Research Centre of Finland (Vainio et al. 2002). This research claims that approximately 2% of the studied building elements are renovated yearly (Figure 3). When comparing the results of this study to data of today, it shows that the volume of renovations has stayed almost the same.



Figure 3. Annual energy refurbishments in the Finnish building stock in the year 2000. On average about 2% of measures are carried out annually. Windows are being improved more often than that. (Vainio et al. 2002)

Other way of predicting the volume of refurbishment projects was to estimate life cycles of different building components and then to link these estimations with the building stock data. For example, window areas for different building types and different age groups can be found from the EKOREM-calculation model. Window area of apartment buildings by the year of construction can be found from figure 4.

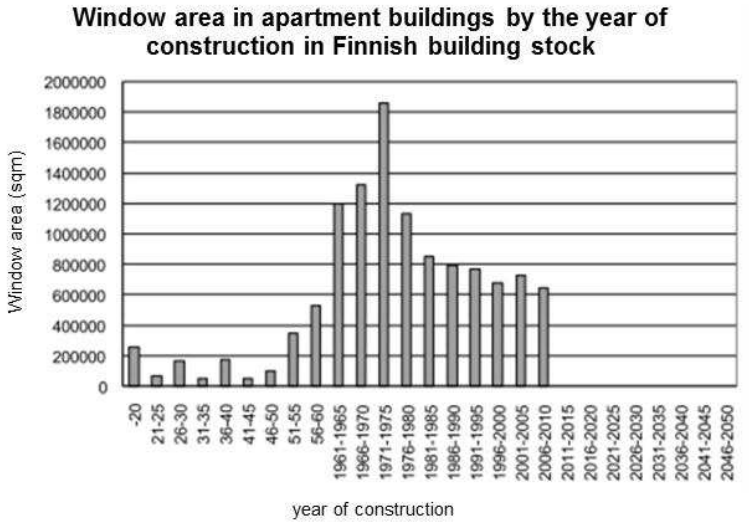

Figure 4. Window area in apartment buildings by the year of construction in the Finnish building stock as presented in EKOREM calculation model. (Heljo & Vihola 2012)

Different renovation profiles of structural elements were created for this study. In figure 5 is presented an estimation in which age windows are usually renovated.

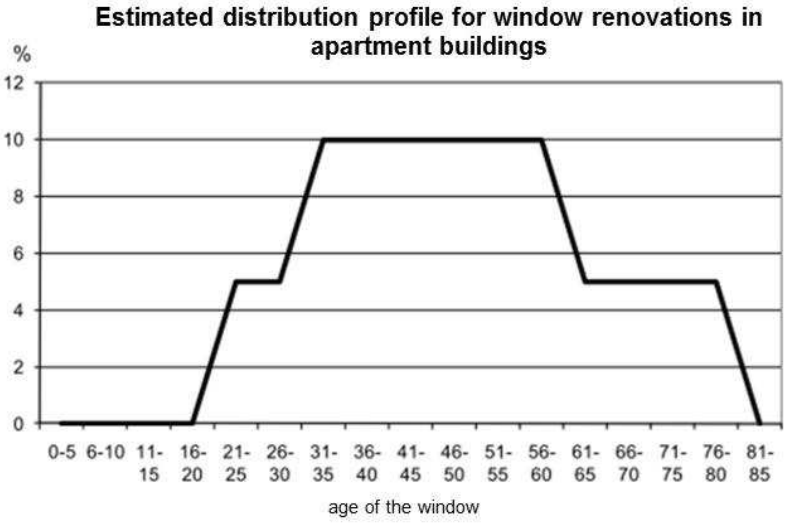

Figure 5. Histogram representing the age distribution when windows are usually renovated in apartment buildings. (Heljo & Vihola 2012)

When combining these two sets of data, one can make a theoretical distribution of window renovations as shown in figure 6. Some of the windows go through two rounds of renovations before the year 2050. In Finnish climate conditions this basically means that in a first round really old double-glazed windows (U-value=2,7 W/K,m^2) are changed to triple-

glazed windows (U-value = 1,4-1,8 W/K,m^2) and in the second round of renovations these are replaced by four-glazed windows (U-value = 0,85 W/K,m^2).

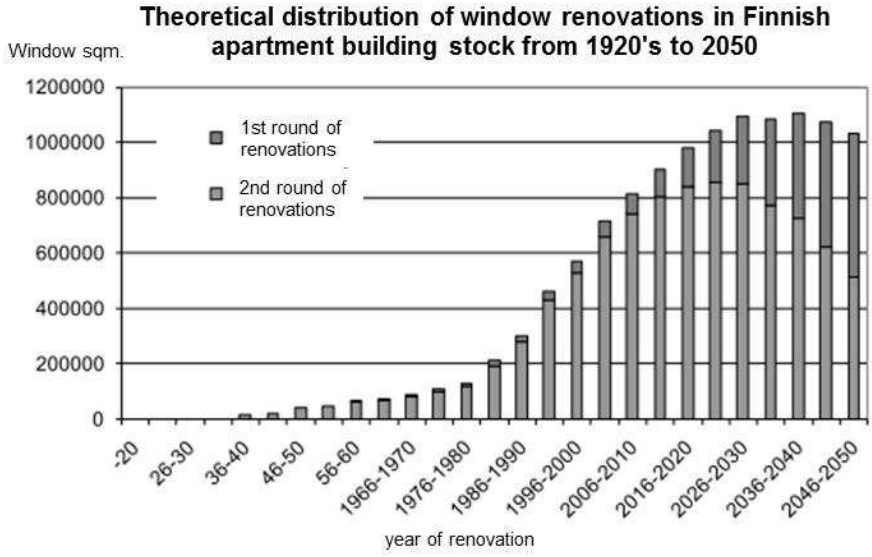

Figure 6. Theoretical distribution of window renovations in the Finnish building stock based on combining the data presented in figures 4 and 5. This can be used as an estimate to calculate feasible energy saving potentials. (Heljo & Vihola 2012)

This type of an examination is only possible in the case of windows and external walls. That is because adding insulation to roofs is not in all cases tied to scheduled renovations. Same goes for ventilation renovations.

Third source of information was so called “Expert Day” which was held during the project. Participants were from different organizations from the fields of construction research, consulting and planning. As a result following table (Table 1) was created of different energy saving measures.

Table 1. Volume of different energy saving measures in different building types in the Finnish residential and service building stock that are done already or will not be done by 2050 according to “Expert Day”.

Experts' estimations of implementation of energy saving measures 2010-2050	Window Exchange		External walls' supplementary insulation		Roof's supplementary insulation		Improving air tightness of building envelope		Adding heat recovery unit to ventilation system		Installing flow meters to reduce hot water consumption	
	Done	Will not be done	Done	Will not be done	Done	Will not be done	Done	Will not be done	Done	Will not be done	Done	Will not be done
Single family houses	15 %	20 %	15 %	40 %	20 %	15 %	5 %	70 %	30 %	10 %	100 %	
Row houses	15 %	10 %	15 %	40 %	5 %	20 %	5 %	70 %				5 %
Apartment buildings	15 %	15 %	8 %	40 %	3 %	75 %	5 %	80 %	5 %	80% / 20%		10 %
Commercial and office buildings	15 %	15 %	10 %	50 %	0 %	75 %	5 %	80 %	50 %	5 %		100 %
Public service buildings	15 %	15 %	10 %	50 %	0 %	75 %	5 %	80 %	50 %	5 %		100 %

Table represents the perception of the experts considering different energy saving measures, and in which scale they might be implemented to the building stock in the future. Feasible energy saving potential is reduced by the fact that some percentage of the measures has already been done and some percentage will never be done because of various reasons. Potential volume of different measures by 2050 can be easily calculated by reducing from 100% the amount of measures already done and the amount of measures that will not be done.

There is a significant amount of uncertainty relating to ventilation renovations. Expert opinions considering on how many of heat recovery unit installations will not be done by 2050 vary from 20 to 80%. Pessimistic opinion of 80% is based on the assumption that technical solutions of ventilation renovations will not be developed profitable and easy enough to put into practice. Calculations of feasible energy saving potentials have been made by using more optimistic view of 20%.

2.3 Reasons for Omitting Energy Saving Measures

One of the main topics during the Expert Day was figuring out reasons holding back implementation of energy saving measures. Plenty of different factors were found and those can be categorized to five groups.

First group includes problems regarding properties of buildings. Building can be too young or in good condition so renovations are unnecessary. In some cases, building might be close to end of its life cycle so there is no reason to renovate. There are plenty of buildings which are considered as architectural monuments and because of that they are protected from any renovations that might change the appearance of the building. There are also buildings that are planned for only temporary use. (Heljo & Vihola 2012)

In second group there are buildings that are situated in areas where economic outlook is bad. Situation there is that even the most profitable energy saving measures are not implemented because funding is not available. Usually when an energy-saving measure is implemented within scheduled renovation additional cost caused by the measure varies around 5-15%. (Heljo & Vihola 2012)

In third group, there are problems regarding lack of know-how and sceptical attitudes towards energy saving measures. These kinds of problems are, for instance, ones regarding ownership of the buildings. 75 % of the Finnish residential building stock is owner occupied which means that there are lots of decision makers and they cannot be forced to implement energy saving measures which they do not see profitable. One of the major problems is lack of experiences considering energy renovations. This reflects straight to level of know-how in the field of construction. Used technologies might be strange and not understandable enough and at the same time there might be a feeling of uncertainty regarding physical functionality of the new structure. Old structural components are also often considered valuable. In most projects, there is not enough time or resources to go through positive effects of energy renovations. (Heljo & Vihola 2012)

Fourth group includes technical and architectural difficulties. In some cases, energy saving measures are hard to carry out from the technical perspective. Especially in old buildings renovations linked up to building's envelope are hard to implement while retaining architectural and physical properties of the building. (Heljo & Vihola 2012)

Fifth and final group includes problems that are connected to profitability and the lack of resources. Usually there is lots of contradictory information available regarding of the profitability of energy saving measures. False information is usually caused by too short-sighted way of evaluating the effects of the energy saving measures. Every decision-making situation that is connected to large scale renovations should involve life cycle analysis of the building to make sure that the most profitable measures are implemented (Kurvinen et al. 2012).

2.4 Different Calculation Scenarios

When the volume of energy saving measures has been estimated, it is possible to use EKOREM-model to calculate energy saving potentials. For the study, four different calculation scenarios were created. These scenarios are:

1. **Basic development** where decrease in building units is included but different energy saving measures are not put into practice. Basic development must be known so that the saving potential of energy renovations can be calculated.

2. **Theoretical saving potential** which is calculated on an assumption that life cycle of the building elements determine the moment of different refurbishment measures. Limitations set by information from the Expert Day have been taken into account.

3. Calculation where **the volume of refurbishments is based on realization of energy-saving measures in the past**. Limitations set by information from the Expert Day have been taken into account.

4. **Theoretical maximum saving potential** where whole 2010 residential and service building stock has been refurbished to be equivalent to current Finnish National Building Code requirements for new production by 2050.

Scenarios 2 and 3 describe situations that are considered feasible. However, they are challenging as well. In calculations an assumption has been made that whenever scheduled renovations are carried out profitable and technically valid energy saving measures are implemented. Yet it has been estimated that at the present time only half of the time that actually realizes.

Scenarios 1 and 2 are made for the comparisons. Basic development without energy saving measures is presented so that feasible savings achieved by energy saving measures could be calculated. Theoretical maximum is possible to reach in single projects where conditions are right, but several factors mentioned before prevent renovations of such a large scale in building stock level.

3. Results and Discussion

The results of the different calculation scenarios have been presented in the figure 7. In the year 2010 the Finnish residential and service building stock is using energy 91 TWh/year. Because of decrease in building stock units, this value is reduced to 56 TWh/year by 2050. However, this reduction in the energy consumption cannot be counted as savings because disposed buildings will be replaced by new production at the same sites or somewhere else. It has been estimated that nearly 30% increase in the residential and service buildings stock is needed by 2050 to cover space requirements set by growth of population and increased demand of services (Vehviläinen et al. 2010, p. 44).

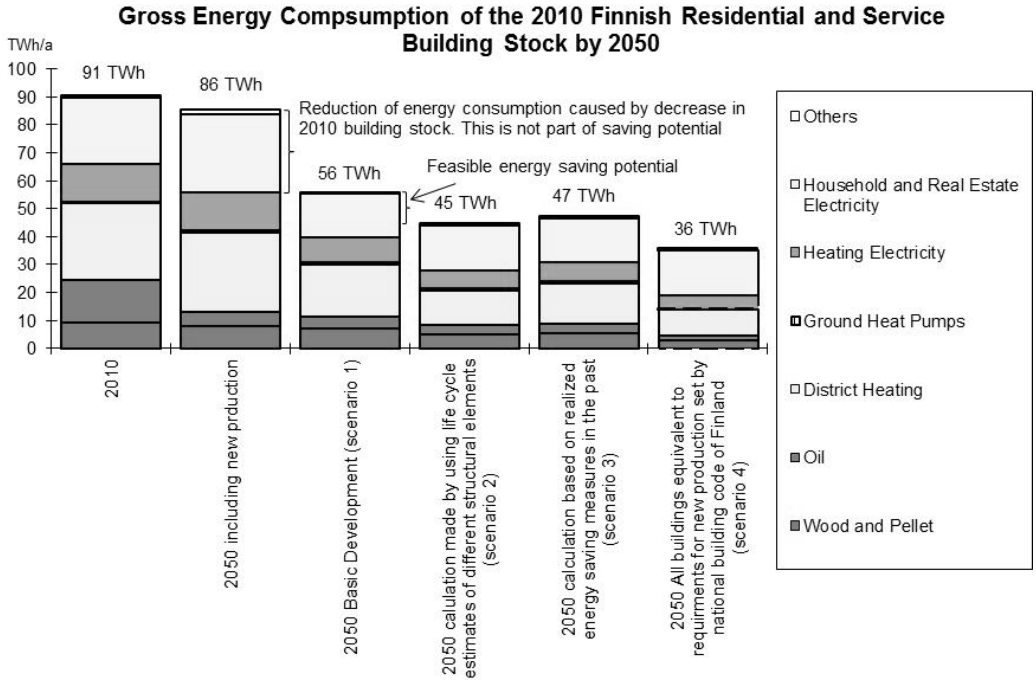

Figure 7. The results of the different calculation scenarios. Scenarios considered feasible are number 2 and 3. Reduction of energy consumption caused by decrease in the 2010 building stock is also represented in the figure.

The calculations show that feasible energy saving potential in renovations is somewhere between 9-11 TWh by 2050. This is approximately 20% from the basic development level (56 TWh) where energy saving measures were not implemented. Annual saving potential is approximately 0,5% per year. If the whole 2010 residential and service building stock were renovated to correspond the requirements for new production presented in the national building code of Finland, then by 2050 its energy consumption would be 36 TWh. Klobut and Tuominen (2010) estimated energy savings potential of nine European Union countries' residential building stock (Finland included). They claimed that on average in these countries 10% energy savings could be reached by 2020 and 20% by 2030.

In table 2, savings from different energy saving measures have been presented separately. Most savings can be achieved through improving heat recovery of the ventilation. However, the problem is that the prediction of ventilation renovation volume includes most uncertainty. The rise in the use of electricity can be explained with the fact that usually when building's quality standard is improved it also means implementing new technical systems and adjustments of old ones, which increase the electricity consumption in the building. In this study, only electricity consumption related to ventilation renovations is considered. Electricity consumption rises because old natural ventilation systems are replaced with mechanical systems equipped with heat recovery unit. Regarding of measures related to building envelope, it seems that improving energy effectiveness of windows and external walls will have the biggest effect on building stock level.

Table 2. Feasible energy saving potentials of different energy saving measures in the 2010 Finnish residential and service building stock by 2050

Measure	Savings
Roof	2,0 %
External Walls	4,3 %
Windows	5,1 %
Doors	0,2 %
Ventilation	9,3 %
Hot Water	0,7 %
Real Estate Electricity	-1,6 %
Total	20,1 %

4. Conclusion

The calculation results indicate that it is more difficult to save energy in the Finnish building stock than in Europe on average. By 2050 the feasible energy saving potential of the 2010 Finnish residential and service building stock is approximately 20%. This estimation is based on the current volume of renovation projects in the Finnish building stock. For various economic and technical reasons, it seems highly unlikely that energy-based renovations could be speeded up much. However, it should be noted that primary energy saving potential is much bigger than 20%. On July 2012 Finland adopted new energy effectiveness regulations for new production. These regulations present new challenges for new production by the form of requirement called E-value. E-value requirement varies depending on a building type and in single family houses depending on building's size. Basically what regulations did was to set E-value limits (kWh/sqm/year) that building must fulfill. The most significant change related to calculation of the E-value are primary energy factors. These factors are used to multiply energy bought in the building with a specific factor depending on how energy is produced. These primary energy factors are strongly favoring the use of renewable energy resources. At the same time they will steer towards low-energy buildings if electricity is used as a primary source of heating energy. In the future this will surely change heating system distribution in the Finnish building stock in a way that primary energy savings will be larger than 20%.

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Revitalization of Kampung and Graveyard Peneleh: towards Urban Settlement Sustainability

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Abstract

As the second largest city in Indonesia, Surabaya has declared its vision to be an eco city. A smart, humane and ecological effort towards the 21st century. One of the development strategies includes revitalization of neglected open spaces, the inactive graveyard. Peneleh graveyard has distinct characteristics which is located inside a kampung (an indigenous urban settlement) and historically significant to the Surabaya development, especially in the Dutch colonialism era. Peneleh graveyard is approximately 4,5 ha and closed from any burial activities since 1955. The condition is severely deteriorated. It is visually and physically blocked from the kampung.

The biggest challenge in revitalizing the kampung and graveyard is how to make the graveyard as an open space for the kampung in such ways that benefits the community, without losing its characteristics as one of the historic landmark of the city. The revitalized graveyard as urban park should acts as a generator or catalyst to increase the quality of life in the kampung.

The historical tourism potentials both of the kampung and the graveyard can be synergized so as to have a sustainable urban settlement. This study aims at identifying and analyzing all the potentials and constraints of the kampung and graveyard. This is done by conducting an in depth interview of the stakeholders, documenting the activities and the physical conditions. The result is an integrated development concept in revitalizing the kampung and graveyard /green open space to achieve a better quality of life.

Keywords: Revitalization, Urban Settlement, Sustainability

1. Introduction

Kampung Peneleh located on the eastern riverbank of Kalimas River, close to the old part of Surabaya. It is a part of Peneleh Sub District, Genteng District. The kampung is surrounded

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by Jalan Makam Peneleh (Peneleh Graveyard Street) in the north, Makam Peneleh (Peneleh Graveyard) in the east, Kampung Plampitan in the south and Jalan Peneleh (Peneleh Street) in the West, which is located on the edge of the river.

The kampung bears a long history back to the 14th century when Surabaya was a kingdom and gains its name from the inhabitant's qualification (means 'choice') as the people living there are the nobles and chosen community. The surrounded kampung names are Kampung Jagalan (refers to 'the butcher' or worker in general) and Kampung Grogol (refers to 'gate'). The kampung and its dwellers played an important role both in the history of Republic Indonesia independence as well as in the development of the city. Despite that the inhabitants tend to come and go to live in, about 70% of Kampung Peneleh inhabitants are those who born in or are the later generation.

Some important person have been living in this Kampung, to mention Sukarno (the first president), HOS. Cokroaminoto (the founder of Syarikat Islam 1920, a later political party), and Raden Rahmat/ Sunan Ampel (one of nine Islam priests/holy men in Java) and those historical buildings they used are still in use such as old mosque and Sukarno's boarding house.

In order to improve the quality of kampung in the pace of Surabaya development, the city government plans to develop the kampung and the adjancent graveyard as part of the open space for the public park.

2. Present Condition

The two aspects of development in the study is the Kampung and the Graveyard. Each has specific characteristics, shaped by the history and their roles in the development of the city.

Kampung is an indigineous settlement in the city of Indonesia. It often assosiated with slum settlement because of the physical condition, which are lack of infrastructure, densely populated, and poor inhabitants. In Surabaya, kampung is strategically located within the inner city central bussiness district, or other major economic and social activities. It serves at least 70% of the housing need in the area, mostly for the low income groups, working in the informal sector to support the city system.

Graveyard according to Indonesian Law number 9/1987 is categorized into 5 types, Public graveyard, Private graveyard, Special Graveyard, Crematorium, and Storage. It can be desribed as an area served to bury or perform burial process. In Europe or America, there are 3 types of graveyard or cemetaries: Monumental, Grass, and Natural graveyard (burying ground)

According to Burra Charter (1979), the object for conservation is not limited to built environment, but also in the form of natural environment and diversity of culture. It focused not only in the physical aspects, but also the non-physical aspects of the object/environment. Therefore, in order to ensure the sustainability of the Peneleh settlements, one should

consider the involvement of the inhabitants and other stake holders in the development process.

2.1 Kampung Peneleh

The total population of kampung Peneleh is 2,943 with density of 288 people per hectare. Within the Peneleh sub district, there are other old kampungs, namely Kampung Plampitan, Lawang Seketeng and Pandean. People are coming from every part of the city with different culture, ethnics, and religious background. The reasons for dwelling in the kampung may vary. Some are related to the closeness to work (23,5%), matrimonial relationship (40%), and other (23%). The number of family living in his/her own house is 14 %. The proportion of male and female residents is equal. Kampung Peneleh consists of two neigbourhood, which are located adjascent to the graveyard.

In term of activities, kampung Peneleh functions as residential, work, bussiness and cultural area. The location in the central of the city is strategic, so as to open a lot of opportunities in economic aspects of the kampung

The kampung layout is linear, all the major pathways are perpendicular the major road. Houses are facing the north-south side. This arrangement is formed incrimentally from the first development of the kampung. Centrally located comes with a benefit of receiving a lot of attention from the city government. Many of the physical improvement programs are implemented such as KIP (Kampung Improvement Program) in 1998 and PNPM (national program in community empowerment). Pathways and housing condition is generally good, shown in figure 1.



Figure 1: Pathways and housing condition in the Kampung (Laboratory of Housing and Human Settlement, 2012)

Drainage system located at the left and right side, beneath the pathways, closed with the concrete slabs. Plants and garbage bin is then put on the slabs. Clean water is accessed by 70% of the community through pipes from the Local Water company. The other 30% use deep-well water. Electricity is available, street lighting is provided by each residents in front of their house.

Historic buildings in kampung Peneleh are the Mosque (dated back to 14th century,older than the Ampel mosque in Ampel, Surabaya), Cokroaminoto House, the birth place of Soekarno- Indonesian first president), and many of old cemetary (Nyai Campa, Buyut Minggir, Buyut Dawa, Buyut Malang, Buyut Bening), Peneleh bookstore, and many other old houses as shown in figure 2.



Figure 2: The Old Mosque-top left, The Cokroaminoto House-top right and old houses with specific architecture style-below (Laboratory of Housing and Human Settlement, 2012)

Kampung Peneleh is located adjascent to the Peneleh Graveyard. Its connectivity was blocked by 2 meter brick wall. The community use wooden stairs as shown in figure 3 to cross the graveyard in order to get the shortest route to the other side of the kampung.



Figure 3: Wall of the graveyard and connectivity to Kampung Peneleh (Laboratory of Housing and Human Settlement, 2012)

2.2 Peneleh Graveyard

Peneleh graveyard is located inside the kampung as shown in figure 4. It was surrounded by houses, incrimentally developed. The graveyard area is 4.4 hectare, divided into 11 blocks of graves, aligned in north-south axis. It opens in 1847, and the last plot was dug in 1916 (RCE,2012). The last burial activities commenced in 1965, by the family member having a plot in the graveyard. One of the important person buried in the cemetary is the former General Governor of Surabaya in Dutch colonial era, Pieter Markus (1787-1844).



Figure 4: Location of the Graveyard inside the kampung (Google earth, 2010)

There are two types of grave in Peneleh (picture 5). The first is vaulted graves, where the body was buried in a vault, 2 meter deep below the ground, made from brick wall and plastered. This type of grave is built to overcome the damp soil of a swampy area, and require a longer time in preparation. The vault is topped with marble or granite slab, engraved with the name of the person. The other type is the more common type of graves in Indonesia, earthgraves. The plot was digged just before the burial. The plot require smaller size than the vaulted graves.



Figure 5: Type of Grave – Vaulted grave-left and Earthgraves-right (Laboratory of Housing and Human Settlement, 2012)

The inactive function of the graveyard since 1965 leads to a deteriorate condition. Most of the graves are in poor condition, as shown in figure 6. The study identifies the condition of the graves in order to determine the area which will be developed into green open space/urban park. From the study, 70%



Figure 6: Categorization of Graves Condition (good-moderate-poor) (Laboratory of Housing and Human Settlement, 2012)

3. Potentials and Challenges

Identification of the potentials and challenges were conducted through observation and interview with the stakeholders. The potentials are:

1. Old houses with various architecture style

2. Adequate infrastructure for the settlements

3. Small bussiness, home based enterprises

4. Close relationships among multiethnics inhabitants

Despite of the potentials, some challenges are also noticed :

1. Most of the houses/buildings are in poor condition

2. The lack of communal space for social and cultural activities

3. The lack of communication and coordination between the community and the government/municipality.

4. Development Concept

The key principles in developing the sustainable kampung and graveyard Peneleh are:

1. Economically sound, ensuring the municipality and community investment for the income generation purpose.

2. Promote the uniqueness of the physical features, such as the settlement arrangement, the historic/romantic ambiance of the graveyard and maintaining the vast architectural style of the houses

3. Connectivity with the city structure, mostly with bussiness district and accessibility from other part of the city

4. Involvement of the community, intensive discussion and communication with the inhabitants

5. Strong commitment from the government/municipality

Based on the potentials and challenges of the development and to achieve the sustainable development of the kampung, the revitalization of graveyard must functions as:

1. Green open space

2. Heritage Cemetary

3. Social and Cultural space

The zoning of the functions is based on the inventory of the graves condition, and also considering aspects of circulation (favourable route in the graveyard, point of entry/accessibility) and shading (existing trees and other vegetation). The layout of the proposed development scheme is characterized by the leveling of the ground as shown in figure 7 and 8.

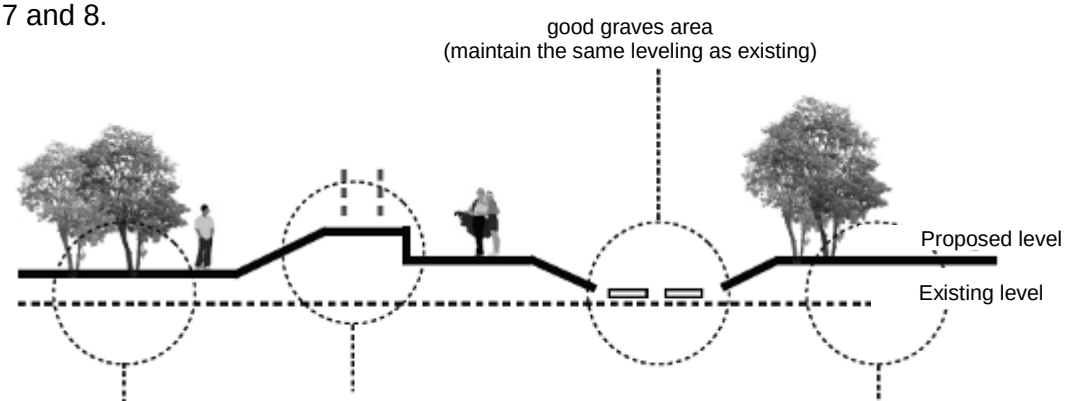

Figure 7: Different leveling of the ground

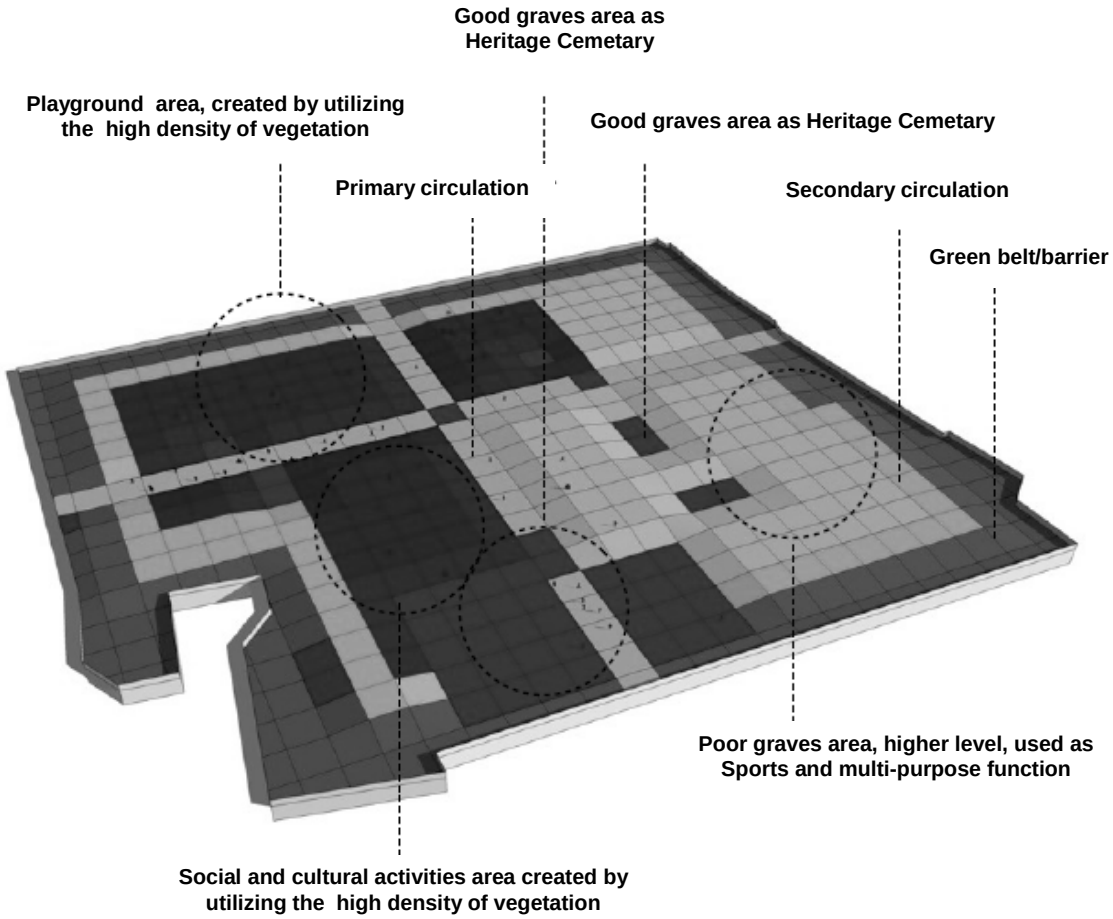

Figure 8: Diagramatic of Development Concept

5. Conclusion

From the study it was found that the potentials of Kampung and graveyard Peneleh can support the sustainability of the urban settlement, with some suggestions:

1. Ensuring the involvement and commitment of all stakeholders (municipality and community)

2. Giving a new function to the new cemetary as urban open space that cater the social and cultural activities of the kampung inhabitants

3. Providing income generating activities

Acknowledgements

The content of this paper is part of a research conducted in 2012 by the Laboratory of Housing and Human Settlements, Department of Architecture, Institut Teknologi Sepuluh Nopember for the Surabaya City Planning Board. Members of the research team are Johan Silas, Sarah Cahyadini, Wahyu Setyawan, Susetyo Firmaningtyas, Happy Ratna Santosa, Muhammad Faqih, Purwanita Setijanti, Andi Mappajaya, Endy Yudho Prasetyo, Defry Agatha Ardianta, Poerwadi, and Andarita Rolalisasi.

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Sustainable Construction in Malaysia: A Consultants' Perspective

Leong Boon Tik, Soon Lam Tatt, Theong May Chuan

Abstract

The government of Malaysia recently introduced the National Green Technology Policy together with a proposed RM 1.5 billion (USD 500 million) Green Technology Financing Scheme to promote green and sustainable technologies. This policy is predicated on the belief that regulatory change is a key driver of innovation as local firms compete to develop new products that are more efficient, greener and safer. For the construction sector, the National Green Technology Policy complements the previous thrust to adopt Industrialised Building System (IBS) as a means to deliver high quality building and to reduce the reliance of the sector on migrant labour. The abundance of cheap low-skilled migrant labour has hindered investments in mechanisation and innovation. The current exemption levy for building with 50% IBS elements is 0.125% of construction cost. In order to encourage the construction industry to deliver high quality and environmentally sustainable housing, the government in 10th Malaysia Plan (2011 – 2015) stated to review tax incentives for the design of buildings that are built in a more sustainable manner. This study aims to investigate the influence of government policies toward the use of sustainable technologies and Industrialised Building System (IBS) in the Malaysian construction industry. Primary data has been collected by questionnaire survey of design consultants. The responses on how these policies affect design and construction decisions were analysed by employing descriptive and analytical methods. The findings of this study concluded that government policies play an important role in influencing the adoption of IBS in the construction industry. The most significant way of promoting the use of this innovated method is through incentives.

Keywords: Sustainable Technology, Industrialised Building System (IBS), Design Consultant, Government Policies, Malaysia

1. Introduction

Climate change is a great challenge to all countries. The world is experiencing the melting of polar ice, drying of Amazon rainforest, flooding of many coastal cities and increase of climate refugees. Being a member of the Intergovernmental Panel on Climate Change (IPCC), Malaysia voluntarily, aim to reduce the carbon emission up to 40% in terms of emission intensity of Gross Domestic Product (GDP) based on year 2005 level by year 2020.

One of the efforts initiated by the Malaysian government is the introduction of green and sustainable technologies (ST) which minimizes the degradation of the environment, promotes the use of renewable resources and conserves the use of energy and natural resources. The National Green Technology Policy launched on 24th July 2009 by the Prime

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Minister spurred demand for green industry as the priority in providing products and services. The policy is designed to minimise the problems of destruction of the environment and depletion of natural resources which have brought to climate change. As a result, green technology is expected to be a driver in accelerating the national economic growth and at the same time promote sustainable development (Kamarul *et al*, 2010).

One of the listed government initiatives in the policy emphasize on building aspect or the construction industry. It is because the built environment uses huge amount of non-degradable resources, produces wastes and emits around half of the carbon dioxide gas. Almost 40% of the world's consumption of materials converts to the built environment and about 30% of energy use is due to housing development (Kamarul *et al*, 2010). As a result, the construction industry has great challenge to deliver economic buildings that reduce the social and environmental negative impacts.

A supportive effort towards green technology has been made by the Work Ministry as the ministry had decided that Industrialised Building System (IBS) is adopted for building construction. Hence, the industry links IBS to the issue of climate change and claimed that IBS industry is able to contribute the sustainable development. Kamarul and Zuhairi (2011) suggested that the fundamental idea of IBS is to shift on-site to a more controlled environment.

Thus, sustainability can be achieved through the application of IBS by transforming the 4D – difficult, dirty, dangerous and dusty construction industry into a controlled production environment. Via this, IBS promotes minimisation of waste generation, effective usage of energy, efficient building materials, etc (Kamarul and Zuhairi, 2011). This can be achieved by the reduction of wastage in the construction industry due to prefabrication of building component. Various sizes of components can be produced in mass volume to suit the requirements of buildings. This reduces the number of trips of transportations.

Allocation of RM1.5 billion in the 10th Malaysia Plan (MP) to stimulate the use of green technologies demonstrates Malaysian government concerns the global climate change issue. With the environmental advantages offered by IBS, the government made compulsory of 70% IBS components in public building project. Tax incentives are offered to buildings that are built in a more sustainable manner. The paper aims to investigate the influence of government policies toward the use of sustainable technologies and IBS in the construction industry.

2. SUSTAINABILITY IN MALAYSIA CONSTRUCTION INDUSTRY

Wet construction method has been adopted in the Malaysian construction industry. Activities carried out in the industry have been considered as one of the major contributors to the environmental pollution (Augenbroe *et al*, 1998). These activities not only consuming large portions of raw materials (Ding, 2005), but also creating wastes to the earth. As a result, the construction industry causes the depletion of non-degradable resources, destruction of landscape and creation of health and safety issue to the nation (Azapagic, 2004).

Environmental issue has started to gain wider attention by the construction industry players. The industry is currently shifting from its conventional approach with little regard on the ecological consequence to a development process with wider concern of the environmental agenda. The change is inevitably leading the industry towards 'green' or 'sustainable'. (Das Gandhi *et al,* 2006).

The concept of sustainable is not new. The philosophy of "Sustainable Development" was introduced in 1987 in Brundtland Report and since then, a lot of strategies and positive efforts had been prompted by many countries. Sustainable construction which plays a critical role of the philosophy is expected to contribute to the protection of environment. Figure 1 mimics the tree diagram of the concept of sustainability in construction. According to Nazirah (2005), sustainable construction concern about environmental protection, social well-being and economic prosperity. Activities carried out in the built environment and uses of natural resources exert an obvious impact to the environment. Builders help in protecting the environment by demanding less non-renewable natural resources and more recycled material in their productivity. Social well-being concerns with workers feelings which relate to security, satisfaction, safety and comfort (Lombardi, 2001) and their contributions of skills, health, knowledge and motivation (Parkin, 2000). Sustainability in construction leads to benefits in both micro and macro economy of the country.

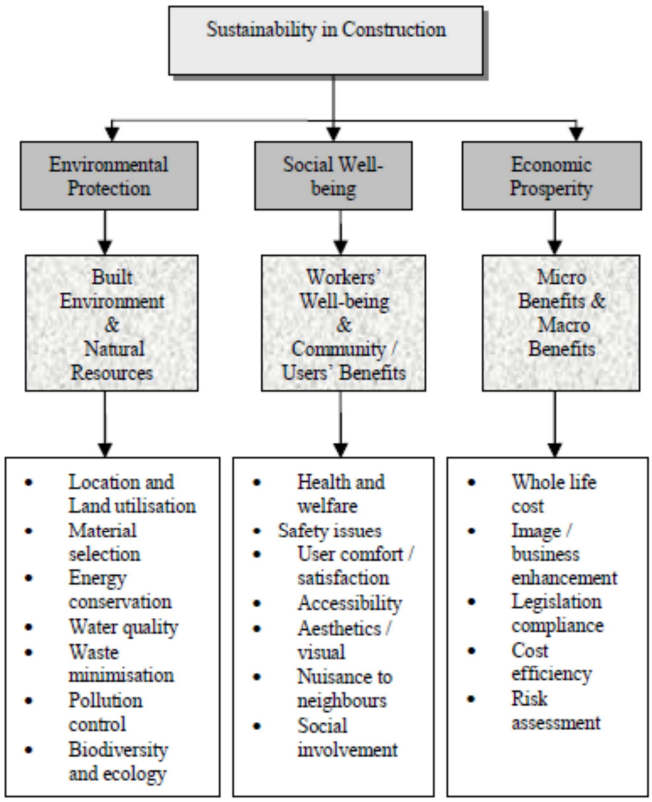

Figure 1: The diagram of sustainability in construction (Nazirah, 2005)

According to Ofori *et al* (2000), practitioners in the construction industry must be willing to change their attitudes and culture in adopting new ideas and approaches. Construction Industry Development Board (CIDB) plays a vital role in directing the Malaysian construction sector towards sustainability. Many efforts have been carried out in the area of waste minimization and management, environmental management plan and construction hazard

identification (CIDB, 2007). The subject of sustainability had been highlighted in the Construction Industry Master Plan (CIMP) 2005 -2015. Environmental practices as well as occupational safety and health are included in Strategic Thrust 3 of CIMP. The Malaysian Green Building Index (GBI) has been developed in year 2009 to promote sustainability in built environment. The introduction of the rating system provides a platform of assessment for sustainable construction and creates new challenges for the industry players.

At present, several sustainable projects are initiated in Malaysia. The projects revolve energy saving housing that blends man-made and natural elements, community development which introduces eco-tourism to the world, zero energy office buildings that promote sustainable from the aspect of economic and social, etc. Nevertheless, the sustainability in the Malaysian construction industry is at its infancy stage (Nazirah, 2005) and a lot more efforts are required to increase the level of awareness among the industry players.

3. INDUSTRIALISED BUILDING SYSTEM (IBS) IN MALAYSIA

As part of the effort in promoting sustainable construction, the Malaysian construction industry has been urged to shift from the traditional wet method of construction to IBS method. The urge is highlighted in CIMP under Strategic Thrust 5 which relates to innovative construction method.

There are plethoras of definitions of IBS found in many literatures. Dietz (1971) for example, described IBS as total integration of all subsystem and components into overall process fully utilizing industrialized production, transportation and assemble techniques. Warszawski (1999) on the other hand, defined IBS as a set of interconnected elements that joint together to enable the designated performance of a building. Lew *et al* (2003) provided a simpler definition by describing it as a system in which concrete parts and components, pre-fabricated at site or in factory are assembled to form the structure with minimum in-situ construction process. All seem to have some common denominator - it is about pre-fabrication i.e. off-site production and mass production of standardised building components that are taken to site for assembly. IBS can be said to be an assembly industry. CIDB defines an IBS project as that which uses 70% IBS components (for government projects) or 50% IBS components for private sector project. IBS is a method of transferring the on-site production processes to the factories and while the on-site works are limited to the assembly of factory made parts and components only. It is about the assembling of pre-fabricated building parts or components (whether standardised or non-standardised).

The concept of IBS is not new as it was introduced since mid-60s. According to Din (1984), in 1964, the government has identified two pilot projects to try out the precast construction. The first project was in Kuala Lumpur to construct a 7 blocks of 17 storey flats and 4 blocks of 4 storey shop lots. This project comprised about 3,000 units of low cost flats and 40 units of shop lots. It is awarded to the Gammon / Larsen Nielson using the Danish system of large panel industrialised prefabricated system. The second pilot project was located in Penang with the construction of 6 blocks of 17 storey flats and 3 blocks of 18 storey flats. The project

consisted of 3,699 units of flats and 66 shops along Jalan Rifle range. It was awarded to Hochtief / Chee Seng using the French Estiot System.

While the sustainable technologies are still relatively new concept in Malaysia, IBS has its potential role in sustainable and green construction. The system components are mostly manufactured in the factory before delivering to the site. The productions take place in a controlled environment and this also helps in reducing construction waste in the site. Majority of IBS components have longer life span than the conventional building components. Ability to produce and assemble the components in large quantities reduces the number of trips of transporting to the site. Thus, waste produced by the transportation system is also lesser.

CIDB has been putting its effort in promoting the use of IBS in the construction industry. Despite the publication of the 2 roadmaps which documented the benefits of IBS, the adoption of IBS is still low especially in the private sector. Majority of the industry players feel reluctant to shift and the root cause is low labour cost (Kamarul *et al,* 2010). In order to increase the adoption of IBS in Malaysia, the Malaysian government had taken a number of initiatives.

During the 9th Malaysia plan period (2006-2010), the government pledged for the construction a total of 709,400 new houses. Special emphasis will be given to housing for the lower-income group where 38.2% of total new houses constructed will be for low-medium cost houses. These were built by utilising IBS in order to deliver the huge number of houses on time. As an incentive to private sectors, construction projects that adopt 50% or more IBS components in the building works are entitle to receive an exemption of construction levy. Generally, levy is imposed by CIDB at 0.125 % of total cost of the project. The new circular by the Ministry of Finance (MOF) emphasized on the full utilization of IBS for all government's projects. The circular emphasised that the use of IBS components in government projects should not be less than 70%. As in 2009, 320 government projects worth RM 9.43 billion have been identified to be carried out using the IBS (Bernama, 2009). Moreover, CIDB had allocated RM 100 million to train skilled workers in IBS (Bernama, 2009). Trained skilled workers play an important role in assembling the IBS components on site. By March 2011, there are 136 manufacturers registered with CIDB and 328 types of products are produced. There are a total of 671 IBS contractors in Malaysia and this builds up of merely 1% compared to 64698 contractors registered in 2009. It shows that only a very tiny portion of contractor firms adopted IBS method of construction.

4. RESEARCH METHODOLOGY

Online questionnaire surveys were employed as a major tool for this research. The questionnaire surveys comprised of three major sections. The first section contains questions that defined the influences of Malaysian policy on the usage of sustainable technologies and industrialised building system (IBS) in Malaysia. The second section defines the positive and negative factors influencing the usage of sustainable technologies and IBS in Malaysia. The third section contains two questions on respondents' information, general suggestions and comments about the research topic.

4.1 Design and content of questionnaire

Table below depicts design and content of questionnaires based on the tackled and investigated issues.

Table 1: Design and content of questionnaires

Question(s) number(s) and type(s)	**Issues tackled/ investigated**
Question 1: Yes / No question	Determination of influence of Malaysian policy to sustainable technology and Industrialised building system (IBS)
Question 2: checklists/ multiple choice	The constraints for Malaysian construction to implement sustainable technology and Industrialised building system (IBS)
Question 3-4: checklists/ multiple choice	Factors influencing the usage of sustainable technologies and IBS in Malaysia
Question 5: checklists/ multiple choice	The influence of Malaysian policy to sustainable technology and Industrialised building system (IBS)
Question 6: checklists/ multiple choice	Factors discouraging the implementation of sustainable technologies and IBS in construction industry
Question 7: checklists/ multiple choice	The benefits of sustainable technology and IBS to country development in Malaysia
Question 8: checklists/ multiple choice	Classification of IBS reducing environment pollution
Question 9- 10: Open-ended (optional)	Respondent's information and general suggestion and comments about the topic

4.2 Data Collection

Respondents for this survey were selected from the list of registered architect under Board of Architect (Lembaga Arkitek Malaysia, LAM) in Malaysia. Architects were selected as respondents as they are generally leader of the consultant team in construction Malaysia. The sample for this study was selected using systematic sampling from the list available online on the Board of Architect Malaysia website. From the list of 1845 registered Architects in Malaysia, 50% of respondents from an existing population were selected to ensure significant responses and representative results. This online questionnaire allowed professional architect to respond to questions and give suggestions and comments according to his or her experiences.

This online questionnaire survey was prepared by a web-based survey tool. It comprised of 10 qualitative questions consisting of 8 compulsory questions and 2 optional or open-ended questions. Each of the closed-ended questions included an option 'Other' to allow respondents to give comments or suggestions in the actual questions about this topic.

5. DATA ANALYSIS, RESULTS AND DISCUSSION

5.1 Analysis of Data

A total of nine hundred and twenty two (922) questionnaire surveys were distributed to registered professional architects in Malaysia. Twenty eight (28) architects responded to the survey, making the response rate 3.04%. This low rate had been expected for an e mail questionnaire. On the other hand, the high percentage of invalid e mail addresses, which is 14.21% or 131 invalid e mails further corrode the response rate.

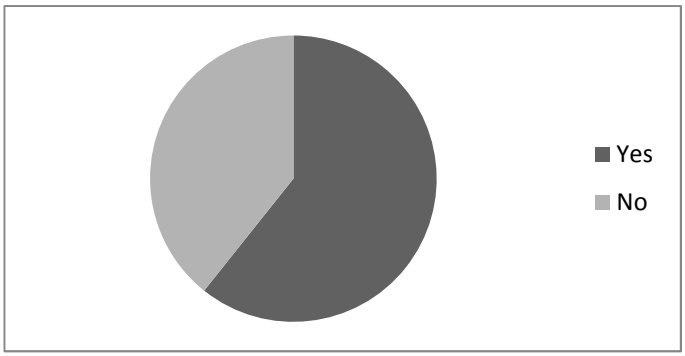

Figure 2: Can Malaysian government policies significantly influence usage of ST and IBS

Refer to Figure 2, out of 28 responses, 60.7% of respondents think the Malaysia government policies can significantly influence the usage of sustainable technologies, primarily Industrialised Building System (IBS) in Malaysia. 39.3% do not agree with the statement. Design consultants believe that government policies play important roles in promoting the usage of sustainable technology.

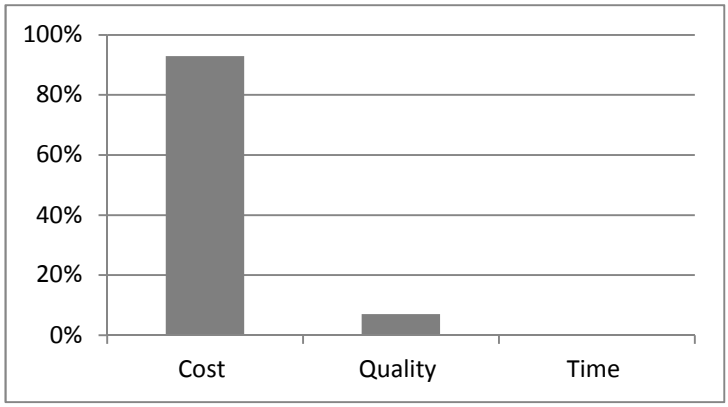

Figure 3: Constraint of implementing IBS in Malaysia

The government take IBS as a strategy to deliver high quality building and to reduce the reliance of migrant workers, the questionnaire requested the respondents to identify the factor that constraints implementation of IBS in Malaysia. 92.9% identify that cost is the constraint of implementing IBS, 7.1% show their worry in quality and none of the respondents take time as a constraint factor.

Incentives are employed as a preferred tool of policies in many areas (Ruth, 2004). The survey shown 42.9% of respondents think as long as incentive is given the usage of sustainable technology and IBS will increase. 28.5% think the incentive should be at least 0.2% of the total construction cost. Anyway, 14.3% of respondents believe that incentive doesn't encourage sustainable technology and IBS. Finally, 14.3% agrees, the usage will increase only upon the government enforcement but not incentive. Hence, a total of 71.4% of respondents agree that different level of incentives can encourage sustainable technology and IBS and 28.6% disagree that incentives works.

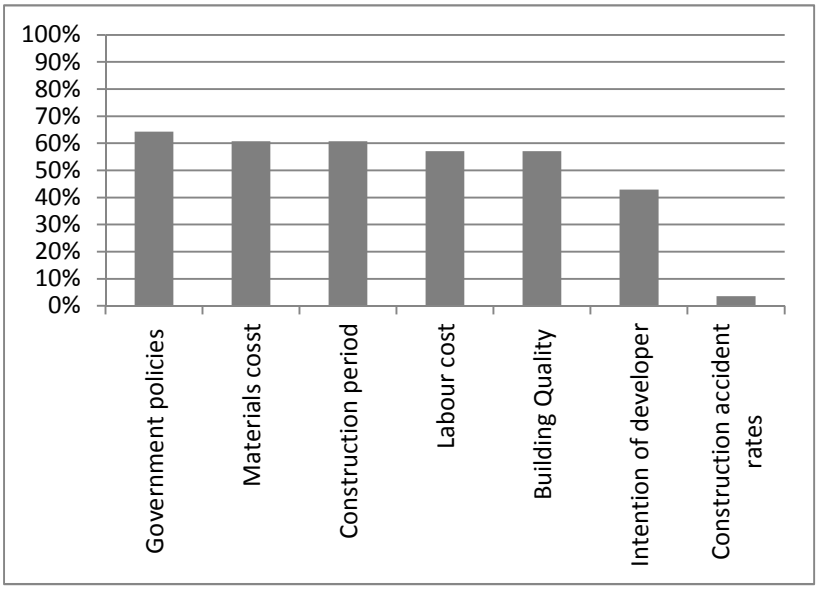

Figure 4: Factors significantly influence the usage of ST and IBS

As for the question on factors that can significantly influence the usage of sustainable technology and IBS in Malaysia, 64.3% of the respondents felt that government policies can bring significant influence. Among others, materials cost (60.7%), construction period (60.7%), labour cost (57.1%) and building quality (57.1%) are factors that supported by more than 50% respondents. 42.9% of respondents think intention of developer brings influence, and only 3.6% supported construction accident rates is the factor that significantly influence usage of sustainable technology and IBS. It is found that the government policies is the major factor influence the usage of ST and IBS, following by time, cost and quality.

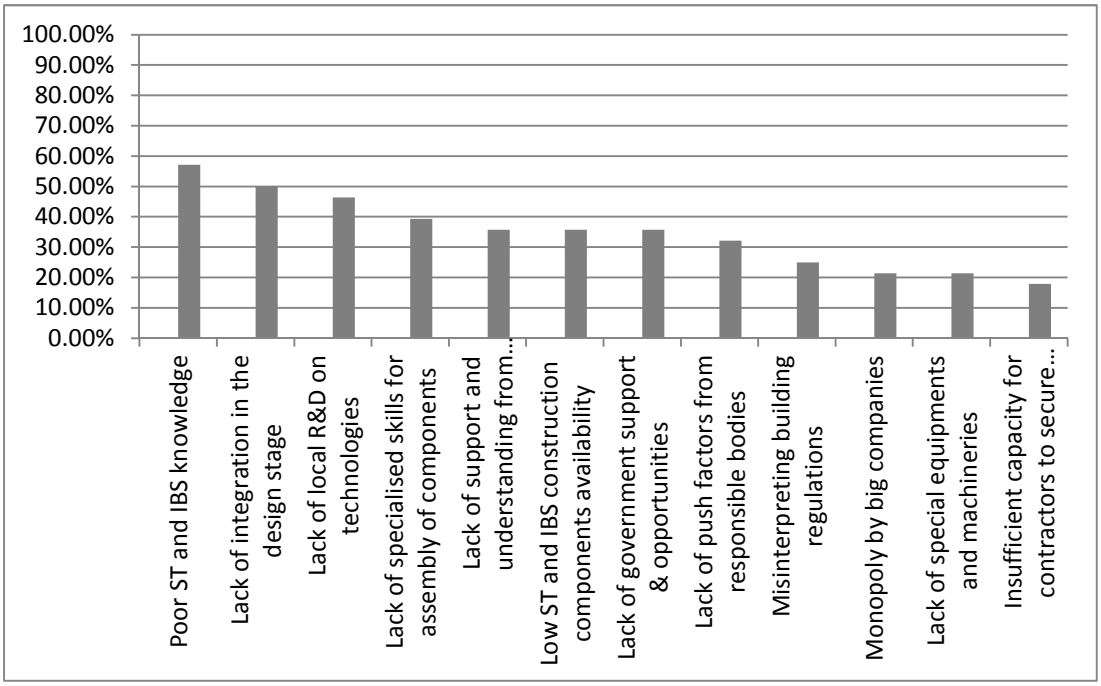

Figure 5: Factors discourage the design consultant from implementing ST and IBS

More than half of the respondents (57.1%) think poor sustainable and IBS knowledge is the main factor of not implementing sustainable technologies and IBS in Malaysia. 50% support lack of integration in the design stage will discourage the implementation. 46.4% think lack of local R&D on technologies leads to discouragement of implementation, 39.3% think the factor is lack of specialised skill for assembly of components. Other factors include lack of support and understanding from professional (35.7%), low sustainable technologies and IBS construction component availability (35.7%), lack of government support and opportunities (35.7%), lack of push factors from responsible bodies (32.1%), misunderstanding and misinterpreting of building regulations (25%). 21.4% think the factor is monopoly by big company, 17.9% support that lack of equipments and machineries is the factor, 17.9% think contractor do not have capacity to secure project.

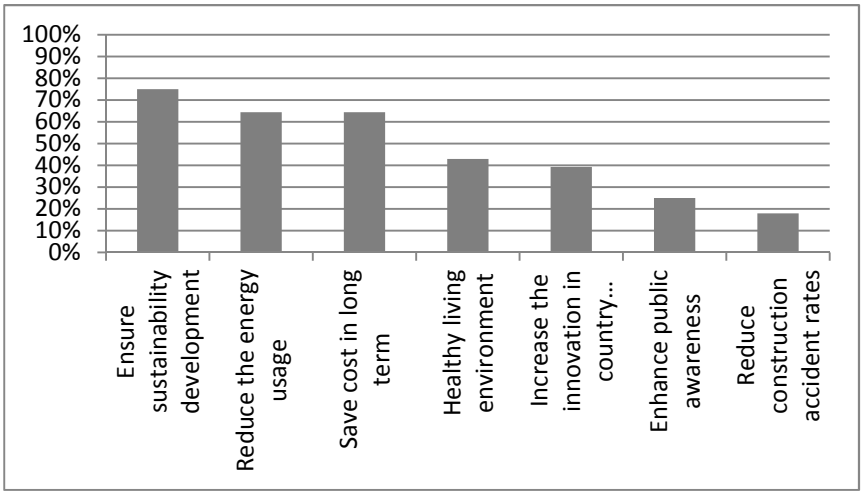

Figure 6: Benefits of ST and IBS

With reference to the above chart, three quarter of respondents agree that sustainable technology particularly IBS will ensure sustainability development. While 64.3% agree that sustainable technology and IBS will reduce energy usage. 64.3% responses they agree with long term cost saving and 42.9% think it can leads to healthy living environment. 39.3% believe this can increase innovation in country development and a quarter supports one of the benefits is enhance public awareness. Only 17.8% of architects think IBS can reduce construction accident rate.

When ask upon which classification of IBS can significantly reduce environment pollution, more than three quarter (85.7%) agree precast concrete framing, panel and box systems will reduce environment pollution. 57.1% think steel frame system can reduce environment pollution, 53.6% agree steel formwork systems can do the same thing. Half of the respondents support that prefabricated timber framing systems is useful in reduce pollution and finally only 42.9% agree block work systems is good in reduce pollution.

As for the optional questions that allow respondents to voice out their suggestions on increasing the usage of sustainable technologies and IBS, the answers were categorised into two categories.

i) Suggestions toward the government

ii) Suggestions toward the construction players

The suggestions toward the government were divided into two parts, the policies and the incentives.

As for policies, there were 3 suggestions to urge the government to make compulsory for all government projects to adopt sustainable design and technology. There is a proposal to have a scoring system as part of the development approvals. One suggestion wishes government to set up policies in collective manner, which this respondent thinks only a few departments championing the technology won't encourage the advancement of the technology. Another suggestion suggested anti-corruption in government project, and this will improve the implementation of government projects.

Total of five respondents wish more incentives can be given in order to gain momentum of the technology adoption. They suggested reducing taxes significantly on imported IBS materials, to provide subsidies to developers which use recyclable components or materials, to offset cost like reduced contribution costs, development charges and Improvement Service Fund (ISF), to subsidise the cost of applying for Green Building Index (GBI) certification. There is a proposal to request government to financially support selected contractors to perform sustainable technology and design. Lastly, there is also a suggestion to increase levy and tighten rules for employment of migrant workers, in order to reduce the migrant workers hence encourage sustainable technologies and IBS.

The suggestions to industry players are as follows.

All agencies or players have to coordinate and work together to achieve a common goal, which is to increase the usage of sustainable technologies and IBS. More engineers should be train to specialise in precast, IBS and jointing system. Industry players, including engineers and architects should do more research and development (R&D) in the local context instead of relying on imported technologies. The professionals need to have more knowledge on IBS costing and the characteristics of waste reduction. Finally, there are respondents who hope the suppliers can prepare more catalogues, manufacture more standard and customised IBS parts and offer IBS certified or GBI certified products.

6. CONCLUSIONS AND RECOMMANDATIONS

The study concludes that the architects as design consultants have the awareness that sustainable technology, particularly IBS will bring benefits to sustainable development, reduce energy usage and save cost in long term. They are also aware of the impact of different classification of IBS in reducing environment pollution.

Anyway, in Malaysia context, the main reasons of not using sustainable technologies and IBS include poor sustainable and IBS knowledge and lack of integration during the design stage.

As a conclusion, most respondents agreed that government policies are able to influence the usage of ST and IBS. Majority of them responded that incentives offered by the government encourage the usage of IBS in construction projects. Therefore, it is suggested that further financial aid by the government become the catalyst in promoting the adoption of sustainable technologies and IBS in the construction industry.

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Should the application and practice of construction adjudication be underpinned by legislative intervention in the South African construction industry?

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Abstract

Adjudication has, through various initiatives of the South African government, the Construction Industry Development Board and the increased use of international standard form construction contracts, become relatively commonplace among both the public and private sectors, as the first tier for dispute resolution on construction projects across the South African construction industry.

This paper shall consider these initiatives and developments to confirm whether adjudication practice in the South African construction industry should be underpinned by legislative intervention and if so, then consider what key legislative measures could (and should) be incorporated into such legislation to effectively regulate the application and practice of adjudication in the South African construction industry.

Keywords: South Africa, **ADR**, **construction adjudication**, **legislative intervention**

1. Introduction

We do not intend that adjudication should be used simply to postpone resolving disputes. We have had enough of disputes within the construction industry. Government, the industry and its clients want to see an end to them; they are expensive and damaging to the industry's productivity and reputation[3].

It certainly seems that construction contracts go wrong; everybody knows that. It is one of the problems of construction. The problems have intrigued, one might say obsessed, the industry and government for 50 years[4]. Since 1995 the post-apartheid South African government have similarly obsessed in the pursuit of procurement reform, especially in

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[3] Robert Jones, Minister for Construction Planning and Energy Efficiency, Hansard, 7.5.96 column 54. Quoted in Coulson Peter (Sir), Construction Adjudication, Second Edition, Oxford University Press, 2011 at page 13.
[4] Fenn. P, *Why construction contracts go wrong (or an aetiological approach to construction disputes,* a paper given at a meeting of the Society of Construction Law in Derbyshire on the 5th of March 2002, (2002), at page 1, downloadable on www.scl.org.uk.

introducing appropriate methods for effective dispute resolution into the construction industry.

Recognising the entrenchment of alternative dispute resolution (ADR) procedures for resolving labour disputes in the Labour Relations Act No. 66 of 1995[5] and successful application of ADR procedures in the private sector, the White Paper on *Creating an Environment for Reconstruction Growth and Development in the Construction Industry*[6] commits the public sector to promoting the application of ADR procedures, in particular adjudication, in the South African construction industry[7].

In promoting adoption of adjudication into the South African construction industry the White Paper confirms that *recommendations adapted largely from the Latham report will be introduced to the construction industry, specifically for public-sector contracts*[8]. Latham[9]among other things *recommended that a system of adjudication should be introduced within all the Standard Forms of Contract (except where comparable arrangements already exist for mediation or conciliation) and that this should be underpinned by legislation...* [10].

2. South African government driven initiatives since 1995: putting adjudication into practice.

Through a series of interventions since 1995 the South African government has, particularly in public sector construction activities, ensured the general implementation of …*an accelerated and cost effective form of dispute resolution that, unlike other means of resolving disputes involving a third party intermediary, the outcome is a decision by a third party which is binding on the parties in dispute and is final unless and until reviewed by either arbitration or litigation...* that *...is not arbitration or litigation*...[11]. The South African government's interventions have unfortunately stopped short of implementing Latham's principal recommendation that the system of adjudication introduced should be underpinned by legislation, typically referred as security of payments or construction contracts legislation.

The Inter-Ministerial Task Team on Construction Industry Development, Focus Group 5[12] published the *ADR Guidelines for Public Sector Contracts, Working Document Draft 5*, largely adopting Latham's recommendations[13] in twelve principles recommended for underpinning the application of adjudication in the South African construction industry. These

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5 The Labour Relations Act No. 66 of 1995 was enacted to, inter alia, provide simple procedures for the resolution of labour disputes through statutory conciliation, mediation and arbitration (for which purpose the Commission for Conciliation, Mediation and Arbitration is established), and through independent ADR services accredited for that purpose.

6 The "White Paper on Creating an Enabling Environment for Reconstruction, Growth and Development in the Construction Industry", published under Notice 89 in Government Gazette No 18615, Volume 391 on 14 January 1998.

7 Refer to note 4 above under paragraph 4.1.5.3 [ADR].

8 Refer to note 4 above.

9 Latham, M. (1993) *Trust and Money*. Interim Report of the Joint Government / Industry Review of the Procurement and Contractual Arrangements in the United Kingdom Construction Industry, London: HMSO. Latham, M. (1994) *Constructing the Team*. Final Report of the Government/Industry Review of the Procurement and Contractual Arrangements in the United Kingdom Construction Industry, London: HMSO.

10 Refer to note 7 above, *Constructing the Team*, at paragraph 9.14.

11 Best Practice Guideline Number #C3: *Adjudication,* September 2005, Second Edition of CIDB document 1011, downloadable on www.cidb.org.za

12 Inter-Ministerial Task Team on Construction Industry Development; Proposed ADR Guidelines for Public Sector Contracts, Working Document Draft 5, Pretoria, Nov 1999.

13 Refer to note 7 above.

principles were subsequently incorporated into the South African National Standards Authority Standard for construction procurement processes, methods and procedures, edition one, 2004 (SANS 294: 2004)[14], which requires that …*[A]djudication shall be applied to all categories of construction contracts (viz. engineering and construction works services and supplies), at both prime and subcontract level, and shall be a mandatory requirement for the settlement of disputes before the completion of a contract*...[15].

Section 2 [*Establishment of CIDB*] of the Construction Industry Development Board Act 38 of 2000[16] established the Construction Industry Development Board (CIDB) as a schedule 3A public entity and juristic person with legislated authority to realise the objectives detailed in section 4 [*Objects of CIDB*] and perform the functions prescribed in section 5 [*Powers, Functions and Duties of CIDB*] of the CIDB Act 38 of 2000. The CIDB was formerly launched by the then Deputy President, Mr. Jacob Zuma, on 24 April 2001.

The CIDB's mandate is to ...*exercise leadership and foster the co–operation of industry stakeholders to pursue development objectives, improved industry practices and procedures – which will enhance delivery, performance and value for money, profitability and the industry's long term survival in an increasingly global arena*...[17]. In realising procurement reform and implementation of adjudication the CIDB issued two pivotal best practice guidelines during 2005.

Although the CIDB's best practice guidelines do not carry the force of law (as do CIDB notices published in the Government Gazette) each one is a critical component of the CIDB's uniform standards, which (together with the ethical standards) pursuant to Section 4 (f) and section 5 (4) of the CIDB Act 38 of 2000 …*regulate the actions, practices and procedures of parties engaged in construction contracts*... Through CIDB Notice 86 of 2010 titled "Standard for Uniformity in Construction Procurement" in Government Gazette No. 29138 of 18 August 2006 these uniform standards (incorporating the obligation to comply with and implement) the best practice guidelines when engaging in construction activities have become firmly entrenched in South African construction practice.

In March 2004 the CIDB issued its own adjudication procedure[18] specifically requiring that …*adjudication shall be conducted in accordance with the edition of the CIDB Adjudication Procedure which is current at the date of issue of a notice in writing of intention to refer the dispute to adjudication*...[19]. This adjudication procedure is based on the adjudication procedure developed by the Institution of Civil Engineers detailed in the Institution of Civil Engineers Adjudication Procedure[20], with minor changes made to incorporate South African requirements and to remove inapplicable references to the Housing Grants, Construction and Regeneration Act, 1996 (HGCRA) and the institute itself.

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14 South African National Standard 294, published by Standards South Africa, 2004 downloadable on www.stansa.co.za
15 Refer note 12 above at page 85.
16 Published in Government Gazette No 121755, Volume 425 on 17 November 2000.
17 Refer note 4 above, item 8.4.1 [*Aims*] at page 54.
18 Construction Industry Adjudication Procedure, March 2004, First Edition of CIDB document 1014, downloadable at www.cidb.org.za.
19 Refer to note 16 above, paragraph 2.1 on page 1.
20 The Institution of Civil Engineers Adjudication Procedure, published by Thomas Telford, December 1998.

Best Practice Guideline #C2: *Choosing an appropriate form of contract for engineering and construction works*[21] requires that ...*[I]n order to make procurement reform effective in the manner intended, employers in the engineering and construction industry need, amongst others, to revisit the standard forms of contract which are in use. The current approach of having, probably, as many standard forms of contract as there are disciplines in the industry, together with a considerable number of in-house forms of contract, neither makes for efficiency nor does it enable a focussed approach to skills training necessary for development and growth. This applies to both private and public sector work*...[22].

The standard form construction contract[23] is negotiated at industry level through an inclusive consultative process with various industry stakeholders and specifically designed to reflect current industry norms and practices. The product is a set of documents representing industry norms and practices as they are perceived and experienced at a particular point in time by a constituent representative group.

Best Practice Guideline #C2[24] requires public sector employers to employ either the Fédération Internationale des Ingenieurs – Conseils 1999 first editions of four standard form construction contracts (FIDIC, First Edition, 1999), the General Conditions of Contract for Construction Works, First Edition (GCC 2004)[25], the Joint Building Contracts Committee Series 2000 (JBCC 2000) and the New Engineering Contract Third Edition (June 2005) family of standard contracts (NEC 3) (with limited variations) to regulate construction activities.

Implementation of Best Practice Guideline #C2[26] has resulted in the practical introduction of multi tiered dispute resolution processes …*spanning the area between the adjudicatory dispute resolution systems (including litigation, arbitration, adjudication, and expert determination) and simple negotiation … as an alternative or precursor to arbitration or litigation*...[27] as a norm in South African construction industry dispute resolution practice.

Best Practice Guideline #C3: *Adjudication*[28] issued during September 2005 reconfirms the applicability of the principles underpinning adjudication practice (as specified in SANS 294: 2004). The guideline requires that adjudication …*be introduced as a means of dispute resolution in all the CIDB recommended forms of contracts (supplies, services and*

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[21] Best Practice Guideline #C2: *Choosing an appropriate form of contract for engineering and construction works,* Second edition of CIDB document 1010, September 2005 downloadable on www.cidb.org.za, sets out in Annexure 1 at page 15, the essential and desirable criteria, as well as the rationale for such criteria, for acceptable forms of engineering and construction works contracts in South Africa.

[22] Refer to note 19 above at page 1.

[23] The South African courts have consistently interpreted industry standard form construction contracts as typical contracts created by the parties before them, falling squarely within the parameters of the general principles of the law of contract with little (if any) regard for the fact that industry standard form construction contracts are industry specific, drafted after extensive input from stakeholders in every facet of the industry with the benefit of cross industry bargaining and consultation. This approach is typified in the judgement of McEwan J in *Smith v Mouton* 1977 (3) SA 9 (W) at paragraph 12.

[24] Refer to note 19 above at page 1.

[25] The South African Institute of Consulting Engineers (referred to as "SAICE") sixth edition General Conditions of Contract for Civil Engineering Works standard form construction contract was replaced in 2004 with the General Conditions of Contract for Construction Works, First Edition (GCC 2004) "... *to satisfy the Construction Industry Development Board's requirements for standard conditions of contract*..." (at page (iii)).

[26] Refer to note 19 above at page 1.

[27] Capper, P. Robert Hunter R, *Choice of Dispute Resolution Procedure* (extract from a note), Lovells at page 8.

[28] Best Practice Guideline Number # 3:*Adjudication,* September 2005, Second Edition of CIDB document 1011, downloadable on www.cidb.org.za

engineering and construction works) identified in Best Practice Guideline #C1, Preparing procurement documents, and in all the forms of subcontract identified in Best Practice Guideline #D1, Subcontracting arrangements…[29]. The principle that adjudication ...*shall be a mandatory requirement for the settlement of disputes before the completion of a contract*...[30] is unequivocally reinforced.

3. South African construction industry participation: adjudication in practice

In addition to the South African government's interventions in ensuring the adoption of an *ad hoc* adjudication into the South African construction practice, the industry itself has largely embraced procedure ...*whereby the parties agree to confer jurisdiction on an adjudicator to decide the particular dispute that has arisen between them*…[31] as a means ...*to find some sensible resolution of their problem and then get back to their real business*…[32].

Bvumbwe and Thwala (2011) conducted a study to determine which of the spectrum of ADR procedures (including specifically mediation and adjudication) are most frequently deployed through the South African construction industry in resolving construction disputes. They concluded that although …*mediation is the most frequently used method in resolving disputes in the construction industry ... the majority of respondents would prefer the inclusion of adjudication as the priority in resolving dispute before arbitration*...[33].

Van der Merwe (2009) conducted a comparative study of the application of both mediation and adjudication across the South African construction industry to determine which of the two dispute resolution methods is better suited to resolve construction disputes in the South African construction industry. In concluding that adjudication is preferable van der Merwe concludes …*that both mediation and adjudication are effective alternative methods of dispute resolution as to litigation and arbitration. Although adjudication has a weakness in the enforceability of the decision of the Adjudicator, it still has an advantage over mediation*...[34].

Maritz (2007) overviews the development of adjudication in the South Africa construction industry, considering its effectiveness in resolving construction disputes, the extent to which adjudication has been utilised since its introduction into the South African construction industry and concludes that ...*[E]xperience in other countries who have introduced adjudication has shown that adjudication without the statutory force is not likely to be effective. Enforcement of the adjudicator's decision is critical to the success of adjudication and before South Africa introduces an Act similar to Acts such as the Housing Grants, Construction and Regeneration Act 1996 (UK), the Construction Contracts Act 2002 (NZ) or*

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29 Refer to note 26 above under paragraph 4.1 [*General*] at page 4.
30 Refer note 26 above.
31 Coulson Peter (Sir), *Construction Adjudication*, second edition, Oxford University Press, 2011 at page 185.
32 Mr. Justice Jackson, *The Tower of Babel: What happens when a building contract goes wrong*, The 2006 Denning Lecture given in Gray's Inn, London on 28th November 2006, downloadable from www.scl.org.uk.
33 Refer to page 35.
34 Refer to page 50.

Building and Construction Industry Security of Payment Act 2004 (Singapore) adjudication will remain largely ineffective and, therefore, underutilised in the South African context…[35].

Gaitskil (2007), echoing Maritz's observations, argues that …*[I]n order for adjudication to have any real impact it had to be compulsory so that powerful employers or main contractors could not simply strike such clauses out of contracts they made. This meant that there had to be legislation which simply imposed adjudication on all parties in the construction industry*...[36].

Following an investigation into the implementation of *ad hoc* adjudication in the South African construction industry Maiketso and Maritz (2009) concluded …*that adjudication has found acceptance in the SA construction industry. However, it still has some way to go before its potential can be realised in full. Certain challenges need to be overcome to enable this to happen, which range from the contractual, institutional and legislative framework, to matters of skills and training*...[37].

4. Finding the appropriate legislative framework to underpin adjudication practice

Statutory adjudication was first introduced into the United Kingdom through enactment of Part II of the HGCRA which came into force in May 1998. The Local Democracy Economic Development Act, 2009 subsequently effected changes to the adjudication and payment provisions contained in the HGCRA. Three years after enactment of the HGCRA the state of New South Wales (NSW) enacted the Building and Construction Industry Security of Payment Act, 1999 (the NSW Act), modelled on the HGCRA. The NSW Act served as the model upon which most other Australian jurisdictions, to varying degrees, based their construction contracts legislation, culminating in the Tasmanian Act which received Royal Assent on 17 December 2009.

Other states and territories across Australia including Victoria[38], Queensland[39], Northern Territory[40], Western Australia[41], Australian Capital Territory[42], South Australia[43] and Tasmania[44] have each enacted similar legislation. The Western Australia and Northern Territory models differ significantly from the other Australian legislation in respect of the underlying conceptual framework and content. An examination of each act not only exposes differences between the West Coast and East Cost models but also significant disparities between the acts within each division revealing the ...*law as a multi-headed hydra rather than a guardian angel*....

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35 Refer to page 9.
36 Refer to page 777.
37 Refer to page 1566.
38 The Victoria Building and Construction Industry Security of Payment Act 2002 (amended in 2006).
39 The Queensland Building and Construction Industry Payments Act 2004.
40 The Northern Territory Construction Contracts Act 2004.
41 The Western Australia Construction Contracts Act 2004.
42 The Australian Capital Territory Building and Construction Industry (Security of Payment) Act 2009.
43 The South Australia Building and Construction Industry Security Of Payment Act 2009.
44 The Tasmanian Building and Construction Industry Security of Payment Act 2009.

The CIDB has made a concerted effort to overcome the challenges referred to by Maiketso and Maritz (2009) by initiating the procedure stipulated in section 33 [*Regulations*] of the CIDB Act 38 of 2000 to put in place the legislative framework necessary to underpin adjudication practice in the South African construction industry.

During September 2012 the CIDB finally approved draft regulations consisting of Part IV C titled "Prompt Payment" and Part IV D titled "Adjudication" (the "draft regulations"[45]) including a Standard for Adjudication ("the Standard") which have been submitted to the Minister of Public Works[46], advising that the draft regulations be promulgated by the Minister of Public Works as regulations under and in terms of section 33(1)[47] of the CIDB Act 38 of 2000[48].

4.1 Key features of the proposed legislative framework

Certain key features of the proposed legislative framework shall be considered in light of similar provisions in the HGRCA Act and the NSW Act.

Section 1 [*Application]* of Part IV C of the draft regulations make the regulations applicable across both public and private sectors where contracting parties have concluded either in writing or orally any contract regulating execution of ...*construction works...* or *...construction works related contract...*[49] (collectively referred to as the "construction contract") despite the provisions of any of those contracts. The regulations will specifically not apply to a home building contract as contemplated in the National Home Building Regulatory Council Act[50].

Unlike under the NSW Act, which restricts access to the adjudication procedure, under sub clause (1) of regulation 26 P [*Right to refer disputes to adjudication*] either party to the construction contract will acquire the statutory right to refer a dispute arising under the construction contract to adjudication.

What would constitute a dispute is specifically defined in sub clause (2) of regulation 26 P [*Right to refer disputes to adjudication*] as including …*any difference between the parties in relation to the contract*...[51]. The broad definition of a dispute arising under a construction contract defined in sub clause (iii) of Part 1: The Adjudicator [*General Principles*] accords with the general approach adopted in section 108 (1) of the HGCRA which provides that …*a*

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[45] A copy of the draft regulations dated 20 August 2012 shall be made available during the presentation of the paper.

[46] Section 8 of the Construction Industry Development Board Act 38 of 2000 provides that the Board " .. *may advise the Minister on policy and legislation impacting on the construction industry or propose amendments to this Act to the Minister*..".

[47] Section 33 (1) of the Construction Industry Development Board Act 38 of 2000 provides that "…*The Minister may, by notice in the Gazette, make regulations not inconsistent with this Act with regard to any matter that is required or permitted to be prescribed. In terms of this Act and any other matter for the better execution of this Act or in relation to any power granted or function or duty imposed by this Act*..."

[48] Refer to note 14 above.

[49] "*Construction works*" are defined under sub paragraph (j) of section 1 [*Definitions*] of the Construction Industry Development Board Act 38 of 2000 as "*..the provision of a combination of goods and services arranged for the development, extension, installation, repair, maintenance, renewal, removal, renovation, alteration, dismantling or demolition of a fixed asset including building and engineering infrastructure* ..". The regulations supplement this definition by including a *"...construction works related contract..."* which defined under section 2 [*Amendment of Regulation I of the Regulations].*

[50] Within the regulatory framework of the South African construction industry homebuilding does not fall under the auspice of the Construction Industry Development Board Act 38 of 2000, but is regulated under the National Home Building Regulatory Council Act. Amendments are being introduced into the National Home Building Regulatory Council Act which will mirror these Regulations.

party to a construction contract has the right to refer a dispute arising under the contract for adjudication under a procedure complying with this section. For this purpose, dispute includes any difference.... The HGCRA allows all types of disputes to be referred to adjudication and enables a contractual adjudication regime to run in parallel with statutory adjudication system. The NSW Act is purely statutory allowing only progress payment related disputes to be adjudicated.

Sub clause (1) of regulation 26 P [*Right to refer disputes to adjudication*] creates a statutory obligation on the parties to a construction contract to provide for an adjudication procedure to resolve disputes arising under the construction contract in the express terms of each construction contract.

Part 1: [*The Adjudicator*] of the Standard defines "adjudication" as the process contemplated in Part IV D, which procedure …*shall be neither arbitration nor an expert determination*...[52]. The characterization of the proposed statutory adjudication procedure as not being an arbitration accords squarely with the position taken by Katheree – Setiloane AJ in *Freeman, August Wilhelm N.O, Mathebula N.O, Trihani Sitos N.O v Eskom Holdings Limited*[53] that the adjudication process ...*is not an arbitration and it is therefore not subject to the common law, or section 3 of the Arbitration Act 42 of 1965...*[54]*.*

The adjudication procedure provided for must …*substantially comply*... with Part IV D. Failing which the provisions of Part IV D read together with the Standard shall by default apply in each instance. In order to …*substantially comply*... with Part IV D the adjudication procedure provided for must be constructed around six fundamental requirements specified in sub clause (4) of regulation 26P [*Right to refer disputes to adjudication*][55]. Should the adjudication procedure not incorporate all six requirements the adjudication procedure will by default be implemented in accordance with the provisions of Part IV D and, more particularly, the Standard.

Sub clause 1(a) of regulation 26 V [*Period within which adjudicator must make decision*] provides that the adjudicator must reach his decision …*28 days after receipt of the referral notice contemplated in 26P...*. The twenty eight day time frame within which an adjudicator must reach a decision accords with the approach implemented under the HGCRA[56]. The NSW Act provides a ten business day period from the date of the adjudicators notification of appointment[57] for the adjudicator to reach the decision.

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53 *Freeman, August Wilhelm N.O, Mathebula, Trihani Sitos de Sitos NO v Eskom Holdings Limited* (unreported judgment of the South Gauteng High Court dated 23 April 2010).

54 Refer to note 51 above at paragraph 23

55 The six fundamental requirements which must be incorporated into the adjudication procedure provided for in each construction contract must " …*(a) enable a party to give notice at any time of his or her intention to refer a dispute to adjudication; (b) provide a timetable with the object of securing the appointment of the adjudicator and referral of the dispute to him or her within seven days of such notice; (c) require the adjudicator to reach a decision within 28 days of referral; (d) allow the adjudicator to extend the period of 28 days by up to 14 days, with the consent of the party by whom the dispute was referred; (e) impose a duty on the adjudicator to act impartially; and (f)enable the adjudicator to take the initiative in ascertaining the facts and the law* ...".

56 Section 108(2)(c) of the HGRCA and paragraph 19(1)(a) of the Scheme.

57 Section 21(3) of the NSW Act.

As Maritz (2007) correctly observes …[*E*]*nforcement of the adjudicator's decision is critical to the success of adjudication...*[58]*.* Neither the HGCRA, nor the Scheme for Construction Contracts (the Scheme) entrenches a procedure for enforcing adjudicator's decisions. The HGCRA simply provides that adjudicator's decisions are binding unless and until overturned by agreement, arbitration or litigation[59]. Paragraph 23 (2) of the Scheme similarly provides that the decision is binding pending final resolution by agreement, arbitration or litigation. The absence of an enforcement mechanism entrenched in the legislation was initially perceived as a critical flaw in the legislation. Fortunately the English courts have consistently adopted a robust approach in the enforcement of adjudicator's decisions[60] ensuring that Parliaments intention in introducing the legislation was not thwarted. In contrast the NSW Act entrenches a procedure for enforcing adjudicator's decisions in the legislation allowing the aggrieved party to recover an unpaid progress payment or an adjudicated amount as a statutory debt in court. These procedures provide certainty as to how the unpaid amount will be recovered.

The NSW decision in *Brodyn Pty Ltd t/a Time Cost and Quality v Davenport & Anor*[61] has been relied upon by Australian courts as authority for refusing to interfere in erroneous adjudication decisions under the legislation. Favouring a policy shift towards a regime with minimum opportunity for court involvement in the statutory adjudication process *Brodyn Pty Ltd t/a Time Cost and Quality v Davenport & Anor* substantially limited the basis upon which adjudicator's decisions were open to challenge to instances where there is shown to be some non-satisfaction of a basic and essential requirement(s)[62] which the NSW Act prescribes for the existence of an adjudicator's determination. The NSW Court of Appeal in *Chase Oyster Bar v Hamo Industries*[63] overturned *Brodyn Pty Ltd t/a Time Cost and Quality v Davenport & Anor* significantly, widening the scope for challenging adjudicators' determinations by holding that adjudicators' determinations are open to judicial review by the courts on jurisdictional grounds.

Sub clause 1 of regulation 26 X [*Effect of adjudicator's decision*] of Part IV D specifically obliges the parties to give effect to the adjudicator's decision within ten days of the decision being notified to the parties irrespective of whether not the decision will be challenged. This approach has been upheld in *Basil Read (Pty) v Regent Devco (Pty) Ltd*[64] with Mokgoatlheng J holding that where ...*the contract and Adjudicator's Rules state that the parties are bound to act in accordance with the adjudicator's determination until such time as it is set aside by an arbitrator. Declaring a dispute in relation thereto does not relieve the respondent of its contractual obligation*...

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58 Refer to page 1566.

59 Section 108(3) of the HGRCA.

60 See for example *Balfour Beatty Construction Ltd v the Mayor & Burgess of the London Borough of Lambeth* [2002] EWHC 597.

61 *Brodyn Pty Ltd t/a Time Cost and Quality v Davenport & Anor* [2004] NSWCA 394.

62 The essential basic requirements are summarised by Hodgson JA at paragraph 53 of *Brodyn Pty Ltd t/a Time Cost and Quality v Davenport & Anor* [2004] NSWCA 394.

63 *Chase Oyster Bar v Hamo Industries* [2010] NSWCA 190.

64 *Basil Read (Pty) v Regent Devco (Pty) Ltd* (an unreported decision of the South Gauteng High Court handed down on 09 March 2010).

Sub clause 2 of regulation 26 X [*Effect of adjudicator's decision*] of Part IV D provides that …*the decision of an adjudicator constitutes a liquid document or in the case where it orders the payment of an amount of money, a liquidated amount as contemplated in rule 32(1) of the High Court rules*... This provision goes further than the HGCRA and the Scheme providing mechanisms to recover unpaid amounts by effectively enabling the claimant to institute either provisional sentence proceedings[65] or summary judgement proceedings[66] on the adjudicator's decision itself as a liquid document evidencing a liquidated amount due, owing and payable.

In addition to the immediate opportunity to institute provisional sentence proceedings afforded by section 2 of regulation 26 X [*Effect of adjudicator's decision*] of Part IV D the High Court of South Africa has by both summary judgment proceedings and motion proceedings[67] for specific performance[68] enforced adjudicator's decisions. There is a clear willingness exhibited through both *Basil Read (Pty) Ltd v Regent Devco (Pty) Ltd* [69] and *Freeman, August Wilhelm N.O, Mathebula N.O, Trihani Sitos N.O vs Eskom Holdings Limited* [70] by the High Court of South Africa to take a robust approach to enforcement of adjudicator's decisions by application of entrenched South African civil proceedings.

5. Conclusion

A form of statutory adjudication has already found a seat in South African legislation through Part F [*Companies Tribunal adjudication procedures*] of the Companies Act[71] which provides opportunity to parties (as opposed to a statutory obligation[72]) to refer disputes arising under or in connection with the application of Companies Act to a public authority known as the Companies Tribunal for resolution. The Companies Tribunal is specifically prescribed when adjudicating referred disputes to …*conduct its adjudication proceedings contemplated in this Act expeditiously in accordance with the principles of natural justice...*[73] and *may conduct those proceedings informally*...[74].

Statutory adjudication is, consequent on the enactment of Part F [*Companies Tribunal adjudication procedures*] of the Companies Act[75], no longer entirely foreign to South African jurisprudence, both the South African government and construction industry have recognised the proven effectiveness of such systems internationally and the South African courts have exhibited a definite willingness to enforce an adjudicator's decision. Therefore, there is every compelling reason for the CIDB's draft regulations to now immediately be given the force of law by the Minister of Public Works.

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65 Provisional sentence proceedings in the High Court of South Africa are regulated under rule 8 [*Provisional Sentence*] of the Uniform Rules of Court.

66 Summary judgment proceedings in the High Court of South Africa are regulated under rule 32 [*Summary Judgment*] of the Uniform Rules of Court.

67 Motion proceedings in the High Court of South Africa are regulated under rule 6 [*Applications*] of the Uniform Rules of Court.

68 Refer to *Farmers' Co-op Society (Reg) v Berry* 1912 AD 343.

69 Refer note 62 above.

70 Refer to note 51 above.

71 The Companies Act No.71 of 2008 , has completely overhauled the South African company law legislative framework.

72 Section 181 [*Right to participate in hearing*] of the Companies Act No.71 of 2008.

73 Refer to note 69 above at Section 180 [*Adjudication hearings before Tribunal*] (1) (a).

74 Refer to note 69 above at Section 180 [*Adjudication hearings before Tribunal*] (1) (b).

75 Refer to note 69 above.

The legislative framework proposed will (once implemented) solidify a desperately needed …*speedy mechanism for settling disputes in construction contracts on a provisional interim basis and requiring the decision of the adjudicators to be enforced pending the final determination of disputes by arbitration, litigation or agreement*...[76] into South African jurisprudence and construction practice significantly enhancing …*delivery, performance and value for money, profitability and the industry's long term survival in an increasingly global arena*...[77].

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[76] Mr.Justice Dyason in the landmark United Kingdom case of *Macob Civil Engineering Limited vs Morris Construction Limited* [1999] BLR 93,TCC at page 97

[77] Refer to note 16 above.

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Radon Sub-slab Suctioning System Integrated in Insulating Layer

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Abstract

A new principle for radon protection, using a system containing a horizontal grid of air ducts pressurised within the rigid insulation material, was presented. The principle was based on the principles for pressure reduction of the zone underneath the ground floor construction. A new element of prefabricated lightweight elements were introduced and demonstrated. The principle was demonstrated on a concrete ground slab floor with a concrete slab on top of a thermal insulation layer above a capillary-breaking layer mounted on stable ground. The thermal insulation and the capillary-breaking layer consisted of a rigid insulation material. The new solution integrates the capillary-breaking layer and a pressure reduction zone, denoted the radon–suctioning layer, in one element. The new solution introduces the radon-suctioning layer as a horizontal grid of air ducts with low pressure to catch air and radon from the ground. The new principle was shown to be effective in preventing radon from polluting the indoor air by introducing low pressure in the horizontal grid of air ducts. A lower pressure than the pressure inside the building must be established. The element was integrated into the insulation material of the ground slab floor. The element and the insulation material were made of expanded polystyrene. The new element can be handled by one man on site.

Keywords: Radon, Protection, Sub-slab, Suctioning, Insulating

1. Introduction

Radon is a radioactive noble gas that develops as a result of the decay chains of uranium and thorium, Clavensjö and Åkerblom (2004). When radon decays into different radon daughters, it generates alpha, beta and gamma rays. These rays are harmful to human beings. Radon originates in the ground and is the primary source of natural radiation in most countries, Danish Enterprise and Construction Authority (2007). Therefore the geological character of the ground, on which a building is situated, sets the level for how high the radon concentration of the indoor air can become. Radon mainly penetrates into a building by air infiltration from the ground through cracks or other unintended openings in the ground construction, Lehmann, Landfermann, Junkert and Schöppler (2001).

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In 2009, the World Health Organization, WHO, recommended that requirements to the accepted maximum radon concentration in the indoor air should be tightened from 200 Bq/m^3 to 100 Bq/m^3. The new recommendations are a result of WHOs evaluation that radon is responsible for 3-14% of lung cancer incidents, depending on the average radon exposure in different countries, Zeeb and Shannoun (2009). These findings showed radon as the second-largest cause of lung cancer; smoking is still the principal cause. Radon exposure must be taken seriously in the fight against radon-induced lung cancer due to the large number of people that are exposed daily in buildings and especially in residential buildings, Zeeb and Shannoun (2009), as a large number of residential buildings are built with a slab on ground. An investigation shows that if people spend their whole life in a building with an average radon concentration in the indoor air exceeding 200 Bq/m^3, their risk of getting lung cancer is higher than 1%, Andersen et al. (1997). This is far too high and higher than what in other contexts is an acceptable single-factor risk. Ensuring a good quality of the indoor air includes a focus on radon and methods for controlling the radon concentration in the indoor air.

In 2010, the requirements recommended by WHO were implemented in the Danish Building Regulations. The Danish Building Regulations now stipulate a maximum radon concentration of 100 Bq/m^3 in the indoor air in all new buildings. For existing buildings, simple and cheap actions are recommended if the concentration ranges between 100 Bq/m^3 and 200 Bq/m^3 in the indoor air; however, if the radon concentration exceeds 200 Bq/m^3, immediate intervention is necessary and more efficient efforts and improvements are recommended in order to lower the concentration of radon in the indoor air, Danish Enterprise and Construction Authority (2010). The first radon provisions were introduced in the Danish Building Regulations in 1995, Danish Enterprise and Construction Authority (1995).

Solutions to prevent radon from polluting the indoor air are traditionally based on a combination of three different principles: i) establishing a protective layer against radon by using airtight materials and membranes, ii) introducing pressure reduction of the zone underneath the ground floor construction, and iii) providing effective dilution of the indoor air with outdoor air. Of these principles, ii), pressure reduction is considered by far the most efficient. Pressure reduction requires a permeable radon–suctioning layer. Shingles, pebbles or coated ceramic pellets are permeable materials traditionally used for creating a capillary-breaking layer. However, today the capillary-breaking layer is made of rigid insulation material. Therefore, new solutions are needed that create a permeable layer within the lower capillary-breaking zone of the rigid insulation material in the ground slab floor.

The paper presents a new prefabricated lightweight element designed to reduce and control the pressure reduction of the zone underneath the ground floor construction. The effect of the element was demonstrated on a ground slab floor, which was constructed of a concrete slab on top of a thermal insulation layer above a capillary-breaking layer mounted on stable ground. The thermal insulation and the capillary-breaking layer consisted of a traditional rigid insulation material of expanded polystyrene, EPS. The new element integrates the capillary-breaking layer and the pressure reduction zone, denoted the radon–suctioning layer, in one element. The solution intends to introduce a horizontal grid of air ducts pressurised to suction air and radon from the ground. Results showing the radon-suctioning layer and the

principles for its establishment within the rigid insulation material are presented. Equations to predict the airflow within the ground slab floor were developed. A finite difference program was used to calculate the airflow. Simulations of airflow within the rigid insulation material were shown for a number of pressure differences between the pressure indoor and the pressure in the air ducts. Simulations of the airflow within the rigid insulation material were carried out for both low and high quality of EPSs combined with flooring that is more and less airtight. Results were used to provide directions on how to obtain an effective radon protection using a system containing a horizontal grid of air ducts pressurised within the rigid insulation material of a traditional ground slab floor.

2. Measures to limit radon indoors

Solutions to prevent radon from polluting the indoor air and to limit and control radon concentration in the indoor air are based on a combination of three different principles: 1) A layer protecting against radon infiltration established by using airtight materials and membranes, 2) Pressure reduction of the zone underneath the ground floor construction, and 3) Effective dilution of the indoor air with outdoor air. The three principles are shown in Figure 1.

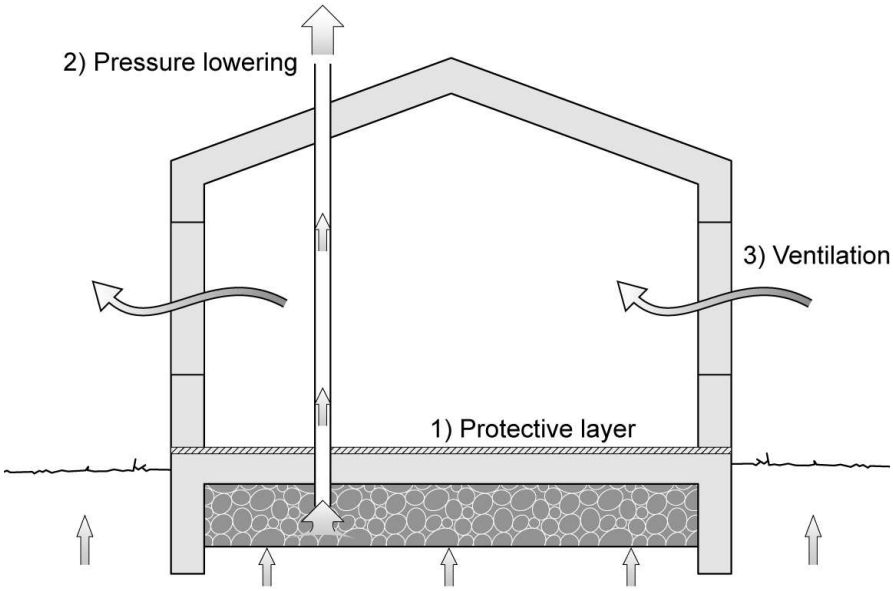

Figure 1: By combining three principles, the radon penetration and concentration indoors can be controlled. 1) Establishing a protective layer that prevents air infiltration from the ground. 2) Lowering the pressure difference over the floor construction of the building facing the ground. 3) Diluting the indoor air in the building with outdoor air.

3. Pressure lowering

The most effective way of preventing air that may contain radon from infiltrating from the ground into a building is considered to be a radon-suctioning system, Valdbjørn Rasmussen (2010). The principle is that the pressure is lowered in the zone underneath the ground slab floor of the building. The pressure difference can be up to 10 MPa between the interior of the building and underneath the ground slab floor. This pressure difference can be equalised by

establishing a connection between the atmosphere and a highly permeable layer underneath the building. In such a construction, the pressure difference, over the floor construction of the building facing the ground, will decrease and result in a decrease of the amount of ground air that can infiltrate. The radon-suctioning system can either be passive or active, i.e. creating suction through the stack effect only or creating suction by means of mechanical ventilator. A pipe can be led directly from the radon-suctioning layer and above the roof. Suction is introduced through the pipe to the radon-suctioning layer.

4. Theory

The Heat2, HEAT2 (2010), finite difference program was used for the pressure equalisation calculations. It was assumed that the pressure difference was so low that the air would not be compressed. Additionally, it was assumed that the speed of the air through the materials of the ground slab floor was within the range of a laminar airflow. Furthermore, the individual materials were porous and homogeneous. Under these conditions, air flowing through a porous material can be described mathematically in the same way as a stationary thermal conductance problem. A stationary thermal conductance problem is described by:

$$\frac{\partial}{\partial x}\left(k_x \frac{\partial T}{\partial x}\right)+\frac{\partial}{\partial y}\left(k_y \frac{\partial T}{\partial y}\right)+\frac{\partial}{\partial z}\left(k_z \frac{\partial T}{\partial z}\right)=0 \qquad (1)$$

Where, T is the temperature and k_x, k_y, k_z are the thermal conductance in the x, y, z axes, respectively.

The differential equation, Equation (1) expresses that the total effect that is supplied to and removed from a control volume is equal to zero.

The result of a thermal conductance problem is a temperature distribution within the analysed element. From the temperature distribution, the effect that needs to be removed or absorbed through the borders, to maintain the stationary temperature distribution can be determined. In the same way, the air pressure distribution can be calculated and the amount of air that needs to be removed or absorbed through the borders, in order to maintain the stationary pressure distribution, can be determined for porous materials. A stationary pressure distribution problem is described by:

$$\frac{\partial}{\partial x}\left(q_x \frac{\partial P}{\partial x}\right)+\frac{\partial}{\partial y}\left(q_y \frac{\partial P}{\partial y}\right)+\frac{\partial}{\partial z}\left(q_z \frac{\partial P}{\partial z}\right)=0 \qquad (2)$$

Where, P is the pressure and q_x, q_y, q_z are the pressure distribution in the x, y, z axes, respectively.

Using the finite difference program Heat2, HEAT2 (2010), for air-pressure calculation, the temperature was replaced by the air pressure, the thermal conductance was replaced by the air permeability and the effect was replaced by the amount of air per time. A stationary air

pressure problem described by Equation (2), then expresses that the amount of air that is brought in and the amount of air brought out of the control volume is equal to zero.

Using the Heat2 program and a PC for the pressure analyses, the input data for the thermal conductance values were replaced by the air-permeability values and the prescribed temperatures were replaced by the prescribed air-pressure values. Calculations were performed to reach air-pressure equilibrium between the air pressure indoors and the air pressure in the ground. For the state of pressure equilibrium, the amount of air per time unit was determined, which it was necessary to remove or absorb through the upper surface of the concrete slab facing the indoor environment.

Usually the air permeability of a material is given as the resistance known as the Z-factor with the unit (h m^2 Pa)/g describing a specific building component of a specific thickness. For these calculations, the air permeability must be determined as the reciprocal value of the Z-value multiplied by the thickness of the building component.

5. Radon Sub-slab Suctioning System

The highly permeable and capillary-breaking layer underneath the building often consists of i.e. shingles, pebbles or coated ceramic pellets but can also be a layer of EPS with a horizontal grid of air ducts.

5.1 Material

The prefabricated element was made of EPS to form an element that could be used as the capillary-breaking layer and the radon–suctioning layer integrated in one element. The air permeability was 0.0144 g/(m h KPa) for a EPS with a density of 20 kg/m^3 and 0.0054 g/(m*h*KPa) for a EPS with a density of 32 kg/m^3, respectively.

5.2 Design

The prefabricated element was produced as units of 600 mm in length and 400 mm in width and 50 mm in thickness. A horizontal grid was cut out and removed from the upper surface of the element, thus creating air ducts 30 mm wide and 30 mm deep with a centre distance of 100 mm. At the border towards the upper surface of the element, an air duct 15 mm wide and 30 mm deep was cut out and removed. The element is shown in Figure 2.

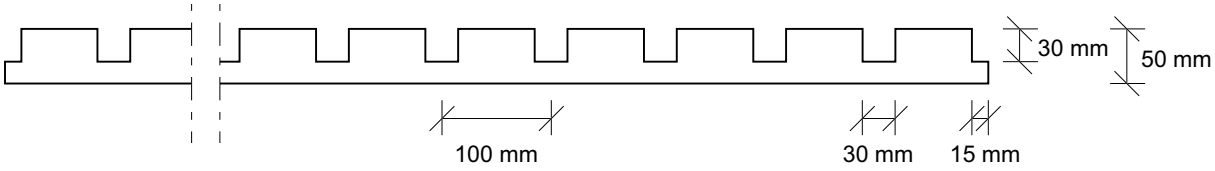

Figure 2: The new prefabricated element made of EPS.

6. Modelling

Calculations of the airflow through the ground slab floor were made using a PC and the finite difference program Heat2, HEAT2 (2010), version 7.0. Calculations were performed with a constant air pressure indoors and a constant air pressure in the ground. Heat2 was used to calculate the amount of air passing through the upper surface of the concrete slab, using a constant air pressure above the concrete slab representing the air pressure inside and a constant air pressure in the air ducts of the element combined with a constant air pressure in the ground underneath the ground slab floor. The air pressure in the ground underneath the ground slab floor was 101 328.6 Pa. An adiabatic interface is bordering to the right and to the left of the model. The ground slab floor is shown in Figure 3 and the model used for the calculations is shown in Figure 4.

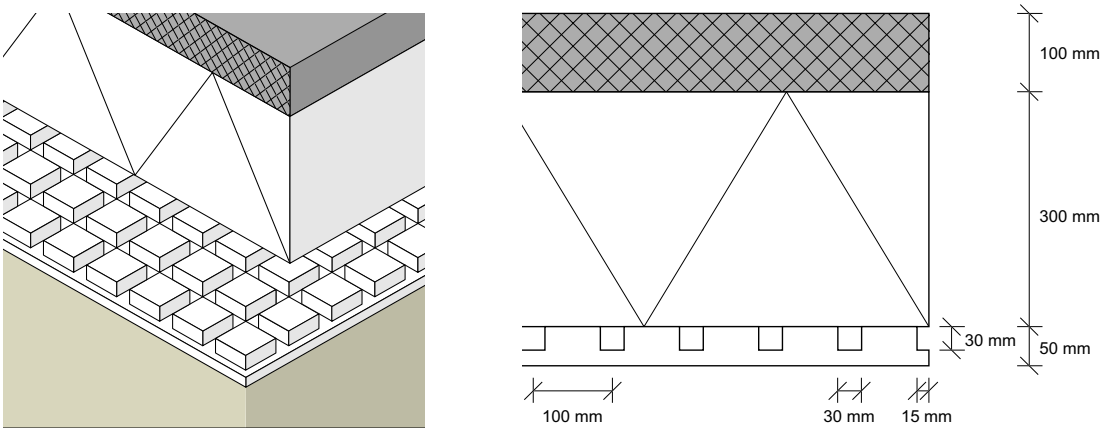

Figure 3: The ground slab floor was constructed of a concrete slab on top of a thermal insulation layer fitted above the new element. The combined capillary-breaking layer and the radon-suctioning layer are shown as the new integrated element. Left; ground slab shown in perspective view. Right; ground slab shown in sectional view.

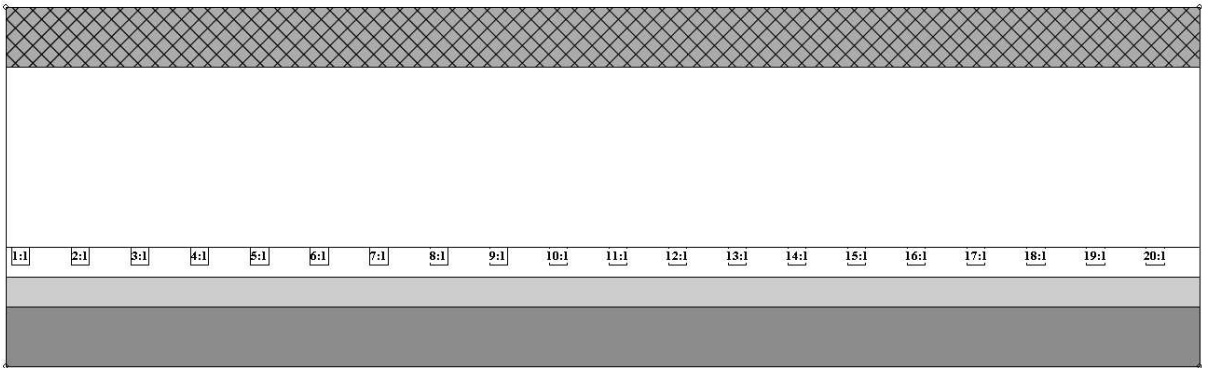

Figure 4: The model used for calculations. The model includes a concrete slab on top of a thermal insulation layer above the new element mounted on stable ground. The horizontal grid of air ducts are shown as square units that are numbered 1:1 to 20:1. Usually the top-soil layer is removed from an area covering the area of the building. The excavated area is then covered with gravel to level the excavated area. Included in the model were 50 mm of gravel and 100 mm of soil. The model was 2.0 m in length.

7. Results

For the calculations, the air permeability of the concrete, the soil and the gravel were 0.018 g/(m h KPa), 0.36 g/(m h KPa) and 0.576 g/(m h KPa), respectively. The atmospheric pressure was 1 atm equal to 101 325 Pa. For the calculations the pressure inside were 101 321.25 Pa, 101 323.24 Pa and 101 324.85 Pa, respectively, Bovbjerg and Gunnarsen (2008), in combination with a number of different pressure levels in the air ducts of the radon sub-slab suctioning system, between 101 325.00 Pa and 101 320.00 Pa. The thickness of the concrete and the layer of thermal insulation were 100 mm and 300 mm, respectively. The thermal insulation was EPS with the air permeability of 0.0144 g/(m h KPa). The radon sub-slab suctioning system was of EPS with an air permeability of 0.0144 g/(m h KPa). Results are shown in Figure 5.

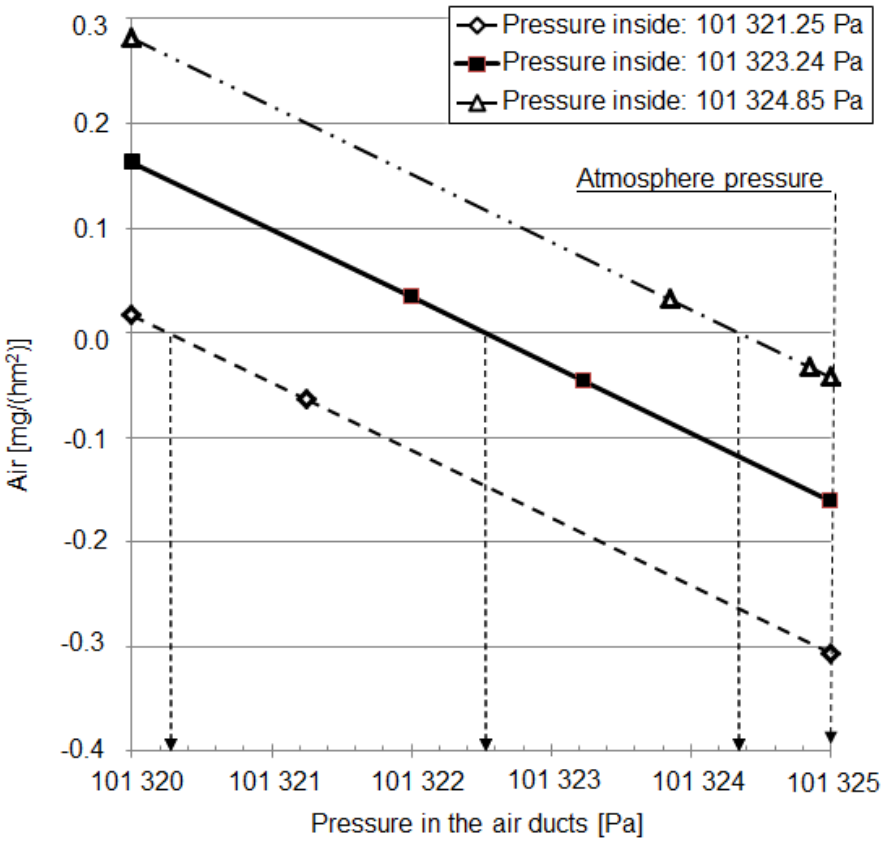

Figure 5: Amount of air passing through the upper surface of the concrete slab in milligram per hour per square metre. A positive number for the amount of air represents air moving through the ground slab floor towards the air ducts.

Calculations were repeated assuming the concrete to be less air tight with an air permeability of 0.36 g/(m h KPa). In addition, the calculations were repeated for a more dense EPS with a density of 32 kg/m^3 and with an air permeability of 0.0054 g/(m h KPa). The air permeability was changed individually. For the calculations, the atmospheric pressure was 1 atm equal to 101 325 Pa. The pressure inside was 101 323.24 Pa in combination with a number of different pressure levels in the air ducts of the radon sub-slab suctioning system, between 101 325.00 Pa and 101 320.00 Pa. The thickness of the concrete and the layer of thermal insulation were 100 mm and 300 mm, respectively. Results are shown in Figure 6.

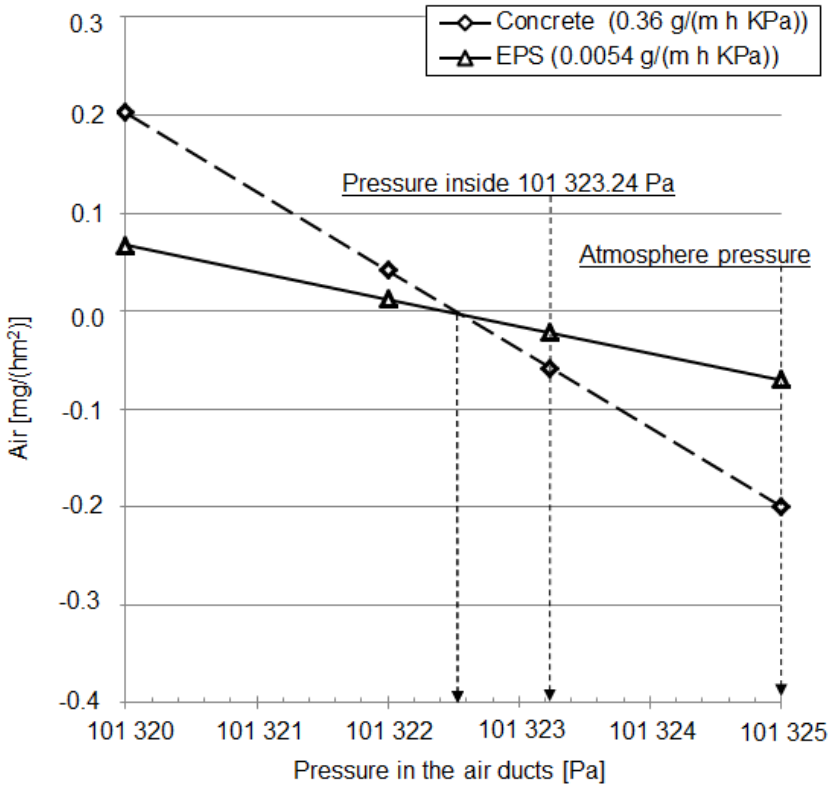

Figure 6: Amount of air passing through the upper surface of the concrete slab in milligram per hour per square metre. A positive number for the amount of air represents air moving through the ground slab floor towards the air ducts. Calculations were made assuming a less air tight concrete with an air permeability of 0.36 g/(m h KPa) and assuming a more dense EPS with a density of 32 kg/m^3 with the air permeability of 0.0054 g/(m h KPa), respectively.

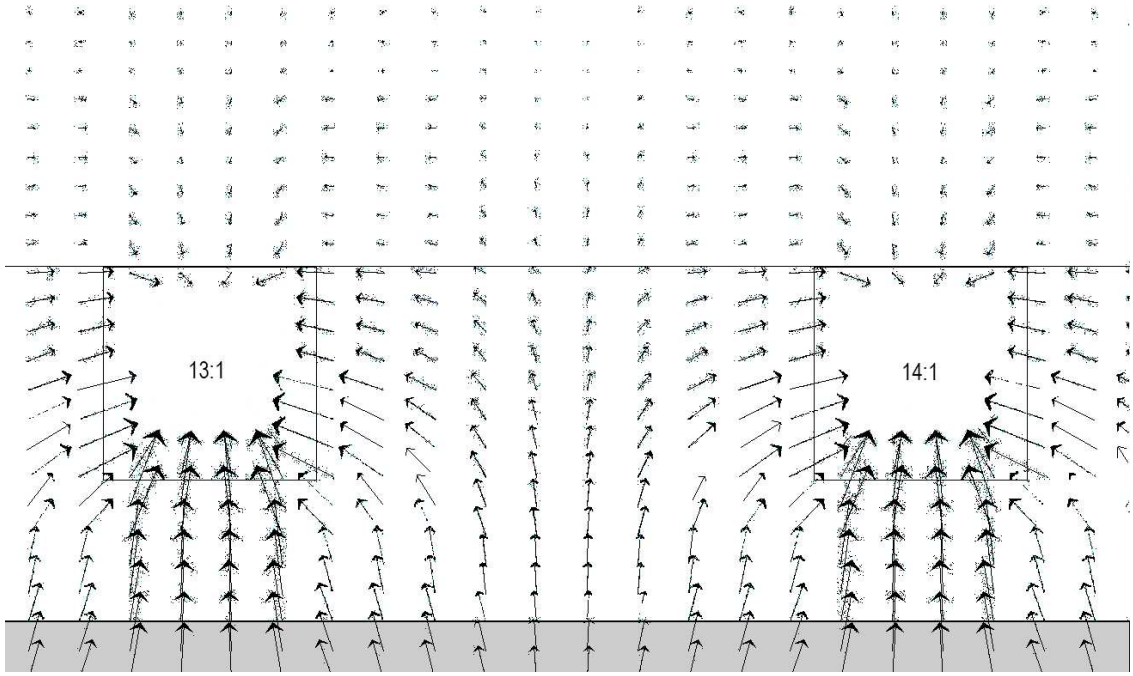

Figure 7: The calculated airflow around air duct No. 13:1 and No. 14:1 in the radon sub-slab suctioning system. The radon sub-slab suctioning system made of EPS is shown mounted on a layer of gravel and underneath the thermal insulation of EPS.

The air permeability of a the concrete was 0.018 g/(m h KPa). The pressure inside was 101 323.24 Pa and the pressure in the air ducts of the radon sub-slab suctioning system was 101 320.00 Pa. The thermal insulation was EPS with an air permeability of 0.0144 g/(m h KPa). The radon sub-slab suctioning system was made of EPS with an air permeability of 0.0144 g/(m h KPa). Arrows show the airflow and the length of the arrows visualizes the relative volume of air flowing.

The calculated air flow in the radon sub-slab suctioning system of EPS and the bordering thermal insulation layer of EPS around air duct No. 13:1 and No. 14:1 is shown in Figure 7. For the calculations, the air permeability of the concrete, the soil and the gravel were 0.018 g/(m h KPa), 0.36 g/(m h KPa) and 0.576 g/(m h KPa), respectively. The atmospheric pressure was 1 atm equal to 101 325 Pa. The pressure inside was 101 323.24 Pa and the pressure in the air ducts of the radon sub-slab suctioning system was 101 320.00 Pa. The thickness of the concrete and the layer of thermal insulation were 100 mm and 300 mm, respectively. The thermal insulation was made of EPS with an air permeability of 0.0144 g/(m h KPa). The radon sub-slab suctioning system was made of EPS with an air permeability of 0.0144 g/(m h KPa). Arrows show the airflow and the length of the arrows visualizes the relative volume of air flowing.

8. Discussion

A new prefabricated lightweight element that can be used to reduce the air pressure in the zone underneath the ground floor construction has been introduced. The new element is made of expanded polystyrene, EPS. The element is produced as one integrated element consisting of units of 600 mm in length and 400 mm in width and 50 mm in thickness. A horizontal grid of air ducts is cut in the upper surface of the element, thus creating air ducts 30 mm wide and 30 mm deep with a centre distance of 100 mm. Along the edge of the upper surface of the element, air ducts 15 mm wide and 30 mm deep were cut and the EPS removed. The element is designed to be handled on site by one man.

Traditionally, a ground slab floor is used that is constructed of a concrete slab on top of a thermal insulation layer above a capillary-breaking layer mounted on stable ground. The thermal insulation layer consists of a rigid insulation material. The capillary-breaking layer consists of either a layer of a rigid insulation material on a thin layer of gravel used to level the excavated area or a layer of i.e. shingles, pebbles or coated ceramic pellets. The new element makes it possible to combine the capillary-breaking layer and the radon–suctioning layer in one integrated element of EPS. The most effective way of preventing radon from infiltrating from the ground into the indoor air of a building is to lower the air pressure of the zone underneath the ground floor construction. By lowering the air pressure of the zone underneath the ground floor construction, the pressure difference over the floor construction can be lowered. A pipe can be led directly from the radon-suctioning layer to above the roof. Suction is introduced to the radon-suctioning layer through the pipe. The suction can either be passive or active i.e. creating suction through the stack effect only or creating suction by means of mechanical ventilator. A horizontal grid serving as air ducts in a layer of EPS could be used as a permeable layer to be used as a radon-suctioning layer underneath the floor construction of a building. The novel element can be used to lower the pressure difference

over the floor construction of the building facing the ground, and in this way prevent ground air from infiltrating from the ground, and additionally prevent the risk of radon polluting the indoor air.

Calculations of the airflow through a ground slab floor were made using a PC and a finite difference program. Mounted on stable ground, the ground slab floor was constructed of a concrete slab on top of a thermal insulation layer and fitted above the new element that works as the combined capillary-breaking layer and the radon-suctioning layer. Calculations were performed with a constant indoor pressure and a constant pressure in the ground. Calculations of the airflow and movements of the air are shown in Figure 7. Arrows show the direction of the airflow and the length of the arrows visualises the relative volume of air flowing. The airflow and the direction of the moving air in the ground floor construction are shown. The airflow in the area around individual air ducts in the radon sub-slab suctioning system is shown in detail for an air pressure difference of 1.76 Pa between the interior and the exterior of the building. The air pressure in the radon sub-slab suctioning system is 3.24 Pa lower than inside the building. Arrows show the movement of air within the ground floor construction. Air is shown to move from the interior of the building to the radon sub-slab suctioning system.

Calculating the amount of air passing through the upper surface of the concrete slab shows that the air pressure in the air ducts of the radon-suctioning layer needs to be lower than the pressure inside in order to prevent radon and ground air to infiltrate from the ground through the floor construction. Figure 5 shows that the amount of air passing through the upper surface of the concrete slab is approximately zero for an indoor air pressure equal to 101 321.25 Pa, 101 323.24 Pa and 101 324.85 Pa and an air pressure in the air ducts equal to 101 320.28 Pa, 101 322.53 Pa and 101 324.35 Pa, respectively for an outdoor air pressure of 101 325 Pa. The needed pressure difference over the ground floor construction decreases as the air pressure inside gets nearer the outdoor air pressure.

Assuming a less airtight concrete slab and calculating the amount of air passing through the upper surface of the concrete slab shows that the air pressure in the air ducts of the radon-suctioning layer needs to be at the same level as the earlier calculations presented here to prevent radon and ground air from infiltrating from the ground through the floor construction. Figure 6 shows that the amount of air passing through the upper surface of the concrete slab is approximately zero for an indoor air pressure equal to 101 323.24 Pa and an air pressure in the air ducts equal to 101 322.53 Pa for an outdoor air pressure of 101 325 Pa. Assuming the use of an EPS with a higher density resulting in a material with a structure more dense and more airtight and calculating the amount of air passing through the upper surface of the concrete slab shows that the air pressure in the air ducts of the radon-suctioning layer needs to be at the same level as the earlier calculations to prevent radon and ground air to infiltrate from the ground through the floor construction. Figure 6 shows that the amount of air passing through the upper surface of the concrete slab is approximately zero for an indoor air pressure equal to 101 323.24 Pa and an air pressure in the air ducts equal to 101 322.53 Pa for an outdoor air pressure of 101 325 Pa. However, as the ground floor construction gets more airtight, less air passes through the upper surface of the concrete slab for an air pressure introduced in the air ducts of the radon-suctioning layer.

The air pressure difference between the interior of a building and the radon sub-slab suctioning system can be controlled by controlling the air pressure in the horizontal grid of air ducts in the radon-suctioning layer. By controlling the air pressure in the horizontal grid of air ducts penetration of air and radon from the ground can be avoided. In this way the radon sub-slab suctioning system will suck up air and radon from the ground to be released to the atmosphere. One should be careful to release the ground air to the atmosphere at locations where it will not be drawn into the building with outdoor air for ventilation.

If the pressure underneath the building is lower than the pressure inside it, air might be drawn through the concrete slab from the inside. This might be a concern if there is a risk of warm, humid air being drawn down through the floor construction, where it is cooled down in organic material resulting in risk of mould growth. However, this is not a concern for the considered floor construction.

9. Conclusion

A new element made of expanded polystyrene, EPS, which can create the radon sub-slab suctioning system has been introduced. The element can be used to reduce the air pressure in the zone underneath the ground floor construction and is integrated in the insulation layer. The element is produced as one integrated element consisting of units that can be handled on site by one man. Elements are mounted on a levelled stamped stable basis of an excavated area of a building. The layer of elements introduces the radon-suctioning layer as a horizontal grid of air ducts with low pressure to catch air and radon from the ground. The principle is shown to be effective in preventing radon from polluting the indoor air by introducing low pressure in the horizontal grid of air ducts. The principle has been demonstrated on a ground slab floor, constructed of a concrete slab on top of a thermal insulation layer above a capillary-breaking layer mounted on stable ground. In this way, the element is integrated into the insulation material of the ground slab floor.

The principle has been demonstrated carrying out pressure equalisation calculations using a finite difference program. For the pressure equalisation calculations, it is assumed that the pressure difference is so low that the air will not be compressed. Additionally, it is assumed that the airflow through the materials of the ground slab floor is in the range of a laminar airflow. Furthermore, it is assumed that the individual materials are porous and homogeneous. Results show that a pressure that is lower than the pressure inside the building must be introduced creating an efficient radon sub-slab suctioning system. The needed pressure difference over the ground floor construction decreases as the air pressure inside gets nearer the outdoor air pressure.

By lowering the air pressure of the zone underneath the ground floor construction, the pressure difference over the floor construction can be lowered. A pipe can be led directly from the radon-suctioning layer and above the roof. Suction is introduced to the radon-suctioning layer through the pipe. The suction can either be passive or active i.e. creating suction through the stack effect only or creating suction by means of mechanical ventilator. Only if a minor reduction of the pressure is needed in the radon-suctioning layer, a passive suction system created by the stack effect can be used. One should be careful not to release

the ground air to the atmosphere in places where it will be drawn into the building with outdoor air for ventilation.

Calculations have been carried out for an indoor air pressure equal to 101 321.25 Pa, 101 323.24 Pa and 101 324.85 Pa, an outdoor air pressure of 101 325 Pa and an air pressure in the soil underneath the ground slab floor of 101 328.6 Pa.

Acknowledgement

This study was supported by the Danish Association for the Plastics Industry, EPS section.

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Potential of sustainability in existing buildings - An assessing method

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Abstract

Today as in the future there is a great demand for sustainable buildings. This is not only true for new buildings but also to a large extent existing buildings. In order to achieve sustainable buildings many factors are to be considered. For this reason it is of strong interest to find tools and methods that are focusing on the potential of sustainability in existing buildings, not only considering the economical aspect but also taking into account the social and environmental aspects. This paper describes the indicators that are relevant for studying the buildings potential for sustainable development and presents a new method for assessing existing buildings. Existing methods found in the literature are evaluated and the best of these tools are extracted and adapted to a tool that can be used on existing buildings. In order to identify the factors that affect the existing buildings' sustainability, depth interviews and a survey among Norwegian property companies and engineering consultants have been conducted. The method is validated through case studies and we believe this will be a useful tool for engineering consultants and real estate companies for evaluation of building performances of building portfolios. The method may help to increase the focus on factors that have an influence on buildings' sustainability, including evaluation of theoretical and realistic potential, and to give useful information to the owner on how to develop a building portfolio.

Keywords: Potential for sustainability, assessment method, building portfolios, input to strategies

1. Introduction

The importance of striving for sustainable buildings is high, both today and for the future. This is not only true for new buildings, but also to a large extent existing buildings. In order to ensure that existing buildings will keep up with today's demand; it is of interest to identify the buildings' physical and technical factors that influence the sustainability of a building. There are many factors that must be taken into account in order to achieve sustainable buildings,

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such as energy efficiency, use of durable materials and facilitation of universal design, as well as good indoor air quality, aesthetics and heritage values that must be maintained and preserved. For these reasons, it is important to explore how to understand the potential for sustainability of the existing buildings. There are currently several methods that in various ways assess aspects of sustainability in buildings, such as BREEAM IN-use (Building Research Establishment Environmental Assessment Method), SURE (Sustainable Refurbishment), SIA (Sustainable Impact Assessment), LCA and LCC methodologies. BREEAM In-Use assesses mainly the environmental performance of existing buildings (BRE Global, 2011), in addition to some aspects of the buildings' social performance. SURE presents a guideline for sustainable refurbishment (Almås, et al., 2011), SIA assesses the impacts of a project or action in a greater context (OECD, 2010) and LCA (Life Cycle Assessment) is a methodology analysing the environmental impact of buildings during its lifetime. As LCA, the LCC methodology does similarly analyse the impacts of a building during its lifetime, however, only the economic impacts. A Norwegian assessment tool, Multimap, does also assess some sustainable aspects of the building by assessing the technical condition and other building factors for building portfolios (Bjørberg, Larssen, & Listerud, 2012). The Multimap method is based on the Norwegian standard for assessment of technical condition surveys for construction works (Norwegian Standard NS 3424, 1995) and uses the registration of technical condition and key numbers to estimate the costs of a technical upgrading of the buildings. Many existing assessment methods are aimed for construction of new buildings and for application in the design phase. However, there is a lack of methods assessing all aspects of sustainability in preliminary phases and for greater building portfolios. The SIA is for instance considering social, economic and environmental aspects of sustainability. Nevertheless it focuses on evaluating the *impacts* of a project that is considered for implementation, more than evaluating the today's situation as a basis for further decision making for a building portfolio. Most property investors want to invest in buildings that have a realistic potential for further development. This is primary to obtain economic profit, but the potential for further development may also include a positive environmental and social development of the building. A methodology for assessing buildings' potential for sustainability for building portfolios, can be a useful tool for property investors, engineering consultants and building owners. This is also the background for this paper. This paper describes a new assessment method to assess existing buildings' realistic potential for sustainability, developed through a master thesis from Norwegian University of Science and Technology (NTNU) (Hvide, 2012).

2. Methodology

The research method for the development of an assessment method included several methodology approaches. A literature study on existing methods assessing sustainability in some way (primarily BREEAM, SURE and MultiMap) was done to extract the best of these methods and adapt it to a tool that could be used for building portfolios. Further on, building factors affecting buildings' potential for sustainability was discussed in in-depth interviews with Norwegian property companies. In addition to the interviews, a survey that included rating of several building factors' influence on sustainability was also conducted. For validation of the developed assessment tool, two case studies were carried out.

3. Objectives

The main objective was to develop a method that could be used to evaluate the realistic potential for sustainability in existing buildings, especially with regard to building portfolios. Such a method could be a useful tool for real estate agents when strategizing further development of building portfolios. By getting a certain indication of the buildings' realistic potential for sustainability, decisions on whether to upgrade, refurbish, rebuild, sell or demolish can be made on a good basis. The criteria for the method were as follows:

- The method should give a result that indicates if the building has the potential to be developed further in a sustainable way (which includes a positive interaction between environmental, social and economic aspects). When considering a real estate portfolio it should provide a good basis for deciding which buildings should be retained, sold or demolished

- The method should be used in preliminary phases as an input to a decision base, and should therefore only do evaluation based on easily retained information. It should not depend on detailed numeric values.

- The method is intended to serve as a tool for engineering consultants, in order for them to make recommendations to property owners on future strategies for their building properties.

- In efforts to collect data for the method, it should be kept as simple as possible without involvement of too many people. People that could be involved: operating personnel, role of the core business management (CEO) and a representative from the owner.

- The tool should be user friendly for both consultants and other users involved in the assessment, and tool should visualize the results.

4. Results

4.1 Existing assessment methods

Based on the criteria listed above, existing assessment methods were evaluated, in order to detect if any of the methods were suited for this type of assessment, and also to identify relevant indicators and approaches to evaluate buildings' potential for sustainability. The methods evaluated were MultiMap, LCA (and Recipe, a method based on LCA methodology), BREEAM In-Use, SURE, SIA and LCC. Common to many of the evaluated methods is that implementation of the methods is too resource intensive and time consuming to assess a large amount of buildings in preliminary phases. For instance, BREEAM In-Use requires documentation to fulfil many of the requirements, which will be too comprehensive to obtain when evaluating a building portfolio. SURE is also considered as too comprehensive due to the many indicators that are supposed to be measured quantitatively that may require special equipment and more detailed inspections of the buildings. MultiMap,

however, has a more suitable level of detailing required for assessments of building portfolios, as there are few indicators to assess in addition to few people required for the assessment. However, it does not assess all aspects of sustainability, which is a criterion for the method as wanted. SIA covers the economic, social and environmental aspects of what is evaluated. Nevertheless is the method considered as too general and not specified for sustainability within buildings. A summary of the evaluation of the methods is presented in Table 1.

Table 1 Evaluation of existing assessment methods (Hvide, 2012)

Existing methods	**Aspects of sustainability**	**Level of detailing**	**Application**
MultiMap	Assessment of technical condition, usability and adaptability. Mainly assessing economic and social aspects.	Low/medium detailing level. Approx. ten indicators for each module (e.g technical condition, usability, adaptability)	Existing buildings
LCA (and ReCiPe LCIA method)	Assessment of environmental impacts.	High detailing level. Requires quantitative values.	Buildings and other products and activities.
BREEAM In-Use	Mainly assessment of environmental impact, but also some social impacts such as indoor climate and comfort.	High detailing level. Requires quantitative values andl documentation.	Existing buildings
SURE (Sustainable Refurbishment)	Assessment of economic, environmental and social impacts.	Medium/high detailing level. Assesses many indicators and requires several quantitative measurements.	Existing buildings (mainly when planning a refurbishment)
SIA (Sustainable Impact Assessment)	Assessment of economic, social and environmental aspects of sustainability	Low detailing level. Very overarching. Requires only the main features.	Projects. Applies mainly to new constructions or new actions, rarely existing buildings.
LCC (Life cycle Costs)	Assessment of economic impacts	High detailing level. Requires quantitative measurements.	Buildings and other products.

The methods discussed above do all have many relevant elements appropriate for an assessment method for sustainability of buildings. However, for a method aimed at assessing a large amount of buildings, many of the existing methods are too comprehensive for implementation in preliminary phases. For further development of a method assessing sustainability for a building portfolio, these elements were adapted, and some adjusted, from the methods listed in Table 1:

- The same approach as in MultiMap and SURE; evaluate today´s situation, decide a level of ambition for the future, and evaluate the gap between these.
- Assessment of various indicators categorized in economic, social and environmental aspects.
- The use of several indicators influenced from SURE and BREEAM In-Use, however, adjusted to fewer indicators.

4.2 Theoretical and realistic potential for sustainability

A buildings' potential for sustainability is in this paper referred to as the opportunities that lies within a building to ensure building users' needs today and in the future in a sustainable way, which includes a positive interaction between the environmental, the social and the economic aspects.

In the process of evaluating a building's potential for sustainability, one should be aware of what conditions that restrict or enhance this potential. These conditions could be economical, physical building conditions or for instance planning regulations. A building's potential could be regarded as the possibilities to improve a building standard from its current situation to a preferred standard. A building's potential for sustainability is also dependent on the future purpose of the building. This paper distinguishes between a theoretical and realistic potential. A theoretical potential is considered as the potential that is possible to achieve in *theory*, when not taking restricting conditions of a building into consideration. A realistic potential, however, is a potential that takes into account the opportunities that *in reality* can be exploited, also considering the restricting conditions of the building.

4.3 Interviews and surveys

In the process of determining how to evaluate buildings' sustainability in the method, real estate companies were interviewed about sustainability in existing buildings. From the interviews it appeared that today's building tenants have high requirements to the environmental standard of buildings. The requirements for environmental standard is however not consistent with the tenants' willingness to pay and other requirements, such as a tenants' requirements for large glass facades that require a lot of energy for cooling. For most companies it is the economic aspects of sustainability that is the main driver. The possibility for economic sustainability is therefore a requirement for whether or not it is possible to improve the building's social and environmental sustainability. Several companies state that factors as indoor air quality, energy efficiency, life cycle thinking and the opportunity for economic profit is essential factors that need to be considered in order to obtain sustainable buildings.

A survey was also conducted in which the respondents were to rank specific building conditions and to what extent they had impact on the buildings' social, environmental and economic sustainability. The respondents included mostly professionals within building consultancy, but also representatives from a real estate company. The survey results can be interpreted as if most of the respondents considered the buildings' energy demand, use of renewable energy sources and to which extent buildings have good indoor climate as essential factors for buildings' sustainability. To ensure economic sustainability, as well as social and environmental sustainability, a long-term perspective on investments and the possibility to have long leases were also ranked as significant.

Based on the interviews, the survey and the evaluation of existing assessment methods, a method was developed and relevant indicators of sustainability in buildings were identified.

4.4 The method

The method is based on a process including several steps that should be iterated to finally determine the building's *realistic* potential for sustainability (see Figure 1). The reason for why the process should be iterated is that while carrying out the different steps in the process, one might have to do some adjustments in the previous steps to be able to finally determine the realistic potential possible to exploit. This could include lowering the level of ambition for the building or for instance changing the purpose of the building.

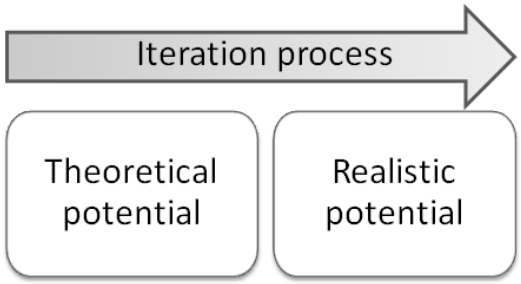

Figure 1: Theoretical to realistic potential by iteration (Hvide, 2012)

Figure 2 presents the different steps. In several steps there are certain indicators that should be evaluated on the basis of the building condition as it is today and further ambitions for the building in the future. A set of indicators have been chosen that are to be scored to a degree of sustainability from 0 (best) to 3 (worst) based on the building as it is today and how it's desired to be, as an assessment in which the compliance of demand and performance is evaluated (as described in Figure 3).

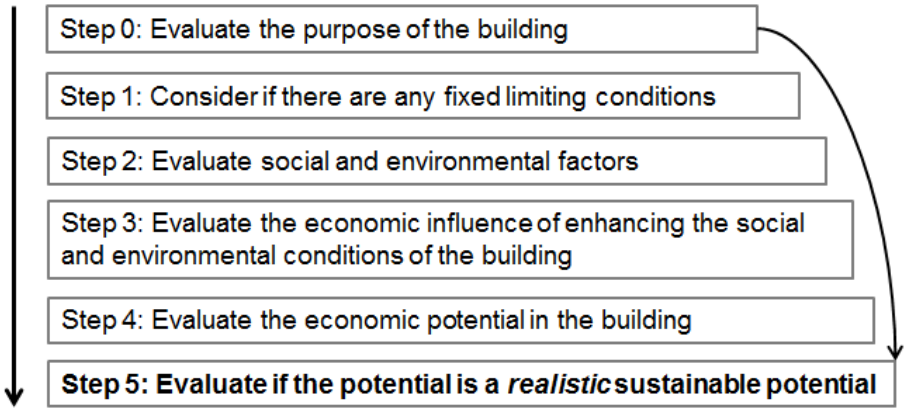

Figure 2: The various steps in the method (Hvide, 2012)

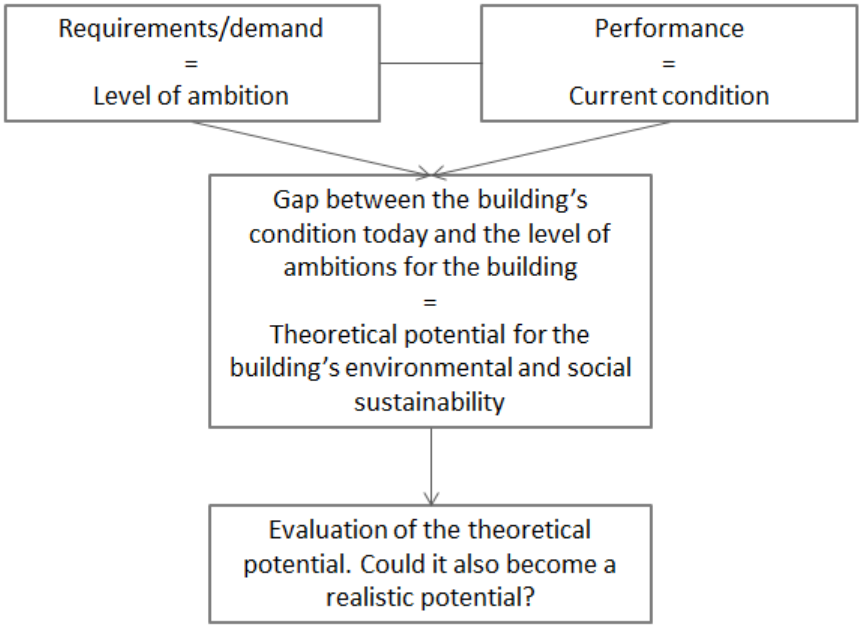

Figure 3: Gap model for evaluation realistic potential adapted and developed from a figure in NS 3424 (Norwegian Standard, 1995)

In **step 0** the building owner should, if possible, decide the purpose of the building. In **step 1**, the building owner must evaluate if there are any building conditions that restrict further development of the building, such as special building regulation, conservation status etc. Further on, in **step 2**, the indicators for the building's environmental and social aspects should be evaluated, by finding the gap between the buildings conditions' current situation and the future ambitions. When evaluating the current situation of these indicators, a person that knows the building well should do the registration, such as the operation manager of the building. Registration of the level of ambitions for the indicators should be done by someone representing the building owner or property investor. Figure 4 presents how the scoring is visualised in a spider diagram, illustrating the gap, which represents a theoretical or realistic potential for environmental and social sustainability. A line along the periphery of the circle indicates highest degree of sustainability. Each of the indicators has also been given a weightage so that the potential could be summarized in a percentage number, indicating the buildings' degree of sustainable potential. For building portfolios these percentage numbers may give an indication to what buildings that have the greatest potential for a sustainable development.

Step 3 is about evaluating the economic impact of enhancing the gap of the indicators evaluated in step 2. Each indicator has been given an *economical influence factor* that indicates how costly an improvement of the indicator will be. In the case studies a self-chosen factor was used, however, this should preferably be a factor generated from a selection of empirical data. By comparing the economic influence factor with the gap of the indicators, it will give an indication on which indicators that are most costly to improve.

In **Step 4**, the building's economical potential is evaluated to determine if it's possible to exploit the building's potential in an environmental, social *and* economic way. This step is to ensure that the economic conditions are economic feasible for the building owner, however, not at the expense of environmental and social conditions. As when evaluating the

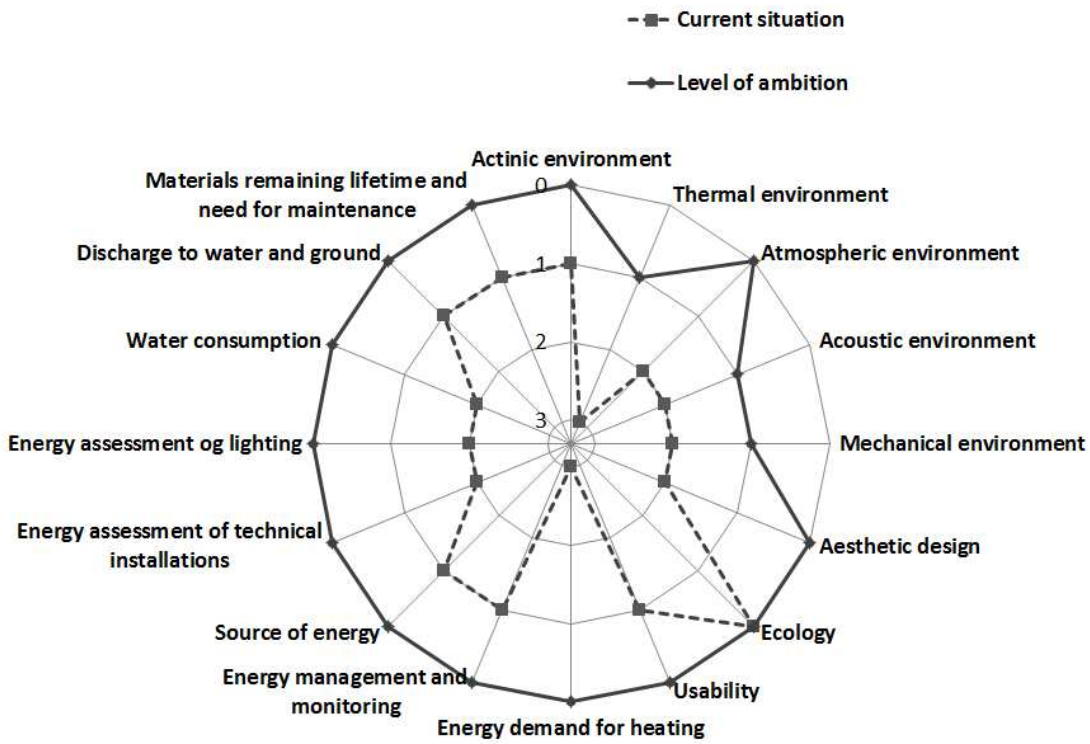

Figure 4: Illustration of the gap between current situation and future ambitions (Hvide, 2012)

environmental and social potential, the economic potential is also evaluated by identifying the gap for the selected economic indicators with respect to the current situation and the future ambitions.

Finally, in **step 5**, one should evaluate whether the realistic potential is found, based on the previous steps, or if it's necessary to iterate the steps and to do some adjustments to be able to identify the realistic potential for sustainability in the building.

4.5 Indicators influencing buildings' potential for sustainability

The indicators that were identified are categorized into how the environmental, social and economic impacts of the building. In addition to this, there are certain building conditions that cannot easily be changed or improved. These building conditions are identified and intended to be evaluated in step 1, in order to early detect if there are any conditions limiting the possibilities to exploit the potential for sustainability in the buildings. The other indicators (environmental, social and economic) are evaluated later in step 2 and 4, as these are more easily changed. The indicators are mainly qualitative indicators that can be evaluated based on normally easily accessible information about the building. For each indicator it's given a description of what conditions categorize as the different degrees of sustainability (from 0 to 3), so that the registration of the indicators are not subject to different interpretations by the persons doing the registrations. An example of this is shown in Table 2. Descriptions for the rest of the indicators are not presented in this paper, but are presented and discussed with the persons doing the registration when using the method in practise.

Table 2: Matrix of descriptions for an indicator's different degrees of sustainability (Hvide, 2012)

Degree of sustainability	0	1	2	3
Energy source for heating	The building has an energy supply that covers 70 % of the energy demand for heating with renewable energy	The building has an energy supply that covers 52.5 % of the energy demand for heating with renewable energy.	The building has an energy supply that covers 35 % of the energy demand for heating with renewable energy	The building has an energy supply that covers 18.5 % of the energy demand for heating with renewable energy.

The indicators used for evaluation in the method are presented in Table 3. The indicators considered as most relevant for the buildings' sustainability, is selected based on the results of the interviews and the survey, in addition to the study of existing assessment methods, mainly BREEAM, SURE and MultiMap.

Table 3 Indicators assessed in the method (Hvide, 2012)

Indicators on limiting conditions: • Planning regulation • Conservation status • Availability to the property • Local area • Adaptability **Social indicators:** • Actinic environment (primarily radiation in terms of lighting) • Thermal environment (temperature, air moisture, airflow) • Atmospheric environment (air quality) • Acoustic environment (noise from persons, equipment etc.) • Mechanical environment (inclusive design, physical design) • Aesthetic design • Ecology (green areas) • Usability	**Environmental indicators:** • Energy demand for heating • Energy management and monitoring • Source of energy • Energy use for technical installations • Energy use for lighting • Water consumption • Discharge to water and ground **Economic indicators:** • Time perspective of investment • Time period of leases • Added value due to branding • Green leases • Loss of rents when rebuilding, refurbishment etc. • Grants due to sustainable measures

5. Discussions

In the discussion of the method's validity and reliability, the registration of the scoring of indicators has been the primary concern. To obtain objectivity during the registration process of the scoring of indicators is an issue that may affect the validity of the results. However, by giving detailed descriptions for each indicator's degree of sustainability, the objectivity is to a large extent obtained.

A consideration of whether the indicators should be quantitative instead of qualitative was done in relation to obtain objectivity during the registration. Quantitative indicators may be easier to measure and also more comparable. However, as this method is supposed to be used in preliminary phases (when strategizing what to do with the buildings), using quantitative indicators might require special equipment and resources, which may be too time consuming and resource intensive in early phase planning. The use of qualitative indicators is therefore considered as best for this assessment method.

6. Conclusions

Based on literature studies, interviews and survey results, indicators for buildings' potential for sustainability have been identified. Buildings' sustainability is influenced by environmental, social and economic factors, and an interaction between these. In more detail, it's the factors as indoor environment, energy efficiency, lifecycle thinking and possibilities for economic profit, which also should include sustainability for building owners, building users and the society.

An assessment method for realistic sustainability potential in buildings has been developed. Within the process of the method, selected indicators are to be scored to a degree of sustainability from 0 (best) to 3 (worst) based on the building as it is today and how it's desired to be, as an assessment in which the compliance of demand and performance is evaluated. Based on the results generated from the various steps in the method, the building owner and engineering consultants obtain a good basis to evaluate the buildings' realistic potential for sustainability. The method is considered as best suited for evaluating office and commercial buildings, but also residential blocks and hotels. However, the method is not considered suitable for buildings of conservation value, as a protection status may restrict the possibilities to do other sustainable measures. The method is validated through case studies. However, experiences from case studies suggest that the description of the various degrees of sustainability should be improved to ensure that the all registrations in a building portfolio are comparable and objectivity is obtained.

The method may contribute to increase the focus on the factors that influence buildings' sustainability. If the method could be of use for real estate agents and engineering consultants to develop buildings in a sustainable way, existing buildings may play a great role in the development of sustainable buildings.

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Determinants of Urban Resilience: an exploration of functional response diversity in a formalising settlement in the City of Tshwane, South Africa

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Abstract

Urban centres in the developing world are experiencing massive settlement growth often in the form of informal settlements with their concomitant informal economies. South Africa is facing similar trends, and the City of Tshwane is no exception. Apart from facing poor living standards and increasing inequalities in service delivery, these urban centres are also vulnerable to global and local economic instability. Improving the resilience of these settlements is one of the main challenges in the process of their upgrading and formalisation according to national and international development goals. This paper explores one of the determinants of urban resilience which is the response diversity in a formalising settlement in the City of Tshwane with specific reference to the function of retail activity provided in these areas. The diversity of responses to this function ranges from, (depending on the scale of operation) an informal trader to a large shopping centre. This paper further examines how the formalising settlement in terms of economic activity responds to the function of retail. This includes the role of the informal sector in the process of adapting to the formalising process. The informal economy is an important role player in South African cities and other developing countries. However, it is often disparaged as a defect in the system which poses a threat to the formal economy and which must therefore be suppressed, if not eradicated. This paper argues that the informal economy plays a vital role in the resilience of human settlements, especially in the face of poverty, unemployment and inequitable access to social services. This will be done by examining various case studies of shopping centre establishments in formalising settlements and field observations. The paper concludes with a model that places the different responses to the function of commerce on a panarchy within the context of a formalising settlement based on certain characteristics. This model can be used as a tool to look at the interdependencies of entire functional groupings within the context of urban resilience.

Keywords: formalising settlements, urban resilience, response diversity, panarchy

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1 Introduction

The informal economy is an important role player in South African cities and other developing countries. However, it is often disparaged as a defect in the system which poses a threat to the formal economy and which must therefore be suppressed, if not eradicated. This paper argues that the informal economy plays a vital role in the resilience of human settlements, especially in the face of poverty, unemployment and inequitable access to social services. This argument is based on the notion of response diversity to particular functions in an ecosystem as a main determinant of resilience (Elmqvist et al., 2003; Walker and Salt, 2006) and the assumption that this concept can be transferred to social-ecological systems such as cities (Pickett et al., 2004; Talen, 2006; Du Plessis, 2012). As such it also draws heavily on the broader theoretical basis of resilience thinking (Gunderson and Holling, 2002; Walker and Salt, 2006, Resilience Alliance, 2010), including the concept of panarchy. The concept of diversity within resilience thinking suggests that an increase in response diversity would provide multiple redundancies to a specific function, which would mean the provision to that function is more stable, resulting in an overall decrease in vulnerability to specific threats to that function. With the introduction of a panarchy model of the various responses, potential interactions across scale can be discovered in the urban or social-ecological system context.

Through both a desk top study of previous case study work and direct observations in the field, this paper develops a panarchy model to explore the response diversity (in one functional category i.e. the response to the function of commerce/retail) in one township area in the City of Tshwane. This township has both formal and informal elements (from housing to transport and retail activities) within close proximity. For the purposes of this paper specific attention will be paid to the formalising of the retail and commercial activities in the area although other formalisation processes are also occurring. The case study will be based around the Central City shopping centre in Soshanguve/Mabopane with specific reference to the retail function of the area.

2 Contextual background

2.1 Townships: Formation and Persistence

Townships in a South African context refer to areas that were created by the Apartheid government (through institutionalised regulation) to mainly segregate the black African population to peri-urban locations away from the central white town or city. The remainder of the black population was located to ethnic “homelands” in far, resource inefficient locations (Zondi, 2011, p.11). The townships served as a low-cost labour pool for the adjacent white areas where most of the economic activities were created. The labour and education regulations and legislation were positioned to exclude the majority black population from economic emancipation and keep the township areas from developing independently from the white areas. Thus a “permanent” state of economic inequality was created. Most South African cities and

towns had this economic system in place (Zondi, 2011, p.11). Although township areas were formally planned, they could not support the large number of residents in terms of housing and economic activity. This resulted in the organic, spontaneous and unsanctioned formation of informal settlements in the township areas, as well as other locations closer to economic activity.

In Post-Apartheid South Africa, townships and the informal settlements within them have remained persistent. The township areas are in constant flux between formal and informal, permanent and temporary and serviced and non-serviced (Weakley, 2012). From an economic and planning perspective, government policy with goals of promoting sustainable, equitable and inclusive cities, has not been able to fundamentally change the apartheid spatial structure (although provision of services have increased dramatically). The continued influx of people (rural-urban, intra-urban, refugee) to these areas has happened much faster than housing and infrastructure could be provided. Informal settlements are essentially an adaptation strategy for people with a low asset base to access urban amenities which they cannot access in a formal way. Trade-offs are made by residents in informal settlements between relatively poor living conditions and some access to urban amenities and employment prospects.

2.2 The study area

Soshanguve/Mabopane is located 35 km north of the administrative capital of South Africa, Pretoria (both within the City of Tshwane Metropolitan Municipality, the third largest city in terms of area in the world). The name Soshanguve comes from the languages spoken in the area, i.e. **So**tho, **Shan**gaan, N**gu**ni, and **Ve**nda, while the adjacent Mabopane was once in a former "homeland". Soshanguve and Mabopane are peri-urban township areas that were established in the 1960's and 1970's respectively to relocate black Africans (into specific ethic groups) from the nearby city of Pretoria or other areas in the region by the erstwhile Apartheid Regime. Challenges faced by residents are closely linked to their vulnerabilities such as crime, environmental hazards including fire and flood, and general conditions associated by poverty.

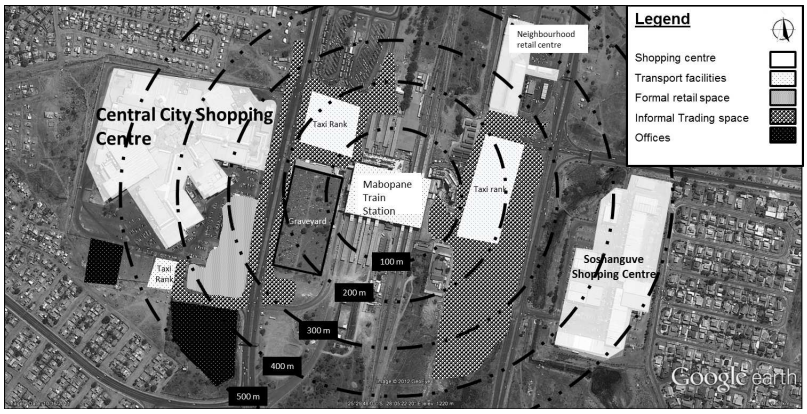

Figure 1: Spatial structure of the study area, in Soshanguve/Mapobane based on field observations done by the author (Base map courtesy of Google Earth, 2012)

For the purposes of this study a dynamic economic hub was chosen which is located around the Mabopane train station and the informal secondary transportation infrastructure provided by private minibus taxis in two taxi ranks flanking the station (described in Figure 1). The area has both informal and formalised settlements with varying levels of service provision. This area includes the Central City shopping centre, as well as two other formal shopping centres. The overall spatial character of the area is similar to a transport orientated development where the main structuring element is the transport infrastructure which supports the informal as well as the formal retail development (including the surrounding residences) surrounding the station (see Figure 1). The informal activity around the centre forms an “informal high-street” of mostly permanent buildings next to the movement paths (street) of pedestrians and cars, including the traffic island separating the opposing traffic streams. In other areas, informal flea markets are evident with less permanent structures including mobile street vendors. The area has a lot of movement in the form of both car and pedestrian traffic intertwining between the formally planned and the sprawling organic informal trade and transport.

3 Theoretical background: Urban Resilience and its Determinants

In order to understand urban resilience within the context of the Soshanguve/Mabopane township area, a brief overview of resilience and its determinants is required. Resilience thinking’ as a conceptual framework is constructed upon the idea of multiple metastable regimes separated by critical thresholds at multiple distinctive scales with cross-scale interactions (the panarchy) (Du Plessis, 2012). Within a panarchy, what happens on one scale influences and affects what happens at a different scale (both in time and space) (Simmie & Martin, 2010, p.34). Cross scale linkages or dynamic interactions exists within and between the sub-systems contained in a system, although they might not be at the same stage in the adaptive cycle, thus responses will differ depending on the scale of the nested systems (Resilience Alliance, 2010).

As one of the determinants of resilience in ecological systems, functional response is based on the concept of functional groupings that provide for a certain specific function such as the function of predators/consumption (Elmqvist et al., 2003, p.489). The responses to that specific ecological function range across scales from lions to spiders and bacteria. Response diversity is referred to “as the range of reactions to environmental change among species of the same function”, and it is seen as “critical to resilience, particularly during periods of ecosystem reorganisation” (Elmqvist et al., 2003, p. 488).

Similarly, as argued by Du Plessis (2012), in social-ecological systems, humans as dominant species also have functional categories/groupings which are determined by the users and resources of the urban environment. In a city different functional categories can be identified such as (but not limited to) business and commerce, residential, industrial, infrastructure, social facilities and green users. Du Plessis adds that within these functional groupings different responses and scales of responses can be identified i.e. in the functional grouping of commerce responses could range from an informal trader to a large shopping centre. Building the range of responses to each of the functional groups and on different scales, multiple redundancies are

built into the system which increases functional diversity within the city which in turn improves the resilience of the city (Du Plessis, 2012).

Multi scale interactions between responses have been studied from an ecological systems perspective. Elmqvist, et al., (2003) created a multi-scale model based on response diversity of herbivores found in a coral reef system (see Figure 2). Response diversity exists because various species operate at different spatial and temporal scales. Disturbances to ecological functions usually only affects some of the responses to the function meaning other scales are undisturbed and can persist.

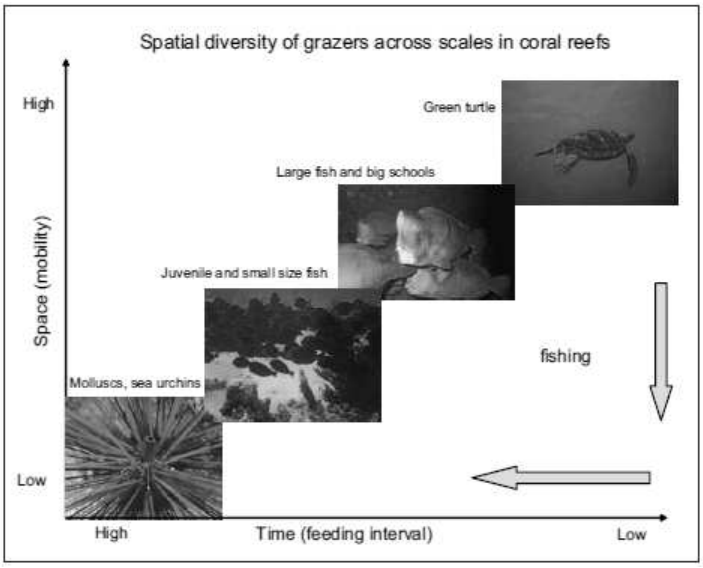

Figure 2: "The multiple-scale nature of response diversity in the functional group of herbivores of coral reefs. Response diversity is enhanced by species operating over a broad range of scales. Over fishing of large species resulted in a situation where grazing is maintained by a set of smaller species operating more intensively at faster intervals" (Elmqvist et al., 2003, p.492).

4 Response diversity to the function of retail in a township area

From a regional economic resilience point of view, Simmie & Martin (2010) argues for an evolutionary approach to resilience rather than an equilibrist. The evolutionary approach to resilience focuses on how economies adapt to changing circumstances rather than returning to a previous state of being which the equilibrist perspective emphasises (p 31). Local areas that have more diversity in economic activities seem to be less vulnerable to perturbations or at least can recover faster from them. Resilient regional economies depends on both longer term and shorter term processes to function. Jacobs adds that a combination of mixtures of activities is fundamental to the creation of successful neighbourhoods (Jacobs, 1969). The importance of neighbourhood resilience has been echoed by various authors (Jacobs, 1969; Tallen, 2006) who suggests that increasing social diversity, income diversity and land use mix will lead to more stable and resilient neighbourhoods economically and socially. Within a township context

this could be crucial in providing more stable economies for a vulnerable and emergent population.

4.1 Commercial and retail investment "landscape" within townships

The retail sector in South African township areas has changed drastically in the past two decades. The retail environment pre-2000 was dominated by informal small scale businesses offering products for the low-income consumer market. Overall spending done in this period was out of the township areas in more established shopping destinations such as the core CBD of the adjacent town or city. This trend has been reversed drastically with the development of shopping centres in "almost all township areas with sizeable population numbers" (Ligthelm, 2008a). The reason for this dramatic shift is the emergence of the black middle class. The Bureau of Market Research at the University of South Africa has recorded the relative market expansion from 1994-2004 which indicates the growth in household expenditure of black households of 239% in that period, compared to white households of just 110% (Bureau of Market Research, 2008). The relative income of black households is very low compared to that of white household but the absolute number of potential base is much bigger (Statistics South Africa, 2012). The provision of the social grant system in South Africa for lower and no income persons have further provided a more stable income, thus decreasing their overall vulnerability and making it more viable to invest in lower income areas such as townships (Urban LandMark, 2011).

Within developing countries, the informal sector provides access to livelihoods, provision of goods and services to the marginalised, including food distribution, and can act as a gateway out of extreme poverty. With this in mind policies that govern economic development in urban centres in the developing world should be sensitive to the existence of the informal and rather than marginalising the sector, put it firmly into the development focus to facilitate the move from survivalist to entrepreneurial enterprises (Rogerson 1996, p179). A more holistic view of economic development is also needed in a formalising context in which the formal businesses sector can also start to explore potential synergies that exist between them and the informal sector (Urban LandMark 2011). Integration and support of informal activities can bridge the segregated nature of South African cities through the exploration and allocation of both private and public policy initiatives (Rogerson 1996). These initiatives can include private business strategies which can integrate the informal and formal, i.e. in the case of the study area the retail typology that exist can give way to new retail forms. The typical shopping centre retail typology focuses inward whereas the study area new forms can be introduced such as encouraging high street retail forms leading up to the shopping centre (Urban LandMark 2011).

4.2 Shopping centre development and related impacts within townships

Although the existence of shopping centre development in township areas is not completely new the pace of development has dramatically increased since 2000. Investors and developers in the formal retail centre development market have realised the potential in township areas.

Currently the biggest growing segment in retail development is the lower income brackets as market saturation has been achieved in many more established traditional retail investment locations, not to say that investment in township areas are not without risks (Urban LandMark, 2011).

Within the township context the development of formal retail activity is one of the only non-governmental investment activities into these areas. Notwithstanding the positive impacts of formal retail developments in formalising areas such as providing increased access to higher order goods and services (including access to banking services) to residents, some negative impacts have been recorded in the local economy. These include the increased competition in the informally dominated commercial/retail sector of the areas, increased openness to global market fluctuations and other lifestyle related impacts such as increased debt exposure (Urban LandMark, 2011).

A study conducted by Ligthelm (2008a), which measured the impacts of recent shopping centre development in Soshanguve/Mabopane, points to an overall decrease in township informal and small formal business within the first six months of the shopping centre opening. The study showed evidence of some of the customers of the original township business gravitating to the shopping centres, but the overall survival of the original businesses was due to adaptation strategies. The main adaptation strategies used by the spaza/tuck shops (small informal sector retail business operating from a residential home or zoned stand) centred on finding a niche that the large shopping centres could not fill, such as moving to a location convenient to consumer dwellings, personalized customer service, flexible business hours, satisfying emergency needs, access to credit facilities and availability of goods in small quantities (Ligthelm 2008a, p 52).

In further studies in Soweto (a large township in Johannesburg), Ligthelm (2008b) commented that small enterprises in townships that were most vulnerable to the new developments were those located in old shopping centres, businesses offering daily household necessities and those businesses closer to the newly developed shopping mall. Similar studies conducted in Soweto points to much more positive interactions between the newly developed shopping centres and the existing business. Studies commissioned by Urban Landmark on the impact of Jabulani Mall in Soweto and Central City in Soshanguve/Mabopane indicates a marked increase in shopping done in the area after the shopping centre development, as well as reduced travel time and transport cost to formalised shopping facilities. Initially support for local traders as an overall percentage of money spent on retail goods and services did decrease with the introduction of the shopping centre. However, the overall income from consumers increased, reducing the impact on traders.

From a consumer perspective the new development was acceptable to very positive, in most cases reporting a need for the mall to expand. Bearing in mind that the circumstances differ similar trends have been noted in other township areas (Urban LandMark, 2011, pp.37-39). Although negative impacts have been recorded, the over 800 street traders in the vicinity of the Mabopane train station is evidence that informal businesses can function and even thrive in the

same area of the formal centres such as Central City, by providing goods and services not provided in the centres or by simply offering a more convenient shopping experience (Ligthelm, 2008a, p.52).

5 Towards a panarchy model of response diversity in the urban context

5.1 Typology of responses to the function of retail activity

The responses to the function of retail activity (distribution of goods and services) in townships have changed as previously mentioned. This change is due to certain characteristics that have changed in the study area, including a social-economic shift to higher and more stable incomes, together with market saturation of traditional investment locations. This change laid the foundation for the entrance of shopping centres into the township retail landscape (Urban LandMark, 2011). The pre-1994 retail landscape was dominated by informal and small formal activities including mobile street traders, informal traders; spaza/tuck shops; informal home-based services like barbers and taverns; and local convenience stores. From the late 1990's the retail landscape expanded to include neighbourhood centres; community centres, minor regional centres and regional retail centres (Ligthelm, 2008a: p 52; Urban LandMark, 2011: p 9). While the larger responses in terms of scale or size such as shopping centres have played a role before 1994 as residents used these facilities outside of the area, they have now become part of the township landscape and a direct competitor to the existing businesses in these areas.

5.2 Application of the panarchy model of response diversity in an urban context

As previously indicated by the response diversity model used to illustrate the ecological function (Figure 2) this paper argues for the use of such a model in the urban social-ecological context. As indicated by Simmie & Martin (2010) and Elmqvist, et al. (2003), large and small responses affect one another and can influence the overall resilience of the functional grouping, as well the resilience of the area.

The introduction of new responses (shopping centres) happened due to the change of neighbourhood characteristics or system change which resulted in viable locations for formal retail development. Such a model is described in Figure 3. With the introduction of the shopping centre into the area a perturbation was felt in the overall system with losses in revenue and changed customer patterns in the other responses (especially informal business). An adaptation period followed where the other responses reacted to the new entrant through various adaptation strategies as discussed earlier. A new equilibrium was reached replacing the previous equilibrium state, thus falling within the realm of adaptive change rather than static recurrence. A symbiotic relationship started to arise from the retail environment between the different responses (formal and informal activity).

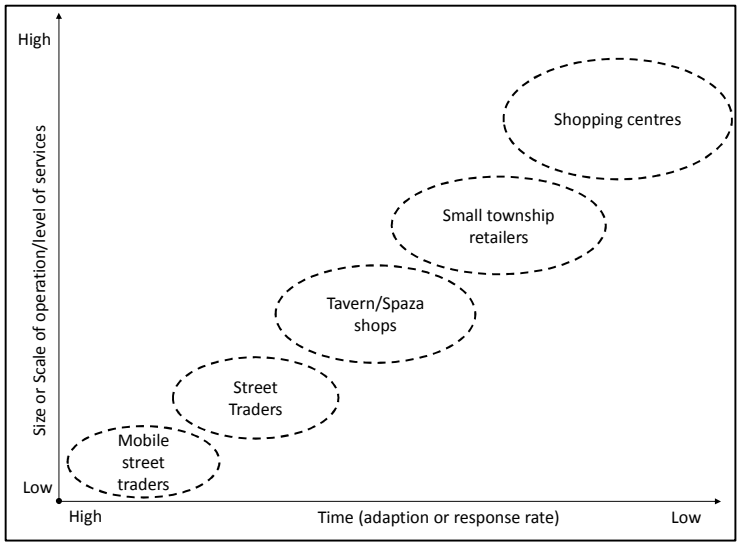

Figure 3: Panarchy model of retail activities in the Soshanguve/Mabopane area (adapted from Elmqvist, et al., 2003 Figure 2).

The panarchy model for response diversity describing the function of retail activities plots the typology of responses according to scale and the response time. Each of the identified responses operates at their scale or level although they influence each other. From the resilience point of view diversification within the responses to functions are crucial in building adaptive capacity in neighbourhoods. The panarchy model illustrates how diversity to a specific function is structured according to scale according to variables such as scale of operation, capital needed for response, good and services provided, survivalist vs. entrepreneurial enterprises, capital available to response actor, vulnerability, adaptability (responses to adversity and response time), and openness to global/local economic fluctuations. The panarchy model does not indicate that one response is superior to another. Rather it proposes that the different manifestations of retail activities (typologies) are part of the same functional grouping and can potentially be in symbiosis with each other. For example, informal traders targeting the convenience shopper or shoppers who can only buy small quantities at a time can purchase their goods from bulk retailers inside the formal shopping centres, while the shopping centre caters for a clientele who may be making some more considered or bulk purchases. A trader providing a service such as a barber may also purchase his supplies from the shopping centre.

Adaptation strategies are key to the survival of businesses on all scales but may differ across scales. For example, on the lower end in terms of scale a mobile street trader can change location or type of product that is being sold, whereas a fixed shopping centre may respond by changing or upgrading the centre or implementing new advertising strategies (Ligthelm 2008a). Although more capital is available at the higher scale of the panarchy, the activities are more rigidly bounded in time and space. Comparative size of operation is also a factor which influences adaptive capacity, as the amount of potential available to the system increases with scale.

As shown in Figure 3 the response or adaptation rate becomes higher at the smaller scale, allowing actors at these scales to respond faster to a perturbation in the system. On the other hand, systems at larger scales have more accumulated potential that allows them to ride through smaller perturbations. An example of such a perturbation could be the operational difficulties and service delivery protests in the nearby train station which forced Metro Rail (the operating authority) to temporarily suspend its operations (SABC, 2012). Informal traders around the station targeting commuters may see a radical decline in patronage, but can shift their operations to the taxi stands or bus station. Traders linked to the funerary activities of the nearby cemetery may not notice any impact on their business or may see new niches opening up. Central City is a destination point in itself and its particular range of responses are not that directly linked to the functioning of the railways. It may be able to ride out the perturbation as its size provides robustness. However, it may be more vulnerable to perturbations at higher scales such as the national economy.

The increased diversity of responses provides multiple redundancies to a neighbourhood in terms of the provision of retail activities. Although increased competition might be perceived as negatively impacting the smaller scale operator in the commercial and retail sector, understanding the system as a panarchy suggests that a mutually beneficial relationship can develop between the responses to a specific function at different scales. Both for the users and the producers (providing the function) more diversity means less vulnerability to a range of perturbations as actors at one scale can step in to provide the function if actors at another scale fail. Actors at different scales can also provide responses in niches that are not open to actors at other scales. The increase in diversity of retail activity furthermore increases the amount of livelihood opportunities. Thus, when taken in the context of a township the existence of the informal economy, by adding diversity, contributes in many ways to the economic resilience of the township.

6 Conclusion

The application of ecological theory or practice in a social-ecological context has been led by various authors (e.g. Elmqvist et al., 2003; Folke, 2006; Resilience Alliance, 2010). The application was only recently extended to larger human-dominated systems such as urban areas which increases the need to explore these contexts (Resilience Alliance, 2010; Walker & Salt, 2006). The panarchy model gives insight into the dynamics that exist between responses at different scales across a functional grouping.

By developing a panarchy model of retail activities in the Soshanguve/Mabopane township area in the City of Tshwane in South Africa, an argument was built for the importance of the informal economy in providing response diversity to the function of commerce in areas characterised by poverty, unemployment and inequitable access to social services. This diversity aids in building the adaptive capacity in the economic system of these areas. It can therefore be illustrated that applying an ecological resilience framework to the understanding of urban dynamics may reveal

avenues for building resilience that see unexpected benefit in scenarios more often perceived as threats to a functional urban system.

Acknowledgements

The authors are grateful to the National Research Foundation who supported the production of this essay through NRF Grant no 78649.

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Thermo-hygrometric and physical-mechanical pathologies of the steel flat roofs: the case of a large industrial plant in Tito (Potenza, Italy).

Filiberto Lembo[1]

Thermo-hygrometric and physical-mechanical pathologies of the steel flat roofs - Abstract

The flat roofs made with steel corrugated sheets on steel structure, with isolation from the above and bituminous waterproofing, arranged according to the construction method called *“warm roof”*, and self-protected by thin embossed sheet of aluminium embedded over the bituminous sheath, are one of the most common construction types, the subject of theorizing in popular manuals, aimed at defining the *"compliant solutions"* and the *"rules of the art"*.

In the proposed case of study, a cover of this type, made on a plant of 7,500 sq. m, which are held in machining of high precision electronic components, in a few years has been the subject of twice total renovations, both consisted of adding one additional layer of waterproofing bituminous self-protected sheet, to end the drip of water inside, which continued to be present in winter, despite the work already done and redone.

And there was going to run the third work of the same type, until the writer has identified the cause of the dripping water in absence of a continuous vapour barrier below the insulation. A work of complete restructuring of the construction’s cover has been then proposed and implemented, without modifying the existing roof, and allowing that the industrial production would remain in operation without any interruption: the waterproofing has been used as vapour barrier of new layers of insulation; higher slopes have been made, very useful for large spans of the deformable cover; a new waterproofing and new insulation layer have been put in place as an "inverted roof", protected from the weather and the sun and drained, for cope with the tropical downpours which have now become common even in the city of Potenza. Interventions on the existing skylights, and a floor that provides ventilation, give the coverage characteristics of a "passive house" and his cheap annual expense, and ensure the durability of waterproofing.

Keywords: steel flat roof, vapour barrier, pathologies, thermal upgrade

1. State of the roof building in 2005

The plant of the WABCO WESTINGHOUSE Segnalamento Ferroviario, then ANSALDO Segnalamento Ferroviario, now Ansaldo STS S.p.A. of Tito (Potenza, Italy, 650 m o.s.l.), has

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been built in 1985-86, for the machining of high precision electronic components for automatic control of railway traffic, and ever growing precision required in productive process determined progressive climate control of the spaces, mostly open spaces. It has a surface of 7.500 square meters (approx. 72,00 x 107,00 m) (Fig. 1), and it was built with an anti-seismic steel structure, made of pillars and wind shear trusses, a flat roof deck in zinc coated steel, with typical structural spans of 18,00 x 12,00 m, and gutters on the corners, of 160mm diameter.

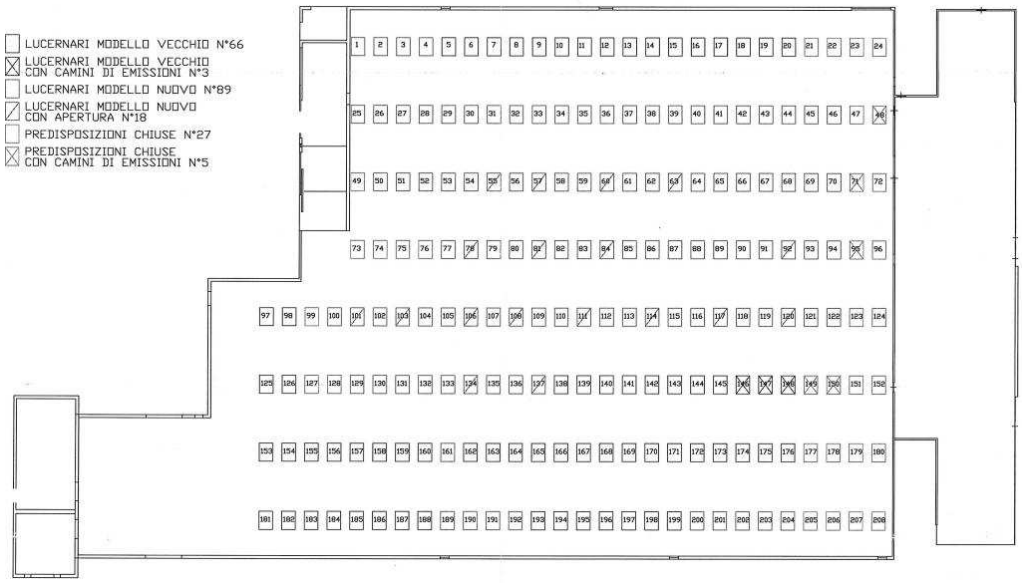


Figure 1: Plan of the coverings of the Ansaldo STS industrial plant in Tito (Potenza, Italy).

The free minimum height under the structure is of 5,50 m; the height of the plain reticular structure which bears the roof is of 1,60 m (Fig. 2 and Picture 1); but the rigidity of the deck is very variable, because in the spans in the middle of the wind shear trusses, typical steel beams, on which are leaned the corrugate sheets, are IPE 220, with span of 6,00 m, very easy to deform. It is their position in height and their inclination, that makes slopes for flowing of the rainwater, with the ratio of 0,5%: in effect there is not a screed for making slopes and for filling the corrugated sheet. The thermic insulation, 3 cm of high density glass fibre wool, with built-in superior bituminous prefabricated membrane, is set directly on the corrugated sheet, and fastened with screws to the metal deck; on this layer has been set waterproofing, originally made by double ply 4+4 mm SBS polymer-modified bituminous prefabricated membranes torch applied, with upper layer with an aluminium facing. N. 208 horizontal skylights, with surface made by hollow polycarbonate and fixed shutters (not very efficient), set in uniform way, ensure lighting.

The flat roof of the building showed, already 4-5 years after the realization, had impermeableness problems, which caused two total renovations, both consisted of adding, every time, almost one additional layer of waterproofing bituminous self-protected sheet, and in some areas, also more than one, to end the drip of water inside, which continued to be present in winter, despite the work already done and redone (see Pictures 2 and 3, which shows two specimens extracted from the waterproofing). And there was going to run the

third work of the same type, until the writer has done a complete campaign of investigation on the roof, for understand reasons of the being pathologies.

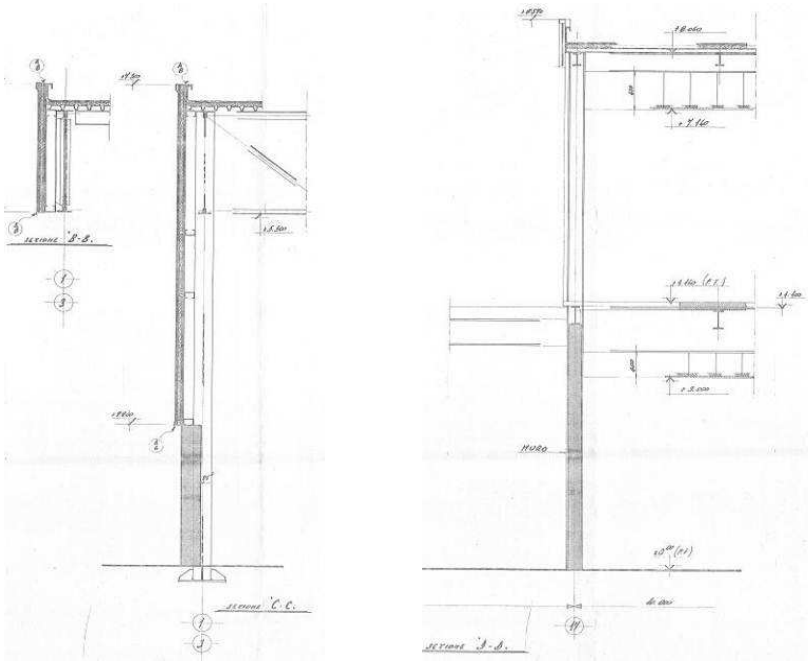
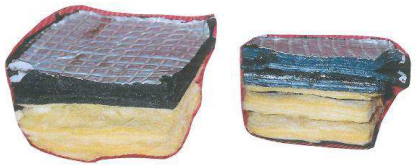


Figure 2: Typical sections of the industrial plant and of the offices



Picture 1: Structure of the roof is characterized by very rigid beams/portal (height 1,60 m on 18,00 m span), alternated with very warpable girder (height 22 cm on 6,00 m span), with the result of fluage and accidental charges cambers different area per area



Pictures 2 and 3: Specimens of the existing watherproofing, exstracted from the flat roof

At the end of 2004-2005 winter, the flat roof of the plant showed extended the dripping water, for this reasons in some areas had been necessary to set, hanging from the ceiling, PVC sheets, for protecting the equipment below. The dripping water appeared not ever in the same points, even if in some places occurred more frequently. Considering the manufacturing type done in the plant, and especially the need of controlled humidity ratio, the occurring of unexpected and sudden dripping water, in random places, leaded to unacceptable risks of damages and malfunctions, with heavy economic consequences, since a signal control cabinet is worth many hundreds thousands euro. On the other hand, already watching from the exterior (see Pictures 4-8), the roof of the plant after a rain was like a quagmire, stained by layers of dust and soil carry by the wind, by the areas in which the clear lack of gradient not allowed to the water of duly flowing, and the upper layer of aluminium embossed facing (third of the layers of this type superposed), showed systematic blistering (Picture n. 9), mark of the presence below of vapour and/or water. Indeed, pressing that blisters, we caused the expulsion of water, if we maked or if there was a crack in the aluminium facing and/or in the prefabricated membrane.



Pictures 4 and 5: After a rainfall, the covering presented itself as one immense quagmire



Pictures 6, 7 and 8: The water was unable to reach downpours, owing to deformation of the covering plane, and to limited slopes

2. First design fault: the lack of a continuous vapour barrier below the insulation

The first cause of dripping water has been identified in the absence of a continuous vapour barrier below the insulation. It must be underlined that normally we think that corrugated steel sheets constitute a vapour barrier, and therefore also on most updated manuals, which are aimed at defining the "*compliant solutions*" and "*the rules of art*" concerning waterproofing, we invent drawings which show "*as model*" steel flat roofs identical to that of this case study; without thinking that, depending on corrugated sheet element selected, every 76 o 100 cm in cross way, and every 330 o 660 cm in longitudinal way, and all facades perimeter long, and all joints with bases of skylights long, the corrugated steel sheets book off, and simply they approach or they overlap to the adjoining sheets , normally (and also in that case) without carry out any vapour sealing, with self-sticking band or liquid sealants, or foams especially formulated for this purpose. In addition, screws for fastening the insulation, anti-wind uplift, make they too thousands of holes in the sheets, and make possible the vapour passing. The result is that vapour coming from internal space reachs the insulation layer, and in it reachs dew point and condenses. This water in liquid state cannot be evacuated towards the exterior trough evaporation (due to the great resistance to vapour diffusion of two prefabricated membranes (later on got four) and their aluminium facings, and due to the total absence of roof vents), after having saturate the insulation, highly decreasing his insulating qualities, dripped in the hollows of the corrugated steel sheets, flowed along them, following their slope, and went out dropping when invented a connection between elements of metal sheets, or a screed hole, or a hook for electric device or false ceiling.



Picture 9: Blistering pathologically large and wide-spread

3. Second design fault: incorrect thermal bridges in correspondence of skylight basements

The basis of the skylights, made in steel galvanized brake formed sheets, completely lacked of insulation (with winter design temperature of -3 °C), and therefore water drippings in their correspondence had to ascribe, at least in part, to the condensations at their perimeter. Due to the presence of n. 208 skylights, every of 1,80 x 2,40 m, distributed in uniform ratio upon all productive plant surface, problem was certainly not secondary.

4. Third design fault: the insufficient slope of the roof

The slope conferred on the roof, with ratio of 0,5%, has proved quite insufficient and, in some area, even absent. The high slenderness of the steel girders of the deck did *fluage* deformations resulted to be equal or more, compared to the slope of the roof (design camber has been the maximum preview by Italian Regulations, 1/200, and then 3 cm on 6,00 m, exactly the same of the slope 0,5% on 6,00m). Therefore, little rise at junctions, caused by crossed orientation of the sheets, has been sufficient to lead to formation of so many little quagmire; while snow load, when present, has buckled deck, obstructing due water drainage, and favoring the inside penetration [CASH 2003, pag.34-35; 39-40].

5. Faults in maintenance intervention done

It was clear that maintenance interventions already done, the first 4 o 5 years after the building, the second in 1997, consisting in torch application of further bituminous prefabricated membranes, with aluminium embossed facing, had not solved problems of the roof, because they:

- had not compensate for the lack of vapour barrier under insulation layer;
- had not solved thermal bridges along the skylight bases;
- had not dehumidified the insulation, ventilating it;
- had not realized slopes, not sufficient or absent.

6. The technological and thermal design for upgrade

Who write then designed and directed the execution in more phases, from October 2005 till September 2009, an intervention of complete restructuring of the roof, which objectives have been:

- to work allowing that industrial production would remain in operation without any interruption, and then without removal of existing waterproofing;
- to use the existing waterproofing as vapour barrier or vapour brake of a new, of necessity thicker insulation, which move dew point above new waterproofing to realize;
- to fulfill the slopes necessary for correct functioning of the roof;
- to remove damp both from the insulation already in situ, both from the new insulation to place for carrying out of slopes;
- to realize an equipment most durable possible, protecting waterproofing from thermal schock and both from the frost, both from solar radiation; and therefore to move from "*warm roof*" typology to that "*inversed ventilated roof*";
- to eliminate thermal bridges and to upgrade in a radical way the energy performances of the roof, both in winter, both in summer, leading that to "*passive house*" performances;
- to operate on skylights too, to set right both to the excessive leakages, both to the dazzling and to the very high and undesired heat gains, due to their horizontal position.

6.1 Digital survey of heights

Firstly, a millimetric survey of heights has been made, with digital diastimeter, which allowed to notice in an objective way the situation of ridges and valleys of the roof, and permitted to

operate selectively in each area.

6.2 The removal of the damp from in situ insulation, the recovery of the waterproofing already existing

After a complete roof cleaning, the aluminium facing has been took away with torch, and the at least for sheets of bituminous prefabricated membranes has been punctured with round holes 8 cm diameter, following a mesh of 6,00 x 6,00 m, setting and welding torch roof vents intended to going through all the layers to set subsequently, in such a way to ventilate insulation in situ, drenched in water. In the same time, all waterproofing has been revised, with welding torch, square decimeter per square decimeter, eliminating every existing blister and crack, making water and vapour come out, and drying humidity existing. This way, waterproofing existing turns "*vapour brake*" if cracked, true "*vapour barrier*" if intact, for the further layer of insulation to set out.

In this stage have been carry out also some thin leveling layers of cold ready-made asphalt and/or bituminous mastic, for eliminating greatest spherical deformations of the deck.

6.3 The carrying out of new slopes

Structural design of the building was to reserve 50 Kg/m^2 for ballasting with gravel waterproofing and insulation, but gravel has never been put in place. We preferred to conserve this charge reserve for making use of that for dry setting a ventilated raised floor, to realize a sunscreen. Therefore has been obliged the choice of carry out slopes (of the further ratio of 1,5%) with EPS pre-shaped panels, 1,00 x 2,00 m, and thickness from 2,00 cm minimum to 12,00 cm maximum on the plant roofing, and from 2,00 cm to 24,00 cm on the offices roofing (Fig. 3).

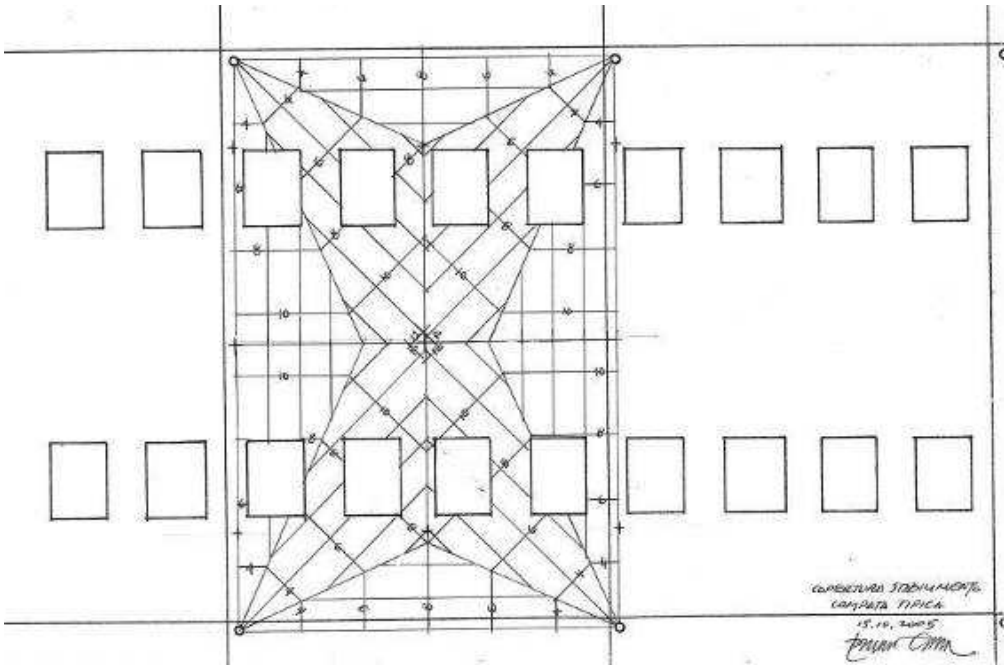


Figure 3: Plan of the typical span of the industrial plant (18,00 x 12,00 m), with EPS panels, used to create slopes. Numbers show panel thickness

These panels, which have on the upper side a smooth built-in membrane bituminous & polymers based, polyester reinforced, with two side flaps projecting (for making possible warm torch welding without fusing the EPS), have been cut on the ground, in the square of the plant, in an area marked out for the purpose (Picture n. 10), numbered and reassembled on the roof, gluing them on more than 40% of surface with bituminous & polymers based mastic, according to a scheme “to star” (Fig. 3), so that to lead really and quickly water of the rain, by most direct way, to the drainpipe. The downpipes already existing, with diameter 160 mm, remain serving existing waterproofing, so that possible leak of new waterproofing is intercepted by that before, which in this way become emergency device, helpful redundancy. In the same downpipes have been leaded new, with diameter 120 mm, into which flows new waterproofing (Picture 11).



Picture 10: The tracing out, cutting, pre-assembling and numbering of the EPS panels with variable thickness for making slopes, has been made at the foot of the building, two spans in the same time, each of 18,00 x 12,00 m



Picture 11: The assembling of new slopes, by means of cold gluing of more than 40% of surface, with bituminous & polymers based mastic . Panels were sealed on the perimeter, to avoid water penetration during work

6.4 New waterproofing and new series of roof vents

At that point has been laid a new waterproofing, made by two layers of distilled bitumen modified with atactic polypropylene (APP), reinforced with non-tissue polyester from continuous spun bound thread, with very high performances (cold flexibility -25°C, very high

tensile, elongation and tearing strength), set with the same orientation, half-module staggered, because this sheets, with composite reinforcing layers, have solved problems of older types, which had a higher tensile strength along the length of the sheet, in rapport with the breadth (Figg. 4 and 5).

A new series of roof vents has been set and torch welded, coaxial with these coming from the layer below, and therefore with the same mesh 6,00 x 6,00 m, delegated to evacuate possible condensation forming in this insulating layer, and water of rain that might penetrate during building (Picture 12). The upper layer has been provided with a mineral surfacing, just because was scheduled a works suspension of one year, was necessary to calculate a temporary protection for waterproofing (Picture 13).

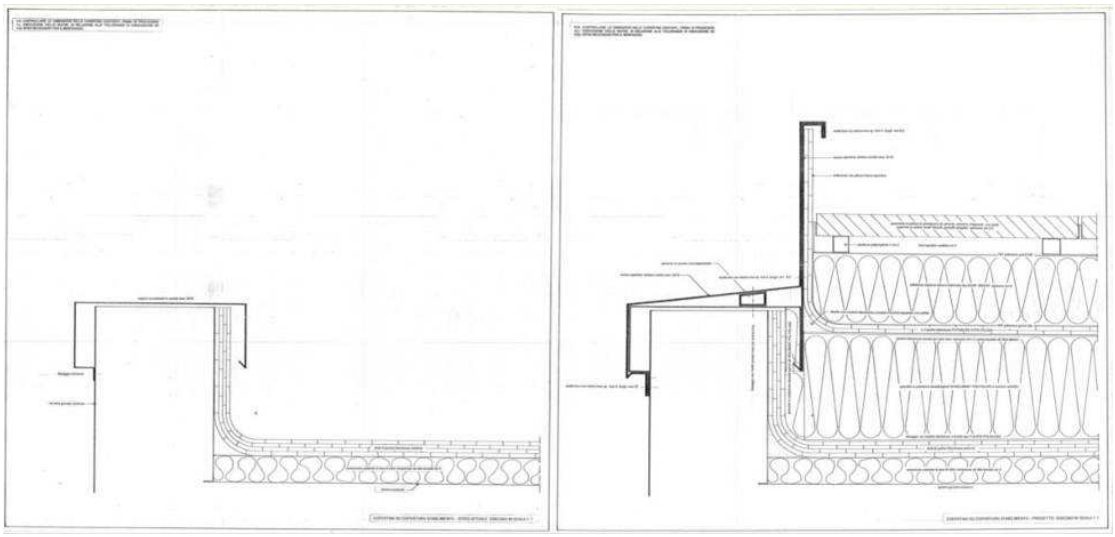


Figure 4: Constructive section of plant covering: on the left, before the retrofit; on the right, after

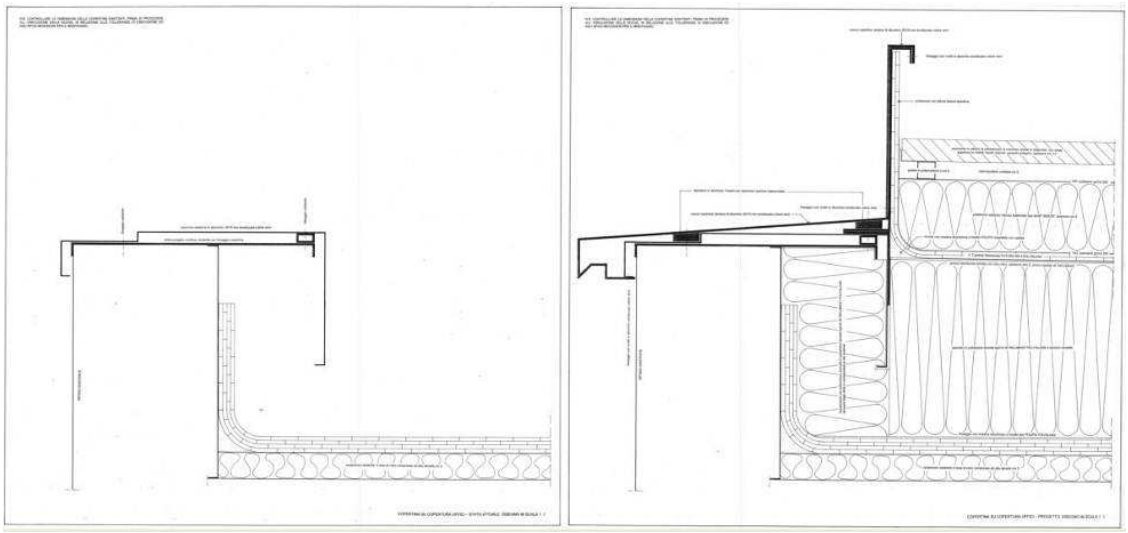


Figure 5: Constructive section of the office covering: to the left, before retrofit; to the right, after

6.5 Permanent protection for waterproofing – thermal upgrading

At that point, for making permanent protection of waterproofing from rays of sunshine and from thermal shocks, it has been made an "*inverse roof*", setting on waterproofing one polyester TNT 200 gr/m^2 sheet, acting as chemical-physical separating layer, and then one layer of XPS with edges "L" shaped, 8 cm thick; then one other sheet of TNT, same of the previous, acting as filter, and then a floor in white concrete stones 30 x 30 cm, reinforced crosswise with zinc plated steel, dry set on circular polypropylene bases, 2 cm high. Summer sun (who in Tito, June 21th, 12,00 am, has a zenithal angle with horizon of 72°) warms stone, who warms the air below, who goes out from 4 mm fissures between stones.



Picture 12: The lying of first layer of bituminous membrane was done partly, little by little was accomplished disposal of EPS panels for making slopes. You can see two coaxial roof vent, the one for venting original insulation, the second for evacuating possible condensations in EPS panels of slopes, and water that might enter during work



Picture 13: The lying of second layer of bituminous membrane, with mineral surfacing, was done as soon as slopes was wholly accomplished

Meanwhile, evaporation of night condensation water keeps cool and to constant temperature both waterproofing, both coverage below (Picture 14). In the phase of setting XPS insulation there had been some "tropical" downpours, who took to open in the panels some drainage grooves, 4 cm deep, 2 cm wide, who constitute preferential ways for evacuating rainwater (Fig. 6). The result, from the point of view of roof transmittance, has been an upgrade of 10 times: from 1,93 W/(m^{2}K) to 0,185 W/(m^{2}K), with an annual saving in primary energy of 262.197 kWh [MARINO, 2009, pagg.188-230, 298-373].



Picture 14: At the end, XPS panels (8 cm thick) of insulation were assembled and reinforced white concrete stones of floor, dry set on circular polypropylene bases, 2 cm high, for protecting and ventilating roof covering

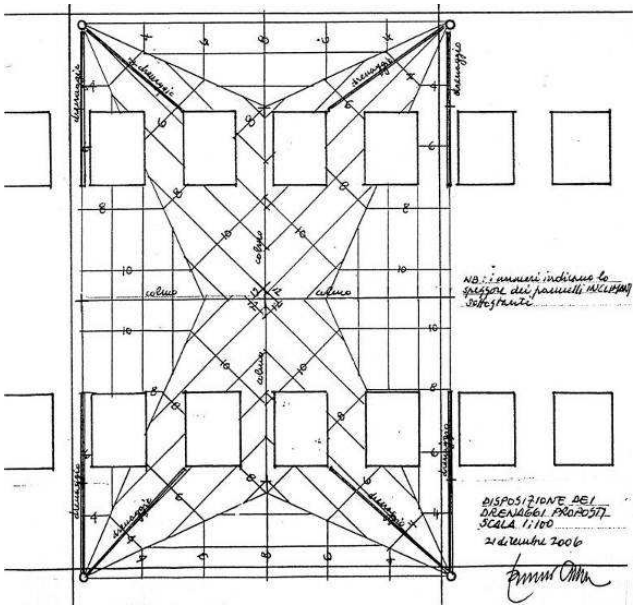


Figure 6: Plan of a typical span of the industrial plant, with drainage grooves added during the work



Picture 15: Then the insulations on the skylight and the flashings for protection and sunshades bases were assembled

6.6 The intervention on skylights

The original skylights were made from hollow polycarbonate, by this time dust stained and

opaque, have been replaced with moulded elements in polymetil-metylacril, with air space anti-condensation, transmittance of 2,27 W/(m^2K). Bases are been raised and full insulate from the exterior, removing thermal bridges (Picture 15). They are now provided of a structure that in summer has a tent made by a shading net, that in winter is removable and stackable.

7. Maintenance instructions

At the end of the works, has been released a document containing recommendations for correct maintenance of the roof, and instructions for inspection, to periodically accomplish.

8. Conclusions

The intervention on the large flat roof of the plant Ansaldo STS in Tito (Potenza) teaches that metallic coverings do not constitute vapour barrier, short of a specific design and execution for the purpose. It will be necessary, in the next editions, to modify the pictures of many manuals and "*rules of the art*" containers. It teaches, more, that "*warm roofs*" are very delicate and very exposed to design faults. In particular, they does not exist "*warm roofs*" without vapour barrier and without roof vents [LEMBO, MARINO, 2002, pagg. 84, 189, 218].

It teaches, more, that slopes must be bigger than *fluage* or charge deformation of the structures on which they are built. It is not intelligent to save a little amount of money to build a structure which deforms herself under the weight of a man who do maintenance on the floor, especially when there are great rigid and breakable, as tree-dimensional skylights of 1,80 x 2,40 m.

In the industrial districts, were in the air there are aggressive electrolytes, it is necessary to schedule very frequent inspection, to watch over the behavior of more elementary things: steel screws tropicalized can corrode, till to break, or to decrease their section, and open passage to water, in four years.

Even more, in the next years, the consideration of "global cost" and of sustainability will lead to invest in better materials and in better constructive solutions, who guarantee better durability, even if of higher initial cost.

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Strategies, Guidelines and Project Level Leadership as Methods for IDDS/BIM Practices in Transition

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Abstract

Construction project forms a multi-disciplinary organization with a goal. Whether that goal is commonly shared or divided and fragmented is a question of management: leadership and shared communication culture as well as design and delivery models with defined roles and authorities. In this paper we discuss the importance of leadership and need for it in project business change in the context of infrastructure development and construction.

We identify and analyse the approaches and concepts to be taken in to consideration for design management for successful IDDS (Integrated Design and Delivery Solutions) and BIM (Building Information Modelling) adoption. Our findings are based on interviews and observations on management and leadership practices as well as assessment of BIM management skills and levels of maturity. The analyses and recommendations describe possible actions in BIM adoption to apply various leadership behaviours and project management roles for desired added-values. The conclusions of this paper highlight the need for managership and leadership in project level integrated practices. Also, management skills and leadership styles and behaviours support BIM adoption.

The purpose of this study is to ensure that relevant approaches and concepts for project level management and leadership are used as point of departure for formulating BIM management guidelines for infrastructure development and construction industry in Finland. Pilot projects and research data originate from the PRE (Process Re-engineering) InfraFINBIM RTD project in Finland.

Keywords: BIM, infrastructure construction, change management, case study.

1. Introduction

1.1 IDDS and BIM adoption issues

In recent years many scholars have brought the change and BIM adoption into discussion from the point of view of understanding the importance of people in the transition. The way forward includes applying strategic and methodological BIM implementation and training

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plans, which are noticed by Smith (2009) and Succar (2009) to be in the core of adaptation strategies in the forerunner companies. Deutsch (2011) argues that when adopting and implementing BIM you are actually adapting to change; it is wise first to adapt and then implement; change is inevitable, but transition is a choice. Kotter (2001) adds that adoption of new approaches is a change situation where strong leadership should be emphasized.

The other relevant issue highlighted is re-engineering, the need to develop a transactional business process models with practical strategies for the purposeful exchange of meaningful information between BIM tools. As BIM matures in steps there are many iterations of re-engineering to be done on project level processes. Succar (2010) introduces a maturity chain starting from ad-hoc maturity, followed by defined, managed and integrated maturity. The chain finally reaches optimized maturity, which often presumes that IDDS based service concepts have been developed and that the whole industry branch has been able to transform their business processes and practices, e.g. all stakeholders share the same level of BIM capabilities and service maturity. This is the premise for successful project performance with desired end user values, leading to BIM based business benefits, which can be formulated as key business indicators (Aranda-Mena et al. 2009).

As the adoption of BIM is on-going, the industry still lacks BIM champions able to implement the technology while understanding the business factors both in their own organization and externally for their clients. The business and technology cases for BIM have already been made and largely accepted. The social case is about to be made for firm culture and project level culture, including working relationship, interaction and intelligence (Deutsch, 2011).

1.2 Procurement model as method of supporting integrated process

Traditional project delivery methods, such as design-bid-build, construction management or design-build, have been widely criticized of being inefficient, too costly and failing to meet quality expectations. In fact, the whole design and construction industry has become increasingly fragmented over the past decades (Lichtig, 2006). Matthews and Howell (2005) identified four major systemic problems with the traditional contractual approach: (1) good ideas are held back; (2) contracting limits cooperation and innovation; (3) inability to coordinate; and (4) pressure for local optimization at the expense of the project as a whole.

Emerging procurement models such as Integrated Project Delivery (IPD) and Project Alliancing are ways to organize projects to achieve lean construction and make integrated design and delivery teams work successfully. With the use of BIM these models provide the industry innovative tools to eliminate waste, cut costs, improve productivity, and create positive outcomes. Key aspirations in developing IPD are to increase collaboration between project team members, align incentives with rewarding high-performing teams, integrate BIM deliveries into contracts and ultimately to increase Value for Money (VfM) for facility owners. IPD is a significant new development in procurement innovation because it integrates design decision making, collaborative contracting and BIM technologies (Raisbeck et al. 2010).

1.3 Leadership as method of supporting people

Leadership and management are two distinct and complementary systems of action, both necessary for success in an increasingly complex and volatile business environment. Good management brings a degree of order and consistency to key dimensions like the quality and profitability of products. Management is about coping with complexity while leadership is coping with change, which makes them complementary to each other (Kotter 2001).

Like Kotter, also Gill (2002, 2012) agrees on the importance of leadership in any organisational change situation. Further, he proposes an integrative model of leadership for change, reflecting its cognitive, spiritual, emotional and behavioural dimensions and requirements. The model comprises vision, values, strategy, empowerment, and motivation and inspiration and can be applied in varied strategic change situations. Leadership focuses on vision, values, strategy, empowerment, and is more focused on supporting people through motivation and inspiration. Pearce (2004) argues that shared leadership is crucial in order to transform knowledge work. Pearce et al. (2003) introduced four types of leadership and their relevant behavioural sets. (1) Directive leadership: issuing instructions and commands; assigning goals; contingent reprimand. (2) Transactional leadership: dispensing contingent material rewards; dispensing contingent personal rewards. (3) Transformational leadership: providing a sense of vision; challenging the status quo; engaging in idealism; providing stimulation and inspiration. (4) Empowering leadership: encouraging opportunity thinking; encouraging self-rewards; encouraging self-leadership; engaging in participative goal setting; encouraging teamwork.

1.4 Research statement

The infrastructure property owners in Finland have described their objectives for using BIM and information technologies through desired impacts: high level of efficiency and safety during design and delivery process and quality of end product (roads, railroads, waterways), as well as generating more innovations. It is also realized that ICT enables changing the nature of the whole procurement process; in planning and design it is possible to improve communication and interaction with citizens and other stakeholder groups (Tiehallinto 2002).

In 2010 the InfraFINBIM project was launched to accelerate the development and adoption of BIM by re-engineering the processes. Common vision of the owners, designers and contractors is that by *year 2014 major infra-sector clients procure only BIM based services, in all project phases from early planning and design to maintenance and operation*. In order to support reaching the vision a set of common BIM guidelines are to be developed for harmonizing BIM based project delivery. One of the guidelines will describe the essence of IDDS/BIM project management.

The pilot projects and the studies in InfraFINBIM project are aimed at process re-engineering, with a clear goal to implement IDDS/BIM in the field of infrastructure construction and development. Development tasks in pilots vary from drafting and testing of BIM guidelines and assessing the feasibility of integrated BIM processes. BIM Guidelines are important tools in design and construction procurement as they identify models to be

delivered and define modelling principals. In the newest set of guidelines for building sector in Finland (BuildingSMART Finland, 2012) also managerial principals are defined; the stakeholders in infrastructure sector are preparing their set of guidelines by the end of 2013. In order to understand the whole picture of management and leadership in IDDS/BIM this study was started, considering project level management and leadership in design phases.

Based on (a) reasoning on IDDS/BIM adoption challenges introduced above, (b) our observations about BIM implementation within building and real estate industry as well as infrastructure development and construction sector and (c) key arguments of leadership thinkers, we argue that in strategic transition situations project organizational leadership actions are critical and should be part of implementation of new approaches.

2. Concepts and approaches for IDDS/BIM management

In this chapter we introduce some relevant concepts and approaches noticed for IDDS/ BIM management in the project business. They are shown as IDDS management pyramid (Fig. 1) where identified key approaches to define BIM management and leadership guidelines are illustrated, with development path to realisation of vision as steps of strategies and actions. We try to limit the approaches to those that have a clear effect on project level actions, but we are aware that most of them are linked to organisational level business strategies at the same time. Also, we do not focus on changing business environments or trends from the society. We try to describe the approaches from an angle that opens their connection to leaders' and managers' behaviours.

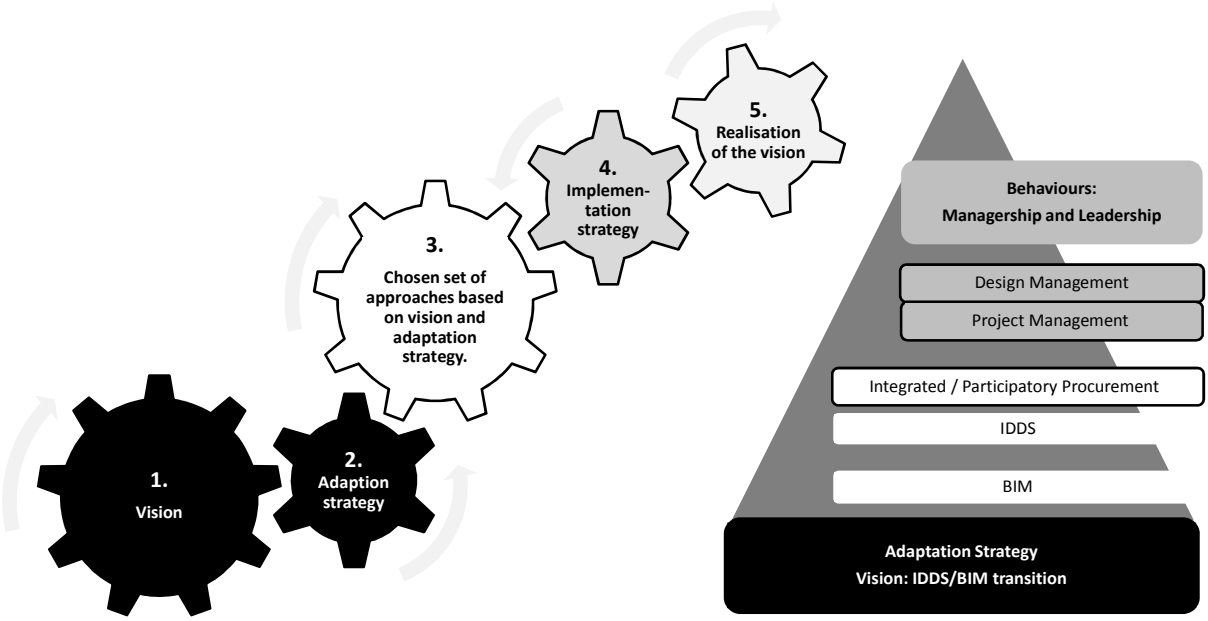

Figure 1: IDDS Management pyramid illustrating key concepts and approaches

2.1 Adaption strategy and BIM transition

The foundation of the pyramid is formed by the adaption strategy that is based on the vision of IDDS/BIM transition and on the principle that it is to be lead, not just followed. Companies

need to recognize their potential BIM benefits and develop relevant business processes and invest in learning and knowledge management. They need to decide whether they implement BIM as a system for data automation, information and collaboration or a key to transform and develop new integrated business models and BIM enabled service concepts. BIM management is a part of service concept and BIM organisational level strategies exist in the forerunner companies.

As BIM matures in steps it is challenging to implement it on project level, with many stakeholders in diverse stages in their own BIM adoption. When reaching for the higher levels of BIM maturity the potential benefits increases. On one hand, BIM is seen as an instrument for valuable and accurate information (starting from the planning phase) as well as leaner processes and smooth workflow with full interoperability. On the other hand, BIM is an enabler for more user-oriented and integrated design concept as well as new service concepts using leadership actions instead of (or in addition to) more traditional management actions. High capabilities of BIM for visualization lead to better understanding and transparency of the project actions, promoting these changes in practices.

We argue that high level of integration is a process level tendency reflecting the growing BIM transition, whereas collaboration and communication are tendencies of growing co-creation between stakeholders (people). Strong interoperability is a tendency of growing need for data transfer technologies and standards.

2.2 IDDS and Integrated/Participatory Procurement

IDDS support collaborative project delivery approaches in construction and seem to lead to smart business strategies. The more focused use of BIM in order to receive benefits and create value is leading to transparent design processes and supporting lean construction and risk management. Both approaches rely on actors in the design and delivery processes and their upgraded skills, as well as motivation and shared aspiration to execute work in a more value adding, efficient and profitable ways. Implementing BIM as a systemic innovation and turning the business focus on IDDS is a strategic change action. The issue of leadership and management rises when project level design and delivery solutions are under adaption to integrated approaches. Integration of the process is happening both in design teams, in project teams and in the interactions with clients and users.

The IPD approach integrates better than the traditional delivery methods all team members to form a collaborative that acts as the core group to manage the integrated project delivery process. However, the formation of project organisation and consistency of leadership are crucial when using IPD (or Alliancing) procurement models. Owner's representatives have to be actively involved in project leadership for the whole project life-cycle. The link to the customer is also very important. Integrated project delivery is supported with the use of relational contracts that recognise the reality of what needs to happen for successful project delivery. An integrated project delivery team shares decision making, pools contingencies, and provides incentives for team performance. Having such contracts in place creates an environment where all team members share risks and rewards based on reaching targets.

The organizational design of integrated/lean project delivery is based on demand, value and flow; open, collaborative and integrated team of key players formed at the outset and added to as the stakeholder group grows. The management/leadership ethos of IPD is from outside-in: act on the system to improve it for customers (helped by those working in it), unlike traditional top-down: manage the contract, manage the programme, manage budgets and manage people (AIA, 2007).

2.3 Project management and Design management

The project manager is essential for the successful delivery of a construction project and has the overall responsibility for the planning, co-ordination and control of a project from conception to completion. The project manager takes on multiple roles in projects. Project management has several sub management layers like value management and team management. Risk management and information management have a straight relation to the IDDS approach as has been discussed in previous articles (Azhar 2011).

The key idea for BIM enabled design process is to produce valuable information for decision making. This is done with help of BIM functions: BIM based analyses, simulations and visualizations, and it is a key task of design management. The whole design workflow will actually be managed with help of information. This leads to adapting the key theories of knowledge management for the project level, for change management and using BIM as instrument rather than a tool (Mäkeläinen et al. 2012).

The design manager takes multiple roles as well as. The essence is not only to track the design tasks but to use means and mechanisms available to create social interaction, influencing and stimulating the team members, even challenge them to create innovative solutions (Rekola et al. 2012). Tatum (2009) argues that leading and implementing integration requires a collaborative approach and special skills. The three levels of champions needed are (1) executive champion (typically project managers) who creates the supportive organization culture and structure; (2) commercial champion (business managers) and (3) technical champion (project engineers). All of them foster integration by providing active advocacy, obviating potential problems, solving those that occur, and always insisting on increased integration when it helps satisfying project objectives.

In addition to project organisational roles, one way to understand design management is through design concepts. In order to answer to the trends and objectives of the society general design concepts have been developed. These concepts can be upgraded to service concepts, which normally highlight several values of design and delivery.

2.4 Managership and Leadership Behaviours

The present leadership and management responsibilities in the infrastructure sector are based on generally proven and known practices, organizational hierarchies and professionalism. Actual formal management and leadership roles, practices or task lists have not been recognized as a general guide for the business. The responsibilities of designers are described loosely in the building regulations. In our study we have raised the issue of

leadership both as behaviour of a leader and as a competence to be held in IDDS transition process in order to achieve understanding of use of BIM. Leadership behaviours are structured by typologies (Pearce et al. 2003), but in practice they are used also together.

In our study we are interested in leadership behaviours and actions and their output in two ways: firstly, in relation to a certain project action situation and to managers' roles; secondly, in relation to industry wide BIM adoption and implementation strategies.

3. Empirical research

3.1 Case study methodology and results

The partners of on-going InfraFINBIM project form a good target group as they all have personal experience of working with BIM in pilot cases and they share an ambition for BIM enabled re-engineering. InfraFINBIM portfolio of pilot projects forms a favourable innovation platform, where 25 different pilot cases act as development and testing environment. Furthermore, as the use of BIM is in its early stages of an industry-wide adoption, the stakeholders have strong susceptibility to notice details in project level culture and change of practices due to BIM implementation. Therefore the personal statements of the experienced managers interviewed are treated as phronetic intelligence (Flyvbjerg et al. 2012) in the analyses. Seven design managers from six consulting companies and three clients' project managers were involved in the two round interviews, where the objective was to identify management and leadership contents and relevance of the pre-chosen approaches (Fig. 1).

The semi-structured short interviews were performed in two rounds. In the first round the managers were asked four general questions on project level management and leadership. The first two questions were related to identification of the present leadership roles and management tasks and the need for changing those. All the interviewees identified similar roles on project level: project supervision (client), project manager, principal designer, experts of different disciplines, design management etc. Depending on the size of the project usually chief designer takes more tasks and roles especially in small, routine projects.

The interviewees believed that the current management methods and practices will remain unchanged even though the design work itself becomes more BIM based: "*The roles of the various parties do not change (administrative and technical management) but the tasks are developing to support more model based design.*" New role of BIM coordinator was expected especially in the projects where the coordination models are necessary. When the BIM based design becomes more common, a BIM quality supervisor's role might arise. The quality controller's role can be performed either as a design task or by an independent auditor. The participants emphasized the importance of the co-ordination of the project consortium as well as general guidelines and supervision to guarantee the continuity of design from one phase to another.

We asked participants how BIM based design and working method have changed the decision-making process. Most of the companies had positive experiences in the use of BIM for visual models during project progress meetings with the client. "*Models play an integral part in the decision-making process in connection to a certain design solution on a practical*

level. The quality of the solutions improves when design issues are considered together." Similarly, the conflicts of the different design disciplines are better detected, commenting between parties is more active and presentations to stakeholder groups like end-users and politicians are better facilitated. The interviewees stressed that although visualization has great importance, the BIM model is not used as visualization model only but as a tool that allows easy access to information and helps co-creating more valuable solutions.

Finally, the interviewees were asked to describe what BIM means to them with four claims: (a) BIM is automating information and data, (b) BIM is communication and information tool, (c) BIM is decision-making tool and (d) BIM is a new design concept. All interviewees agreed that at the moment BIM is a communication tool automating information and data (a and b). The benefits are improved validity and reliability of information. They also agreed that data transfer and compatibility issues can be resolved in time. BIM as a decision-making tool was considered more a target or vision for future which is possible to achieve when the use of BIM-models is part of the daily routine. As emphasised by the owner, models were expected to bring clarity and support to decision-making processes in the infrastructure property management. BIM is not a new concept in construction industry according the interviewees. Most of the participants had noticed that BIM based work will require behavioural changes.

In the second round informal material on leadership practices and methods were delivered to interviewees and they were asked to identify the leadership styles and behaviours in their own working environment and roles. Many of the leadership styles were recognised in their own organisations and in connection to changes in practices. At the moment the project environment does not support any other styles or behaviours than the administrative and technical management roles and directive leadership styles. However, the interviewees were able to separate benefits and disadvantages between different leadership styles and their usage in different situations. In particular, the participants noticed that they were working according to certain management style without questioning or any estimation whether the management method is correct and fits for the purpose. In general the current management practice was rated to be good enough. More innovative and supportive leadership could be exploited in demanding projects in order to achieve better end results.

The last exercise of the study focused on the development and maturity of BIM skills. Four project managers of recent BIM pilot projects, where the target had been to test boundaries of BIM collaborative practises and design model content were interviewed. The project managers were asked to estimate the level of skill maturity of the BIM designer and group design manager of their own company. The results show that neither of the skill maturity levels rise very high (Table 1). Leading companies in BIM based design give clearly better scores themselves than those who have not adopted BIM in their common design practices.

Table 1: Skill levels observed in pilot cases with scale 1 (poor) to 6 (authorised) – skill levels explained in Table 2

Pilot case	Level of BIM designer skills	Level of group design manager
#1	3 (good)	3 (good)
#2	2 (satisfactory)	2 (satisfactory)
#3	3 (good)	2 (satisfactory)
#4	4 (very good)	3 (good)

3.2 Analyses

The final analyses were done by the research group, when the predicted approaches connected to management and leadership was matched to new findings from observations and interviews (Fig. 2). As a summary we conclude that interviewees related management roles and managerial behaviours to most of the levels of IDDS managerial pyramid. The relationship between procurement and management issues was not as clear.

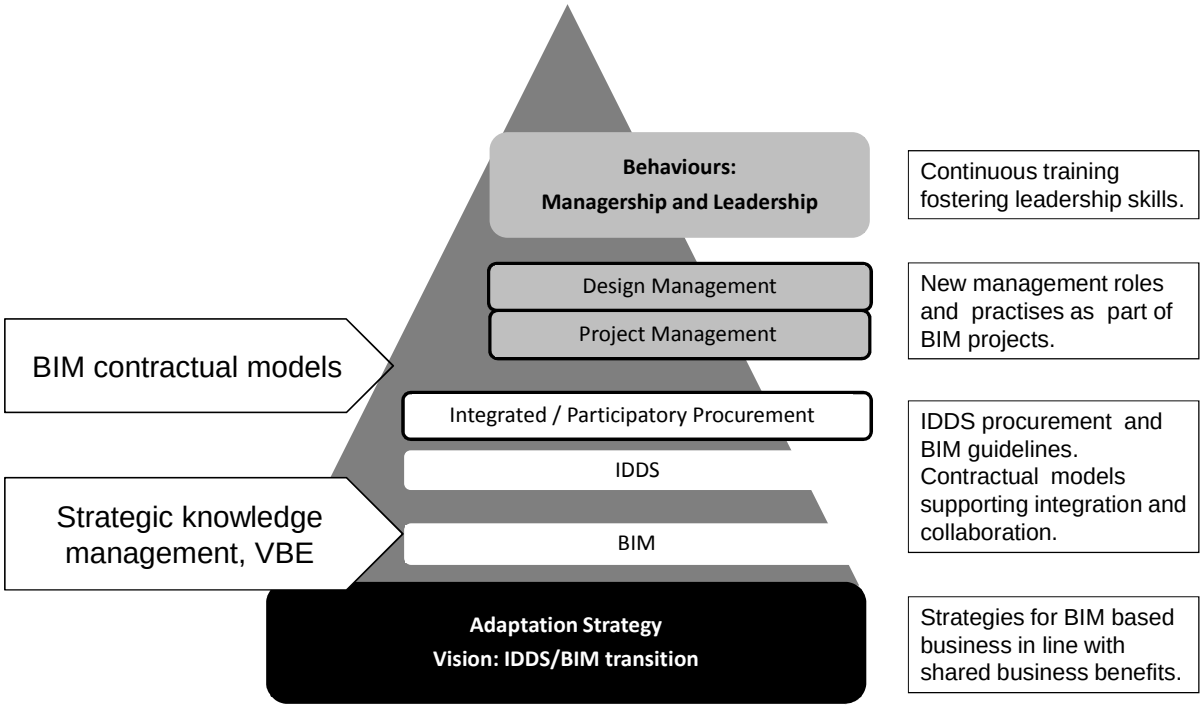

Figure 2: Summary of the interviews and analyses as updated managerial pyramid

Findings from the interviews were expanded with our observations from management styles used in pilot projects. These observations were done by researches that had followed the pilot projects in the interaction events of design meetings or in public presentation events. The observations were upgraded into management roles and description of the levels of skills as part of BIM project maturity matrix with recommended leadership styles to be exploited (Table 2). Seven roles with 2-3 leadership styles were defined and identified in connection to the main objectives of each role.

During analyses some examples of the management procedures were defined including preferences of leadership styles to be exploited for their supportive effect on output or change. (1) Support adaptation: ensure that all stakeholders understand the new process where creation of valuable information is in the key role. Leadership styles to be encouraged: directive and transformational. (2) Create a BIM Plan for the project. Create the descriptions of BIM actions together with the team and schedule them. BIM focus area is a value adding, pre-planned and described task or row of tasks executed in a certain phase during the process with defined BIM actions. The task description include definitions of responsibilities, objectives and roles: Together with BIM function the BIM action method

describes what is done, with which model and who are involved in executing action. Leadership styles to be encouraged: participatory, use people-oriented and task-oriented together. (3) Strive for value. The overall aim for a BIM focus area is to provide valuable information to decision making. Management focus should be in striving for value with help of BIM in project level and support and develop new IDDS practices on company level. Leadership styles to be encourages (a) in planning: transformational and empowering; (b) in design and delivery: transactional and empowering.

Table 2: The analyses of matching leadership styles with the objectives of project level roles shown in a maturity matrix table

	Integration champion	BIM expert Coordinator Technical champion	BIM Modeller, Designer	Design group manager, Chief designer	Project manager (consultant of owner)	Project manage-ment of the owner	Super-vision of design disci-plines (owner)
Leadership styles to be exploit in challenging projects (levels 4-6)	Servant and Trans-formational and Participatory leadership	Participatory and Trans-formational	Task-oriented and Partici-patory	Empower-ing and Partici-patory	Directive and Partici-patory	Trans-actional and Partici-patory	Task oriented and Servant leader-ship
Skill level 6 authorised	Authorized qualifications with wide experience in challenging IDDS/BIM project environments. Very high customer satisfaction.						
Skill level 5 excellent	Strong experience and qualifications with wide competence on IDDS/BIM integrated and value based practices. Project control, guidance, problem solving and people leadership is executed well to support project goals without heavy work load to the team. High customer satisfaction.						
Skill level 4 very good	Strong capabilities and experience in integrated BIM practices with references on successful project and satisfied management. Strong customer satisfaction.						
Skill level 3 good	Good capabilities and competency on integrated BIM practices. Some experience on use of BIM functions on task level in project environment.						
Skill level 2 satisfactory	Basic capabilities and understanding of key concepts exists on BIM practises. Little experience in BIM based projects.						
Skill level 1 poor	Poor capability on BIM practices. Negative or suspicious attitude to BIM benefits. No experience in BIM based projects.						

4. Conclusion

Results were diverse in the area of leadership styles usage. One reason for this is the short history of BIM based project practice in the field of infrastructure development and construction in Finland. It was clear that management and leadership skills are both needed. Especially when working in a BIM process that is still new for the stakeholders and either adaptation and nor implementation is fully finalized. Results from the analyses indicates that when defining the roles and skills needed in integrated design and delivery the importance of leadership styles and tactical use of behaviours have a place and meaning. Therefore we recommend that the guidelines describing the essence of BIM project management should include the essence of BIM leadership. As the roles of the project level business environment are going through a change process it is possible to develop supportive leadership behaviours as personal managerial skills. Leadership skills can be consciously

developed - as any needed skill - in similar ways than strong leaders on organisation level can be fostered (Gill, 2012). Results of BIM skill maturity development are greatly influenced by how well the company has adopted a BIM based design strategy as its own way of action.

The benefits of leadership are direct when building up IDDS/BIM maturity and capability levels. When catching up with the knowledge of leadership theories and getting more familiar with leadership practices and the orientation of each style, it is possible to accelerate (a) BIM adoption (b) BIM maturity and capabilities, and (c) value-adding actions in the process. As leadership is a key component to be introduced and discussed in BIM managerial guidelines. The results of our study support the idea that issues of management and strong leadership should be emphasized more in procurement and delivery models and project organizational and contractual structures. Management principles should be communicated through requirements and guidelines as they are part of design collaboration culture in transition.

Infrastructure development and construction projects are complex and high value large projects which should be lead systemically with strong project management. Intense city structures with connection to building design and construction form even extra challenges. In this kind of district level projects there is (a) a need for multidisciplinary management systems to support decision making and (b) a need for strong management and leadership in order to motivate many disciplines evolved to integrated design practices. Further research is needed to show if there is a certain project quality level which cannot be reached without strong leadership actions. It is highly evitable that the need for leadership actions and use of variety of styles is higher when stakeholders move further in IDDS/BIM maturity.

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Pathologies as a direct consequence of design mistakes: the case study of the “New Fruit and Vegetable Market” in Molfetta (Bari, Italy)

Francesco Paolo R. Marino[1]

Pathologies as a direct consequence of design mistakes: the case study of a “Fruit and Vegetable Market” in the southern of Italy Abstract

This report concerns the study of a new building, designed for being an indoor fruit and vegetable market in Molfetta (South of Italy), which after its completion has been used for only few weeks, because temperature, humidity and indoor air quality were not appropriate for the conservation of the goods and for the healty of the people working there, due to evident errors, attributable to design choices related to the used materials and to the construction typology, completely inadequate if compared to the climatic context in which the building is located.

In particular, has been detected that the building acts with a behaviour typically defined as "greenhouse effect", which determines high values of temperature and humidity content, in absence of a correct longitudinal and transverse ventilation. The research was aimed to study all the failures and pathologies and to identify design solutions to improve the performance of the thermo-hygrometric and internal ventilation of the building, and in general the conditions of the microclimate, in order to ensure a condition of comfort to the users and to ensure, at the same time, a suitable air quality for the preservation of fruit and vegetables. It is targeted to a solution that, using techniques of passive cooling, is able to control and exploit the geometric, locational and technological characteristics of the building, ensuring the maximization of air efficiency and thermal exchanges between the building and the outside. Through a bioclimatic approach, have been proposed solutions able to low the inside temperature in the central gallery of the market in the summer period and an adequate exchange of air: the interaction of the existing building with the external environment has been exploited to produce the necessary internal cooling, thanks to a model that works with "stack effect", by combining solar chimneys and properly designed earth-air heat exchangers in the ground.

Keywords: greenhouse effect, **thermal discomfort**, **ventilated geothermal cooling**, **heat exchangers**, **solar chimneys**

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1. Design criteria and construction characteristics of the building

This study is concerned on a building used as a covered fruit and vegetable market, located in the industrial area of the city of Molfetta. The building case study highlighted a number of issues related to the microclimate that has been established within the covered space; the adopted design choices, in relation to the used materials and to the constructive typology, revealed immediately an inadequate behaviour compared to the climatic context in which the market is placed. The building is rectangular in size 150.00 x 35.00 m and so with a total area of5,000 square meters (see Fig.1). The interior layout of the space is built around a large central gallery with the function of exposure and handling of the fruit and vegetable products (see Picture 1); however, a total of 30 boxes are located on the sides of it, with an area of 992.15 square meters, used as retail with above offices placed in two rectangular blocks with flat roof (see Picture 2). The internal height is variable for the effect of the arched shape that characterizes the cover, ranging from a minimum of 8.55 m to a maximum of 10.85 m, in correspondence of the central zone of the gallery

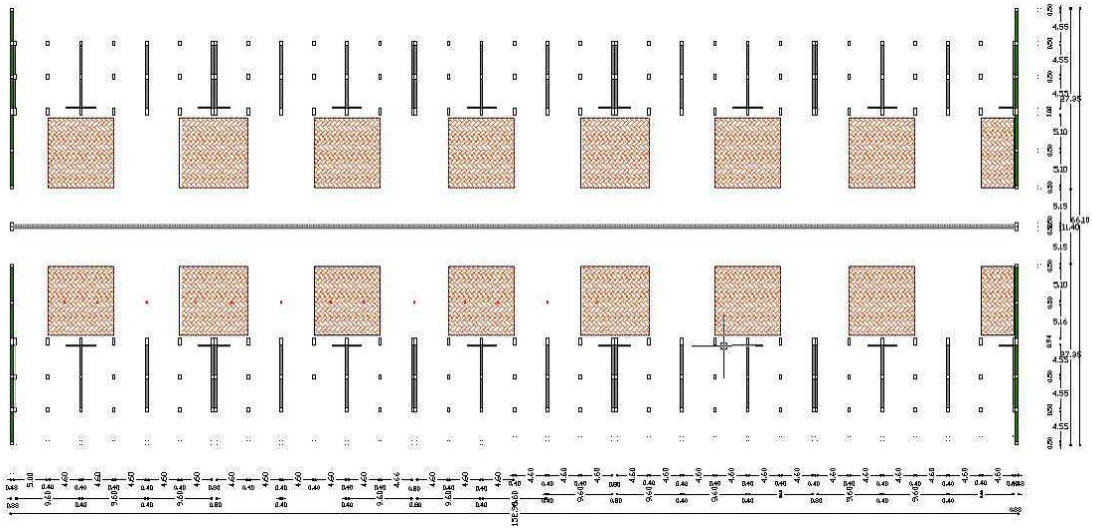


Figure 1: Ground floor plan



Picture 1: Central gallery overlooking the West (left) and East (right)

The building envelope, whose walls are infill cassette with two layers made of blocks near-vibrated concrete, face view and polished, "bull" type, with a thickness of 19.5 cm and 9 cm layer of still air (with a transmittance U equal to 0.908 W/m^{2}K), is not isolated and is open along the perimeter. In fact, in the side elevations of the building (those exposed to the North and South, see Fig.2) are the openings of the box (two for each box, closed with metal shutters) and, at the top, are arranged fenestrated openings and no windows openings,

which also contribute to establishing a continuity with the external environment. Moreover, in correspondence of the main elevations (shorter ones, exposed to West and East, see Fig.3), are present the openings used for the maneuvers of loading and unloading of goods, placed in constant connection with the outside. Even in the coupling of the cover with the vertical closures of side elevations, there are spaces directly communicating with the outside.



Picture 2: Box at the sides of the tunnel (left) e inside the box (on the right)

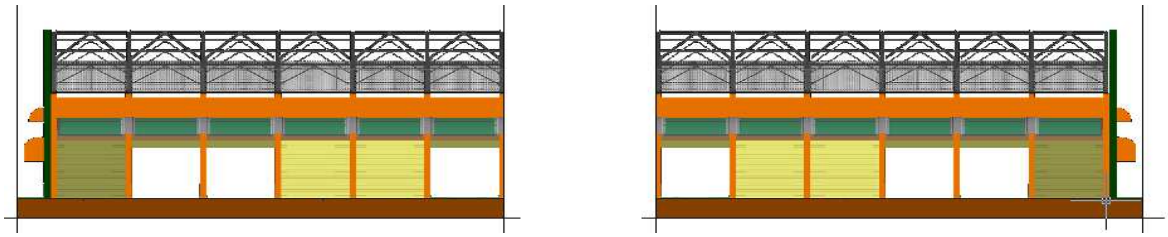


Figure 2: South side elevation

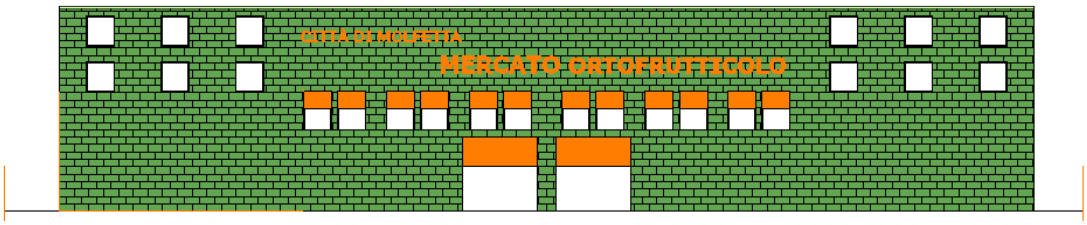


Figure 3: East side elevation

The building has been realized in mixed concrete-steel: the structural part in elevation and the structures of the box were made of reinforced concrete type Rck 300, while the cover has been realized with steel trusses, of arched shape, with a span of approximately 37.60 m. The distance between the upper and lower rafters of composite trusses varies from a minimum of 1.50 m to a maximum of 2.30 m, and are positioned at a variable pitch; at the bottom, the crosspieces are placed at a pitch of 1 m, and act as supports for the cover package made of alveolar polycarbonate, 10.00 mm tick (see Picture 3). The beams, connected to each other through special bolting, are: - type HEB 260, for the upper and lower rafters; - type HEB 140 for the beams of vertical connection; - L-type 80 for connecting beams between the upper rafters; - of HEA 140 for the crossbeams on which the cover rests. The sealing layer is made of polycarbonate multiwall sheets of thickness 10/10.

2. Problems encountered

The building has highlighted a number of problems related to the microclimate that has been

established within the covered space. In practice, the building envelope as it was designed, immediately showed inadequacy of design choices, especially in relation to the choice of the used materials, and compared to the climatic context in which it is inserted. In fact, inside the building there is a behavior which is typically defined as "*greenhouse effect*", mainly caused by the type of material used for the cover. Concurrently, however, other causes involved generate overheating within the covered market and which will be represented below.



Picture 3: Coverage of the fruit and vegetable market

The causes that contribute to the thermal discomfort in the fruit and vegetable market, in addition to coverage type, as mentioned above, are: - heat determined by the overheating of the closing blinds made of galvanized steel; - the lack of isolation of the cover of the box office, on which was placed only a bituminous waterproofing layer; - the presence of impermeable surfaces completely asphalted (black) in outer space that surrounds the covered market; - the lack of vegetation to mitigate the effects of the hot weather outside; - the lack of proper ventilation. A series of measurements have been carried out using specific thermo-hygrometric analysis of instrumental type, performed with the microclimatic station BABUC-A and the microclimatic control unit HSA DGT TECORA, positioned in correspondence of the central zone of the gallery at an height from the ground equal to 1.1 m, precisely adapted to detect the microclimate conditions inside the market. These measurements returned values of operating temperature between 34.53 ° C and 37.44 ° C with a relative humidity between 59.9% and 68.4%, and with an air velocity which has always been found to be lower than 0.6 m/s. These values are not consistent with those required by current legislation on temperature-humidity and air quality characteristics that should be secured in a working environment (in fact, with these values the heat exchange by convection is drastically reduced, the sweat fails to evaporate, and then fails to subtract heat to the body, remaining on the skin and increasing the sense of discomfort of workers). Instead, the average radiant temperature, indicative of the average temperature of the surfaces of the gallery, and therefore of the radiative exchange of the human body, was between 42.14 °C and 49.59 °C.

The tens of tons of fruit and vegetables that are daily exposed in the gallery increase their respiration processes, because of the microclimate registered in the air exposure, and accelerate biochemical reactions, leading to the production of additional heat, reducing the amount of oxygen and increasing the production of CO_2, ethylene and other substances. As a result, oxygen-poor air, stale and often smelly, partly because of rotting waste products, negatively affects a thermal environment already compromised. The interior microclimate that has been created, rather than slow down, accelerates the maturation and degradation of

fruits and vegetables, resulting in serious damage to the economic activities of the traders. The measurements have therefore shown that the structure does not adequately protect the inside from the outside weather conditions, typical of peripheral urban areas at latitudes of the country characterized by hot humid summers with high radiation, and temperate winters with wet winds predominantly from the North-West.

The cover slabs of polycarbonate, preventing the re-radiation of heat of the internal surfaces at low temperatures, in the summer determines a greenhouse effect inside the tunnel worsens the microclimatic parameters and contributes in a decisive manner to cause the high values of average radiant temperature registered.

3. Retrofit project proposals

The thermo-hygrometric analysis showed that the building is not functional as a working environment, not providing comfort conditions and respect for the welfare of temperature and humidity conditions for workers and users; and even less to its destination use of fruit and vegetable market (bad maintenance of products and economic losses for market vendors).

The climatic analysis of a site is a priority in the design, because the climatic characteristics of a site affect the designer in the choice of materials and building typology and orientation features, in defining the building envelope technology and installation of engineering solutions. As a support of the climatic analysis the UNI 10349 has been used: it provides the climate conventional data necessary for the design and verification of both the buildings casings, and both of installations for heating and cooling. This legislation, in addition to providing daily and monthly average climate data needed for the calculation of the energy requirements and the humidity checks of buildings, presents the project data concerning the verification of exceeding the maximum or minimum values of specific parameters, and the dimensioning, in terms of thermal power, of the heating and cooling systems.

The main parameters determined in the climate analysis for the site concerned by the intervention under study are: - temperature values daily, monthly, yearly (minimum, average and maximum); - direction and force of the prevailing winds in summer and winter; - values of the solar irradiance, monthly and daily; - air humidity (minimum, maximum, average); - period of shade; - sun exposure. Considering the hot and humid climate of the city of Molfetta, as resulted from the construction of the Olgyay and Givoni diagrams, it is necessary to operate the monitoring of temperatures (air, mean radiant and operative), ventilation and relative humidity, in order to restore the conditions for thermal comfort inside the confined environment of the fruit and vegetable market. Some of the building retrofit project interventions were thus envisaged, aimed at resolving the problems encountered, choosing, in accordance with the dictates of bioclimatic architecture, passive cooling techniques (together, geothermal and ventilated).

3.1 Ventilated geothermal cooling

In systems of ventilated geothermal cooling, the transfer of heat between the inside and the ground takes place by means of the air that circulates in pipes in contact with the depth soil

and so that it cools before entering inside. The air is circulated through buried pipelines, via a fan (hybrid systems) or passive systems operating at Bernoulli-Venturi effect (downwind extractors) and stack effect (high windows, ridge openings).

It was chosen to use a system of ventilated geothermal cooling, with air circulation mode "open cycle": the system enters outdoor air in the building, after it has been cooled through the passage in the ground; thus the function of cooling is combined with that of ventilation (heat exchangers). The fresh air fed from the bottom in the confined environment, heats up, moves upward as a result of the aerostatic thrust and is extracted through appropriate openings in cover (system operating at "chimney effect").

3.1.1 Heat exchangers

Horizontal heat exchangers "ground-air" were used. The crucial parameter for the assessment of the potential of cooling of the air that passes through the soil, is the temperature of the soil at various depths. In theory, this value can be measured, but in reality, only few weather stations perform measurements of the surface temperature of the soil, while soil temperatures at various depths are even less monitored.

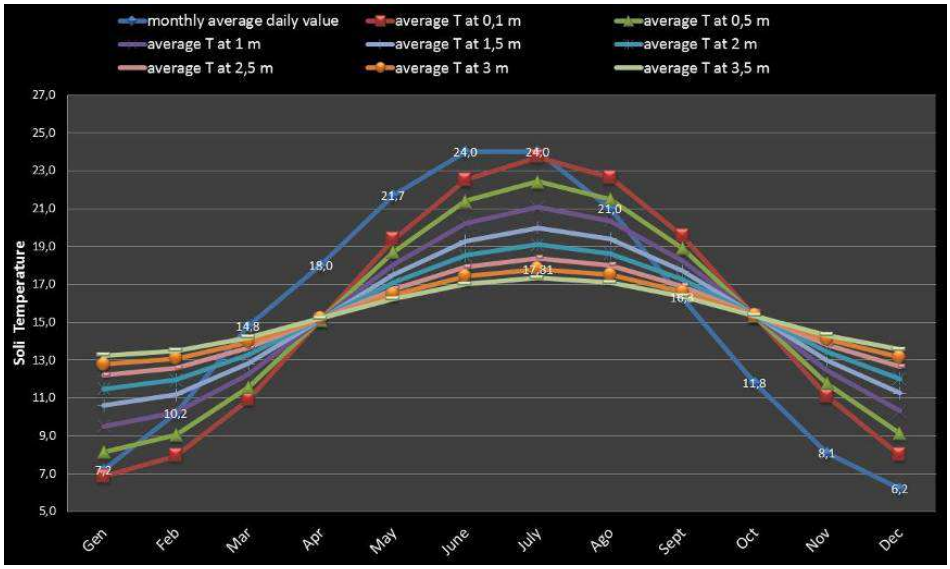
An alternative to the direct measurement of the values of the soil temperature at the different heights is given by some algorithms that have been developed. For homogeneous soils (Santamouris & Asimakopoulos, 1996), with constant thermal diffusivity, the temperature of the soil at any depth “z” and at every hour is:

$$T(z,t) = T_m - A_s EXP\left[-z\left(\frac{\pi}{365\alpha}\right)^{\frac{1}{2}}\right] * \cos\left[\left(\frac{2\pi}{365}\right)\left(t - t_0 - \frac{z}{2}\left(\frac{365}{\pi\alpha}\right)^{\frac{1}{2}}\right)\right]$$

Where: T_m = average annual ground surface temperature (°C); A_s = Amplitude of the variation of the surface temperature (°C); z = depth in the soil (m); α = thermal diffusivity of the soil (m^2h^{-1}); t = elapsed time from the beginning of the year; t_0 = a constant period (number of hours, from the beginning of the year, with average surface temperature lower). This equation shows that the temperature of the ground at a certain depth depends only on the surface temperature and the thermal characteristics of the soil. The ground surface is subject to sinusoidal variations in temperature that are dampened with depth. The effect of the thermal inertia of the soil is such that there is the convergence of the soil temperature at values practically constant when the depth increases.

The values of the relative temperature of the soil at the study site, for depth varying from 0.1 m to 3.0 m, obtained using the above algorithm and starting from the temperature during the season and, of course, on the characteristics of the soil, show that the highest average soil temperature is reported in August (25.63 °C to 0,1 m or 20.25 °C at 0.5 m, 18.37 °C to 1.0 m; 17.82 °C to 2.0 m; 17.79 °C to 3.0 m), even if the values of the average outer temperatures that are higher in July (24.6 °C versus 24.4 °C). This difference of values may be simply explained by the tendency of soil to accumulate heat, thanks to its large thermal

inertia, due to its semi-infinite extension, for which the adaptation to external conditions always records a delay by determining a time difference between the two reference values. The following graph (see Picture 3) is representative of the trend of soil temperature at different depths throughout the year.

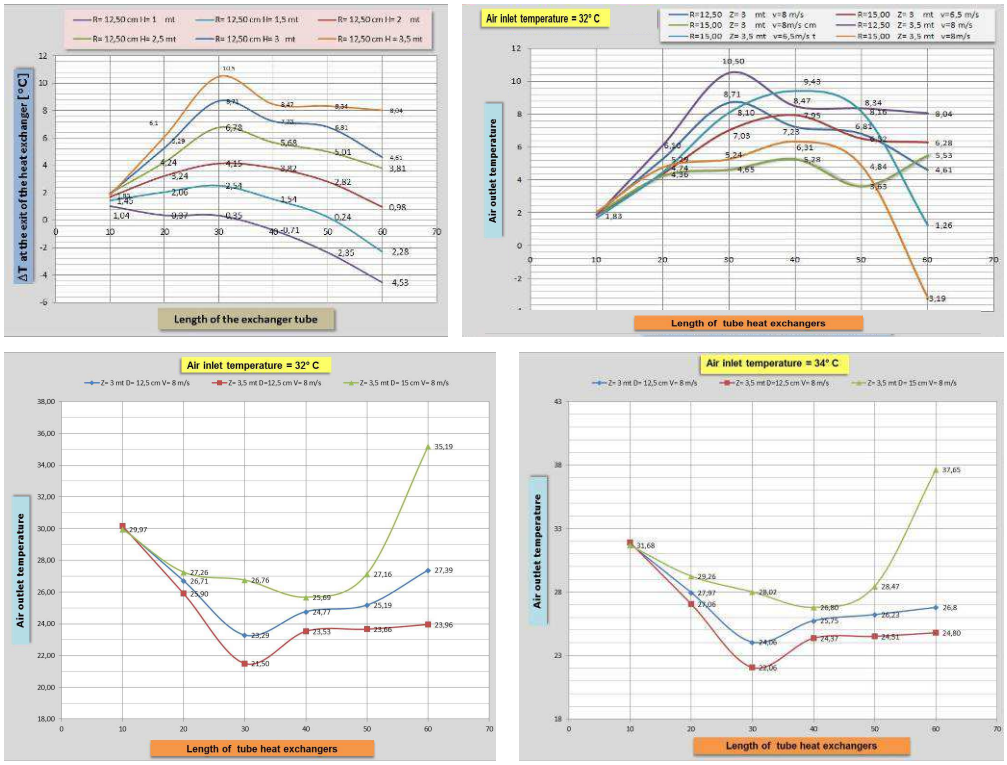


Picture 3: Soil temperature trend throughout the year at different depths (Molfetta)

Interestingly, the trend of temperature variation has a deeply felt values at soil depths close to the ground surface; the curves are gradually flattening as depth descend, until assuming constant values during the year in correspondence with a depth value equal to 3 m.

For the definition of the behavior of the heat exchangers and for the determination of their efficiency, simplified parametric models have been used that relate the geometrical parameters of the tube (length and radius) with the burial depth of the pipe and the air speed inside the heat exchanger. To calculate the overall efficiency of the heat exchanger, a dimensionless coefficient is also defines which compares the difference of the air temperatures at the exit of the tube and that of the undisturbed ground, with the difference of the air temperatures at the inlet of the tube and that of the undisturbed ground. The pipe sizing of heat exchangers air-ground was made by applying an iterative method aimed at finding the best features that will return the maximum efficiency in terms of lowering the temperature at the exit of the duct. Operationally, a tube with a radius of 12.50 cm was chosen, evaluating the function at the burial depth of 1.50 m, 2.00 m, 2.50 m, 3.00 m 3.50 m, for a heat exchanger of variable length in the range between 10 and 60 m. The values were calculated with reference to the warmer period of the year, thus considering the most severe operating conditions, and by setting an air velocity inside the pipe equal to 8 m/s. It is useful to specify that the choice of the air speed of 8 m/s has been conditioned by the availability of experimental coefficients (a_0, a_1, a_2) assigned in correspondence of the flow rate, the minimum value of which table is set equal to 0.393 m^3/s. However, considering that the air is impractical at a such speed within the market, it will be necessary to provide in correspondence of the output section, a widening of the same by using a tube of variable cross-section, such that a value of the output speed is guaranteed equal to 1 m/s, speed that is considered pleasant to high temperatures.

In the graphs below (see Picture 4), the results of calculations are summarized, relating to the determination of the length of the pipe exchanger, depending on the different installation depth, the speed of the airflow, as well as the tube diameter exchanger. As can be seen from reading the graphs, the study has shown that the depth of burial that yields the best results is equal to 3.50 m. With the reduction of the depth there is a proportional reduction in the efficiency of the heat exchangers which, if placed at a depth of 1.50 m or 1.00 m, in correspondence of greater lengths, even produce a temperature increase in the output of the exchanger: this confirms the strong influence of the external temperature at a depth of soil near the surface.



Picture 4: Variations of temperature and absolute temperatures at the exit of the heat exchangers

Subsequently, the behavior of a heat exchanger with a radius of 15 cm was evaluated, without changing other boundary conditions, considered as optimal (depth = 3 m, length = 30 m, V_{air} = 6-8 m/s). The result of the simulation confirmed the greater effectiveness of the heat exchanger of R = 12.50 cm, since the increase of the tube section has returned an air temperature at the exit of the heat exchanger, higher than in the lower section of pipe.

The choice of the geometry of the heat exchangers was made primarily on the basis of the values of the output air temperature as calculated; for comparable values of this parameter, the length of the exchanger has been chosen able to favor a planimetric arrangement such that the normal handling maneuvering of vehicles loading and unloading not to compromise and, in addition, the shadows of the wind to avoid. Along the south elevation, a non-rectilinear path has been necessary to follow in order to reach the desired length and an adequate "buffer zone" ensure in proximity of foundations, necessary for the excavation operations and piping installation. In order to obtain a uniform distribution of the heat

exchangers inside the market, suitable to guarantee a fair benefit to the different utilities, two exchangers every three box have been chosen to position. Therefore, a total of n. 44 heat exchangers will be put to work, each capable of providing an air flow equal to 0.393 m^3/s. Therefore, in one hour, air is fed into the market equal to 0.393x44x3600 = 62,251 m^3/h. The material chosen for the exchangers is aluminum which gives a good response in terms of transmittance.

3.1.2 Solar chimneys

The ventilated cooling is guaranteed from the extraction of the heated air through the "solar chimney", often also called "thermal chimney", which is a constructional element of a building structure used to induce natural ventilation inside buildings, through the convection; and this, to keep the internal temperature close to the optimum level of comfort. Numerous studies have focused on the various models of solar chimneys, which have been studied and analyzed in order to identify the most suitable solutions for different needs. The solar chimneys can be classified as follows: according to their location in relation to the building, solar chimneys close to the walls and solar chimneys positioned in the top of the construction (see LI A., et al, 2004); in accordance with their arrangement, vertical solar chimneys and solar chimneys positioned with different tilt angles; depending on the material used, cylindrical solar chimneys and cylindrical solar chimneys transparent coating (see JYOTIRMAY M., SANJAY M., 2006-1). Referring to these and other studies - on the angle of inclination to be assigned to a tilted solar chimney, in order to maximize the summer performance (see JYOTIRMAY M., SANJAY M., 2006-2) and the width of the cavity of solar chimneys to induce a natural ventilation (see GUOGHI G., 2006) - it was possible to choose the type of solar chimney in terms of positioning, tilt, geometry and materials of use, taking into account the constraints dictated by the geometrical shape and structure of the existing fruit and vegetable market.

The solar chimneys will be located at the existing coverage. The data shown in the graphs relating to the experiments described above were used for their sizing. In particular, considering the values of the air flow as a function of the ratio B/H and the length of the solar chimney, it is deduced that the higher efficiency is obtained for low ratios of B/H and for high values of the length L of the solar chimney . In particular, the optimal curve is obtained in correspondence with the value B / H = 0.1; then, starting from this value and by selecting a length of the solar chimney equal to L = 3.5 m, an air flow of 2, 5 Kg/s is guaranteed, and therefore of 9,000 Kg/h. By opting for a B = 0.35 m, a value of H = 3.50 m is the result, able to ensure the chosen ratio of 0.1. Moreover, having noted the advantage of appropriately tilt the solar chimney in order to maximize the heat captured as a result of solar radiation, the solar chimney tilt of 50° with respect to the vertical has been considered, corresponding to the more efficient inclination when referred to the latitude of 41°12' on the site of the fruit and vegetable market. The disposition in coverage of solar chimneys will occur in such a way as to ensure no overlap of their projections of shadows which would lead to a decrease of efficiency of the individual elements. Having defined an input area at the base of the chimney equal to 0.35 x 4.0 m^2 and following the report (A_{ru}/A_{re} = 0.6 to 1) which binds the entry area of the air flow with the exit area, an output area equal to 0.28 x 4 m2 has been defined and a distance of the top of the opening from the top of the chimney of 0.35 cm was

calculated, according to the relationship S_c-S_a = 0,1H. The structure of the solar chimney will be quadrangular and made of aluminum profiles, in order to impart a poor overload to the existing coverage. The facade exposed to the sun will be constituted by a laminated safety glass with each thickness of 4mm, and the remaining walls are suitably insulated with EPS of 7.5 cm and a layer of aluminum 10/10 mm, suitably black colored, to attract more sunlight; the outer coating is made of corrugated sheets standard.

To define the number of solar chimneys to be installed to allow an exchange of air sufficient to ensure the comfort conditions inside the confined environment the chimney must be sized to allow the expulsion of about 52,000 m^3 of air, having estimated 52,014 m^3 of the air volume enclosed by the covered market envelope, and wishing to ensure n=1 air changes per hour as required by reference legislation for the workplace. Because every single solar chimney, as mentioned earlier, is able to expel an air flow of 2.5 Kg/s, it follows that the volume of air extracted in one hour will be equal to 9,000 kg/h; and because 1 m^3 of air is equal to 1.293 Kg, then we will have approximately 6,960 m^3/h. N.12 solar chimneys have to be installed to ensure that a total air volume of 83,520 m^3 is expelled, also because a double-layered glass type "Optiwhite" of Pilkington from 4 + 4 mm, with a transmission equal to 0, 83 and a U = 4.7 W/m2 ° K, has been employed for safety reasons (see Picture 5).



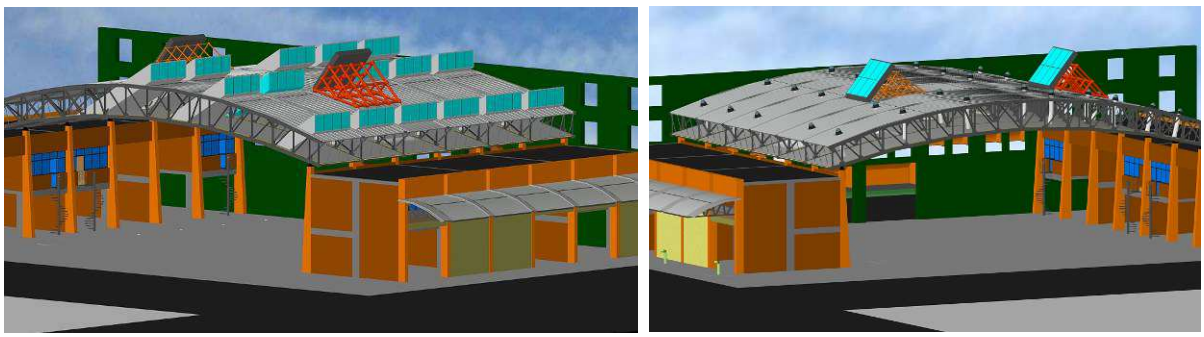
Picture 5: Exchangers-solar chimneys overall operating scheme

3.1 Other interventions in coverage

Other interventions concern the modification of the roof covering package, with the preparation of a second sealing layer on the roof and the shield of polycarbonate sheets: design choice obliged to remove the predominant cause of overheating inside the covered market. First, a static verification of the actual state of the building coverage was necessary to assess the ability to support different loads, and possibly additional, by the truss structure. The analysis of the loads imposed on the knots was priority; then, the stresses imposed on them were calculated with the use of SAP2000, through the modeling of the structure in knots and connecting rods. The verification phase of the tensile and compressive member resistances was then performed according to the UNI 10011. The alveolar polycarbonate has been set in correspondence with the lower currents of trusses and higher currents have been exploited as a base for supporting a second roof covering, consisting of material obviously different from that already present, of metallic type in pre-painted aluminum (thickness 0.7 mm) with draining joints. The requirements requested were, on the one hand, the ability to reflect solar radiation and, on the other, a lower weight, for not excessively

overloading the existing structure. In order to reduce the absorption of heat by the polycarbonate, it has been furthermore provided the laying of insulating panels type URSA DF 40. They are made of water-repellent glass wool felt treated with special thermosetting resins. The glass wool consists of long, thin, elastic glass fiber, devoid of material not fibrate and of high mechanical resistance. These properties are obtained thanks to the use of a vitrifiable mixture, consisting of selected and assayed (of inorganic nature) components and to a complex system of fusion and production of fibers. In addition, an insulator reflector in rolls, such as "Over-Foil 2L-2", will be prepared on the layer of glass wool. It has the peculiarity of having the aluminum faces covered with a thin polyethylene film; this film protects the aluminum from oxidation in any extreme situation, also in contact with the fresh concrete and rainwater. Under the aluminum layer there is a double bubble of inert air between the layers of polyethylene, coated on both faces. The composition of this multi-layer insulator gives excellent thermal insulation value and ensures the conditions of comfort, thanks to the reflective surfaces that cancel the effect of direct radiation.

Furthermore, two different solutions have been proposed to allow natural illumination of the buildings within the limits of the law (windowed area greater than 1/8 of the area of the floor; average daylight factor ≥ 2%), whereas the technical difficulty determined from having to interact with a truss roof structure: the creation of vertical shed oriented to the north, the construction of tubular skylights on the roof. The shed, oriented to the north, receive direct sunlight only for a few hours in the middle of summer, in the afternoon (from 4 pm onwards). The influence of solar irradiance and the resulting glare and heat, is minimal. This again means that, during the daytime working hours, the penetration of natural light takes place exclusively by diffusion, that creates additional advantages from the point of view of lighting (since shadows are avoided courses) and from that of a higher vertical luminance. The 81 shed (inclined at 45 ° respect to the vertical so as to improve the internal distribution of light, each with 5.61 m2 of windowed area) guarantee an $A_{f\ tot.}$ = 453.6 m^2 and the compliance with the law (see Picture 8a). The tubular skylights in the roof (consisting of a sensor device with optical RIR, reflected interactive refraction; consisting of a tubular duct super reflective and of a diffuser) are n.120 from φ 650 arranged in 6 rows by n.20. They ensure that the illuminated area is between 1% and 2% of the FLDM, and combine the advantage of transporting natural light within each individual spaces (see Picture 8b).



Picture 8: Overall view with chimneys and shed (right) and chimneys and solarspot (left)

4. Conclusion

The building under study proved to be particularly interesting for the evaluation of pathological phenomena as temperature and humidity discomfort, due to a behavior which is typically defined as "greenhouse effect": the microclimate of the confined environment is characterized by high values of temperature and humidity levels, moreover in the absence of a correct longitudinal and transverse ventilation, condition much more burdensome when the use of the building is considered.

Starting from the study of anomalies and pathologies induced, design solutions for technological, functional and energy retrofits were sought, in order to improve the conditions of the microclimate that ensures an environment of comfort to the users and to ensure at the same time air quality, appropriate to the preservation of fruit and vegetables. The study addressed, applied to an industrial building, has been a valuable and interesting opportunity to approach the theme of bioclimatic, as delicate as relevant. In fact, preferring a bioclimatic approach that would allow to overcome the usual use of air conditioning systems (low efficiency and high cost of management) and that resorted to passive cooling techniques, intervention solutions have been proposed able to ensure on the one hand the reduction the temperature inside the central gallery of the market in the summer period and the other an adequate air exchange. The interaction of the existing building with the external environment has been exploited to produce the necessary cooling inside the market, and a working model for "chimney effect" has been proposed, created by combining solar chimneys and ground-to-air heat exchangers, appropriately designed. In the design phase, it is of fundamental importance the careful and thorough evaluation of techniques and energy resources which have to be used in an appropriate manner with respect to the function to be performed by the building. The use and exploitation of the potential of the natural environment can return good results, even for the existing buildings, in terms of intervention effectiveness and energy saving, with the dual benefit of environmental protection and economic savings from natural air conditioning of closed spaces.

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Systematic Decision-Making and Design Processes in Social Housing Projects

Antti Kurvinen[1], Juhani Heljo[2], Jaakko Vihola[3], Kalle Kähkönen[4]

In this study the decision-making practices of social housing companies have been analysed. Contextually, the explored decision making addressed suburban residential area development. Methods and models for the design processes in projects which include retrofitting as well as infilling were developed. The aim of the research was to guide suburban housing towards more advantageous, comfortable and, especially, energy-efficient direction. Decision-making was analysed on the basis of a case project, comprising development of a full scale residential building block. Analyses were made by examining the design process of targets there and related decision-making. Decision-making was reviewed specifically from the viewpoint of social housing companies, but the results are broadly applicable to other decision-making environments as well.

Classification of the factors that influenced decision-making revealed that decision-making related to the suburban block development is a quite complicated totality. The most essential factors influencing practical decision-making were divided in six larger groups. Yet, the resulting entities appeared to be closely interconnected. From the analysis it appeared that despite to the global objectives energy efficiency is easily overshadowed in the overall decision making. To lead social housing towards sustainability, and reach national and international energy efficiency goals a new type of planning process management is needed. An essential task in this study was to include energy efficient decision making as a natural part in that process.

Advantageous, comfortable and energy-efficient housing requires that design and decision-making always consider the impacts of solutions and decisions on the whole and not focus too much on individual components. New operational modes are needed in suburban development and improvement of energy-efficiency, and some attitudes must also change. This paper analyses the decision-making in relation to the suburban residential area renovation and infill development, and presents a systematic decision-making process as the concrete model for making energy-efficient selections as part of planning. The suggested method allows systematic comparison of alternative solutions during the planning process and guides selection towards the solution providing best life-cycle economy.

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Keywords: decision-making, design process, life-cycle economy, social housing, energy efficiency

1. Introduction and Background

Typically, building block development projects are expected to achieve successfully many kinds of objectives. In building-level a set of main objectives can incorporate, for example, qualities for improved conditions (e.g. indoor climate), functionality and quality of the building as well as to increase building's energy-efficiency and the occupants' comfort of living. On regional level the building block-level objectives can encapsulate, for instance, particular measures to improve the image and appreciation of a whole residential area. It seems to be widely acknowledged that with the help of suburban development the attraction and desirability of suburban areas can be remarkably increased (Evans 2008; Heljo & Peuhkurinen 2004). The improved degree of attraction can also lead to increased demand for consumer services. Due to its many documented benefits, it can be considered that by putting effort on restoring neighbourhoods, the risk of suburban degeneration can be remarkably reduced (Evans 2008). Traditional examples of suburban development measures are urban infilling and quality improvement of existing buildings in the area (Heljo & Peuhkurinen 2004). Urban infill and higher density of suburban areas have also been found to be effective measures in decreasing the amount of greenhouse gas emissions (Evans 2008; Ewing et al. 2007). Additionally urban infill can seemingly in most cases be considered clearly more profitable from the perspective of overall economy than building completely new residential areas (Nykänen et al. 2012; Evans 2008). Nonetheless, it is not exceptional that the desired benefits of compact urban infill development may not be recognised in the public domain (Lewis & Baldassare 2010).

However, it cannot be taken for granted that the objectives set for building block development projects would automatically be achieved, but the successful execution of this kind of projects requires extensive expertise in many fields. Decision-making in relation to the design phase in building block development projects is challenging and a clear need exists for criteria and tools to support it. Achieving the desired result is more likely if decision-making can be based on research data instead of less factual assumptions. Nonetheless, practice has shown that due to the very limited time available for design, projects are normally able to come up with only a few design alternatives (Welle et al. 2011). In addition, decisions are made in a tight schedule and the comparison of the alternatives is often inadequate. Thus, all the essential impacts will not be discussed before making the final decision. The lack of sufficient indicators can be considered a partial reason to this. At present, it is very common that investment costs have a pronounced role in decision-making. Development of suburban social housing requires remarkable investments, and effective targeting of financial resources is in a prominent role when pursuing the set objectives. However, investment costs alone are not sufficient indicators for decision-making, and thus, their impact must not be emphasized too much. Well-balanced decision-making also requires other indicators, which should have an adequate weight on decisions. The objective of this paper is to provide information on decision-making and design processes in relation to suburban development. Useful methods and information on social housing companies' decision-making are presented for this purpose.

2. Research Objectives and Methods

In a recent study completed at Tampere University of Technology (TUT), the decision-making practices of social housing companies have been analysed. Contextually, the explored decision making addressed suburban residential area development. The aim of the research was to guide suburban housing towards more advantageous, comfortable and, especially, energy-efficient direction. Decision-making was analysed on the basis of a case project, comprising development of a full scale residential building block. Analyses were made by examining the design process of targets there and related decision-making. Decision-making was reviewed specifically from the viewpoint of social housing companies, but the results are broadly applicable to other decision-making environments as well. The research project covered also development of methods and models for the design processes in projects which include retrofitting as well as infilling.

Academic scholars and industry professionals were effectively linked together in the research effort behind this paper when the research team members' took also part in the real design process of the case area. This mode of action remarkably enhanced the information flow between research and practice, and can be considered as an effective method in research projects where sufficient amount of resources available.

The already existing methods (e.g. Aalto & Heljo 1984; Abel 2010) and calculation models formed an important point of departure. These methods and models were not only utilized but also developed further within the main research effort. This kind of constructive research was seen as a chance to produce novel decision-making method for the needs of suburban development projects and programmes.

The project had the following five main tasks and objectives:

1. **Analysis and development of the decision-making for suburban social housing projects**

   The objectives of this task were to study practices of social housing companies' decision-making in suburban development projects, and on the basis of made findings to propose potential ways to develop the decision-making towards more favourable direction.

2. **Energy-efficiency and environmental impacts as part of decision-making**

   The objectives of this task were to study how energy consumption and unfavourable environmental impacts can be reduced, and find ways to integrate this to the design process covering both individual buildings and entire suburban blocks.

3. **Life-cycle economy as a criterion**

   The objectives of this task were to find out how life-cycle economy should be taken into account in social housing related suburban development projects covering both individual buildings and entire suburban blocks. In addition to life-cycle costs also value factors were supposed to be covered.

4. **Utilization of building information models to support decision-making**

   The objectives of this task were to study how building information models (BIM) could be utilized in order to develop the design process of suburban social housing.

5. **Comfort of living and airtightness**

   The objectives of this task were to study factors impacting on suburban comfort of living also including research on ways to measure internal airtightness of buildings', and to study the significance of internal airtightness for the comfort of living.

To achieve the objectives of the first task research team members' took part in the design process of the case area and analysed the decision-making within those processes. On the basis of these analyses, a list of factors impacting on the decision-making in practice was compiled. The list was further processed into a form of mind maps for illustrate the relations between different factors. This analysis gave a good basis for developing further the decision-making process.

In the second task, mainly based on the earlier studies executed at TUT, but also on the basis of literature an illustrative profitability model for energy saving measures was presented. The model makes it possible to study impacts of different measures on economy, energy-efficiency and greenhouse gas emissions. It is as well applicable for individual buildings as for larger block-level studies. The overall decision-making process presented in this paper closely integrates the profitability model in the design process.

A starting point for the studies of the third tasks was the results of earlier research and development at TUT. Earlier developed calculation models were utilized and further developed to fulfil the requirements of suburban development projects. In addition to calculating life-cycle costs of new buildings this also requires being able to take into account special features of renovations, demolition, and infill development. Value factors have to be considered as well. The development was accomplished by case analyses and literature.

In the fourth task possibilities of BIM were studied. Building information models were utilized in the architectural design of the case project, which offered great opportunities for the research. The most importantly, the applicability of BIMs created by the case architect was studied for the needs of energy simulations. The expertise of TUT's Virtual Building Laboratory was also exploited in this task.

As energy analyses and defining energy saving potentials were in a very prominent role in this study, energy calculations were made using two different methods. One of them was a straighforward method to calculate the toal sum of monthly used energy. This method has been widely used in Finland during the recent years. It is also included in the Finnish building code. These energy calculations were made using software called DOF-Energy (ver. 2.0.11). The other used method was more sophisticated BIM-based energy simulations. Energy simulations were made using software called IDA-ICE (ver. 4.2) by utilizing the architectural BIMs prepared for the case project.

As a starting point for the studies of the fifth task, the state of comfort of living in the case project was studied with the help of occupant survey. The results of the survey indicate that the smells and noises from neighbour flats were common problems of social housing. It was concluded that a partial reason behind the situation is highly likely the inadequate internal airtightness between apartments. Because of this a clear need was identified for finding a method to measure internal airtightness. The development of an appropriate method was started on the basis of measuring plan drawn up by the research group on building physics at TUT.

3. Case Project Description

The case project behind the research comprised development of a multiform social housing block in Tampere Finland. The project included both infill development and renovation of the existing buildings. VTS Homes, which is local social housing company in Tampere, owns all the buildings in the block. The development in the area was planned to be executed in two phases. The first phase was executed during the research project, and the second phase is to be executed after research results and new methods from the first phase are already available and can be applied. In this way, the implementation of new methods is highly effective. An illustration of the case project can be found in Figure 1.

In the first phase of the development, five existing slab form blocks were retrofitted close to the quality level of new buildings. New apartments were built in the first floors, which were earlier mostly used as storerooms. In addition to renovation, the social housing area was also developed by the means of infilling. An illustration of the case project can be found in Figure 1. The rectangles marked with “wide downward diagonal” fill are new point access blocks and an additional floor on top of a building is marked with “dashed horizontal” fill. The land use was also made more effective by building three new row houses on the same lot. These are marked “large grid” fill in Figure 1.

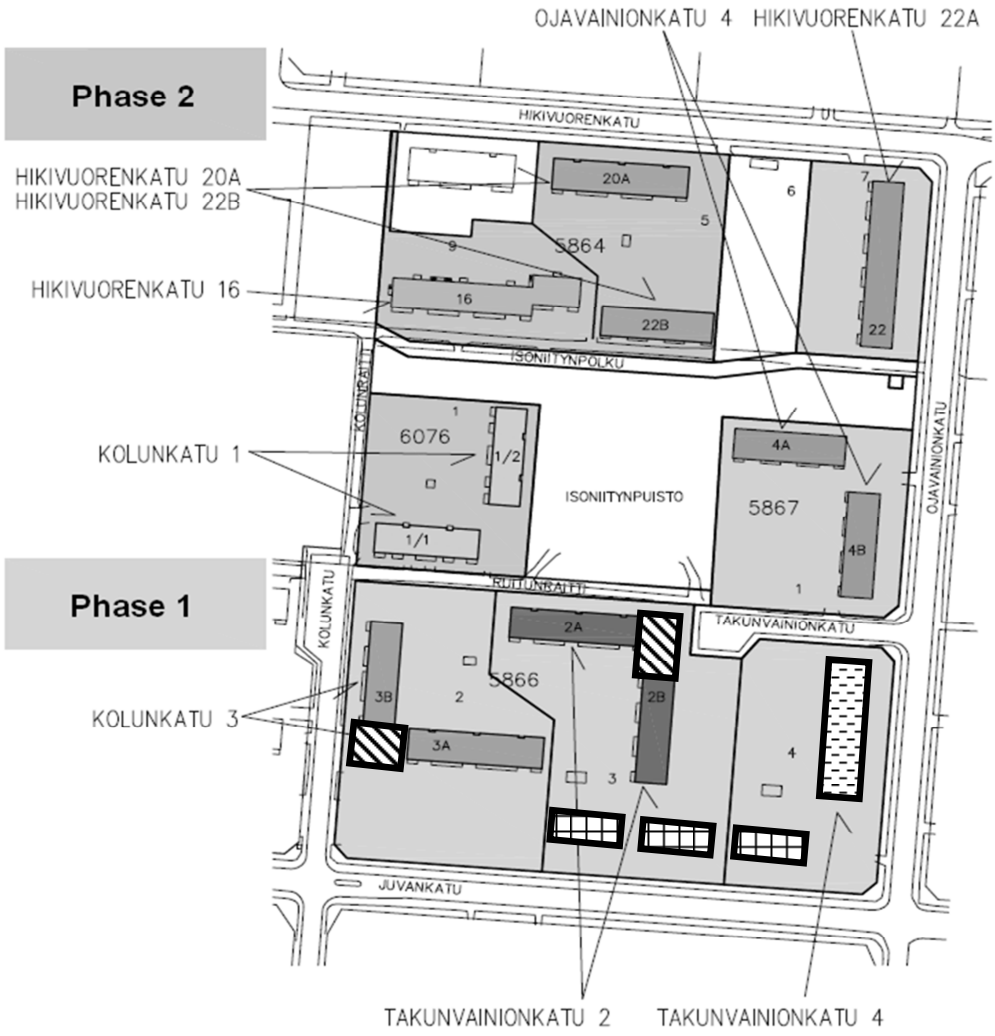

Figure 1: The case project included housing block development in Tampere Finland.

Partnering model of contracting formed the basis of construction works carried outin the. This was a very important factor in enhancing the flow of information between project partners. This kind of cooperation forms are steadily becoming more popular in Finland because of the new kinds of needs arising from the development of residential areas. This can be considered as a very desirable trend, for example, due to its favourable impacts on information flow. To share and receive more reliable information in earlier stages of project life-cycle is very welcome because the decisions defining the big part of final results and costs are already made in that stage. Thus, it is highly likely that utilization of partnering model creates better conditions for decision-making.

Partnering model can be considered quite similar to project alliances, which also emphasize trust between parties, engagement to objectives and cooperation. However, there are also differences between these forms of cooperation like, for instance, that partnering model is juridically based on traditional procurement methods, such as lump sum contract and design and construct contract (Yeung et al. 2007; Ross 2004). However, when utilizing partnering model the project partners usually agree on the common principles as a first step. Thoses are to be obeyed during the project, but this agreement is not a legally binding document. In

project alliances juridically binding contracts clearly differ from the traditional ones. (Lahdenperä 2009.)

4. Results of the Project: New Models to Facilitate Decision-Making

Classification of the factors that influenced decision-making revealed that decision-making related to the suburban block renovation is a quite complicated whole, where a clear-cut classification of related factors poses a great challenge. The most essential factors influencing practical decision-making were divided in six larger groups. A rough categorization of the factors was discussed in the design meetings (Figure 2). Yet, the resulting entities were not independent, separate entities, but appeared to be closely interconnected. Thus, for example, it is not possible to treat energy-efficiency in decision-making as a separate entity, but it has to be considered as part of a bigger entity. On the basis of the rough categorization a guideline framework for the decision-making of social housing companies was developed (Figure 3). The framework is not all-embracing, but can be utilized as a checklist in decision-making.

With the present energy prices, the share of energy costs is 10–20% of the rent in Finland. If the energy prices rise, energy costs' share of rents increases as does the pressure to raise rents. Although energy costs constitute a significant expense item from the viewpoint of life-cycle economy, and future pressures to raise rents can be restrained by improving energy efficiency, it would appear that energy efficiency nevertheless easily becomes overshadowed by other issues in planning. Thus, a new type of planning process management will be needed to reach national and international energy-efficiency goals.

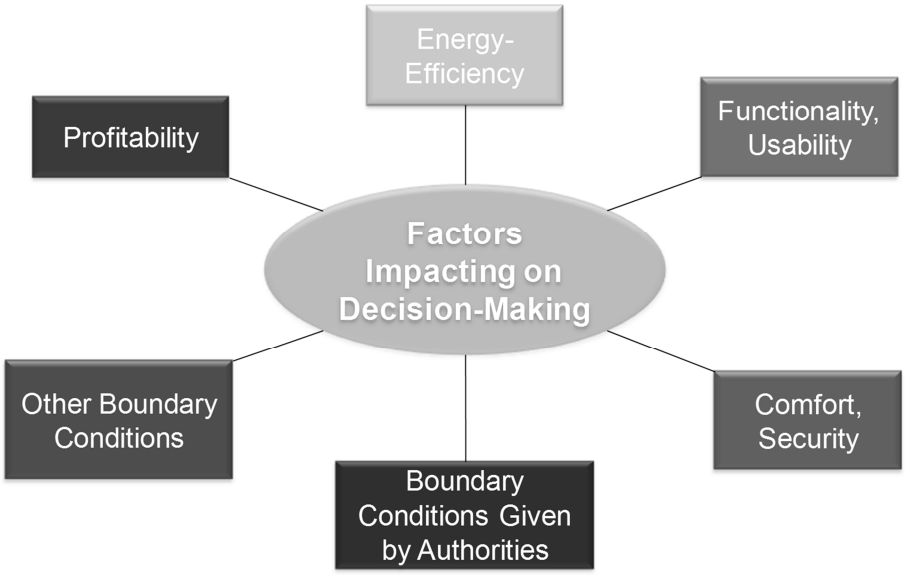

Figure 2: A categorization of impacting factors that were discussed in the design meetings. (Kurvinen & al. 2012a)

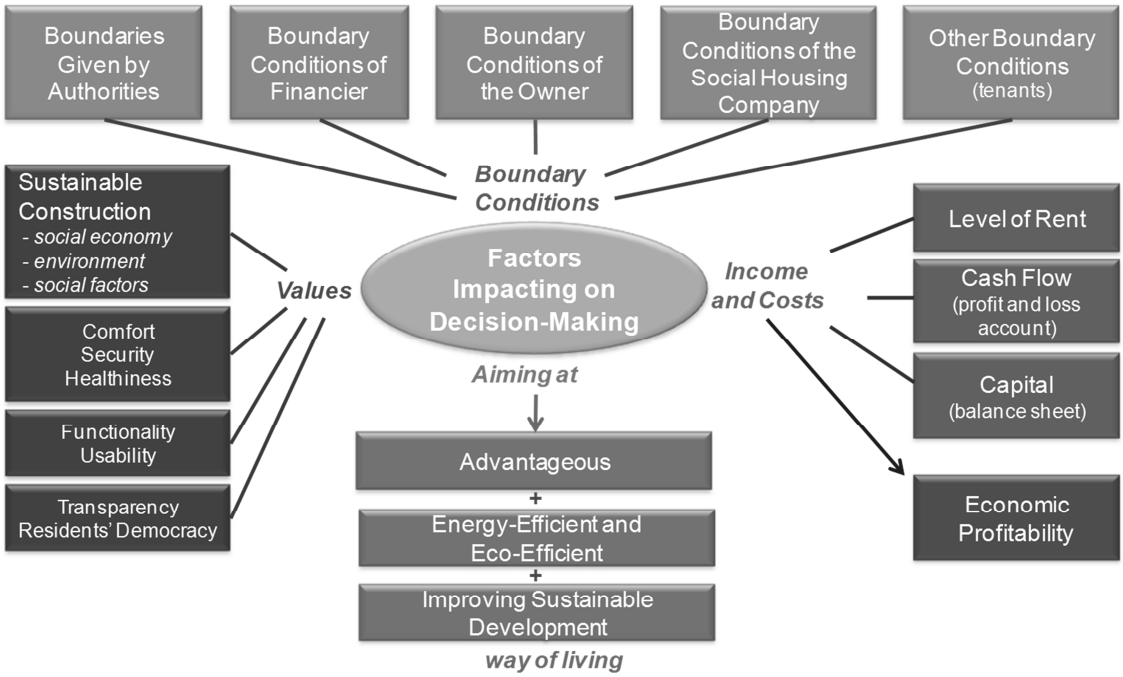

Figure 3: A framework for the decision-making of social housing companies (Kurvinen & al. 2012a)

A systematic decision-making process is suggested as the concrete model for making energy-efficient selections as a part of planning process. The suggested method allows a systematic comparison of alternative solutions during the planning process and guides selection towards the solution that is providing best life-cycle economy. Life-cycle economy refers to the relationship between life-time values and costs. The suggested process divides into five stages: definition of factors influencing a project's basic data and selections, planning of the basic solution, selection of system alternatives on the system level, selection of energy-conservation measures on the structural and equipment level (profitability model for energy-conservation measures) and comparison of entities and decision-making. The process chart has been shown as a whole in Annex A.

The development work of stage four of the suggested decision-making process (selection of energy-conservation measures on the structural and equipment level) was of high importance in this project. The profitability model for energy-conservation measures was developed as a tool to support this phase. It allows a graphic comparison of the profitability of energy-conservation measures with different design solutions. The model can be used to determine the measures' impacts on economy, energy consumption and greenhouse gas emissions. The energy-conservation measures of a comprehensive solution can be chosen purely on the basis of economic return requirement or value factors can also be considered. The examination may be expanded from the building level to block level which allows controlling a bigger entity at a time and targeting available financial resources to it. The profitability model enables choosing sensible measures for planning solutions which, again, allows comparison of comprehensive solutions based on life-cycle economy and subsequent selection of the most favourable alternative for implementation. An example of output when profitability model is utilized on block-level is presented in Annex B.

The completed study shows that the profitability of energy-conservation measures is higher in renovation than in new building construction but only under certain conditions. Typically, in a building renovation project the basic level of thermal insulation is significantly lower than in new construction. Such conditions result in a situation where a decision has been made to implement certain renovations in any case. The definition of the basic renovation solution essentially impacts the profitability assessments of energy-conservation measures of renovation projects since they are based on the additional costs from energy-conservation measures and exclude the cost of the chosen basic solution. It is also good to remember that determining the energy savings resulting from measures implemented and the related extra costs is always subject to considerable uncertainty.

It seems that social housing companies are more interested to use the life-cycle cost analysis as a basis of their decision making than is the case today generally in the construction sector. However, it still seems difficult to prepare reliable life-cycle cost analyses for social housing companies –further development is required in that area. An effort must be made to increase understanding of systematic renovation and suburban development further, and tools are needed to support decisions, including calculation models suited for life-cycle cost analyses of buildings applicable to area development projects involving both renovation and new construction. The analysis models which are available at the moment for investment calculations do not appear to be as such suitable for a kind of analyses where the discussed viewpoints are present in a well-balanced manner. Presently, construction costs are emphasised in selections which means that measures that are profitable from the life-cycle economic viewpoint may not be taken. Since rental payments are the key source of revenue for rental housing companies, the impact of measures on the level of rents would appear to outweigh life-cycle costs in decision-making.

It is sometimes necessary to consider the demolition of old buildings as an alternative in connection with life-cycle cost analyses of area development projects. The completed examinations show that in some cases it may be more economical to tear down an old building and build a new one in its stead. Yet, there are no universal truths concerning the profitability of demolishing buildings; each case must be examined separately. Moreover, it must be taken into account that examinations based solely on monetary value may differ from those that also include the ecological viewpoint.

Only relatively limited amount of information about the effects of different solutions is available when decisions that lock costs have to be made. This seems to be a problem of decision-making in the construction and renovation of suburban social-housing blocks. BIM-based design and data transfer could help to solve this problem by producing sufficintlyreliable and representative data in support of the design process at an earlier phase than before. This requires that the various project parties have enough capabilities to exploit information models and BIM-based data transfer. At present, BIM know-how is still quite inadequate in general.

One aim of the project was to guide housing in a more comfortable direction. The conducted resident satisfaction survey showed that smells and sounds caused by neighbours are often considered a problem. The internal airtightness of buildings is at least a partial reason for the

transmission of smells and sounds, and it would appear that its impact is not emphasised enough today. Airtightness may be a more complex issue than assumed, and its practical implications are perhaps not understood well enough yet. In addition to its impact on comfort, it is also significant for energy economy.

5. Conclusions

Characteristics of energy efficiency in social housing development projects were the main focus of the research effort behind this paper was, The conducted examinations show that certain energy-conservation measures can be profitable when implemented in connection with renovations, but the achievable savings are rather small. Thus, energy efficiency is hardly improved and the savings targets will not be reached if the economic return requirement is set too high. The most effective measures, such as ventilation heat recovery and adding extra insulation to walls, are often omitted in renovation. Although energy efficiency is much talked about, it is only a part of the multiform problem field of decision-making in suburban development.

Advantageous, comfortable and energy-efficient social housing requires that design and decision-making always consider the impacts of solutions and decisions asholistically as possible and do not fall into the trap of local optimization i.e. putting focus too much on individual components. New operational modes are needed in suburban development and improvement of energy efficiency, and some attitudes must also change. The study presented in this paper has been one step towards that direction, and the authors believe that the generated models are useful when put to practice. Although, the research context have been that of social housing the developed methods can be considered to be widely applicable also in other decision-making environments.

There are clear future research needs for developing the pre-design phase of suburban development. More attention should be put in the pre-design phase since decisions that lock costs are made in a quite early phase. Design processes are complex multi-criteria problems and due to the limited time available the pre-design effort is often inadequate despite of its high its significance. For improving the pre-design process the use of building information models (BIMs) could be beneficial. Such models need to be integrated to different design tasks and cost analysis. A building pre-design tool that enables effective multi-criteria optimization and facilitates decision-making before construction phase could be an object for further studies.

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Annex A

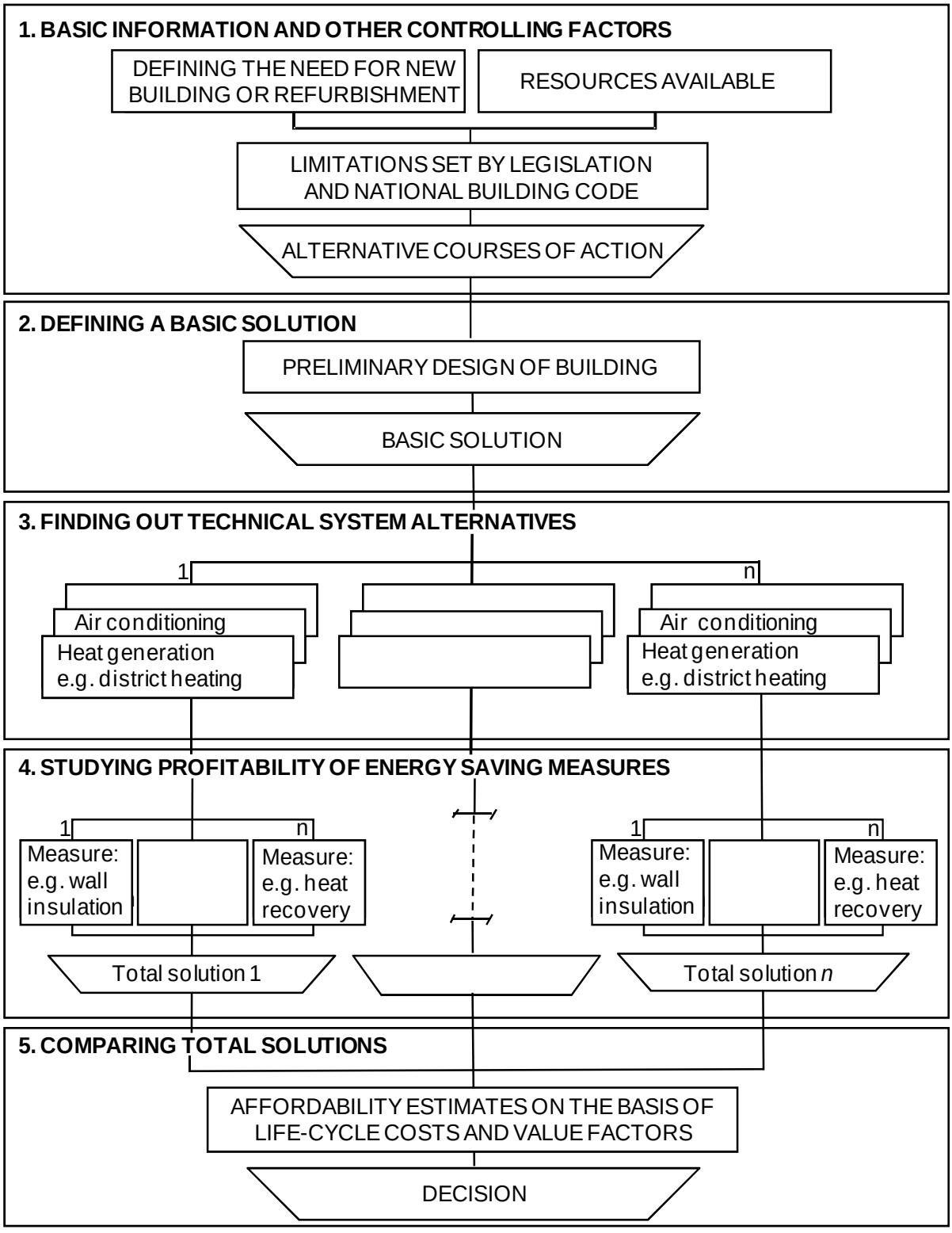

Figure A: Phases of systematic decision-making (Kurvinen et al. 2012b)

Annex B

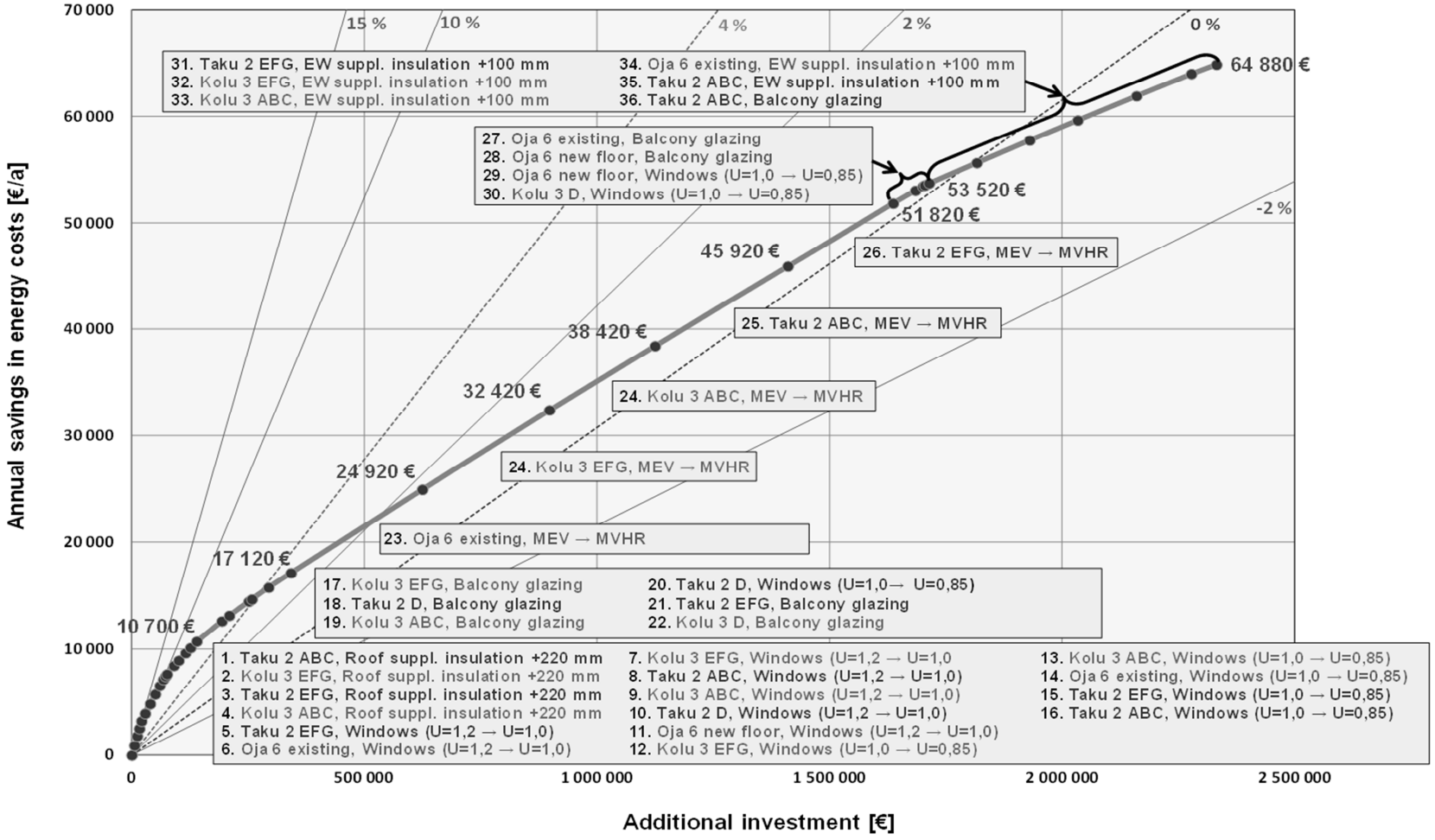

Figure B: Profitability model, impacts and profitability of energy saving measures in block-level (Kurvinen et al. 2012a).

“Piloting the Common Metrics”, a research project of the Sustainable Building Alliance

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Abstract

For new buildings the consumption of energy in a 50-year period is as much as the impact of the manufacturing and construction processes, hence assessment and comparison methodologies encompassing the whole building life-cycle are required. As studies about the environmental performance of buildings also address issues related to waste, water or other resources and emissions, Life Cycle Assessment (LCA) has become a recognized assessment method.

LCA is being integrated in building certification schemes worldwide for assessing the life-cycle environmental impacts. Several standards have been developed in Europe and worldwide, but finding agreement on life cycle stages, contributors and indicators is necessary for comparing and harmonizing obtained LCA results. The main goal of the ‘SBA Common Metrics’ project is reaching this agreement.

In particular, the project aims at setting up a common approach for calculating a set of indicators according to common rules, parameters, elements, building phases and local features. This approach should be integrated in the existing certification schemes to promote comparability worldwide.

During 2009 and 2010, the ‘Indicators Core Group’ of the Sustainable Building Alliance (SBA) selected a set of environmental indicators, the ‘SBA Common Metrics’, and developed a ‘Framework for Common Metrics’. The document provides a method for calculating, using and communicating the chosen indicators: global warming potential, use of non-renewable primary energy, water use, solid waste and indoor environment quality, in compliance with the CEN TC 350 standardization work.

In 2011, The ‘Framework for Common Metrics’ was pilot-tested in projects involving real buildings to analyse its feasibility concerning data availability, calculation, comparability of results and integration in the existing rating schemes (HANS et al, SBA report phase 1

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(2012)). The pilot-test indicated that despite some differences due to national specifics, the integration of these SBA metrics within (existing) building assessment schemes(BREEAM, HQE, DGNB, …) will be possible, although this will occur according to the 'ambition level' of each country.

Finally, the consistency and comparability of the 'Common Metrics' which was studied in 2012, will, together with the pilot-test results, enable the SB Alliance to improve the 'Framework for Common Metrics'. This paper presents the research results.

Keywords: Building life cycle assessment, Sustainable buildings, building performance indicators, green building, harmonisation.

1. Introduction

The construction sector is now irreversibly turned towards design, construction, maintenance and renovation of sustainable buildings. Thus, the LCA (Life Cycle Assessment) methodology has been recognized as a systematic tool for assessing the environmental performance of buildings. In this context, this project is aimed at ensuring the operational harmonization and comparability of current LCA methodology for assessing the environmental performance of buildings.

The study of the environmental performance of buildings involves analysis in terms of the following scales:

- Temporal scale, as the impacts of the buildings are now studied along its full life cycle;

- Spatial scale, as the building is taken into account as a part of the neighborhood and of the city, by analyzing the transport induced during the in-use phase, or the local energy production or storage;

- Complexity scale, as the environmental assessment is a multi-criteria analysis, taking into account energy (non renewable, renewable, etc.), waste (hazardous, non hazardous, inert, etc.), resources, air pollution, global warming potential, water consumption. Furthermore, it is necessary to assess these impacts regarding the functionality provided by different building contributors or specific requirements (comfort, safety, accessibility etc.).

Under these perspectives, LCA methodology is used increasingly in certification schemes all around the world in order to account for the overall impacts of the different stages of the building lifecycle. Recent standards (EN 15978), methodologies or guidelines (such as EeBGuide (2012)) have been developed in several European countries and at an international level. However, there is still a strong need to reach agreement on processes or elements included within the system boundaries (life cycle stages, contributors considered, etc.). All these items form "the engine" of this project.

2. Work description

The goal of this project is not to develop a single new assessment system, but to cooperate for the development of a group of indicators that would be calculated in the same manner and considering the same parameters and life cycle stages. This common calculation approach should be integrated in the existing certification schemes for the promotion of comparability worldwide.

During 2009 and 2010, the SBA working group “Indicators Core Group” (composed of BRE, CSTB, DGNB, QUALITEL and VTT) prepared a draft Framework for Common Metrics to be calculated, used and communicated in a common way for the assessment of buildings.

As a first stage, the Common Metrics draft currently includes the following indicators (Figure 1), in compliance with CEN TC 350 standardization work:

- Global Warming Potential (GWP)
- Use of non-renewable primary energy
- Water use
- Solid waste production
- Indoor environment quality (IEQ) (currently considering thermal comfort, indoor air CO_2 concentration and formaldehyde concentration)



Figure 1: The six indicators developed in the Framework for Common Metrics (2010)

Since the certification systems imply different calculation and assessment methods, a distinction between the LCA-oriented indicators (GWP, energy, water and waste) and the indoor environment indicators was made.

In 2011 the Framework for Common Metrics was pilot-tested within existing assessment systems and in real projects, in order to analyze its feasibility consistency and comparability.

Among other aspects the feasibility analysis consisted of checking the existence of efficient and practical tools, methodologies as well as LCA data, such as provided via environmental product declarations (EPD), which offer necessary input data on material level for the calculation of indicators for all the life-cycle stages of buildings. Practical tests and modeling of the SBA common metrics framework were also performed by each member country to illustrate operational feasibility and applicability (Figure2).



Figure 2: Some of the projects modelled in the SBA project

The consistency and comparability analysis focused on the assessment of LCA results of the previously mentioned practical tests and the evaluation of minimum requirements for LCA modeling. The analysis identified differences in existing calculations and potential improvements to be made, for example with regard to the type of environmental data such as the type of EPD (cradle to gate and cradle to grave, different standard…), the contributors that are taken into account in the Building LCA calculation for each country (for instance, availability of data for equipment), the type of operational energy related services available for the modeling, etc.

In 2012, the Framework for Common Metrics was also checked in greater depth on a single building to clearly identify the necessary improvements in terms of the contributors' scope and the service life data of the building elements.

As a result, a document of recommendations will be written for an improved version of the SBA common metrics framework to move forward towards compliant and adapted certification systems for buildings.

3. Results

3.1 Feasibility analysis

To reach the goal of implementation within existing building certification systems, the SBA Framework for Common Metrics had to be first evaluated with regard to feasibility aspects. A clear understanding of the indicators defined and a thorough investigation of the framework by each partner formed the basis for analysis. The focus was set on the complexity of the framework itself, and the LCA-oriented approach for environmental indicators as well as on the diversity of methods, data and tools linked to existing certification schemes among the countries involved.

Consequently, it was found to be necessary to distinguish between “technical” feasibility and “operational” feasibility:

- Technical feasibility indicates the availability of tools, data and methodologies (scenarios, etc.) to assess the impact of the contributor on the indicators either on the market or in the R&D sectors;

- Operational feasibility indicates how the impact of the contributor on the indicators is taken into account in the existing certification schemes (as DGNB, HQE, LEED, BREEAM, Perfil de Calidad, PromisE, SBToolC, etc.). The goal was to analyze the current capability of calculating the indicators in the existing schemes, (tools, data, methodology and scenarios used).

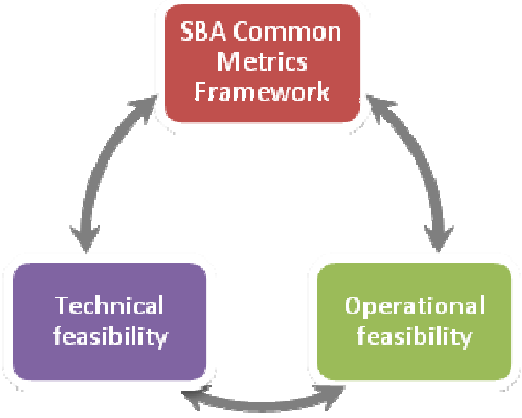

Figure 3: Establishment of the SBA metrics framework on the basis of metrics in current certification schemes (operational feasibility) potential metrics according to availability of data and tools (technical feasibility)

3.1.1 Methodology

The group decided to work through detailed feasibility tables, to be completed by each member. The principles and structure of the tables were defined collectively.

Three feasibility tables were developed:

- The first table aiming at showing the availability of data, tools and methodologies for calculating the LCA-related indicators for each building contributor, as well as their consideration in each rating scheme, including additional information;

- The second one aiming at specifying the availability of environmental data (EPD) in the different life-cycle stages of buildings and for each contributor and metric, as well as their involvement in each rating scheme.

- The last one explaining in qualitative terms, but as precisely as possible, the availability of data and tools regarding the IEQ indicators and their inclusion in each certification scheme.

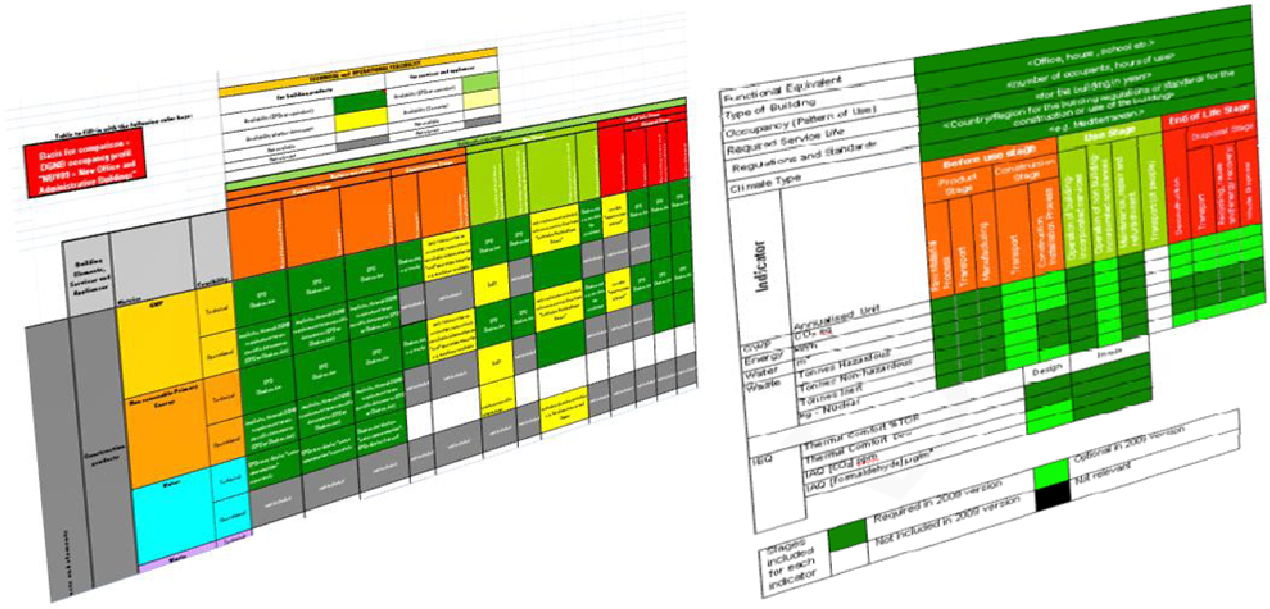

Figure 4: Overview of the two first feasibility tables

3.1.2 Results

The detailed feasibility tables allowed the definition of a common list of building contributors; this was a key aspect for the comparability of the results. Each participating country provided

its own national tables and feasibility analysis corresponding to its rating scheme, together with data sources and data availability details.

For easier reading, the main information was gathered in summary tables, as shown in Figure 5. The detailed results are available in the report (HANS et al, SBA report phase 1,(2012)).

	Feasibility based on availability			Conditions for a harmonized practice of SBA Common Metrics	
	Methods availability	Data availability	Tools availability	Conditions and time needed for an optimal feasibility in certification schemes	How SBA framework for Common Metrics needs to evolve?
Contributors for the assessment of environmental impacts (GHG, energy, water, waste)					
Building products / elements (LCA)					
Products (mandatory)	Yes, as LCA is a recognized method (basis: International standard ISO 14040 & 14044) to quantify environmental impacts of building products (basis: European standard EN 15804), systems and buildings (basis: European standard EN 15978)	Data with good quality & coverage available on building products, structural parts or systems for all life cycle stages Increasing availability of EPDs (approx. 200 up to now) and a national data base on construction products available (Ökobau.dat) "DGNB navigator" as database on building products which offers free available information (e.g. also for harmful substances within products Producer specific information	Yes, e.g. "GaBi Software & databases" for conducting the LCA of building products or equipment e.g. "GaBi Build-It" and "LEGEP" for conducting the LCA of buildings by using available data e.g. "simple user-specific Excel-tools" implementing calculation rules acc. to DGNB	DGNB system should expand their indicators mainly for "waste and water" to be consistent with SBA Metrics More input data for the assessment of indicators "waste" & "water" have to be made available, e.g. through increasing the number of EPDs, where such information is given DGNB system should be expanded for the system boundaries (e.g. transport product to construction side)	No evolvement of SBA framework necessary for the implementation of SBA Common Metrics within Germany for the environmental part of sustainability.
Products (optional)					Suggestion to include decorative wall finishes/coatings, doors, heating/cooling systems within mandatory elements
Equipment (optional)					
Aggregation at the building scale	Yes, pre-defined calculation rules available incl. the use of security factors for neglecting specific building parts (e.g. only boiler is accounted for heating HVAC)				
Energy services					
Main building-related appliances	National calculation method: Energieeinsparverordnung (EnEV)	Data available through ENEV calculations, technical data on heating, cooling systems etc	Yes, e.g. "LEGEP", "ennovatis ENEV" , TRNSYS, ...		
Other building-related appliances	Not available within DGNB system				
Non-building related appliances	Not available within DGNB system	Sporadic EPDs			
Water services					
Building related appliances		Increasing availability of EPDs (approx. 200 up to now) Producer-specific data available		DGNB system should be adapted to include operational and energy related information about water services	
Non-building related appliances					
Assessment of Indoor Environment Quality (design and operation)					
Thermal comfort	building simulation (According to EN 15251, EN 12831,ISO 13792, ISO 13791) Heiz-/ Kühllastberechnung (DIN EN 12831) VDI 2078	Not applicable	Yes, Building Simulation Tools, e.g. Trnsys EnergyPlus Excel - Tools	DGNB is more detailed	Adapt requirements from DGNB
CO_2 concentration	EN 15242 available	Not applicable	Yes, Building Simulation Tools, e.g. TrnFlow	DGNB requirements similar to SBA	
Formaldehyde concentration	Standardized Measurements during operation	Increasing availability of EPDs (approx. 200 up to now) indicating if products contain TVOC or formaldehyde		DGNB requirements equal to SBA	

Figure 5: Feasibility summary results, illustrated for DGNB scheme, for LCA based indicators (GWP, primary energy, water and waste) and IEQ indicators

Relevant differences, for each contributor, in the availability of methods, data, tools and their consideration in the certification schemes have been identified as being due to different conventions. However harmonization of these differences will be possible. The differences highlight the importance of sharing EPD based on a common standard using a methodology at an international level and encompassing the same life cycle stages. On very practical aspects, they also display the need to use a common way to describe buildings and extract the quantity take off(?). The degree of harmonization will be clearly associated to the concept of level of ambition in the number of common contributors taken into account in the framework. For example, it is known that equipment impacts on the SBA metrics, but it is

difficult to have access to EPD for equipment in each country and so initiallythe common metrics have to be envisaged without these types of construction products.

3.2 Practical LCA modeling to assess the SBA metrics

In parallel to the technical and operational feasibility work, each partner analyzed at least one building based on the SBA common metrics and with regard to LCA-oriented indicators. The selected buildings met the current standards of sustainable construction, as defined by respective existing national building certification schemes. The objective was to study the applicability of SBA Common Metrics to real buildings, using available input data in each participating country.

The applicability of the calculation rules of the SBA framework was achieved for some indicators (e.g. energy use) but varied in a relevant manner for other indicators (e.g. water use, waste). The modelling exercise also displayed quantitative results for indicators which enabled the estimation of the deviations due to different modeling conventions.

3.2.1 Illustration with the French case study

The general approach for LCA modelling is illustrated by the example of the French case study in the following paragraphs.

In total, 74 real buildings were tested in practical application and calculation of SBA indicators, comparing their results and framework to the practical application of “HQE Performance” Indicators in France. Indeed, 74 buildings (commercial, offices, residential, etc.) were tested using the HQE Performance framework and ELODIE LCA calculation tool, with the help of the HQE certification bodies (QUALITEL subsidiaries and Certivéa) from the period of January to July 2011.

Ultimately, 8 of these buildings were equally modelled and tested under SBA framework which allowed the comparison of the results obtained when considering HQE Performance indicators (that cover a larger perimeter of contributors than SBA), and when considering the SBA indicators with and without its optional contributors (contributors = elements that enter in the calculation process of the indicator).

Today, the integration of life-cycle analysis processes in the building certification procedures may currently present some operational difficulties. This highlighted the importance of the Building Modelling stage in the SBA pilot test: the modelling of real buildings operated by real HQE certified clients, by the certification bodies (CERQUAL–QUALITEL) and by research centre (CSTB) identified difficulties and/or progress already achieved in France in terms of:

- Result of the training of professionals in LCA tools, such as ELODIE®, including the appropriation and generalization of its use by the market stakeholders.

- Data Input process: Recovery of data about products' quantities and products' environmental impacts (EPD, etc.), as well as the identification of the potential difficulties in terms of description and modelling of Buildings;

- Identification of the time needed for data gathering, organization and analysis of that data (regarding the eventual needs of additional information and time, when compared to market normal practice);

- Identification of the necessary procedures and time for the control of the modelled building projects and of the accuracy of the results obtained for each indicator calculated (for third-party certification purposes).

To promote the national and international convergence of approaches and in order to test the integration of the SBA Indicators in the French HQE certification reference frameworks, the French modelling of real buildings was voluntarily done looking at 3 different perimeters of contributors, namely:

- HQE Performance, with all its environmental indicators (17) and its larger amount of contributors (elements taken into account in the calculation of each indicator);

- SB Alliance Indicators, including in the calculation all the mandatory and optional contributors, as detailed in the SBA Indicators Framework (2009);

- SB Alliance Indicators, including only the mandatory elements, and excluding all the optional contributors, which consequently has a specific impact in the accuracy of the values obtained.

The Key Elements for the Modelling process

The modelling process necessarily required the life-cycle analysis of each pilot building, for each of the following stages, referred in the SB Alliance and HQE Performance frameworks:

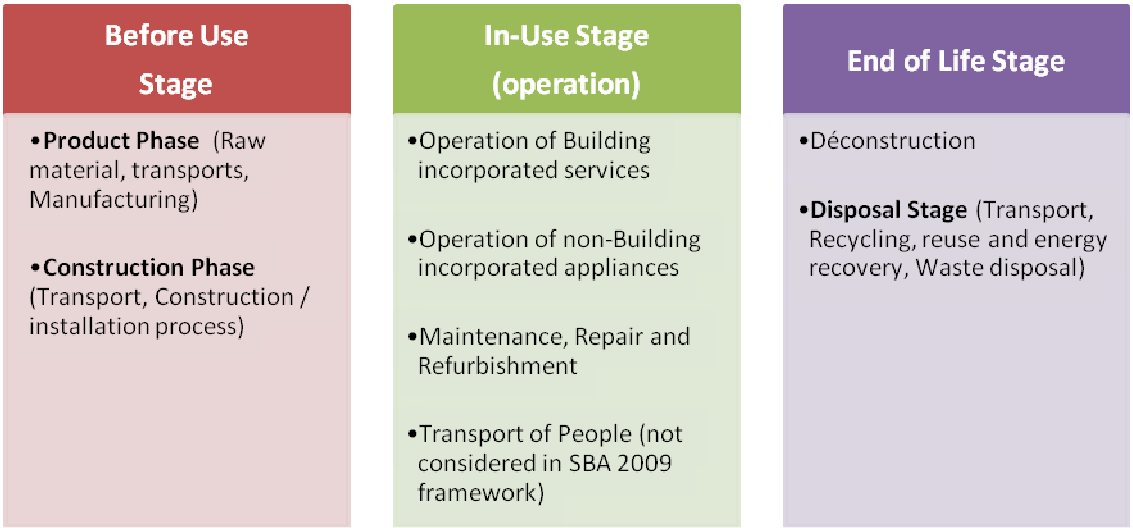

Figure 6: Stages of the building life cycle for the SBA evaluation scheme contributors

By gathering the necessary elements (written pieces of the detailed project, thermal and energy study, drawings, etc.) and by using a life-cycle analysis tool (ELODIE), the detailed modelling of the building was possible, as well as the analysis of its impact regarding each of the indicators.

The main guiding aspects were the following:

- Choice of the estimated service life: 50 or 100 years.
- Building Modelling and Environmental impact analyses done with ELODIE®, which is a software tool, developed by CSTB that allows the calculation of the environmental performance of a building project. This tool is connected to the French database INIES, containing construction products EPD. ELODIE was used by the HQE certification bodies for the HQE Performance and SB Alliance pilot tests.

3.2.2 Case studies results

The aim of this paper is to illustrate the process and the methodology, as well as the results in terms of the decision to build up a common framework of metrics, although the results in terms of the LCA calculation cannot be described. The detailed results are available on the SBA report.

Table 1 below shows the results obtained when calculating the **SBA indicators**, with its perimeter of **mandatory and optional** contributors.

It is interesting to note that Primary non-renewable energy consumption 'at Product stage' consumes 38.2 kWh_{ep}/m^2.year which corresponds to almost 35% of the total non-renewable primary energy consumed during all the life cycle of the building.

Also note that the construction stage is rather negligible but, considering the general absence of data about this building stage and taking into account that some parameters were not filled in the modelling tool, it is hard to appreciate the impact at this stage.

Table 1: Calculation of SBA indicators, with mandatory and optional contributors

Environmental Impacts Summary Table			ALL life-cycle and ALL Modules			ALL Life-cycle : module **COMPONENTS** (products and materials)			ALL Life-cycle : module **ENERGY**			ALL Life-cycle : module **WATER**			ALL Life-cycle : module **CONSTRUCTION SITE**		
			Total	per year	per occupier	Total	per year	per occupier	Total	per year	per occupier	Total	per year	per occupier	Total	per year	per occupier
Non renewble primary energy		(kWh / m² SHON)	5490	110	289	1908	38,2	100	3374	67,5	178	88,5	1,77	4,66	60,2	1,20	3,17
Water Consumption		(L / m² SHON)	52960	1059	2787	7948	159	418	1086	21,7	57,1	43484	870	2289	221	4,43	11,6
Waste	Hazardous	(kg / m² SHON)	13,7	0,27	0,72	1,71	0,03	0,09	0,0051	0,0001	0,0003	11,93	0,2385	0,6276	0,0229	0,0005	0,0012
	Non-Hazardous	(kg / m² SHON)	527	10,53	27,7	517	10,3	27,2	0,8817	0,0176	0,0464	8,52	0,1703	0,4483	0,0493	0,0010	0,0026
	Inert	(kg / m² SHON)	2685	53,71	141	2572	51,4	135	83,7	1,67	4,41	22,3	0,447	1,18	3,53	0,07	0,19
	Nuclear	(kg / m² SHON)	0,1096	0,0022	0,0058	0,0487	0,0010	0,0026	0,0542	0,0011	0,0029	0,0022	0,0000	0,0001	0,0023	0,00005	0,0001
Global Warming Potential		(kg équivalent CO2 / m² SHON)	1049	21,0	55,2	539	10,8	28,4	479	9,59	25,2	26,5	0,5297	1,39	2,32	0,0463	0,1219

4. Conclusions

The modeling exercise offered an insight on how the definition of the building contributors or life cycle stages (considered according to the first draft of the SBA framework) influenced the accuracy, and consequently, the comparability of results, and how these definitions depend on the philosophy and scope of the rating tools and calculation methods. By using results from real buildings, the pilot test has permitted the proposal of recommendations on how to consolidate the indicators for the participating rating tools as well as a robust development of further common indicators. It is also remarkable that the availability of homogeneous EPD in each country will mean that as many contributors as possible can be takeninto account .

Regarding the feasibility and modelling results and their relative heterogeneity, different levels of SBA common metrics were suggested, that may be called “Ambition Levels”, allowing an improvement of maturity versus time as described in Figure 7.

	Non-renewable Primary Energy	GHG emission	Water	Waste (Hazardous, Non-Hazardous, Inert, Nuclear)	Comment
Building products and equipments (LCA)	Significant	Significant	Negligible	Very significant	Mandatory contributors to be specified
Operational energy-related services	Very significant	Very significant	Negligible	Negligible excepted Nuclear waste	Mandatory energy uses to be specified
Operational water-related services	Negligible	Negligible	Very significant	Negligible excepted Hazardous waste	Environmental profiles to be developed more

Key:
Level 1
to be added for Level 2
to be added for Level 3
to be added for Level 4
Note : the significance has to be interpreted relatively to each column

Figure 7: Levels of ambition proposed for the SBA scheme

Starting with the current and strict intersection between all the partners’ results, it appears as a very narrow frame, including only non-renewable primary energy and GHG emissions and only during the operational phase. This is the minimum common core, named “Level 1”. As these 2 issues are of course of great importance for every country, it should be necessary to go more deeply in the conventions and calculation rules, in order to ensure a high degree of comparability between rating systems. The study also shows that the contribution of building products and equipment is significant on three LCA indicators (energy, GWP, waste). This is crucial with energy efficient buildings and even more with plus-energy buildings. Furthermore, regarding the water indicator, the first short term aim is to develop an accurate and harmonized method for quantifying operational water use.

Upon completion of this research towards a framework of common metrics, it is anticipated that better harmonization between rating tools will pave the way for cross-tool comparability, for example, using a common core of (SB Alliance) indicators. Once a common methodology is agreed, these scientifically measured indicators could constitute a future "environmental building declaration" – a stable basis shared by various rating tools.

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Materials: an informative tool for a best informative quality in the constructive sector

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Build information to give information

The study presented, is the contribution of the team of researchers participating in the program of activities of Lama - Laboratory of the Materials for the Architecture of the DARTE, University of the Mediterranean Studies of Reggio Calabria, with respect to the methodology for the control and improvement of the quality of buildings. The team has made an information system on Materials Products and Components, Materials, active on the WEB and in testing phase.

Keywords: Technical information Crisis, Design Control, Informative Specialization, Production sector, Decision Support Systems.

1. The General Problem list

The mode of design are radically transforming in recent years, due to the mutated cultural context, the new boundaries of technology, of the renewed information possibilities: factors, that determine a new freedom for the designer and that allow to explore the field of complexity in the actual architecture panorama. With respect to occurrence of this complexity, it becomes important to confront the actual constructibility of projects: investigate the potential of innovation, the new arrangements for the building industry oriented more toward flexible systems of production, the opportunities for new materials and components transferred from other areas. The interest for the network communication, the ease with which can reach the information sought, the enormous range of data and images to the internet, have plagued the world of design.

The rapid dynamics of innovative industrial production in the sector, in addition, together with the confusion that characterizes the transfer of technical information and the regulatory aspects in the field of building construction, it does not allow, increasingly often, an easy structuring of knowledge and an acquisition of information useful to the project definition of architecture and its innovative characteristics associated with the current instances of efficiency and environmental effectiveness, energy savings, durability, etc.

This fact is of extreme importance.

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Often, in fact, are precisely the designers, who, however expressed, cannot access linearly to the wide landscape of existing technical information (production, Enterprise, regulator). This is probably to be placed in close connection with the dynamic innovative rapid production world that doesn't allow easy structuring and utilization of knowledge. A great deal of confusion, in fact, characterized, generally, the management of the transfer of technical information and standards within the construction industry. The necessity of passing a similar cultural gap, which risks to regress the quality of knowledge brought contemporary requires technical structuring informational analytical knowledge paths – crosshair critics to the redefinition of the complex landscape of technical information related to the project.

The themes of *Design Control and* of *Information* as an instrument of Control and Technical-material innovation, represent, then, the new categories effective to decline, in updated way, the specific theme of Production of the Project. The open questions, proposals, are so the issue of structure information, integrated, critically, from a question of specialization information for the control of the design process. A key ring, therefore, to combine the paths of material's knowledge to the control strategies.

2. The scope of scientific inquiry

The integration between the technical knowledge, available resources, the social organization and the translation in question of the individual and collective needs, can still be identified as a preferential path for improving environmental quality and not urbanized.

In line with this, is need a reaffirmation of a design culture that, through the acquisition of a widespread culture of build, proves able to legitimize the work choices. This is because, increasingly, the buildings cost too much of management; have a too rapid obsolescence; need too frequent maintenance and often are not programmed. These serious failings, surely attributable to very different causes, but they are mostly caused by shortcomings in the design process. And so, the construction product quality can be guaranteed only through the identification of new audit methodologies and tools.

In this context, then, the designer must manage an increasingly wide range of knowledge, and a diversified flow of information. The large number of people involved in the building process, the complexity and size of the final product, the need for different types of representations and technical verifications during the design phase, the variety of professional specializations of components and materials required for the building construction, in fact, make the construction industry, an industry with a high information content.

In view of this consideration, the most immediate realization for researcher who investigates technical information tools in the current landscape, is the absence of unifying landmarks, which organize the production of informative documents on building products according to

rigorous accession criteria technical standards in force. Also on the information consumption, typological highlights the lack of a unified repertoire. Consider, for example, to transfer out of context-based approach to compliant solutions – from manuals, catalogues, directories, etc. - to the project. The result of this trend is that the technical information is supplied by producers in a substantially different manner, especially in terms of quality of information content. What can be surmised, on the other hand, is the Organization of instruments that convey the information on technical, technological and quality materials of components or systems. First of all, in this sense, a good point from which to start studies in accordance with these guidelines, is discoverable in UNI 9038. The various paths of study and research oriented, to define a higher quality standard for unified information dissemination in the construction industry, have also had to cope with a landscape extremely complex and varied merchandise. With reference to the issue, the study's objective presented, provide a contribution to the development of an information instrument, capable of integrating the existing conditions of design development, ensuring control of operational choices in the conduct and development of the project.

3. The research path

Given the overall objectives, has formalized a methodology that considers, in an integrated unit, the subject of quality of technical information for the project’s control.

The development of that phase is structured around a task critical acquisition of documentary and regulatory repertoires products domestically and internationally, in order to reconstruct the most significant references to catalog the operational experiences, updating the status of knowledge on the meanings of: *informative Instrumentation; information transfer; appropriateness; roadworthiness tests*; bringing these insights to the following consequences:

-acquisition, management and transfer of information on materials, products and components;

-modeling of instruments aimed at improving the quality policy.

In this logic, this cognitive phase descendant from the processing of the data acquired during the investigation, detection allows the definition and construction of a data base system, the contents of which constitutes the object of the subsequent realization of Informational Pathways, which lead to the achievement of results expected output.

3.1 The classification system adopted

The methodological path used to process the information system, developed from the definition and adoption of an appropriate classification system to data acquisition and the subsequent processing and delivery of technical information on products, components, materials.

The goal is to provide useful information for both the didactic activity, oriented to knowledge of materials, their characteristics, compatibility and applications both of the professional activity, oriented to knowledge of new scenarios, productive and constructive materials.

The first step involved surveying and analysis of some aspects of the main systems of classification. These are provided by the major existing training bodies and the thematic content of the survey of the most important technical information portals currently on the net. The recognition of such materials, has made possible to identify many issues related to the lack of common definitors apparatus, including the identification of categories of use too generic and, therefore, ineffective informational purposes. The same reconnaissance, allowed to identify in PC/sfB classification system, a first possible reference suitable objectives in charge. The SfB system identifies as basic principle in relation to the stages of the construction process, that the choice among those *available resources* are transformed by *construction activity* in *definable results* in amounts and positions as parts of a building. The salient feature of the SfB consists precisely in his particular decomposition approach of a building or a project into parts, each part can be considered under three main aspects:

- the *function* for which it is created; is the view of the user: the part so regarded is a building element (table 1: elements);

- the *way* in which it is created; is the view of the constructor as well considered is a processing (table 2: processing);

- the *material* with which it is made; is the point of view of the producer so regarded is a material (table 3: materials).

With regard to the above, the field of investigation on the SfB, was restricted to: Processes (table 2) and materials (table 3).

Table 2 content was deduced the formalization of the first draft of the classificatory system on representative products and components the current production offer; the Table 3 was deducted, instead, a first hypothesis, material classification for defining the production offer, in terms of products and components.

4. The final product

Identified, therefore, the cognitive basis of reference, we proceeded to the formalization of a methodology that includes the definition of an informatic container, structured trough information paths, based on the use of relevant databases (materials, products, components) between their related and modeled in relation to levels of informational character output, referring – in the design phase-the definition and control of the choices of executive and technical nature.

The investigative path articulate, so around the construction of a tool for decision support (DSS) – informational database, able to assist a specific users to make decisions – details will, as a result, operating an information tool to satisfy a request information through the

articulation of a broad and structured response to cover up, outboundan application developed, inbound, intersecting differentiated areas.

The phase of modeling, represents the moment in which the debugging of the instrumentation is formalized predisposed for achieving the construction of an informative tool, flexible, manageable and implementable online; based on the theme “transfer of the information and control of the design process. This will be, therefore, possible through the development of a first general model that, the system of connection among the different informative paths, formalizing the following path of support to the design:

- informative path duct through the definition of the *Constructive Actions* (or Categories)

- informative path duct through the definition of the *Use Classes*

- informative path duct through the definition of the *Product Classes*

- informative path duct through the definition of the *Material Classes*

- informative path duct through the definition of the *Landscape products.*

Departing from the precedents acquired theoretical presuppositions, the team of researchers inside LAMA have elaborated The Archive Products of the LAMA, *Materials*, an informative Database that, through a whole correlated files according to a logical relational model tree, allows to offer a specific informative quality.

Flexible and implementable, *Materials*, is an innovative instrumental apparatus that captures information on products and components from the world of production. The peculiarities of *Materials* consists in processing these incoming data, placing the products/components in the database, within the classification system adopted.

Materials, usually done through alternative demand conditions, bases its user interface on defining a path of investigation managed by software (DBMS) applications with client-server structure and query language, allowing, through the management of a set of alternative conditions related archives of dialogue: free research, single criterion or multicriteria.

Its consultation keys are:

- *Categories* (Constructive Actions)

-*Uses* (functions of technical elements)

-*Products* (product types)

-*Materials* (material classes).

The four groupings provide a tree structure, which, starting from the identification of the general definition of the functions of the technical elements (Uses), arrives at the

specification of the product offer, through the identification of the products (Products) to each specific use Class.

The branch of trade covered range from raw material to completion, following all building construction phases: structures, roofs, external closures, insulation, etc. Not specifically treated currently are special spaces devoted to machinery, construction tools and services.

Categories (or Constructive Actions) of the system, useful to orient in a designer targeted its research, are seven and precisely (fig. 1):

-Support loads

-Cover and repair

-Separate and divide

-Waterproofing and insulating

-Finish and complete

-Improve yields and performance

-Restore

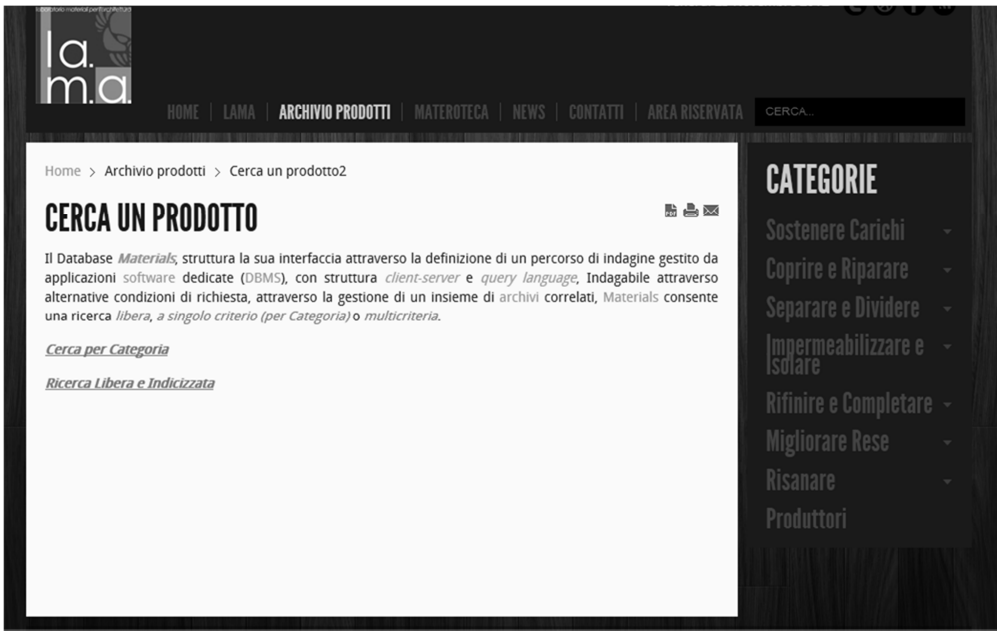

Figure 1, To the right screen, the Categories of the System, related to System "Materials". In the central screen the different research modalities (free research, single criterion or multicriteria). Provisional website filed to www. lama.unirc.it .

For each *Action,* it can see the different *Use Classes*, representing the rational selection of individual functional parts of the building and/or some processes.

For each *Use Classes* it can consult the different classes of associated product or set of products and components offered by the production for that specific use. Classes represent the informational database paths, on which were designed, interrelations through tree structures between *Use Classes- Product Classes-Materials Classes*. The archive includes all products that have an interest in design and construction of civil works (residences and infrastructure). In general we may say that the catalogue extends to those branches of production related to the sectors of construction, architecture and design.

By way of example, the screen of the first entry of the Categories, "Supporting loads", with an indication of the Use classes corresponding in related right part (fig. 2).

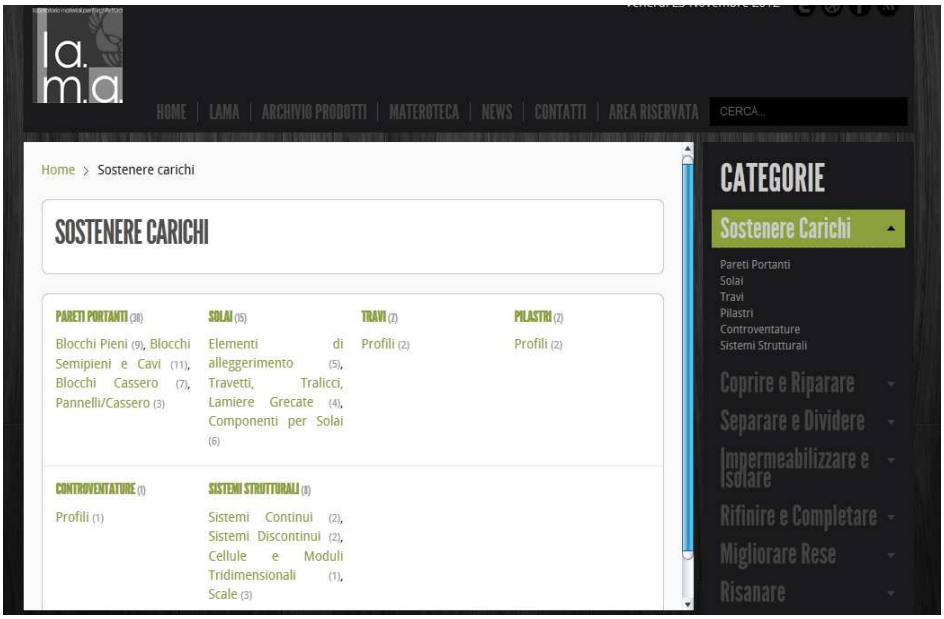

Figure 2, First item of Categories, "SUPPORT LOAD", indicating the Use Classes related, in the central screen. Provisional website, filed to www. lama.unirc.it.

In the central part of the screen, are received Product Classes (fig3), related to the individual classes of use listed. For each product class are highlighted individual products related to specific use, with a final technical specifications, as well as a short description, indicates some basic information and direct connection to the company, to contact for further information.

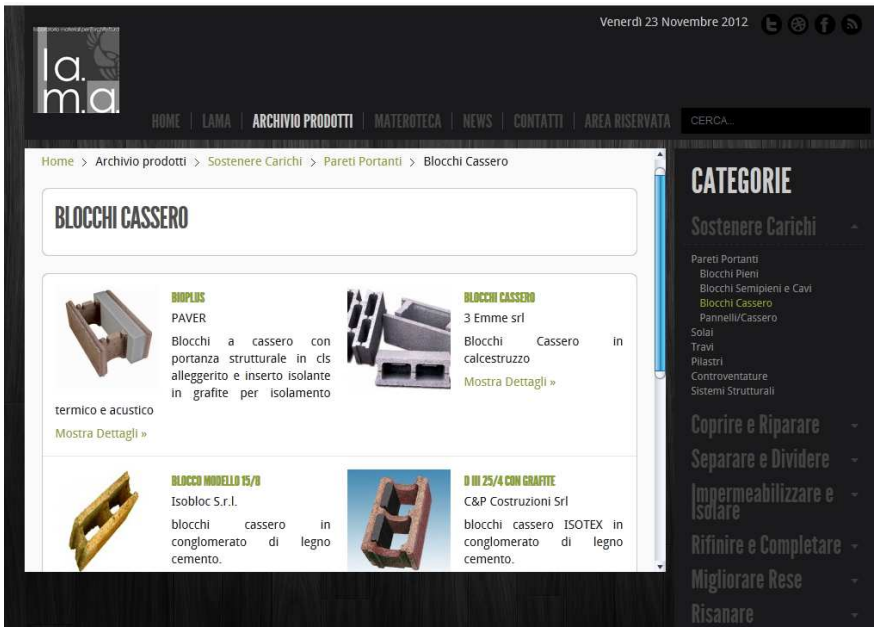

Figure 3, Product Classes "Block mold " related to a single Use Class "Load-bearing wall" of Categories, "SUPPORT LOAD". Provisional website filed to www. lama.unirc.it.

Materials, in fact, consists of a set of product sheets (fig4), which describe, in detail, a product from commercial description, specifications with product images, applications examples, realisations, the specifications, the variants etc..

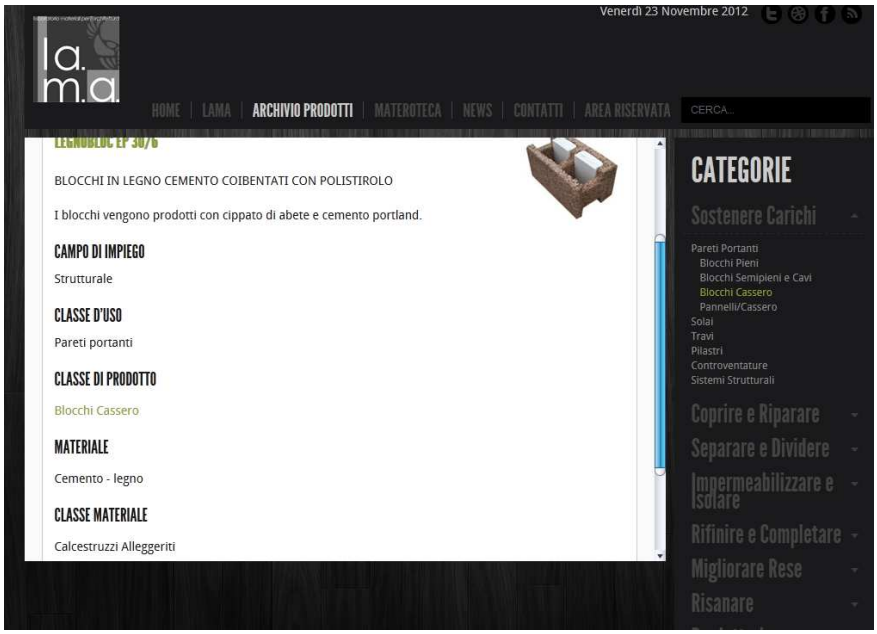

Figure 4, Example of Technical Sheet with different voices: Field of application, Uses Classes, product Classes, Material, Material Classes. Provisional website filed to www.

Follow link to paper catalogues in pdf, cad blocks, videos etc ... Through the consultation of product designers and companies can not only be informed but interact directly with manufacturers, requiring information electronically and in real time directly to sales offices. The product sheets are made from technical editing of *Materials*. All the material (texts, images, attached files etc.) posted in tabs is absolutely original and reworked from material provided directly from the manufacturers product holders.

5. Conclusions

At the end of how much illustrated, it shows a picture of final thoughts on research conducted which investigated and studied the specific issue of transfer of information to the control of design process given the methodological structure and strategic objectives achievable with their use, the DSS, in spite of the apparent discrepancy between the managerial scope from which originate, and the construction sector, which, in this location are applied, were here, considered responding to be adopted as a conceptual model for the delineation of new information on the real character paths the current landscape of industrial production. This is because these instruments have proved to be congruent to meet the special needs of current cognitive and informative view of the production of the building project.

Archive WEB platform products, *Materials*, run by a relational database, network deployable and useful for updating of scholars and designers, can be considered a current information source that refers to the current material universe of industrial production of the construction industry, combines specialized information needs with the evolutionary dynamics of computing equipment, achieving a desired structural gap exceeded inadequacy of current landscape of technical information.

The result, operating, so strongly a support tool evaluation and cognitive activities, geared to mitigate the incidence levels of decision-making design process uncertainties. Such action, able to structure the motivations of the choices by having to conduct, through the use of selected information, proves to be able to contribute to the acceleration of informative and knowledge of technical materials and innovations to the affirmation of their application.

A support tool, so that through the special operations platform, is an instrumental apparatus which, thanks to its open structure, is able to acquire additional contributions and information coming from the network itself, and, therefore, in terms of information content, being able to self-sustaining. Ultimately, a location can offer a structured information that combines the features of a scientific hypertext with the most traditional type information in a comprehensive way.

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Sustainability in FM: Trends in Policy and FM competence consequences

Abbas Elmualim[1]

Abstract

Sustainability is emerging as a core business strategy and obligation for many organisations. The facilities management (FM) profession is at the forefront of delivering sustainable practices at the operational, tactical and strategic management levels. The profession, however, faces more demands and challenges as the goals of sustainability agendas change over time and must be equipped with new knowledge, tools and competencies to overcome the challenges. An annual sustainability survey was conducted to examine how facilities management (FM) professionals are engaging with sustainability in their business environments over the past 4 years. The objectives are to provide insights to the relevant knowledge, skill sets and best practice that can enhance their professional competencies. It further aims to provide the FM professionals with up to date sustainability toolkits, techniques and information that can enhance their competencies in dealing with the challenges posed by the sustainability agenda. The sustainability survey report provides an insight into the issues and trends influencing the delivery of sustainable policies and practices across different organisations and economic sectors. The analysis provided valuable information on the overall impact of the sustainability agenda on Facilities managers' professional work. Similarly, the findings provided the FM professionals with information that may be used to enhance professional competences of facilities managers in dealing with sustainability management and operation issues, develop sustainability good practice guides and education and training in particular continuous professional development (CPD) modules/courses.

Keywords: Sustainability, facilities management, policy, CPD and competences.

1. Introduction

Benefits of sustainability in the built environment are well known to facilities managers but the practice of sustainable FM is rapidly evolving due to the three Cs of customer demands, competition from competitors and climate change (Department for Environment Food and Rural Affairs (DEFRA) 2005; Elmualim *et al.* 2009; Warren 2010). Global, national and local sustainable development agendas continue to demand that organisations develop and implement sustainability policy that respond to the challenges. However, identifying the most appropriate approach is a major test for most organisations especially facilities managers who are often tasked to deliver sustainability goals and objectives with financial prudence (Elmualim *et al.* 2010). Although, this is an opportunity for FM professionals to

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make a real and measurable difference in improving businesses they seem not to have easy access to the specialist knowledge, tools and case study material necessary to make this a reality (Loch 2000; Shah 2007). As a leader in advancing the FM profession, the BIFM seeks the relevant knowledge, information and skill sets that will enhance FM professionals' competencies in dealing with the demand, challenges and opportunities of delivering sustainability in business environments.

The Sustainability in FM research programme aims to provide the FM profession with sustainability toolkits, techniques and information to ensure FM organisations or managers become more reactive or proactive towards sustainability challenges. The project objectives are to develop tools and information on sustainable FM; help FM professionals respond to the increasing importance and challenges of climate change and meet their environmental responsibilities. A key component of the Sustainability in Facilities Management programme (SFM) is the annual sustainability survey. The annual survey aims to investigate how FM professionals are engaging with sustainability in their business environments. The objectives are to provide insights to the relevant knowledge, skill sets and best practice that enhance professional competencies in delivering sustainability developments and practices. The survey identifies the most relevant issues and emerging trends being emphasised by facilities managers. The 2010 survey builds upon previous studies. Previous annual sustainability surveys were conducted in 2007, 2008 and 2009. The insights gained set the objectives of future sustainability surveys enabling any changes in the data collected to be measured.

Importance of FM in driving sustainability

Sustainability is now a major obligation and expectation across many businesses (Stern 2006). Pressure from key stakeholders, governments and competitors are driving organisations to implement the sustainability agenda in business activities (Department for Environment Food and Rural Affairs (DEFRA) 2005; Nousiainen and Junnila 2008). For example, economic, social and environmental factors like climate change and limitation of energy resources point toward FM professionals being challenged to do more for their organisations. As most business activities occur in built environments, the quality of the built environment can be a noticeable manifestation of an organisation's sustainability credentials. Walker *et al* (2007) suggest that "the only credible route an organisation has to achieve for appropriate environmental management is to take a systematic approach to promote a sustained, continuous improvement in performance." Though final organisational responsibility for committing sustainability rests on the highest level of management, FM professionals are at the forefront of integrating sustainable practices to their operational and management activities (Shah 2007; Elmualim *et al.* 2009).

In the past FM professionals were responsible for managing the non-core business activities that support the core business strategies. Increasingly facilities managers are at the forefront making valuable strategic contributions toward their organisation's sustainable business as sustainability and CSR become a core business in many organisations (Loch 2000; van Ree 2007). Hence, the FM profession has an opportunity to drive sustainability policies within business environment by addressing core business strategies (Brandon and

Bentivegna 1997; Tay and Ooi 2001; van Ree 2007). In addition to their technical and operational skills, FM professionals have a great opportunity to expand their activities into boardrooms as they provide managerial skills in support of core business strategies for organisations as a whole. As a result facilities managers need to understand how the growing emphasis on sustainability is affecting the way they discharge their duties. FM professionals must become professionally competent and knowledgeable about sustainability issues that will impact on their business environments both operationally and strategically (Cooper 1996; Puddy *et al.* 2001; Warren 2010). By examining the emerging trends and issues influencing FM professionals' engagement with sustainable practices across different sized organisations and economic sectors, the new knowledge gained will help develop FM professionals' understanding of the issues underpinning effective sustainability management. In addition, the new knowledge can be used to support trade organisations interested in sustainability to develop more effective approaches to interact with FM audience.

2. Survey Method

As in the previous surveys, the questionnaire was primarily distributed and administered by BIFM to its members and other interested stakeholders as an online survey. The questionnaire instrument involved 20 closed questions and 5 open questions. Compared to 251 respondents in 2007, 168 in 2008, and 222 in 2009, a total of 268 respondents completed this year's survey online. The data was transferred into spread sheet for analysis (See Appendix for a copy of the questionnaires). To draw out new knowledge, similarities and differences in trends and shifts a simple comparison of the perceptions of respondents conducted for each question. The new results are then compared to previous years' results. As with previous survey data and reports, the analysis of the current data is based on the following format:

- Demographics of respondents. This provides information on the background of the respondents and organisations completing the survey.

- Trends on Sustainability/CSR Policy development, implementation and management issues especially areas of concern to facilities managers.

As respondents were self-selected, the results of the survey should be taken as only an indication of the perceptions and observations of facilities managers in general. They represent the views of facilities managers interested in sustainable FM. Furthermore, as respondents were not asked to specify their position within their organisations, perceptions and observations reported here may not necessarily represent the views of specific organisations and professionals – however the BIFM status of respondents allows for a high proportion to be practicing FMs.

3. Results and Discussion

3.1 Demographics of respondents

This section provides demographic information about the background of the respondents and the organisations they work in. The respondents were asked questions about their current BIFM membership status, academic qualifications gained, type of organisation and its economic sector, the level of annual turnover and the size of the organisations in terms of employee numbers. These data will be analysed for changing trends in surveyed professionals. A total of 268 people responded to the 2010 annual sustainability survey. The data collected were as reliable as the survey will allow.

over 90% of the respondents are either associate, corporate, certified, student or full members of the BIFM. Over 63% of the respondents are identified as full member of BIFM meaning they have at least five years of management experience and over three years of FM experience. over 50% of respondents worked FM departments in End-user organisations (in-house departments). A further 16% worked in FM companies that have been out-sourced as FM service providers. Other FM organisation where respondents worked were Independent FM Consultancies (11%), FM service providers (9%) and FM product suppliers (1%). 10% of respondents, however, indicated “other” type of FM organisation. over the last four years, over 50% of respondents worked as facilities managers in in-house FM departments (End-users organisation) even though the proportion of respondents from the End-user organisational category has decreased by 10% since 2007. The proportion of respondents from out sourced FM organisations and consultancies has remained fairly constant over the years. The only exception is that respondents from full FM service provider organisations have increased by 7% since 2007. As a whole, the result reveals that overall, 68% of the respondents worked in large organisations employing more than 250 people while the remaining worked in SMEs (organisations employing less than 250 people).

3.2 Development and management of sustainable FM

This section of the paper focuses on respondents’ perception of the levels of sustainability policy and the effectiveness of sustainability management within their organisations. The results showed that in 2010, as shown in Figure 1, 72% of respondents indicated that their employers had a sustainability policy in place. 6% did not know whether their employers had one or not. The remaining 22% indicated that their employers did not have a sustainability/CSR policy. Clearly, a majority of the respondents believe that their organisations do have sustainability/CSR policies in place.

Figure 1 also indicates the proportion of respondents indicating that their organisations do have a sustainability/CSR policy rose steadily from 65% in 2007 to 84% in 2009 but dropped significantly by 12% in 2010. The proportion of respondents who indicated their organisation had no sustainability/CSR policy, however increased by 6% (Figure 1). Also a sizeable amount of respondents do not know whether their organisations do have a sustainability/CSR policy. The results are worrying given that sustainability is growing in importance as a core business strategy and the FM profession has a great opportunity to

add value to their organisation's sustainability agenda. Although there might be reasons for the sharp drop and the increase of respondents who don't know, there is an urgent need to encourage FM professionals to develop and manage sustainability policies and activities in their organisations.

Regardless of the levels of uptake, the issue of "effective implementation" is not addressed in this question; therefore one should not assume that the "development" of a policy framework implies appropriate management of the policy. The management of the policy is a much broader concept that considers the core project cycle stages (Identification, formulation, appraisal, implementation, monitoring and evaluation). shows that approximately 40% of the respondents´ revealed that their organisations have had either a sustainability or CSR policy for a period of 2 years or less. 30% of respondents indicated their employers have had a sustainability or CSR policy for 2-4 years. A further 30% indicated that their organisations have had a sustainability or CSR policy for more than four years. Clearly, majority of the respondents believe that their employers have had a sustainability/CSR policy in place in the last four years or more.

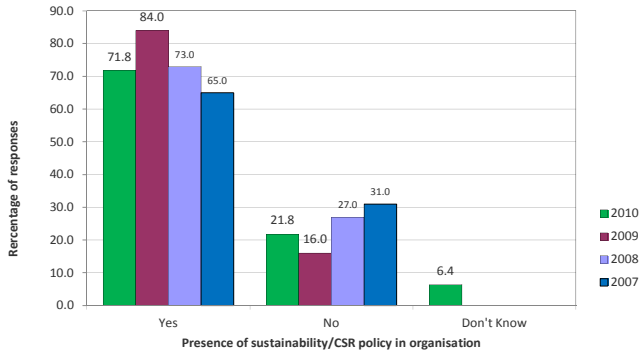

Figure 1: Organisations with a Sustainability/CSR policy

The survey shows nearly 40% of respondents rated their organisation's effectiveness in implementing and managing sustainability responsibilities as adequate. An additional 25% of respondents rated their organisation's effectiveness as very good to excellent, while 24% of respondents ranked their organisation's effectiveness as inconsistent. 11% of respondents however, rated their organisation's effectiveness as poor. Clearly nearly two-thirds of Facilities managers rank their organisations' effectiveness in implementing and managing sustainability/CSR policy as ranging from adequate to excellent. However, the remaining third view their organisations' effectiveness as ranging between poor and inconsistent. Comparing the present result with previous findings as shown in Figure 2, a majority of respondents have consistently ranked their organisation's effectiveness as adequate (nearly 40%). On the other hand, the proportion of respondents ranking their organisation's effectiveness as poor has consistently decreased since 2008 (overall by 13%). Similarly, the percentage of respondents ranking their organisation's effectiveness as

"very good" has decreased by 10% (31% in 2009 and 21% in 2010). Presently, nearly 66% of all respondents rank that their organisation (s effectiveness as ranging from adequate to excellent compared to 72% in 2009. The overall decrease may be attributed to fewer respondents ranking their organisations effectiveness as excellent or very good.

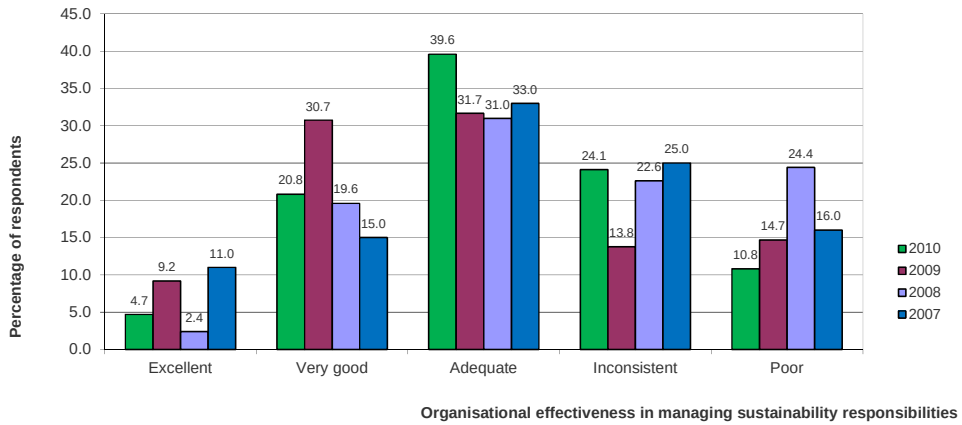

Figure 2: Organisational effectiveness of implementing and managing Sustainability/CSR responsibilities over last four years

3.3 What aspects of sustainable development are covered by the sustainability Policy

Figure 3 shows that 90%, 89% and 81% of the respondents reported that waste management and recycling, energy management and carbon footprint respectively, are the key aspects covered by their sustainability policy. Also highlighted were Health and safety (69%), and sustainable travel (66%). Other aspects covered by the sustainability policies are targets, measurement and reporting, ethical purchasing and community engagement, specification of sustainable products and services. Only 35%, 30% and 26% reported that building disposal, biodiversity and staff productivity has coverage in their policies. Clearly, the surveyed facilities managers consider waste management and recycling, energy management and carbon footprint as the aspects of sustainability mostly covered by their policies. However, there could be a danger of these areas being the easiest to implement hence their presence in sustainability policies. Hence there is a need to develop professional competencies and knowledge in all aspects so that only the relevant issues and activities are included in the policies. Although the least covered aspects are biodiversity and staff productivity, there is also a need to develop competencies in all aspects of sustainability.

Comparing similar results from previous studies (Figure 3); there are significant similarities as well as differences over the years. For example, the 2007, 2008 and 2009 surveys indicated that the three key issues covered by sustainability policies were waste management and recycling, energy management, and health and safety (Figure 3). Carbon footprint was not significantly covered then. However since 2009, there has been steady rise of carbon footprint coverage by sustainability policies. A reason is the increase in tighter legislation and higher taxes on carbon emissions and the efforts made by organisations to

gain financial savings on the carbon-end. In addition, Carbon footprint is intrinsically linked to other aspects such as Energy, Waste and Sustainable Transport management issues, hence leading to wider coverage.

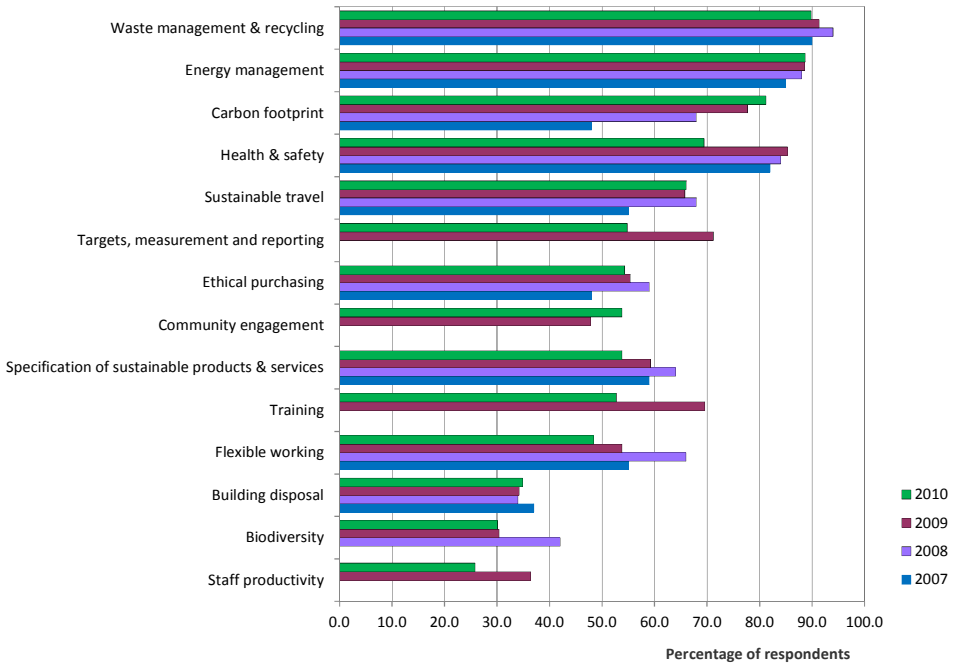

Figure 3: Aspects covered by sustainability policies over last four years

As shown in Figure 3, coverage for Health and Safety issues has declined. A reason may be these issues are highly regulated by legislation anyway and therefore addressed outside the sustainability frameworks. An important distinction is continued coverage of issues such as training, staff productivity biodiversity and an increased coverage community engagement. This is a reflection of increased awareness by policy developers of the value of sound sustainability frameworks that address environmental, economic and societal issues through more balanced approaches. Clearly Waste management and recycling and energy management continue to dominate issues covered by sustainability policies. However, carbon footprint issues are seen as highly relevant and thus covered by the policies. Other aspects of sustainability issues covered are health and safety, flexible working, ethical purchasing, staff productivity and biodiversity.

With regard to stakeholders that are recipients of sustainable development reports. 53% of respondents indicated that they reported their sustainability to Clients/customers. A further 46% reported to employees, 42% to Government and 40% to Shareholders. Only 22% of the respondents reported their sustainability activities to the local community. Perhaps indicating that either the benefits from actively engaging with local communities are not fully known, or knowledge regarding effective methods for achieving this is not well known. At 10%, Donors/Sponsors remain the least reported to. Often the donors and sponsors who require sustainability activity reports are the Charitable and Not-for-profit organisations. However, it is important to notice that a small yet significant percentage of respondents (7%) have selected not to report to any group of stakeholders. Although reporting may be seen

as a complex activity by some organisations, learning and understanding the issues involved in reporting appropriately should be part of any organisation´s agenda in its pursuit to trigger a wider range of benefits from its sustainability policy.

The showed that over the last three years, Employees, Client/customers, Shareholders and the Government remain as the top four most popular stakeholders for whom sustainability reports are produced. Although most respondents identified Employees as the top stakeholders to whom sustainability reports were prepared for in 2009, in 2010 as in 2008, most organisations are now reporting to their clients/customers. A reason may be that either clients/customers are now demanding such reports or organisations are reporting the benefits from its sustainability policy to its customers/clients instead of employees. The findings indicate that clients/customers, Employees, Governments and Shareholders are the main stakeholder organisations for whom sustainable reports are produced.

3.4 What aspects of sustainability does your organisation report on?

As shown in Figure 4, Majority of respondents identified Energy Management (79%), Waste management and Recycling (76%) and Health and Safety (68%) as the top three aspects of sustainability most organisations reported upon. A further 67% of respondents identified Carbon footprint as a key aspect that organisation reported on. 44% identified Sustainable Travel an aspect closely related to managing carbon emissions. Other topics include Training (39%), Community engagement (35%) and Specification of Sustainable Products (33%). The aspect least reported upon is biodiversity (18%), building disposal (21%) and ethical purchasing (23%). Biodiversity may be least reported as a result of organisations not engaging with the wider community and/or specialist organisations in the field. Overall, the results highlight aspects of sustainability seen as intrinsic parts of the process for implementing an effective sustainability policy. Although much effort is placed on reporting on issues such as Energy Management, Waste management and Recycling, Health and Safety and Carbon footprint, other aspects of sustainability should be encouraged and reported upon. Such a report may be seen as a collective effort seeking to drive forward wider sustainability goals. The findings indicate Energy Management, Waste management and Recycling, Health and Safety and Carbon footprint as the main aspects of sustainability most organisations report on. The least is biodiversity.

Figure 4 showed that the most popular aspects of sustainability reported upon over the past three years are Energy management and Waste and recycling, and Health and Safety. However, Carbon footprint is increasingly becoming a popular topic in sustainability reports. Its continuous rise probably exacerbated by the introduction of new carbon related legislation such as the Carbon Reduction Commitment (CRC) (Department of Energy and Climate Change (DECC) 2010). This also confirms the weight that legislative drivers place over the implementation of sustainability policies. Interesting, respondents who identified the Targets, measurement and reporting, and Ethical purchasing aspects has declined by a massive 30% (Figure 4). A reason may be that organisations are responding to the needs and requirements of their clients/customers and stakeholders rather than the organisation itself (Loch 2000; Nousiainen and Junnila 2008). On the other hand, Biodiversity, Building

disposal and Ethical purchasing continue to be the least popular topics reported upon during the last three years.

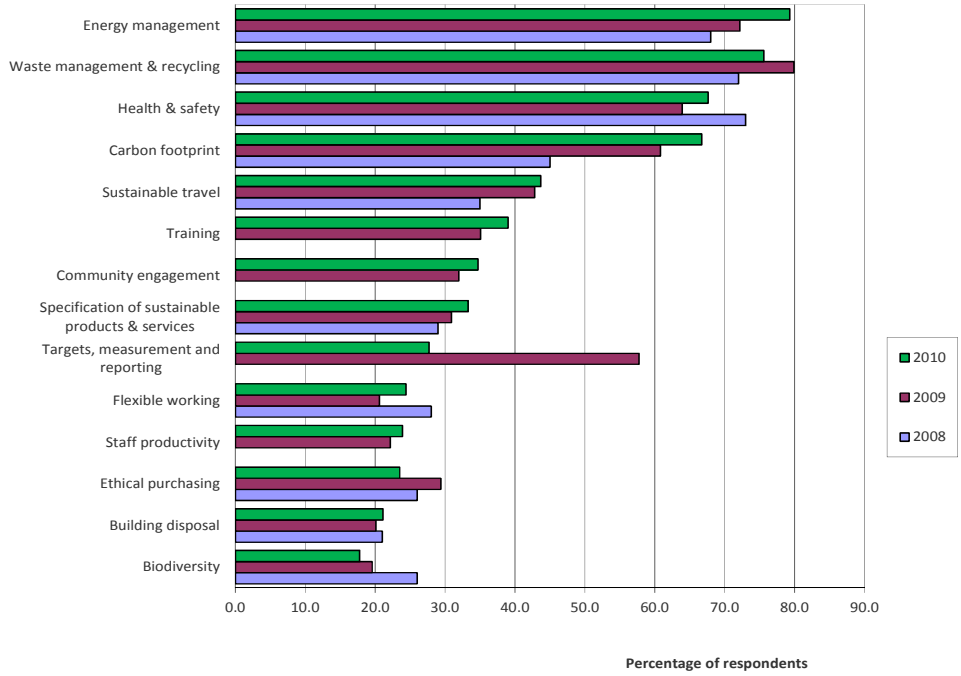

Figure 4: Aspects covered in sustainability reports over the last three years.

3.5 What methods of reporting are used in communicating sustainability aspects?

Figure 5 indicates that 52%, 50% and 36% of respondents identified Separate reports, Annual reports and Intranet are the most preferred methods of communicating sustainability issues respectively. Separate reports are excellent methods for reporting on sustainability as the criteria (e.g. time and audience) are defined according to the specific needs of the organisation. The use of Intranet is also effective as it presents an easy and direct way for organisations to engage with their employees. However, it may restrict any other organisational efforts to communicate their performance. Other methods of communicating aspects of sustainability identified use of websites and other forms of reporting mechanisms. Other forms of reporting include monthly reports, notice boards, community newspapers, emails, weekly toolbox talks, Case studies and regular meetings. A reason for using other forms is that different people have different preferred methods for learning. The best approach is to provide a balanced approach.

As shown in Figure 5, for the fourth year in a row, a steady decline has been observed concerning the use of Annual Reports as a mechanism for sustainability reporting (71% in 2007 and 50% in 2010) while the use of separate reports has remain essentially the same. Interesting, the use of intranet is identified as the recent survey (36%) while it had not been selected in earlier surveys. However the use of websites is in decline while other forms have remained the same. Clearly, Separate reporting, annual reports and intranets are now the preferred method for reporting on sustainability.

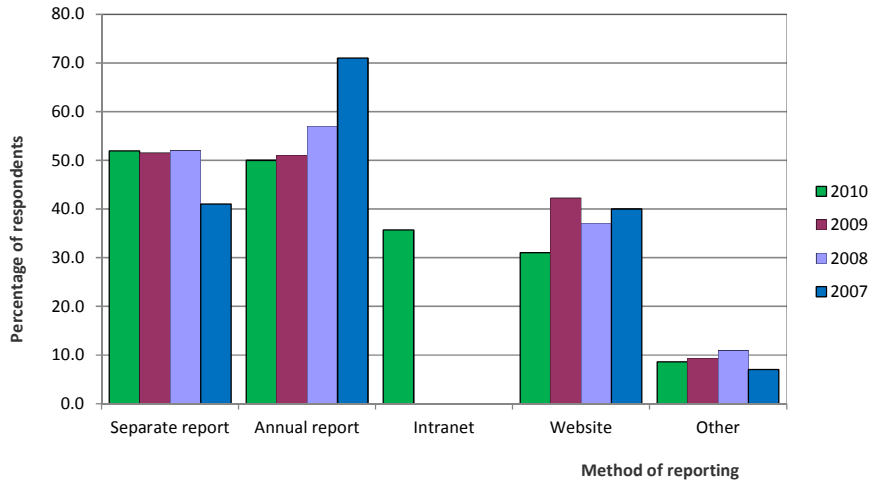

Figure 5: Methods used in reporting on sustainability over the last four years

3.6 FM responsibility on sustainability issues

The study findings revealed that more than 80% of the respondents identified waste management and recycling, energy management and carbon footprint as the key issues covered in organisations' sustainability policies. The trend is correlated in sustainability aspects covered in sustainability reports, with energy management, waste management and recycling, health and safety, and carbon footprint rated as the key issues reported upon. Similarly the trend is correlated with the management responsibilities of Facilities managers. Survey findings indicate that Facilities Managers are increasingly being put forward by organisations to manage their sustainability activities. Nine out of every ten of the respondents are in charge, formally or informally implementing and managing activities that support the organisations´ wider sustainability strategy.

Accordingly, majority of Facilities managers have responsibility for energy management, waste management and recycling health and safety, carbon footprint management and targets, measurement and reporting. However these issues have been part of FM professional agenda long before the sustainable development (Alexander 1996; Pitt and Hinks 2001; Tay and Ooi 2001). Carbon footprint, however, is quickly climbing up the responsibilities list. The ever tightening legislation around the carbon market like the carbon reduction commitment (CRC) legislation and carbon emission related issues means that facilities managers are expected to increasingly take ownership over activities flagged under the carbon emissions or energy management arena. The findings indicate that the issues covered within sustainability policies are ultimately reflected in sustainability reports. The issues then become an intrinsic part of the process for implementing sustainability policy. Such an approach can overshadow equally important sustainability issues like biodiversity and staff productivity in FM organisations, and limiting knowledge, expertise and competence in such issues. Ultimately such diverse issues should be encouraged as a collective effort to drive forward a wider sustainability agenda that protects the environment and sustains development (Cooper 1996). Professional institutions like the BIFM can improve its members understanding of sustainability by providing relevant information,

knowledge and guidance materials that are up to date especially where it is less emphasised. Awareness and understanding sustainability issues can be aligned with the core competence requirements of members.

3.7 Uptake of sustainability policy, management effectiveness and associated barriers to implementation

The findings indicate that 72% of respondents believe that their organisations have sustainability/CSR policies in place. Similarly, 70% of the respondents indicated that their organisations have had a sustainability/CSR in place for less than four years. Worryingly, a significant 22% of respondents also suggested that their organisation do not have any policy on sustainability/CSR and 12% less respondents believed their organisation had a sustainability/CSR policy. Clearly, there is a need to encourage facilities managers to become competent and knowledgeable in sustainability issues as new demands, challenges and opportunities arise in their organisation. Institutions like the BIFM can provide relevant information and knowledge resources by raising members' awareness through the education and training services it offers. Two-thirds of the respondents suggest that their organisations are performing at either an adequate to excellent level, a noticeable improvement regarding 2009 results. However findings also indicate that FM organisations' effective in implementing and managing policies sustainability/CSR policies were rated as only 'adequate' and 'poor' by a significant 40% and 35% of respondents, respectively. It is evident that the importance and relevance of sustainability in FM continues to grow as a primary requirement and expectation. Therefore there is a need to encourage all FM professionals to improve their competencies and skills in sustainability and CSR issues.

4. Conclusion

A longitudinal survey was conducted over the past four year to investigate trends in sustainability policy within FM industry. The survey results have revealed trends in how facilities managers and organisations are engaging with the sustainability agenda within the built environments over the last four years. Sustainability is emerging as a core business strategy and FM professionals are at the forefront of implementing and managing it in the workplace. However, it is necessary that facilities managers enhance their understanding of sustainability and sustainable development as challenges and opportunities arise. FM professionals need to develop their understanding of the key issues of sustainability. One way of achieving this is by commissioning and conducting research on the trends in sustainability and sustainable development. There is evidence of a gap in the coverage of environmental and social components of sustainability agenda which are most appropriate for the built environment. Thus recommendations for more studies will include investigating how Facilities managers are engaging with the commitment, understanding, development, implementation and management, responding, controlling, monitoring and reviewing environmental, social and economic sustainability issues and responsibilities. Findings of such surveys will enable professional institutions like the BIFM to tailor and provide relevant information, training, education, guidance and leadership to enhance the competencies of Facilities managers in the areas of sustainability and efficient energy use.

Acknowledgement

The author would like to acknowledge the support of the EPSRC and the project's Technical Group and the BIFM Sustainability SIG members, who kindly gave their time to encourage, guide and support the research project.

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Three stories describing the impact of research on the development of Norwegian Construction industry

Torill Meistad[1], Marit Støre Valen[2], Ole Jonny Klakegg[3]

Abstract

Increasing focus on energy and climate performance is challenging the construction industry. At the same time globalization of the economy is a driving force for improving competitive advantages. Involving research and developing new technology are among the strategies to meet these challenges. This paper presents three role model projects with goal-breaking performances. The history of these projects illustrates how R&D is involved in the ongoing processes of change and improvements within the construction industry. The cases includes Vennesla library illustrating innovative use of wood, Powerhouse #1 illustrating innovative energy solutions, and Brøset neighborhood illustrating plans for ambitious sustainable urban living. Using an innovation system approach we focus on the institutional framework supporting the development processes. Four elements are found to be of special importance in the development history of the three case projects: a) collaboration via research centers with industry partners, b) support from funding institutions combining financial and expertise support, c) industrial development programs triggering competition, and d) a tradition for government / industry collaboration in policy development. Professional networks are crucial for R&D processes, both regional, national and internationally. Finally the paper discusses whether the findings are specific for a Norwegian or Nordic context. Our findings support previous studies in that the Nordic countries have developed a variety of the knowledge based economy strategy that emphasize learning, knowledge transfer and collaboration in R&D processes.

Keywords: Low energy use, Wood, Construction process, Innovation, R&D involvement.

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1. Introduction

1.1 Background

Increasing focus on climate performance in buildings and demands for higher energy efficiency are drivers for a changing construction industry in Norway. Industry partners, researchers and public enterprises cooperate to reach higher performance levels involving new technology and new collaboration methods. The last couple of decades represent a period of high activity level within the industry, challenges from a global market and also new technological opportunities.

The Norwegian construction industry is the third largest industries in Norway regarding occupation and turnover. However, the relative share invested in research and development (R&D), is low compared to other industries (Espelin and Reve 2007). In the increasingly more knowledge-based economy collaboration between industry and researchers is crucial to upkeep Norwegian and European competitiveness (European Commission 2007).

In this paper we present three role model projects in order to explore how the impacts of R&D are bringing the construction industry forward.

We are especially interested in exchange and uptake of knowledge during the development process.

1.2 Theoretical approach

For this purpose we apply a system approach to R&D in industrial development and innovation. This theoretical perspective acknowledges that progress is carried out through a network of various actors underpinned by an institutional framework (Asheim and Coenen 2005). The innovation system involves the various actors in the value chain of the construction industry. The framework includes institutions and measures constituting the current research and innovation policy. In Norway this framework includes universities and research institutes, centres for research-based innovation, funding for research and industrial innovation, and various development programs (Norwegian Ministry of knowledge 2008-2009). This policy model is in accordance with theories describing the dynamics of innovation as a Triple Helix of university – industry – government relations (Etzkowitz and Leydesdorff 2000).

The system perspective is also useful to enlighten how the production system interacts with and responds to changes in its surroundings (Luhmann 1996). Of special relevance in this paper is how the construction industry responds to incentives for improving environmental performance.

1.3 Research questions

Purpose of this paper is to enlighten how R&D ideas are translated into industry outcomes. The analysis will address the question of what institutional framework are involved in successful R&D processes.

The case presentations will focus on what actors and networks that are involved, what research contributions role model projects draws upon, and what challenges triggered the industrial innovations.

Finally the paper discusses the relevance of the Norwegian (or Nordic) context for R&D uptake in the construction industry.

2. Material and methods

The case projects are selected among recent and on-going projects with goal breaking ambitions and results.

The material on which we base our analysis is partly published in project reports and partly in form of news and reports published at various industrial magazine's and web pages. The Brøset and Powerhouse cases also include interviews with the project partners.

2.1 Case presentations

Vennesla library illustrate the development of using wood as a design and construction material. *Powerhouse #1* is a concept project for a building design optimized for sun energy production in Nordic climate and *The Brøset district* is planned to become a sustainable neighborhood that motivates for a extremely low climate gas emission life style.

2.1.1 Case 1: Vennesla library – wood as a design and construction material

Wood has a long tradition as construction material in Norway and is considered environmental friendly and a natural building material among Norwegians[4]. Back in the Viking age wood was a natural building. As experts of their time the Vikings used the huge forest resources to build Long houses of timber logs and Long ships of oak. The tradition of building houses with timber logs lasted until the beginning of the 19th century before steel and other materials as concrete took over as construction materials.

Its use has a long tradition, including mountain villages of log houses, urban neighbour houses that is internationally recognized on the UNESCO World Heritage list as Bryggene i Bergen (Hansiatic wharfs houses) the wooden mining city of Røros and the stave churches. In general Nordic people like the idea of being surrounded with healthy and natural materials in a modern community with increasing focus on technology.

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[4] 94 per cent (Norsk Monitor 2005)

In the 90'ties there was an upswing of using wood as a construction material as new technology made it possible to develop new products that could handle larger span and larger dimension and stronger wooden beams of glulam and massive wood elements. This story tells the impact of the R&D investment between research organizations and actual stakeholders on wood as a construction material.



Figure 1: Vennesla library and culture centre (Photo: Moelven)

Vennesla library is a project exploring the characteristics of wood as construction material both from engineering and an architectonic point of view. Figure 1 show the wooden ribs that not only are carrying the load of the building, but also integrate the interior in a spectacular way. The architect[5] company Helen & Hard has specialized on wood constructions combining environment ambitions and outstanding design, and has become internationally recognized also for the Norwegian pavilion at Expo Shanghai (2010) and the Pulpit Rock Mountain Lodge (Preikestolen, 2008). Vennesla library has been awarded a number of prizes for innovative architecture and use of wood as construction material.

The Vennesla library illustrates a history where new design, technology and research are combined with a traditional material and cultural recognition. Vennesla library represents a continuation of development of wood constructions in Norway and the Nordic countries, and draws upon a number of R&D inputs, among others on load-carrying capacity in various shapes of massive wood.

Development of glulam came as a result of an industrial network around the Moelven timber mill in the Hedmark region. Existing practical knowledge on wood were combined with research at the Norwegian Wood Technology Institute[6] resulting in innovative glue techniques. The leap into this new product were triggered by a national political initiative to invite the national construction industry to promote Norwegian culture and values in the new facilities to be built for the Olympic Games at Lillehammer (1992) and the new Oslo airport (1994). The crucial challenge of fire protection was solved via collaboration with a chemical industry partner within the same region.

2.1.2 Case 2: Brøset - Development of urban green living

In general, settlements in Norwegian cities are densely built. In these times of urban growth there is a challenge to develop environmental sustainable neighbourhoods in urban areas. This example presents the plans for Brøset in Trondheim and show how experiences and research contributions is included in the front end phase.

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[6] www.treteknisk.no

Traditional urban settlement and industrial buildings in the 1000 years history of Trondheim are built on wood. Major parts of the central city still have the characteristics from this tradition. Recently the Trondheim municipality has decided that wood will be a preferred material for new public buildings. This came as a result of major R&D impacts. Among these are new experiences on the potentials of multi-storey buildings in wood, and new knowledge on greenhouse gas emission qualities of wood and forestry as alternative to other construction materials.

Trondheim municipality presented the plans for the first environmental friendly neighbourhood in 2003. The plan for Rosenborg Park included ambitions for reducing energy consumption to 50 %, improving waste handling and recycling, reducing the number of private cars and including landscape architecture as part of the plan for 500 new dwellings. The project was one of six projects in a national initiative for urban environmental pioneering, supported by the Norwegian Housing Bank, Enova and SINTEF Building and Infrastructure as a research partner. There was also international comparative research on the initiative[7]. The project succeeded in improving environmental performance, and provided valuable experience for further urban development. However, the fact that a very high number of dwellings were accepted to be built in this area got a lot of negative attention in the media.



Figure 2: The area planned for the new Brøset neighbourhood. Experimental garden and outdoor shed with information (Photo: Trondheim municipality)

When the Ministry of environment initiated the development program *Cities of the future* in 2008, Trondheim applied as partner, and introduced the plans for a new carbon neutral neighbourhood, Brøset. Cities of the future is an initiative to meet the national ambitions for improved environmental sustainability, and is a cooperation between Norwegian municipalities and the State. The program will provide valuable know-how for future urban planning. Especially there will be intensified exchange of experience among the three municipalities aiming to develop similar green urban livelihoods; Kristiansand, Bærum and Trondheim.

The ambition for Brøset is to be a carbon neutral neighbourhood, using little energy and ”healthy” materials and being a socially sustainable living environment. There are ambitious plans for reducing traffic and energy use and at the same time uphold living comforts.[8]

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[7] The international research initiative included participation from 14 countries in Europa (Husbanken, 2003).

[8] http://www.regjeringen.no/en/sub/framtidensbyer/the-participating-cities-/trondheim/a-new-city-of-the-future.html?id=548223

The Brøset project has accomplished an architectural competition with four parallel contributors. This material is used to develop a zoning plan in 2012. All throughout the process citizens of Trondheim have been invited to participate at open workshops of the architectural competition and then through the public hearing of the zoning plan. The hearing in itself is experimental, as citizens were invited to visit the area throughout the summer 2012, and to meet planners in an outdoor shed close to the experimental garden (see figure 2) where people could rent a bed to grow vegetables and useful plants. In addition the plans received a lot of attention in media.

The Norwegian University of Science and Technology (NTNU) and the research institute SINTEF follow the process (Gansmo et al 2011). The research team includes a broad span of disciplines in order to match the many aspects of the planned neighbourhood, in particular designing settlements that enable people to lower their total "carbon footprint". Preliminary calculations on carbon neutral living arrangements are among the inputs.

Throughout the process there is built a special relation with the city Freiburg in Breisgau in Germany[9]. This Green City Freiburg has approximately the same number of inhabitants and similar goals for environment friendly living, housing and transport. In contrast to Trondheim, however, Freiburg has nearly thirty years of experience, being a result of strong local engagement in the Green Alternative Movement since the 1980ies. Inspired by Freiburg a *Climate Centre* will be located at Brøset, for the purpose of demonstration and documentation for the industry during the development, and for inhabitants and visitors.

In this case we find that planners and politicians are the primary partners in R&D activities. Due to the global challenge of improve climate performance, national policy has provided financial support for local initiatives, and institutional support via research programs and international exchange of knowledge. R&D uptake is most active in relations between the public representatives, local community planners, universities and expertise within the Housing bank and Enova. Municipalities are exchanging experiences while at the same time competing about the most innovative green project. Meanwhile the construction industry is expectant and awaits convincing market opportunities.

2.1.3 Case 3: Powerhouse #1 – development of energy efficient and energy producing commercial buildings

The Powerhouse alliance was established in 2010 by a property and developing company, an entrepreneur, an architect, an aluminium producing company and an environmental organization.

The alliance wants to demonstrate that it is possible to build energy-positive buildings not only in warm climates, but also in colder climates such as that in Norway. The first project, Powerhouse #1, is planned as a new office building for business tenders. The intended location is at the city harbour of Trondheim. The project includes energy saving

[9] http://www.fwtm.freiburg.de/servlet/PB/show/1199617_l2/GreenCity.pdf

measurements, integrated ventilation, heating/cooling solutions, and electricity production integrated in the building's construction (see figure 3). The ambition is to develop Norway's first − and the world's northernmost – energy-positive office building.

While Powerhouse #1 is still in the concept phase the Powerhouse alliance is now designing its first rehabilitation project. New façade solutions, new technology for energy production and control systems are among the planned measurements. The ambition is to transform the existing building from the 1980ies into net energy producing buildings – "plus buildings".



Figure 3: Powerhouse #1 at Brattøra port, Trondheim (Photo: www.powerhouse.no)

The Powerhouse Alliance[10] draws upon experience from the various partners. The environmental organization Zero took the initiative by challenging the Norwegian construction industry to increase the investments of research for renewable energy. Among those responding is the aluminium company Hydro. Hydro has during it's more than hundred year's history been active in research and development activities. The current priorities are building systems and façade solutions with integrated energy production. The property and developer company Entra joined the alliance due to its environmental friendly business concept[11]. Entra contributes with experience from a major energy efficient rehabilitation project and later the completion of Norway's largest office building with passive house standard[12]. Similarly the construction company Skanska and the architects Snøhetta joined the alliance with international experience and high ambitions regarding energy efficiency and environment performance.

[10] http://powerhouse.no/en/
[11] http://www.entra.no/en/
[12] Papirbredden II, Drammen. Completed 2012. Low carbon concrete and geothermal energy wells.

The Research Centre for Zero Emission Building (ZEB) [13] is part of a national program for environmental friendly energy research, involving NTNU, SINTEF and a group of industry partners and international research partners. ZEB has become an associated partner in the Powerhouse #1 project. ZEB is responsible for the challenge of calculating embodied energy in the building material[14] and comparing various alternatives.

The story of Powerhouse exemplifies the behaviour of industrial actors seeing a potential market for innovative solutions. Similar to the Vennesla story, a group of individual enterprises saw an opportunity to collaborate due to supplementary expertise. The alliance draws partly on internal R&D capacity and partly on the newly established ZEB centre. Both include relations to international R&D networks. Special in this case is that a non-governmental organization triggered the initiative, that R&D investments are basically financed by the industrial partners, and that the ambition is to prove that the innovative building concept can be realized on a commercial basis (as a business rental building).

3. Findings

The institutional framework for R&D in Norwegian construction industry has some characteristics that are illustrated by the three case stories in this paper.

Firstly it is the funding institutions. The national housing bank (Husbanken) has a long tradition to be a financial instrument to implement national policy regarding housing in Norway. As for environmental and energy ambitions, Husbanken share this role with the more recently founded institution Enova. They both provide support from highly qualified experts. They also honor initiatives with goal-breaking results status as Role model projects. The three case stories illustrate how R&D activity in the construction industry is encourage by an institutional framework that combines promotion with expertice and financial support. This finding is supported by previous studies revealing that R&D uptake in a market dependent industry depends on the potential economic value of new knowledge (Saviotti 1998, Schartinger et al 2002).

Secondly there are the centres for research-based innovation. Examples illustrated by the cases are The wooden centre, TreSenteret at the technical university NTNU and the Zero Emission Building research centre (ZEB). They both have industry and research partners and operate on long term conditions. Previous studies have explored how research centres operate as a source for learning for their industrial supplier companies (Bozeman 2000), and the three case stories illustrates this mechanism.

Thirdly there are the development programs. The case stories illustrate how ambitious clients and visionary politicians have succeeded to trigger the industry with programs such as Cities of the Future, Future Built and Norwegian Wood. Award-winning buildings and Role

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[13] http://www.zeb.no/index.php/about-zeb

[14] Embodied energy covers energy consumed in obtaining, processing and transporting the building materials for the construction, maintenance during operation life span and final disposal of the materials.

model projects receive a lot of publicity and interest from the market. Previous studies have revealed the dynamic of regional innovative systems (Cooke & Leydesdorff 2006, Asheim & Coenen 2005),and how competition can be a driving force in innovation processes.

Fourthly there is the tradition for government/ industry collaboration. Involvement of industrial actors has proved to be a key to success in development processes. Organizations within the construction industry are involved in formulating new building regulations, and only research-based knowledge is considered legitimate to underlie new regulations. Such involvement contributes to implement R&D investments into practice, and is in accordance to recent theories including the element of democracy into innovation systems of the twenty-first-century (Carayannis & Campbell 2012).

4. Discussion and conclusion

The institutional framework identified in this paper may have some characteristics that are specific for the Norwegian or Nordic countries. Variations in the political economy between the Nordic countries and others may provide an explanation for the specific institutional framework for R&D based innovation. In “coordinated market economies” the state and its government plays an active regulative role in the construction market and are also active in supporting R&D activities together with industrial bodies. In such economies strategic interactions between firms and public actors are important for innovation and environmental improvements, compared to liberal market economies. There are discussions among scholars what implications this has for translating R&D into industry outcomes. According to Hall and Soskice’s theory (2001) actors within the Nordic countries have a strong developed knowledge absorptive capacity. The focus is on incremental innovation while the capacity for creating radical innovations is weaker than for liberal market economies. Empirical studies however have not proved this distinction, and rather suggest to focus on the productivity of R&D processes independent of economic and political systems (Akkermans et al 2007)

Norway and other Nordic countries have applied a variety of the knowledge based economy strategy that might be characterised as “learning economy” (Asheim and Coenen 2005). In a learning economy innovation is understood as an interactive process which is socially and territorially embedded and culturally and institutionally contextualized (Lundvall 1992). The learning perspective implies a dynamic notion of innovation, drawing the attention to knowledge transfer and collaboration in R&D processes. The three case stories presented enlighten how innovation and development progress step by step and who are the driving actors.

The three case stories illustrate some mechanisms and processes of the innovative development within the Norwegian construction industry. The system approach has revealed the relevance of networks and roles of various actors involved. The examples indicate that “the learning economy” has proved as a striking institutional framework for translating R&D into environmental ambitious projects.

In addition to national collaboration also international exchange of R&D is most relevant. Norway has great advantages from learning from European countries[15] regarding the use of wood, energy efficiency and green urban living. Similarly Norwegian experiences are conveyed to other countries. The Moelven glue laminated wood has been developed further and the production of massive wood element is now transferred to the Holtz 100 massive wood technology. Research and product development performed by Hydro for a European market is about to become recognized in Hydro's home country. The Scandinavian Architecure is internationally recognized due to several status projects done by architects with international education and background. They are among the driving forces for new and green urban settlements in Norway.

R&D investment impacts should be considered at a long time-frame. Research investments on massive wood has a long history in Norway. Research on energy efficiency has a shorter history than wood. However existing research institutes and universities are mobilized by extensive research programs during the last few years. Green urban living, on the other hand, is a new research area, and so far there exist no research investments dedicated for this purpose.

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Automated Building Code Compliance Checking – Where is it at?

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Abstract

There has been an extensive amount of research conducted internationally over the last four decades in the area of automated and semi-automated regulatory compliance checking for the Architecture, Engineering, and Construction (AEC) industry. This paper summarises the earlier research initiatives, explores common themes and different approaches used, as well as comparing the strengths and limitations of a number of major code compliance checking tools. Some of these tools have been implemented commercially and others are beginning to be adopted or are in their final stages of development. The paper also examines how readily these tools can be applied in the context of a performance-based code as found in New Zealand.

Due to a recent push for innovation and productivity improvement in the AEC industry, there is an increased uptake of building information modelling (BIM) and the Industry Foundation Classes (IFC) open standard data model for interoperability. The availability of high performance personal computers, efficient web-based technology, and new initiatives in legal knowledge representation modelling should make the development of commercial compliance checking systems more viable than ever. However, the quest for an industry agreed unified approach seems to be far from over.

Research is being conducted to develop a computer interpretable representation of New Zealand's performance-based codes using an open standard legal data exchange protocol. This is to be integrated into a web-based BIM compliance checking framework. The fire safety clauses of the New Zealand Building Code (NZBC) are used in the case study.

Keywords: building information modelling (BIM), industry foundation classes (IFC), automated compliance checking, performance-based code, standards representation

1. Introduction

We live in a built environment designed around rules to ensure our safety and well-being. A building is subject to multiple regulatory compliance assessments throughout its entire life. As part of the design process, building designers ensure that every aspect of their design adheres to various regulatory requirements. The design is then subject to formal audit by the consent processing authority as part of the approval process. During construction and

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commissioning, every building component is checked before and after installation to ensure that the quality of products and workmanship conforms to the specified standards. The facility management of a building also requires regular compliance audits to ensure that the building is used and maintained as required and as designed. Even at the demolition stage, compliance checking is vital to ensure safety of occupants in the neighbouring buildings and to protect the surrounding environment during the work. In New Zealand, these codes are performance-based.

The conventional practice of code compliance checking in the industry has largely been a manual process, which is laborious, costly, and error prone. There have been numerous attempts over the last three decades to automate the process, but the progress has been slow. The fragmentation and diverse nature of the industry, complex network of stakeholders, competitiveness, declining productivity and a lack of motivation to adopt new technology have certainly contributed to this (El-Diraby and Kinawy, 2008; Froese et al., 2007; Masterspec - Construction Information Ltd, 2012).

The ability to share and interoperate pertinent information efficiently between the stakeholders in a building project (e.g. architects, engineers, project managers, contractors, building owners and local authority) is a key ingredient for an automated compliance checking system. The need for interoperability in the industry has long been identified (Gallaher et al., 2004; Halfawy et al., 2002), but it has remained as a challenge. The cost of inadequate interoperability in the US capital facilities industry was quantified by NIST in 2004 to be US$15.8 billion annually (Gallaher et al., 2004). This is equivalent to around NZ$295 million annually for commercial and residential construction projects in New Zealand.

Research by Business and Economic Research Limited (BERL) in association with Building Research Association of New Zealand (BRANZ) and Price Waterhouse Coopers (PWC) has shown that a 10% change in efficiency in the construction sector would bring about a 1% change in GDP. Also, as the industry makes up 8% of the economy a 1% gain in the productivity is worth NZ$300 million in annual GDP improvement (Nana, 2003). This has been a motivation for the recently established government's initiative "Building and Construction Productivity Partnership" that aims to increase the productivity in the industry by 20% by 2020 (Page and Curtis, 2012), which is a potential saving of about NZ$6 billion per annum (Masterspec - Construction Information Ltd, 2012). One of the first undertakings in this initiative is the New Zealand national on-line consenting system currently being developed, which could utilise a code compliance checking system.

1.1 Research Methodology

The techniques of Systematic Literature Review (SLR), or Systematic Review (SR), have been used to help identify the available primary studies relevant to this research topic. Borrowing the PICOC (Population, Intervention, Comparison, Outcome, Context) criteria from the medical SR guidelines (Kitchenham and Charters, 2007), a search strategy was developed. Using these criteria with references gathered from several main primary studies, a set of keywords were derived for use in literature searches. A total of about 320 relevant references spanning across 40 years have been identified. Some of the more significant

primary studies identified and their influences have been presented in a timeline (Figure 1). The development of personal computers, internet technology and CAD systems are plotted as a background reference.

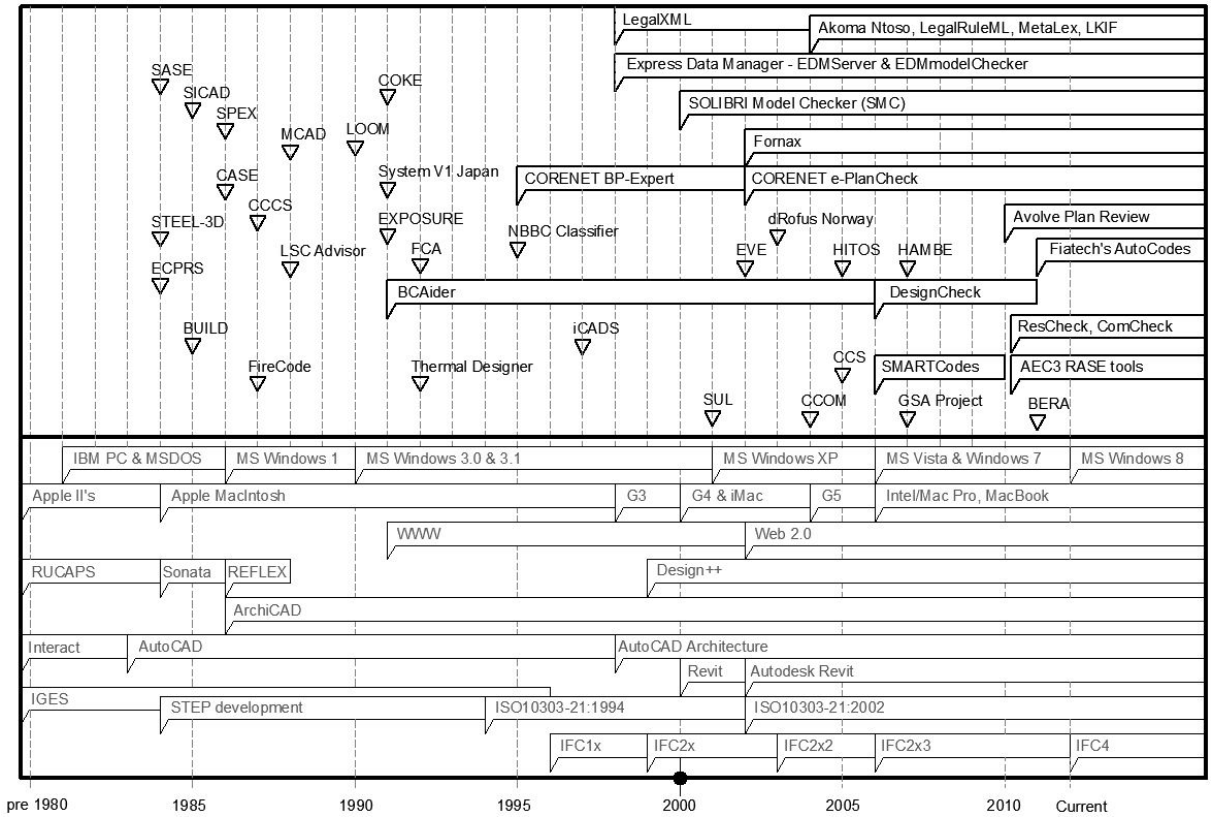

Figure 1: Timeline of International Research into Code Compliance Checking

2. Regulatory Framework for AEC industry in New Zealand

The regulatory framework for the AEC industry in New Zealand consists of the Building Act 2004, which is the official legislation; Building Regulations, which are made under the Act; and the NZBC, which is part of the Building Regulations (Merry and Spearpoint, 2008).

2.1 Compliance with NZBC

NZBC is a performance-based code and consists of two preliminary clauses and 35 technical clauses covering aspects such as fire safety, structural stability, health and safety, access, moisture control, durability, energy efficiency, services and facilities. Each technical clause specifies functional requirements as well as qualitative or quantitative performance criteria to which the completed building and its components must conform throughout its intended life. A performance-based code does not prescribe how a design and construction process should be carried out, but instead allows for innovation and uniqueness in designs, which must be proven by established scientific and engineering principles.

There are two ways to comply with the NZBC, namely the “Acceptable Solution” or deemed-to-satisfy solution, which shows full compliance with the relevant prescriptive requirements of

the accompanying compliance documents, and the “Alternative Solution” by means of a proven engineering design, which usually involves calculations and/or simulations as well as an external design review process.

3. Automated Compliance Checking

A common approach to automated compliance checking is systematic comparison, i.e. comparing each object or system in a building model representation with the constraints in a standard. The output is usually a list of non-conformant objects.

A major challenge has been the quest for suitably practical digital representations of both the building and the standards (Nawari, 2012). A few factors attributed to the slow progress have been the unavailability of an industry standard data model specification and the lack of computing power. Another contributing factor is the complexity in representing regulatory texts as computable objects (Drogemuller et al., 2000; Moulin, 1992) and there has been little research contribution in this regard from the legal domain until recently.

4. Building Model Representation

CAD has been used to represent a building two dimensionally since the early 1960’s. It has since developed into a 3D representation tool through systems such as RUCAP, Sonata, REFLEX, as well as ArchiCAD and AutoCAD, and now shifted into object-based Building Information Modelling (BIM) paradigm (Eastman et al., 2011).

The emergence of BIM technology and the IFC open data model specification for interoperability has provided a reasonable method and a generally agreed protocol for the digital representation of a building. IFC2x4, or IFC 4, is the latest model specification that is currently being accepted as International Standard ISO 16739 (Liebich, 2010).

5. Standards Representation

Researchers have spent a lot of effort in formulating an ideal digital representation of regulatory requirements for compliance checking applications. Most of the research focused on encoding prescriptive regulations and their derivatives as rules in knowledge-based systems. One important early attempt was the implementation of decision tables in 1969 with the AISC (American Institute of Steel Construction) Specifications. The decision logic tables approach lends itself well to a procedural standard such as the AISC Specifications. This was implemented as a design tool for steel structures for at least 15 years (Fenves et al., 1969). Further work in this area resulted in the development of SASE (Standards Analysis, Synthesis and Expression) model by US National Bureau of Standards (now NIST) in 1984, which was one of the most significant early standards representation systems. SASE was implemented to manage the creation and maintenance of the decision tables and structure of the standards (Fenves et al., 1995; Lopez et al., 1989).

Throughout the 1980’s, there is evidence of different approaches being investigated to computerise building regulations in various parts of the world (Vanier, 1989). One approach

was hyper-document modelling and the use of hypertext to represent regulatory provisions (Turk and Vanier, 1995; Vanier, 1989), which was the state of the art at the time. The concept of marking-up regulatory texts to create a computable representation has been revisited in a more recent work (Hjelseth and Nisbet, 2011; See, 2008).

Knowledge-based and expert systems were popular throughout the 1990's. They provided methods to encode regulatory information for use in design (Eastman et al., 2009; Frye et al., 1992; Mugridge et al., 1996; Rosenman and Gero, 1985), which is useful as long as the underlying knowledge-base is kept up to date with the current regulatory provisions. Despite the inherent inefficiency and the reliance on manual updates, the investigations into automated or semi-automated extraction of information from regulatory texts into rules and other computable objects have continued until today (Hjelseth, 2012; Kiyavitskaya et al., 2007; Zhang and El-Gohary, 2011, 2012).

A noted trend during the 1990's is the hard-coding of regulatory criteria into engineering design and analysis software suites (Fenves et al., 1995). This "black-box" approach of code representation has received a lot of criticism due to its non-transparency and inflexibility to regulatory changes. However, this practice has continued until today, although to a lesser extent, e.g. some hard-coded criteria are now provided with customisable parameters.

Creating an independent representation that derives data from legal sources maintained by a third party is far from ideal, unless it is linked to the source data and there is an automated update process in place. Otherwise, the representation would need to be manually updated to reflect the current status of the source documents, which are subject to on-going changes.

In the absence of an ideal digital representation of standards and regulations for the industry, the quest for a better interim solution continues. There have been projects using object-oriented and constraint-based approaches, as well as applying industry specific taxonomies and ontologies in combination with Artificial Intelligence (AI) and Natural Language Processing (NLP) techniques to allow machines to interpret regulatory texts (Cheng et al., 2008; Zhang and El-Gohary, 2011). Semantic modelling and the application of deontology, deontic logic, and Computational Law with NLP on an underlying domain ontology has also been explored (Salama and El-Gohary, 2011). The use of Description Logic (DL) languages, which is based on a concept developed in the late 1970's (Hakim and Garrett, 1993), was also investigated to allow automated description of engineering design knowledge as comparable objects. This concept was further improved with Typed Feature Structure (TFS) techniques by researchers in Australia (Woodbury et al., 2000).

Regulatory texts are generally not written for machine interpretation and the effort put into making that a possibility has not been very successful so far. Furthermore, standards and building regulations often consist of complex multiple inter-related documents that are poorly structured and subject to frequent amendments, which is challenging for automation.

Provided that any standards representation can be linked to the source legal documents, AI and NLP techniques may provide a method of keeping the representation up-to-date by automatically capturing and incorporating any changes. However, an agreed data exchange

protocol, that seems to be the current gap, would greatly facilitate this. The International Code Council (ICC) that develops model codes in the US took an initiative and filled the gap by producing SMARTCodes in 2006 containing official representations of a few important standards. SMARTCodes provided the legislative body with an authoring tool to manage the amendments of the codes. Unfortunately, SMARTCodes development ended in 2010 due to a lack of funding. The underlying mark-up concept used by SMARTCodes has been further developed by AEC3 (UK) Ltd (Hjelseth, 2012). It is pertinent, however, that the application role remains with the legislative body, otherwise any representative standard created by the end user would require manual amendment every time the source information is updated.

Recently, there have been independent investigations undertaken by the legal domain in the field of legal informatics, legislation modelling and digital representation of regulations (Vitali and Zeni, 2007). These works are originally intended to facilitate the legislation process and providing easier public access to the legal resources, e.g. Crown Legislation Markup Language (CLML) of UK. However, recent work also includes some useful new initiatives in the legal data exchange protocol, e.g. Legal Knowledge Interchange Format (LKIF) and LegalRuleML which is being standardised by the Organisation for the Advancement of Structured Information Standards (OASIS) as an open standard data model.

As indicated earlier, a computer interpretable standard representation should ideally be published and maintained by the government department responsible for producing the standards. The UN's e-Government initiative, which is being adopted around the world including New Zealand, provides a good platform for that purpose. In combination with the open standard legal data interchange initiatives and the work undertaken by OASIS, this may provide the solution the industry has been seeking for several decades.

6. Compliance Checking Applications pre-2000

This section reviews some of the early applications developed using data representations discussed in previous sections. The successful implementation of AISC Specifications in 1969 as a network of decision tables motivated a number of developments well into the 1980's. Examples include an advanced 3D graphical CAD system known as STEEL-3D for the design of steel frames to AISC Specifications (Pesquera et al., 1984), a software tool developed at Carnegie Mellon University for the design of reinforced concrete beams (Noland and Bedell, 1985), an automated compliance checking system developed at University of Austin (Jaeger and Harelik, 1985), and computerised building standards research at VTT Finland (Kähkönen and Björk, 1987).

Following the successful implementation of SASE, two compliance checking applications were developed. SICAD (Standards Interface for Computer Aided Design) incorporates one-way mapping functionality to assist the user to navigate, evaluate and extract required information from standards. Missing or incomplete data is managed by additional inputs from the user. This was implemented successfully as a design tool with AASHTO Bridge Design System and used for several years (Lopez et al., 1989). The Standards Processing Expert (SPEX) was another software application developed in 1986 based on SASE as a

knowledge-based system to determine conformance of component materials, structural and geometric properties with the design standards (Delis and Delis, 1995).

The application of Artificial Intelligence (AI) techniques were explored by researchers in Australia in the mid 1980's. They came up with a prototype expert system called BUILD (Rosenman and Gero, 1985) as a proof of concept. Some of these techniques were later used in the development of BCAider and DesignCheck (Ding et al., 2006).

In New Zealand, research into the application of expert systems in this domain saw the development of FireCode in 1987, which was used to check design conformance with a draft prescriptive Fire Safety Code. Other related software applications developed included "Seismic" for checking building design against earthquake and wind loading requirements, WallBrace to assess compliance with light timber-framed building standards, an object-oriented system "ThermalDesigner" for checking conformance of a residential building with the Thermal Insulation Code in 1992, and the ALF spreadsheet tool for conformance checking with thermal insulation standards for residential buildings (Amor, 1992).

In the US, Life Safety Code (LSC) Advisor (1988), a rule-based compliance checking tool was developed for auditing architectural plans against the prescriptive requirements of LSC (known as NFPA 101) that regulates building design for life safety and fire protection. LSC Advisor was later extended and developed into an expert-system Fire Code Analyzer (FCA), at Massachusetts University around 1991. FCA is closely related to SICAD and uses a frame-based architectural model representation, a set of rules as well as some geometric algorithms (Delis and Delis, 1995). EXPOSURE, an expert system version of NFPA80a was also developed around this time for fire protection design of building exteriors (Smith, 1991).

iCADS (Intelligent Computer-assisted Design System) was another expert-system example developed around 1990 with an extended knowledge-base covering space layout, structural system selection, day-lighting, artificial lighting, noise insulation, climate control and energy conservation, and construction costs. It incorporated a CAD system, a geometry interpreter, a relational database and an expert design advisor (Myers et al., 1992).

7. Compliance Checking Applications post-2000

Since the emergence of the IFC open data model, we have seen the development of several important tools that are being used today, namely Express Data Manager (EDM) Suite (now incorporating EDMmodelChecker), Solibri Model Checker (SMC), Fornax plan checking tool, Avolve plans review, Design Data System (DDS), etc.

In 1995, the Building Construction Authority (BCA) of Singapore initiated the CORENET (Construction and Real Estate Network) electronic consent submission system incorporating an in-house developed Building Plans (BP) Expert System to check 2D plans for compliance. The system was upgraded in 2002 to CORENET e-Plan Check replacing the 2D BP Expert System with the 3D IFC data model (Khemlani, 2005).

Express Data Manager (EDM) Suite was developed by Jotne EPM Technology in Norway in 1998 as an object database with tools to manage complex Product Data Models. It started out as a collaboration tool, but has since incorporated several additional modules including EDMmodelChecker that supports open development using the EXPRESS data modelling language (ISO 10303-11) (Yang, 2003).

BCAider was an expert system released in 1991 by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) in Australia. It was commercially available for compliance checking against the Building Code of Australia (BCA) until 2005. In 2006, CSIRO announced DesignCheck, a new system that incorporated EDM as the core rule bases and compliance checking engine for the BCA (Ding et al., 2006). DesignCheck has not been used commercially and it appears that there is no plan for further development.

Solibri Model Checker (SMC) was developed in Finland in 2000 and started out as a BIM model quality assurance and validation tool, but has since developed into a stand-alone graphically-driven rule-based compliance checking and reporting application. SMC has a set of built-in rules that can be managed by a ruleset manager. A ruleset can be replicated, but the extent of user customisation is limited to changing parameters (Eastman et al., 2009).

The US Department of Energy produced and published ResCheck (Residential Compliance) and ComCheck (Commercial Compliance) to allow anyone to check a building design against the applicable energy standards, e.g. IECC and ASHRAE Standards 90.1. Both of these compliance checking applications have all the standards criteria hard-coded into the tools, although managed by the government department that have control over any amendment to the standards (Halverson et al., 2009). Similarly, the US GSA (General Service Administration) Courts Design Guide automation project also incorporates an independent ruleset manually derived from the textual standards (Eastman et al., 2009).

An expert system of the nineties that has survived the test of time is Design++. It has been developed into a knowledge-based design automation tool in conjunction with BIM. Design++ has been incorporated into a number of commercial products including Bluethink's House Designer. Apart from giving advice to designers based on the evaluative rules, this system can also incorporate a set of generative rules for creating objects automatically (Huuskonen and Kaarela, 1995). Again, the rulesets are encapsulated into the application and can only be managed within the application.

One of the latest efforts reported is the collaborated project between ICC, Solibri and Fiatech together with a few other software companies to develop AUTOCodes. This is currently a prototype system that promises an integrated compliance checking capability for the US building model codes (Fiatech, 2012).

All of the approaches discussed so far, including current commercial systems, appear to have one thing in common. They all use an independent regulatory data representation either directly or via other dependent systems, and the representation is hard-coded into the system and is subject to manual updates by the software developers. For example,

CORENET e-Plan is using the Fornax library in conjunction with EDM that has regulations and additional rules hard-coded in EXPRESS.

8. Performance-based Code Compliance Checking

In contrast to earlier approaches the development of a software tool is being investigated to assist with converting NZBC Clauses C1 to C6 “Protection from Fire” into a set of rules using one of the open standard legal data exchange formats such as LegalRuleML or LKIF. Adopting an open standards specification allows revisions to be easily assimilated into an existing representation without the need to reconstruct it. Both the prescriptive requirements and quantitative performance criteria are to be represented in this way.

In the intended framework, the compliance checking component would read an IFC-based building model and audit the model against a selected set of open standard constraints. For clauses requiring subjective qualitative performance, the user can select a data exchange schema to allow the system to interact with external calculation or simulation modules. The returned result of the calculation can then be checked against the selected performance criteria either qualitatively or quantitatively.

9. Conclusion

Most of the research on automated compliance checking has focused on procedural standards and prescriptive regulations as they tend to be easier to manage and code (Yang and Li, 2001). Where research has examined performance-based codes, consideration was mainly given to the prescriptive parts of the codes (Han et al., 1998; Han et al., 2002; Hjelseth, 2012). Compliance checking against qualitative and quantitative performance criteria can be achieved semi-automatically using a combination of human input and data exchange with calculations or simulations modules. Unfortunately, there is little research in this particular area. The current research attempts to fill this gap in the context of New Zealand’s performance-based codes.

Based on the New Zealand National BIM Survey 2012, there is a strong trend of rapid uptake of BIM in the industry. However, there is a noted lack of agreed industry-wide protocols, tools and frameworks for interoperability (Masterspec - Construction Information Ltd, 2012). The initiative taken by the ICC with SMARTCodes and AUTOCodes is a positive step in this direction, but these systems still employ embedded rules that would require manual updates and maintenance in response to codes changes. As legal knowledge is being converted into digital resources for interoperability by officials in the legal domain, adopting an open standard legal data model may alleviate the need to maintain yet another set of rules. Revisions of standards can simply be imported into the system as an update to existing representations. In view of the general direction taken by standards authorities in various jurisdictions around the world to adopt a standard legal data exchange protocol, any attempt in the interim to represent standards and regulations for the purposes of computer-assisted compliance checking may benefit from investing in an open standard protocol offered by the legal domain such as those currently being developed at OASIS.

10. Acknowledgement

The first author gratefully acknowledges assistance from the Building Research Levy for his research.

11. List of Acronyms

AI: Artificial Intelligence
AISC: American Institute of Steel Construction
BCA of Singapore: Building Construction Authority of Singapore
BERL: Business and Economic Research Limited
BP Expert System: Building Plans Expert System
CLML: Crown Legislation Markup Language
ComCheck: Commercial Compliance Checker
CORENET: Construction and Real Estate Network
CSIRO: Commonwealth Scientific and Industrial Research Organisation
DDS: Design Data System
DL: Description Logic
EDM: Express Data Manager
FCA: Fire Code Analyzer
GDP: Gross Domestic Products
GSA: General Service Administration
iCADS: Intelligent Computer-assisted Design System
ICC: International Code Council
IFC: Industry Foundation Classes
LKIF: Legal Knowledge Interchange Format
LSC: Life Safety Code
NIST: US National Institute of Standards and Technology
NLP: Natural Language Processing
NZBC: New Zealand Building Code
OASIS: Organisation for the Advancement of Structured Information Standards
PICOC: Population, Intervention, Comparison, Outcome, Context
PWC: Price Waterhouse Coopers
ResCheck: Residential Compliance Checker
SASE: Standards Analysis, Synthesis and Expression
SICAD: Standards Interface for Computer Aided Design
SLR: Systematic Literature Review
SMC: Solibri Model Checker
SPEX: Standards Processing Expert
SR: Systematic Review
TFS: Typed Feature Structure

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Exploring a Methodological Framework for Understanding Adaptive Change in Cities

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Abstract

Resilience is about change and how systems respond to change. To understand resilience it is therefore important to understand how cities respond to change. Cities can be described as social ecological systems that react to change and perturbations through responses at various spatial and temporal scales. In the study of resilience of ecosystems, this is described through the concept of panarchy and the metaphor of the adaptive cycle. The adaptive cycle is used widely as a key metaphor to describe resilience. Central to this metaphor is the idea that systems undergo periodic cycles of change without fundamentally changing functional identity, remaining within a particular basin of attraction. However, internal or external pressures may also cause the system to tip into another basin of attraction or system state, with a different functional identity.

In ecosystems, these different states are well described and the characteristics indicating a change in identity are well defined. However, in the study of urban social ecological systems, this is still a mainly unexplored topic and the methodologies for identifying and mapping different urban system states and phases within the adaptive cycle, let alone the application of the adaptive cycle concept requires further investigation.

This purpose of this paper is to present a proposed a methodological framework for describing the movement of cities or neighbourhoods through the various phases of the adaptive cycle and possibly, different system states. This method is illustrated using the example of two neighbourhoods in South Africa and the changes they experienced over a period of approximately one hundred years.

Keywords: Resilience, **Panarchy, adaptive cycle, urban systems**.

1. Introduction

Cities, like ecosystems, are complex adaptive systems (Holland, 1996; Gunderson and Holling, 2002; Johnson, 2002; Taylor, 2005; Davoudi et al., 2012). As a great deal of work on resilience has been done on the study of ecosystems, and social-ecological systems

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(Davoudi et al., 2012) it would seem only appropriate that in our quest to understand urban resilience that we build on and apply the thinking and concepts that have already been developed within this field. However, unlike ecosystems, the processes and methodologies for describing urban systems and the way they change have not been fully explored. Such exploration is necessary as resilience in the urban environment may mean something different to resilience of an ecosystem. This paper aims to explore a possible methodological framework to map adaptive change, based on the concept of panarchy and the metaphor of the adaptive cycle. This framework was developed while reflecting on previous studies of two neighbourhoods in Tshwane that the authors have undertaken.

2. Background to key resilience concepts

2.1 Panarchy

Among the most notable of theories that describe resilience of social-ecological systems and explain how these systems naturally change and evolve is the concept of panarchy and the metaphor of the adaptive cycle introduced by Gunderson and Holling (2001). The concepts behind the panarchical view of social-ecological systems as described by Gunderson and Holling (2001) are:

1. Social-ecological systems should be treated as complex adaptive systems in which the various agents are constantly adapting to the changes within their environment. Due to the interactions by the various components the system may produce unpredictable behaviour.

2. A system can have more than one stable state instead of a single point of equilibrium. Change can still happen within each stable state; however a few, normally three to five, important variables and interactions remain the same. A system with more than one stable state can move quickly between states when a critical threshold or tipping point is reached. A prime example of this is the cycles of growth and recession that happen within an economy.

3. “Panarchy emphasizes the importance of relevant interactions across geographic and time scales” (Gunderson and Holling, 2002, p3). This highlights the importance of a system’s history as well as that a system interacts at higher and lower spatial scales, also referred to as nested systems. Systems at higher scales tend to move at a slower rate though the adaptive cycle than those at the lower scales. “In panarchies transformational change can be generated from below or from above. At the same time larger, slower levels can act to reinforce and sustain the panarchy” (Gunderson and Holling, 2002, p25).

The concept of panarchy still needs to be tested on urban systems. The Resilience Alliance 2010, p30) suggested that the city be seen as the focal scale, with neighbourhoods forming sub-systems, and one can add, within neighbourhoods the streets or buildings forming sub-systems of the neighbourhoods. This understanding comes from the practice of defining large ecosystems such as a watershed as focal scale. However, the complexity of the city

and the diversity in its smaller sub-systems suggest that for urban resilience it would be more practical to look at a smaller scale such as the neighbourhood or city district as focal scale.

2.2 The Adaptive Cycle

The metaphor of the adaptive cycle is used to describe the movement of a system through four distinct phases typically followed by social-ecological systems. The various phases of the adaptive cycle are: Growth (r); Conservation (k); Release (Ω) and Reorganisation (α) and are described in further detail in Table 1 below.

Table 1: A summary of the characteristics of each phase of the Adaptive Cycle as described by (Gunderson and Holling, 2001, 2002; Folke, 2006; Davoudi et al., 2012)

Phase of Adaptive Cycle	Characteristic of each phase	Level of Resilience
r Growth	This phase occurs early in the cycle and is characterised by a period of rapid growth, and an accumulation of resources, as 'agents' (often innovators or entrepreneurs) seizes opportunities after a disturbance and make use of this time to exploit new niches. The system components are weakly interconnected with little or no internal regulations. There is an increasing degree of diversity; however the system is more vulnerable and far more easily influence by external variability. The agents (individuals) that function best in this phase are those that are best "adapted to dealing with the stress and opportunities of a variable environment – the risk takers, the pioneers, the opportunists"(Gunderson and Holling, 2001, p 43). These agents typically operate at a local scale and over short time periods.	High, but decreasing
k Conservation	The transition from the r phase to the k is a slow incremental process that happens as resources begin to accumulate (as the system moves closer to the k phase its growth rate slows). The connections between the different agents increase as the system moves towards a more regulated but stable state. The increase in stability comes at a cost as the system is only able to deal with a decreasing range of situations. The agents that reduce uncertainty are now favoured over those that functioned better in a variable environment. The shift from the k to the Ω (Release) phase can happen at any time as the system is now more vulnerable to shocks.	low
Ω Release	When a system transitions into this phase it is usually rather sudden and happens when a disturbance pushes the system past a particular point or threshold. The resources that were accumulated during the k phase are now released as the strict regulations and interconnectedness of the system is now broken. This continues until the disturbance has dissipated.	Low but increasing
α Reorganisation	The shift from Ω to α is characterised by the system having weak internal controls; the opportunity for innovation; high potential. However there is a large degree of uncertainty and a reorganisation of the system's structure. The system is also easily influenced by external factors which can lead to renewal or collapse of the system.	high
*An agent can be an individual, household, firm, organisation, government, etc.		

The concept of the adaptive cycle falls within the lager concept of panarchy whereby social-ecological systems form sets of nested adaptive cycles that operate at varied scales. The

larger scales tend to have slower cycle speeds while the lower, smaller scales, tend to have more rapid cycles through the adaptive cycle (Gunderson and Holling, 2001; Folke, 2006; Resilience Alliance, 2010). It is by examining how systems undergo these changes and their behaviour at the various phases that we may begin to better understand resilience in general and more specifically, urban resilience. It is also important to note that “transitions between the four phases of the adaptive cycle do not always follow the same sequential pattern” (Resilience Alliance, 2010) as described by the adaptive cycle. Some systems may skip a phase completely and move onto the next or even go back to the previous phase (Resilience Alliance, 2012).

2.3 What has been done before

The Resilience Alliance (2010) has developed a workbook for assessing the resilience of social-ecological systems that draws on insights derived from complex adaptive systems and concepts such as panarchy and the adaptive cycle. This workbook provides a process to assess the resilience of a particular function of a system or sub-system. It is based on the development of a conceptual model of the social-ecological systems being studied, with the intention of identifying critical thresholds between different system states. To develop the conceptual model the assessment process uses an issue based approach to a) focus the assessment; b) determine the boundaries of the focal scale, and c) identify critical stakeholders and elements. It further uses the tool of historical narrative to map the movement of the system through phases of the adaptive cycle, as well as identify disturbances, cross-scale (spatial and temporal) interactions, different possible system states and the variables that determine these states and which point to the thresholds between states. However, there are a number of uncertainties that are not yet resolved in a satisfactory manner, especially as concerns its use in urban systems. The primary focus of the assessment process is on ecosystems and the effects of human systems on the environment and vice versa, and therefore the examples that have been used are rooted in ecological science and or disaster risk reduction. There is very limited guidance on how to address the concerns of urban resilience, with the urban environment being evaluated as an integrated system. In particular, the workbook does not provide adequate guidance on how to identify the key elements, drivers and agents, especially within the urban system. As practitioners continue to engage with the assessment workbook, more of its shortcomings are exposed and gaps in understanding are bridged. Haider et al, (in Davoudi et al, 2012, p 317), suggest a number of ways to improve the usefulness of the workbook, one of them being a larger diversity of examples of how the resilience assessment has been used. This paper (and the studies on which it is based), attempts to contribute to the development of the assessment process by including the urban social-ecological system. What we are suggesting is not an assessment framework, but rather a process for understanding the adaptive change cycles that an urban area undergoes and the forces that shaped the study areas, so as to discover the key elements, drivers and agents within the urban system being studied. As such it is seen as another tool in the larger assessment framework proposed by the Resilience Alliance workbook.

3. A Proposed Methodological Framework for Understanding Adaptive Change within Cities

The methodological framework that is being proposed was developed through deliberation of the processes that the authors have developed while investigating urban systems and their resilience. Its theoretical base stems from the rationale that the urban environment is a complex adaptive system, and the concepts of panarchy and the adaptive cycle as a primary means to describe changes that systems undergo. Although the panarchical and adaptive cycle concepts have been developed for use for social-ecological systems (Gunderson and Holling, 2001), with the focus being on the ecological system, we believe that these concepts can be adequately translated to describe the urban system.

As discussed, cities are a particular subset of social-ecological systems and any method that seeks to assess or understand their resilience needs to look at the integrated urban system, considering the interactions between not only its ecological and socio-economic systems, but also its spatial and physical attributes and the requirements of community resilience. Furthermore, it should be able to deal with the diversity of its sub-systems and with the complexity and sheer amounts of data that is required. The complexity of the issues means that the rule of hand often cannot capture the critical dynamics at the scales where social and individual resilience come into play and where the tensions between remember (the slow-changing spatial and institutional structures) and revolt (critical self-organization at neighbourhood scale that combines to change or threaten the larger scale functions of the city, e.g. enclosed neighbourhoods or service delivery protests destroying infrastructure) creates the greatest dangers for tipping the system into another system state.

We are proposing that for urban resilience the appropriate focal scale should be at the level of neighbourhood or city district as the level that sits between the self-organising activities of individual agents (households, businesses) that ultimately shapes the structure and functions of the city, and the larger urban system that provides the slow changing variables. This brings in the multiple scale perspective that lies behind the idea of the panarchy. Furthermore, because a “city is a kind of pattern-amplifying machine: its neighbourhoods are a way of measuring and expressing the repeated behaviour of the larger collective… [as] those patterns are fed back to the community, small shifts in behaviour can quickly escalate into larger movements” (Johnson, 2002, p40). The neighbourhood forms a subsystem of the larger city system while the street and site level form subsystems of the neighbourhood system.

The case studies that we will use as examples are based on a study completed in 2011. This study explored spatial change and the drivers behind it within the context of a South African neighbourhood. We have reinterpreted and added to the data from the original study in order to begin to look as how neighbourhoods go through a cycle of adaptive change. Throughout the description of the proposed framework, reference will be made to previous studies in the form of examples as well as part of the reflective process of what has been done.

The two case studies used were of Lyttelton Manor (Lyttelton) and Irene, both in the former town of Centurion that now forms part of Tshwane (Tshwane is the municipal area that

includes Pretoria). These neighbourhoods are located in close proximity to each other but have developed very differently over the past one hundred years. The studies involved a historical overview of the development of the two neighbourhoods, and considered social, economic and institutional factors that played a role in shaping their spatial structure. The findings of the studies suggested that, in the case of these two neighbourhoods, the availability of water, the community attitude to development, location in relation to employment centres as well as to services and retail facilities that are in close proximity are amongst the principal forces that have shaped these neighbourhoods (Nel, 2011). The findings further indicated that no one specific factor can be attributed to having the largest effect of transforming these neighbourhoods spatially. It was rather a combination of different factors, and the interaction between them that occurred at different times and scales, throughout the history of the two neighbourhoods that influenced them. This confirms the idea that one needs to consider the urban environment holistically as a complex adaptive system. However, due to the nature of the studies no ecological data was included. Future studies should take this into consideration.

3.1 Towards a Methodological Framework for studying adaptive urban change

This section outlines the methodological framework used. This framework builds on the Resilience Alliance assessment process (2010), but adapts it to suit the urban system. Examples will be given from the mentioned case studies to help the reader understand and to help support the concept.

Step 1: Select a focal area and set boundaries

To begin an assessment the study area must be selected and boundaries must be set (Resilience Alliance, 2010, p10). Boundaries are placed in order to maintain the focus on the focal area. The bounding of the focal area becomes increasingly important as systems are open to their environments and rarely have clear, well defined, boundaries (Meadows, 2008; Innes and Booher, 2010). The boundaries that are applied should be not only over space but time as well. They should take the form of soft/porous boundaries; which acknowledge that there are cross scale interactions and that systems cannot be cut off as they are open to outside influences. The boundary is placed as a means to keep the study practical. Setting boundaries is up to the discretion of the observer and may have to be adjusted to include or exclude some particular aspects as the assessment is carried out;. This is a very iterative process. For the case studies the existing boundaries of the two neighbourhoods were used, as they were already well defined (see Figure 1).

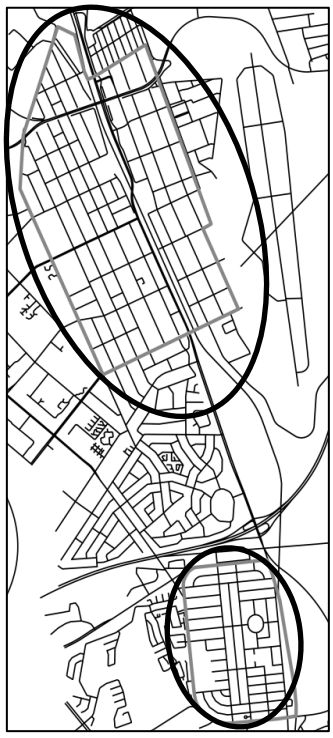

Figure 1: Lyttelton (top) & Irene (bottom).

Step 2: History of the focal area

Once the boundaries have been delineated for the study, the second phase of the framework is to compile a history or timeline of the focal system. A system's history matters, as its present and future behaviour are largely due to its past (Cilliers, 2000; Geyer and Rihani, 2010). As we will illustrate, the history of the system will begin to allude to the system's resilience. Developing such a timeline needs to consider various sources from the different physical, institutional and social systems at play. Throughout this process it is important to begin to identify spatial and temporal patterns that repeat themselves. The history of the focal system should be done as far back as possible, while remaining plausible and relevant to the study.

A one hundred year period was selected for the case studies as this was when the two neighbourhoods were established. There was also sufficient historical information available to allow for a study over this length of time.

Step 3: Identification of key events and changes

The next phase is to begin to look for 'frozen accidents'; events which have inadvertently set the system on a specific path or become an underlying part of that system which in turn shapes the system's current and future behaviour (Holland, 1996; Gunderson and Holling, 2001; Geyer and Rihani, 2010). Once a 'frozen accident' has been identified it is important to describe the circumstances that created it, as this will allow for a better understanding of the drivers of change. The changes and events, as well as their impacts, will begin to guide the study in identifying the relevant information needed to describe the events and subsequent changes that form part of the systems history. The relevant data that will be needed for the study will begin to 'emerge' from the systems history. To help with this it may be useful to look at the timeline through various 'lenses', i.e. social, economic, spatial, institutional, etc. The different lenses bring different types of changes and events into focus.

Step 4: Multiple scales:

A panarchical view requires that, significant events and changes that have happened at a higher and lower spatial scales, i.e. city, street, national or international scales, be added to the focal scale timeline. This is important because lower and higher scales within the panarchy will have an effect on the focal system (Gunderson and Holling, 2002; Resilience Alliance, 2010). From the case studies, an example can be given where the combination of economic recession in the 1980s, due to sanctions posed on South Africa, as well as an aging white population, had a large effect on Lyttelton leading to a large number of subdivisions within the neighbourhood (Nel, 2011)

Step 5: Distinction between changes

Within this step the identification of the various characteristics that have changed, and when these changes have happened, will be needed. This should be done by firstly distinguishing the changes and events according to the magnitude of the effect that they had on the system. These groupings can be defined as small, medium and large events/changes (this should be done in terms of what the long term effects of that event/changes were on the

system or, for more recent events, what the perceived long term effect will be). Secondly, these events/changes are differentiated into categories or types of change, i.e. social, economic, spatial, and institutional. Some events may fit into more than one of these categories, which may also fit into different levels of magnitude, i.e. the decision of the community of Lyttelton to decide against having small blocks with internal roads during an urban renewal process was a 'small' social event, however it had a significant 'large' long term effect on the physical and spatial nature of the neighbourhood.

From the differentiations between magnitude of change and type of change a new series of timelines can be created, were the history of the area has been divided into various separate components. These timelines also represent specific change within the system. This part of the process is to ensure an understanding of the events and changes, and how these may affect more than one category, i.e. spatial and ecological, and possibly various scales of impact. Figure 2 illustrates an example of how this can be represented using the two neighbourhoods changes as an example.

Lyttelton	Large	P	E	P										P	I	E	S	S		E	P	S	I	E	P		P	I	E	S	P	I								
	Medium										P	I	S	P	S	I		I		E	P	S	P	I	E	S	P	I	E	S	I	S	E		P	I	E			
	Small			P	I						I	S						S	I	S	I		P	S	I		I	S	E		P	I	E	S						
		P-1900		1900			1910	1920			1930			1940				1950		1960			1970				1980				1990				2000					
Irene	Small			P	S	I	P				I	S		I						S	I	P	I	P			S	I	P											
	Medium							P	S	I	P	I	S	P	I			P	S	S	I	P	S	I	P		S													
	Large	P	E	P	S						P	S		S				P	E	I	S		P	I	E	S					P	S	E		S	E	I			

Key
P – Physical E – Economic I – Institutional S - Social

Figure 2: How the various characteristics and magnitudes of change where separated in the cases of Lyttelton and Irene

Step 6: Combine timelines

In order to understand the system wide changes that have occurred, as opposed to the specific changes, the various timelines are now reconstituted into a new 'combined' timeline

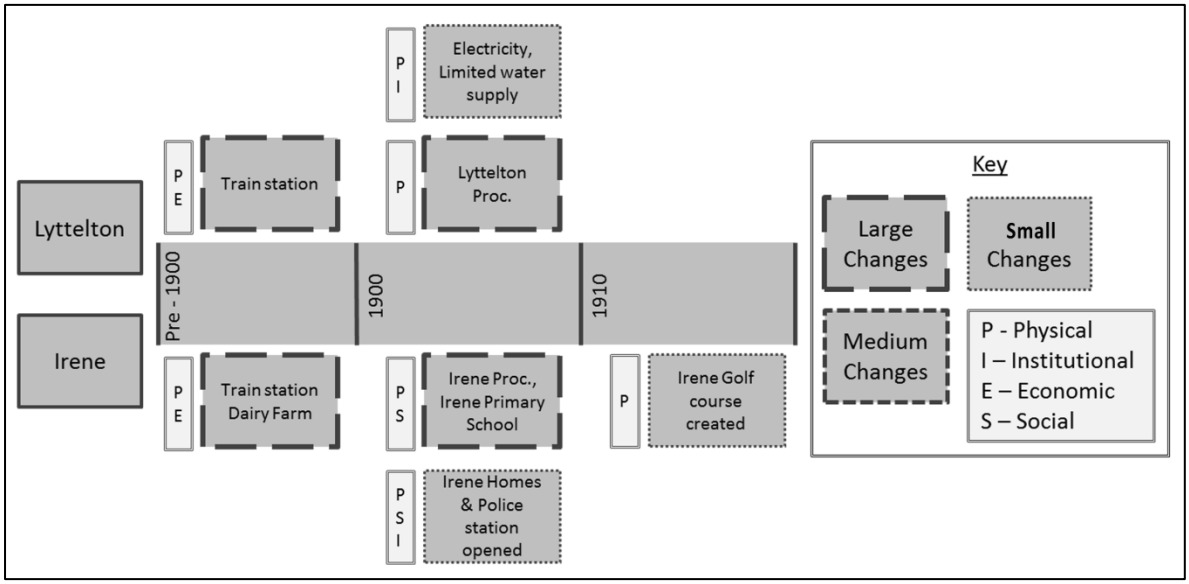

Figure 3: A breakdown of the events, characteristics and magnitude of changes for Lyttelton and Irene. Adapted from Landman and Nel, 2012, p5

that explores the events from different perspectives. During this process, as in the cases of Lyttelton and Irene, key events that had major effects on the system begin to become apparent. These key events point to tipping points or frozen accidents that have profoundly impacted the course of the systems history and the nature of its behaviour.

Figure 3 shows an example of how the original timeline can be recombined with the 'new' timeline; the example only shows a short period of the two neighbourhood's timelines. The key events have been separated into their different characteristics and magnitudes of change that were determined previously. The value of this part of the process is that it helps to show that over the course of a system's history various events from the past have a long term effect on the system and that during some periods there may be many different events and in other times there may be only a single small event. This new timeline will also be vital in determining the weight of each event/change has in the overall movement of the system though the adaptive cycle.

Step 7: Adaptive change though a systems history

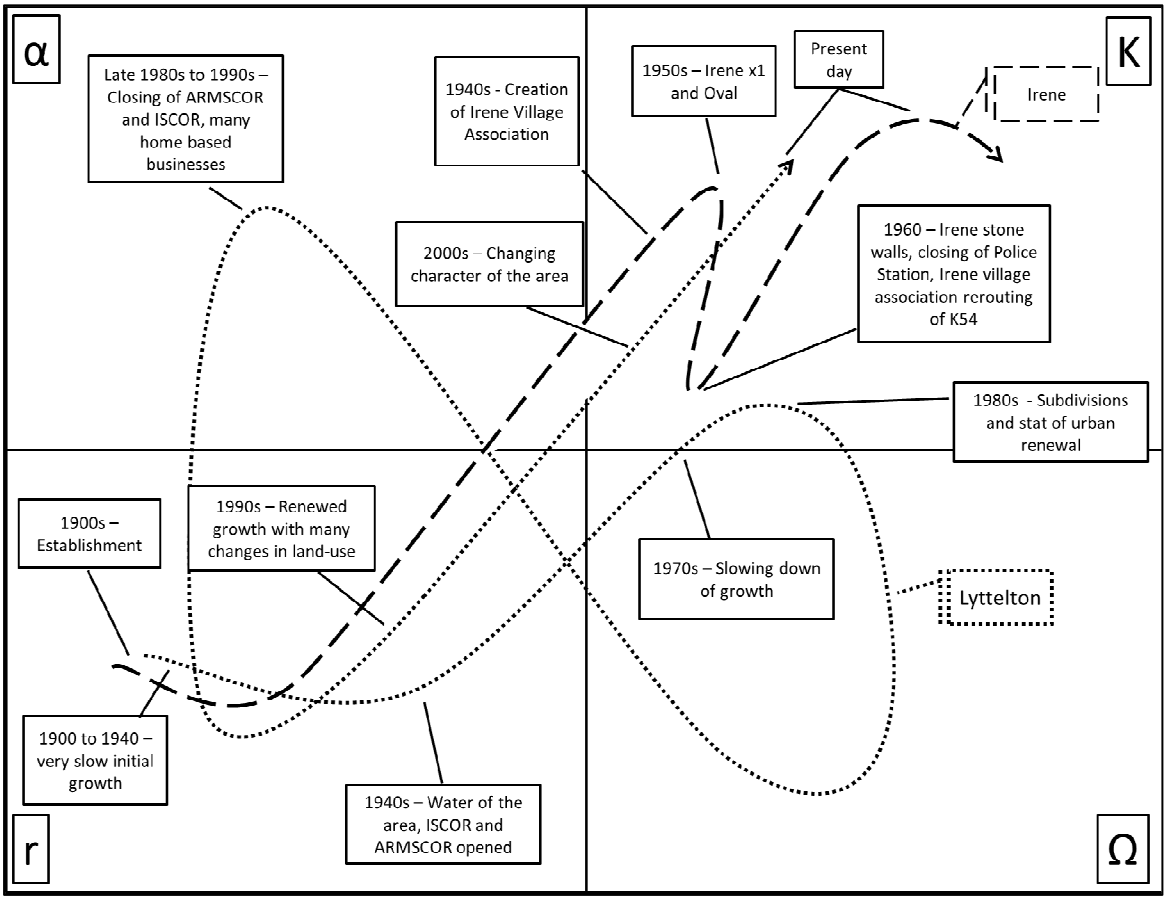

Figure 4: A representation of changes and movement of Lyttelton and Irene through the adaptive cycle with key events and changes being indicated as well as when they occurred. Adapted from Landman and Nel (2012, p9)

The adaptive cycle is now brought back in to focus as the means to describe change, as well as the characteristics of that change in terms of the systems resilience. Reconsidering Table 1 and looking at the characteristics of each phase of the adaptive cycle, one can now compare them to the system's general timeline of change; using the systems history to identify and 'match' the various stages of the adaptive cycle. By using the identified differentiation between the magnitudes of the long term effects, its gives guidance to which events have more weight and provide a greater pull or push factor in moving the system though any particular phase of the adaptive cycle.

Table 2 shows the simplified movement of Lyttelton and Irene though the adaptive cycle where Figure 4 shows a stylised version of the movement of the two neighbourhoods through the adaptive cycle, with the key events that have moved or halted progress the system through the adaptive cycle indicated for each of the neighbourhoods.

The value that Figure 4 adds is that allows us to visualise the movement of the system through the adaptive cycle, which in turn, begins to help to understand how some key events can greatly affect the system's movement though the adaptive cycle as well as the long term behaviour of the system. Understanding how systems adapt to changes may help us to better understand and manage change in the future.

Table 2: The development of Irene and Lyttelton in terms of the adaptive cycle

Phase	**Irene**	**Lyttelton**
Growth – r	1900s – 1960	1900s - 1940s
Conservation – K	1960s – Present	In the late 1970s
Release - Ω	Not happened yet	1980s
Reorganisation - α	Not happened yet	Late 1980s - 1990s
Growth – r	Not happened yet	1990s
Conservation – K	Not happened yet	2000s

4. Conclusion

In searching for a method to describe resilience and how complex adaptive systems go through a process of adaptive change, we have considered the Resilience Alliance's existing and well used approach contained in the 'Assessing Resilience in Social-Ecological Systems: Workbook for Practitioners'. We found the concept of panarchy and the metaphor of the adaptive cycle useful tools to describe changes within the urban environment.

However, the methodologies available are not yet adequate to describe the urban system and all its complexities as an integrated social-ecological system. The Resilience Alliance's workbook is also not clear enough as to how to identify the key elements, drivers and agents, especially within the urban system. To bridge this gap we have developed a methodological framework for identifying key drivers, events and agents and how these push or pull the urban system being studied through the phases of the adaptive cycle. We have proposed that the appropriate focal scale would be the neighbourhood and that by

comparing the changes in adjacent neighbourhoods, it will also be possible to identify the elements, drivers and agents at higher system levels. This method still needs to be tested further on different scales as it may not be appropriate for different scales other than on the neighbourhood level.

Throughout the study there were many challenges. One of the biggest being the challenge of translating the language and concepts of panarchy and adaptive cycle, and the associated terminology, that comes from the field of ecology, into the concepts and language used within the built environment. This is not just a matter of applying terminology to a different type of ecological system (the social-ecological system) or a translation of language. For resilience thinking to become a truly useful concept for the planning and management of urban systems, what is required is a translation of concepts.

Acknowledgements

We would like to thank the National Research Foundation who supported the production of this essay through NRF Grant no 78649.

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Sustainable Redevelopment of Real Estate Properties and its Social Impact

Armin Ohler[1]

Abstract

This paper focuses on the sustainable redevelopment of real estate properties. The investigation comprises case studies of eleven redevelopment projects in Hamburg and at other locations in Germany of areas which were once used for industrial, commercial, military or residential purposes. A calculation method was developed which enables the evaluation of the quality of the redevelopment measures carried out for the projects. A number of criteria were found to be decisive including the physical and geological layout of the premises, the infrastructure, the level of soil contamination and protection of the environment, the quality of land used for residential and non-residential purposes and its social impact.

A weighted scoring scheme has been developed that quantitatively expresses both the technical part of the redevelopment and the social benefit. This enables a process of mathematical exploration rather than a rough estimation of all factors involved. By taking into account all the parameters studied, a “quality factor” has been determined to assess the quality of any redevelopment. It has emerged that social benefit is a key issue in the redevelopment process and must be given a high priority. It is believed that the scoring scheme could serve as a tool for investors, planners and decision makers in companies and building authorities before, during and after the redevelopment process.

Keywords: Sustainability, Planning, Redevelopment, Social benefit

1. Introduction

In many countries, especially in the densely populated countries of Western Europe, the development potential of real estate properties is very limited. However, many cities or other urban regions possess a large number of premises which in former times were used for industrial purposes. When the industry abandoned those sites, they were no longer used. Often the location of these premises is excellent; sometimes it is in the city centre, and sometimes in its immediate vicinity. For this reason it is a necessity to study the different ways of redeveloping those properties taking into account a large spectrum of decisive economical, ecological and social aspects.

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2. Definition of redevelopment

Within the context of urban renewal, the term “redevelopment” is widely understood to mean building new parts of town by converting old, abandoned and/or contaminated industrial properties or formerly habitable lands. When focusing on buildings, the term “refurbishment” is understood to describe all efforts made to adapt a building to better and modern standards of living. In the course of this research it became apparent that environmental aspects are definitely crucial for the redevelopment of spaces. Aspects of rehabilitation and revitalisation of habitable lands must thus be an integral part of the decision making process.

Therefore, the term “redevelopment” should comprise all the above described parameters including a complex description of all the different parameters involved. It shall refer to the whole built environment, its refurbishment, damage repair, decontamination and rehabilitation.

3. Background

3.1.The need of redevelopment and its social impact

As mentioned above, the need to stop extensive land use for new building projects in large areas of Western Europe becomes increasingly important. In Germany, for example, the demand of new untouched land for settlement purposes (residential or non-residential) was at an average of 113 ha per day in the last two decades (see Figure 1).

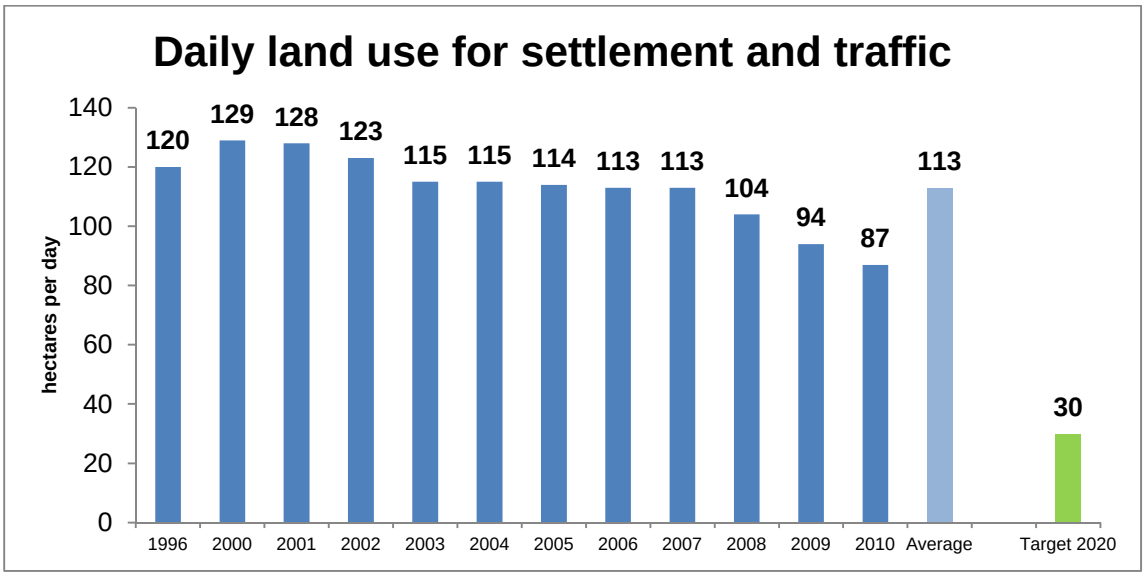

Figure 1: Land used for settlement and traffic in Germany from 1996 to 2010 in ha per day (Federal Bureau of Statistics, 2012, [Lt. 1])

Although a decline in land use since 2007 can be noticed, there is a political goal to reduce the demand of land use to 30 ha per day by 2020. This very ambitious target requires a wide range of different measures, such as the redevelopment of premises.

In many European cities, like for example in the city-state of Hamburg, the contamination of land formerly used for industrial purposes must be given special attention. According to a report by J. Hilbers at a conference on contamination in the City of Hamburg in 2010 [Lit. 5], more than 6,000 premises are registered as contaminated, are deemed to be contaminated, or are being monitored for contamination. In response to this large number of contaminated areas, which roughly cover 20% of the usable land of Hamburg, the regional government has recently launched a programme entitled “Special Investment Programme Hamburg 2010” (Lit. [4]) which aims to revitalise and redevelop those areas by giving financial incentives, reducing legal obstacles, facilitating building permits and providing technical assistance.

3.2. Advantages and risks of redevelopment

The redevelopment of real estate properties offers numerous advantages, such as:

- Integrating unused premises into the urban context of the city.
- Reducing land use in the outskirts of the city.
- Avoiding urban sprawl.
- Remediating and reducing the extent of contaminated soil.
- Contributing to forming habitable city centres rather than growing suburbs.
- Enhancing the quality of social life in the city.

However, such urban planning processes carry the following risks that must be taken into account:

- Increased land prices due to decontamination costs and/or the refurbishment of damaged buildings.
- Time schedules for erecting buildings on such premises exceed those for developing new projects on “clean soil” in the outskirts.
- Sometimes there are legal obstacles to acquiring property rights due to difficult circumstances and/or pending legal cases.

Consequently, the redevelopment process of real estate areas demands a thorough approach considering all aspects involved in the planning and execution process. Every investor or decision maker must take into account all relevant aspects to provide a reliable basis for proposed investments or other decisions. In this respect, any tool will be welcome to assist making the complexity of the parameters outlined above more transparent.

4. Investigation

4.1 Research methodology

The research methodology applied in this investigation included the following steps:

- Selecting seven appropriate real estate properties which in the last decade have been subject to a redevelopment process,

- analysing the redevelopment measures implemented in the projects,
- listing of seven main criteria to assess the redevelopment projects; the criteria were used to analyse all redevelopment measures implemented,
- developing a concept to assess the degree to which the redevelopment measures analysed in the individual projects satisfy the main criteria,
- expressing the results of the assessment in a mathematical form by applying a "weighted quality factor" for all projects analysed.
- developing an interpretation scheme to classify the success or quality of each redevelopment measure implemented based on an average quality factor; thus, each redevelopment project could subsequently be assessed on a mathematical basis.

The steps are explained in detail below.

4.2 Description of the projects analysed

In this research a total of eleven real estate properties were explored which were subject to redevelopment measures carried out in the last decade. The locations were once used for industrial, commercial, military and residential purposes. In almost all cases, they were abandoned by their previous users and had partly been derelict for years. The inspection and evaluation of the individual projects was carried out on site by the author, with the exception of projects No. 2 (Lit. [6]), 4 (Lit. [4]) and 11 (Lit. [4]) which are based on a literature review.

The redevelopment processes carried out comprised one or more of the following measures:

- Disposal of contaminated soil.
- Enclosure of contaminated soil with sealing walls.
- Sealing of ground area with concrete or bitumen.
- Demolition or structural redevelopment of existing building fabric or reconstruction.

New utilisation of real estate properties after the implementation of redevelopment measures depends on their prior use, the degree of possible contamination, local planning regulations and the financial possibilities of the investor. Table 1 lists all redevelopment projects studied and their use before and after the implementation of redevelopment measures.

Table 1: Description of the projects investigated and their use before and after the implementation of redevelopment measures

Name of project	Use before redevelopment	Use after redevelopment	Contamination before /after redevelopment/ implemented measures

1	Hamburg Moorfleet, 8.5 ha	Industrial, manufacture of plant protection products	Industrial, new buildings include barracks and containers for logistics companies	Yes / yes/ containment by sealing walls
2	Frau Sophienhütte Süd, Langelsheim, 3.1 ha	Industrial, lead and zinc works, contaminated with heavy metals	Industrial, installation of power plant	Yes/no partial soil exchange, partial containment by sealing walls
3	Schlieffen barracks, Lüneburg ca. 75 ha	Military, contaminated with armament, oils	Commercial and residential	Yes/no partial soil exchange
4	Channel Hamburg, 3.0 ha	Industrial, harbour facilities	Residential, channel tower 75 m high	No/no
5	Bogenallee Hamburg, 955 m²	Residential, masonry building, 1524 m² of living space	Residential, refurbished building	No/no
6	Schmalenbroek, Hamburg, 7 360 m²	Residential, 4-storey masonry building	Residential, refurbished building	No/no
7	Speicherstadt, Hamburg, 1 600 m²	Commercial, 120-year-old masonry building	Commercial, refurbished building	No/no
8	Bleiweißfabrik, Ingelheim (Rhein), 4 ha	Industrial, manufacture of white lead, contaminated with lead-containing compounds	Commercial, warehouses	Yes/yes, partial soil exchange, partial sealing of surface with concrete
9	Messerschmidt airplane facilities Regensburg, 1.3 ha	Commercial, assembly hangar for airplanes	Commercial and residential, shopping centre, retail	Yes/no, soil exchange
10	One family house, Rosengarten (Hamburg) 4 620 m²	Residential, one family house	Residential, one family house	Yes/yes, contamination by gas emission from soil not eliminated
11	Water City Povel, Nordhorn, 18 ha	Industrial, textile factory	Residential, 500 residential units	Yes/no, partial soil exchange, partial cleaning of soil using biological methods

4.3 Detailed description of two case studies

Problems naturally arise during the redevelopment process. To gain an impression of these, two of the eleven projects listed above were selected and presented in detail below.

4.3.1 Industrial site in Hamburg Moorfleet

Situated in the south-east of the city of Hamburg covering an area of 85,000 m², Moorfleet had been the production site of a pharmaceutical company for more than 60 years and was abandoned in 1984. The company produced pesticides which were found to be highly toxic liquids and were constantly injected into subsoil layers thus contaminating not only the site itself but also neighbouring premises due to subsurface currents. After many years of political and legal turmoil, the site was successfully redeveloped by enclosing the whole area with sealing walls, installing an extensive system of monitoring wells and draining surface water as shown in Figure 3 and according to a report by Lilienweiss (Lit. [6]).

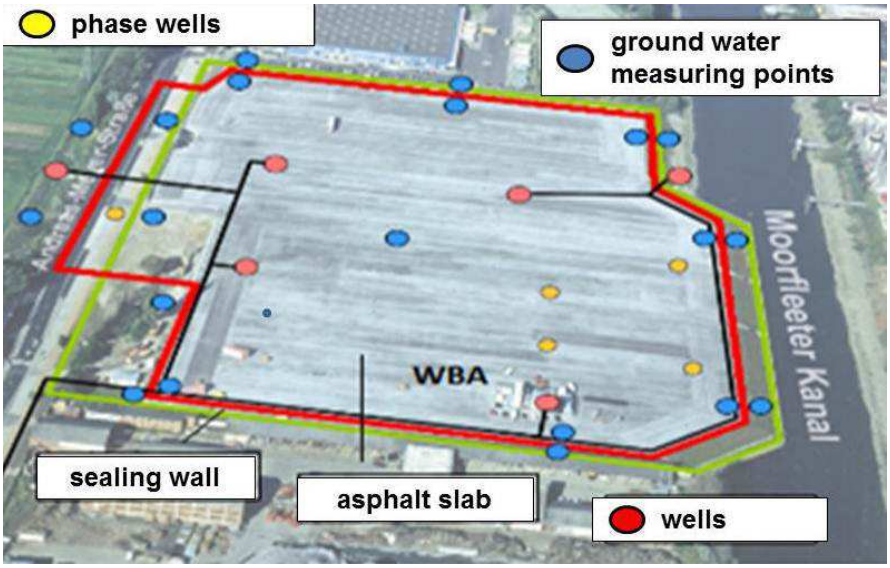

Figure 3: Redevelopment of a contaminated site in Hamburg Moorfleet

Today, there is on-going monitoring and documentation of the surface layer, the surface rainfall water and subsoil gas emissions. The whole site is reused and let to a logistics and forwarding company that does not require costly foundation structures for its administration buildings. The rental income covers all expenses for monitoring and maintenance. So from the technical, economic and ecological point of view, the redevelopment carried out in this case is considered a success. However, as will be shown later, a high weighted score was not achieved when taking into account the complexity of the parameters to be looked at in this process. Not enough attention was paid to the social benefit in particular (see Table 5).

4.3.2 Warehouse in the “Speicherstadt” Hamburg

A good example of a refurbished building is the 120-year-old warehouse in the Hamburg harbour area (see Figures 4 and 5). The warehouse is a listed building which means that it is protected as a historic building by the local building authority and its original facade must be preserved in the development process. It was formerly used for customs purposes and the investor carried out a vast modernisation programme which included complete refurbishment of the roof construction, windows, balconies, stairs, electronic and plumbing installation, heating, air conditioning and sanitary installations. Figures 4 and 5 show the facade and interior of the building after construction works. The building has gained a high degree of acceptance by commercial users due to its architectural beauty. Nowadays it is used as an

office building achieving high rental income due to its excellent location in the harbour area close to the Hamburg city centre.



Figure 4: Facade of former warehouse in the Hamburg harbour area



Figure 5: Interior of former warehouse in the Hamburg harbour area after refurbishment

4.4 Evaluation of the projects investigated

4.4.1 Selection and scoring of evaluation criteria

The main objective of the research project was to demonstrate the success of a redevelopment measure by applying verifiable criteria. A total of seven criteria were defined to assess each redevelopment project (cf. Table 2):

Table 2: Main criteria for the assessment of redevelopment projects studied

Number	Main criteria
1	Physical and geological layout of the premises
2	Infrastructure at a macro- as well as micro-scale level
3	Soil contamination and protection of the environment
4	Quality of land use for residential and non-residential purposes and its social impact
5	Legal and political framework and obstacles
6	Technical feasibility of erecting buildings
7	Market acceptance of the premises after redevelopment

These criteria were developed to reflect the sustainability, legal and technical feasibility and social needs of the users of the buildings or sites. The quality of a redevelopment project provides the basis for further investment. It is therefore crucial for each project to determine how and to what extent the project complies with these specific criteria. For this purpose, a weighted evaluation was developed which not only expresses the importance of each of the seven criteria when compared to each other (cf. Table 3) but also the degree of compliance with the main criteria for each project analysed (cf. Table 4).

Table 3: Score value "a" to describe the importance of each criterion

Score value a for importance	Degree of importance
1	Low importance
2	Average importance
3	High importance

Table 4: Score value "b" to describe the degree of compliance with the main criteria

Score value b for compliance	Degree of compliance with main criteria
1	No compliance or compliance not required
2	Poor compliance
3	Average compliance
4	Good compliance
5	High compliance

4.4.2. Calculation of the evaluation factor

The success or quality of the redevelopment measure used in each project was assessed by applying the criteria outlined above. In order to mathematically express the result the following so-called “weighted quality factor” was developed. If the values in Table 3 are identified as “a” and those in Table 4 as “b”, then the result will be the desired “weighted quality factor” according to Equation1:

$$F_{qu} = \sum a \times b = (a_1 \times b_1) + (a_2 \times b_2) + \ldots\ldots + (a_7 \times b_7) \qquad \text{Equ. (1)}$$

where

“F_{qu}” is the factor to assess the quality of a redevelopment project in terms of sustainability and social impact
“i” is the numbering of the criteria, running from i = 1 to 7 (cf. Table 2)
“a” is the score value of importance taken from Table 3
“b” is the score value of compliance taken from Table 4.

Thus, the “weighted quality factor” represents a valuation score for each project analysed. If limits are set for score values “a” and “b”, then F_{qu} will result in a minimum value of 7x 1 x 1 = 7, and a maximum value of 7 x 3 x 5 =105, based on the seven criteria listed in Table 2. The F_{qu} -value of each project investigated was calculated according to equ. (1). Table 5 below shows the results.

Table 5: Score values a and b and weighted score F_{qu} of the redevelopment projects

	criteria / name of project	Score	criterion No. 1	criterion No. 2	criterion No. 3	criterion No. 4	criterion No. 5	criterion No. 6	criterion No. 7	Sum of weighted score F_{qu}
1	Hamburg Moorfleet Industrial site before and after redevelopment	Score a	3	1	3	1	1	1	2	
		Score b	3	4	1	1	4	2	3	
		Weighted score	**9**	**4**	**3**	**1**	**4**	**2**	**6**	**29**
2	Frau Sophienhütte Süd, Langelsheim Industrial site before and after redevelopment	Score a	1	1	1	2	2	2	2	
		Score b	3	2	3	3	3	3	3	
		Weighted score	**3**	**2**	**3**	**6**	**6**	**6**	**6**	**32**
3	Schlieffen barracks, Lüneburg Commercial and residential use after military use	Score a	3	3	3	2	1	2	3	
		Score b	3	4	2	4	1	3	4	
		Weighted score	**9**	**12**	**6**	**8**	**1**	**6**	**12**	**54**
4	Channel Hamburg, Residential use after industrial use in harbour area	Score a	3	1	1	3	1	3		
		Score b	3	5	1	5	1	3	5	
		Weighted score	**9**	**5**	**1**	**15**	**1**	**9**	**15**	**55**
5	Bogenallee Hamburg, Residential use before and after redevelopment	Score a	1	1	1	3	2	2	3	
		Score b	3	5	3	4	3	3	4	
		Weighted score	**3**	**5**	**3**	**12**	**6**	**6**	**12**	**47**
6	Schmalenbroek, Hamburg, Refurbished residential building	Score a	1	1	2	2	1	2	3	
		Score b	3	3	3	3	3	4	5	
		Weighted score	**3**	**3**	**6**	**6**	**3**	**8**	**15**	**44**
7	Speicherstadt, Hamburg, Commercial refurbished building	Score a	1	2	1	2	2	2	3	
		Score b	1	5	2	4	3	3	4	
		Weighted score	**1**	**10**	**2**	**8**	**6**	**6**	**12**	**45**
8	Bleiweißfabrik, Ingelheim (Rhein), Commercial use after industrial use	Score a	3	2	3	2	2	2	2	
		Score b	3	3	4	3	3	3	4	
		Weighted score	**9**	**6**	**12**	**6**	**6**	**6**	**8**	**53**
9	Messerschmidt airplane facilities Regensburg, Commercial use before and after redevelopment	Score a	2	2	3	1	1	2	2	
		Score b	3	3	4	3	3	4	3	
		Weighted score	**6**	**6**	**12**	**3**	**3**	**8**	**6**	**44**
10	One.family house, Rosengarten (Hamburg), Residential use before and after redevelopment	Score a	3	1	3	3	1	1	2	
		Score b	2	1	1	1	1	5	1	
		Weighted score	**6**	**1**	**3**	**3**	**1**	**5**	**2**	**21**
11	Water City Povel, Nordhorn, Residential use after industrial use	Score a	2	2	3	3	2	1	3	
		Score b	3	3	4	3	3	4	4	
		Weighted score	**6**	**6**	**12**	**9**	**6**	**4**	**12**	**55**

4.5. Outcome

The results, as shown in Table 5, can be further analysed by determining an average importance and average degree of compliance for F_{qu}. If score values “a” and “b” are taken as average values in Tables 3 and 4 and are inserted in equ. (1), then the weighted score will yield the following factor:

$F_{qu, av} = 2 \times 3 \times 7 = 42$

Based on this average value, an evaluation scheme (cf. Table 6) was developed that enables the interpretation of the individual F_{qu} values in relation to the average value $F_{qu, av}$. As outlined above, in each redevelopment project F_{qu} is the sum of the product of “a” times “b” covering all of the seven main criteria listed in Table 2.

Table 6: Evaluation scheme to assess the quality of the redevelopment project

F_{qu}	Up to 31	32 to 41	42 to 51	More than 52
Final assessment of the project	Very poor quality, project carries unforeseeable risks, not successful	Poor quality, project carries considerable risks, not successful, should be revised	Average quality, successful project, but still carries risks to bear in mind	Good quality, successful project, few risks but kept under control

Table 6 allows to judge whether the project is successful or not and/or if it still carries risks.
As a result of the evaluation of Tables 5 and 6, it can be concluded that three cases exhibit a poor or very poor redevelopment quality, four cases an average quality (F_{qu} between 42 and 51), and another four cases a good quality (F_{qu} over 52). Taking a closer look at the way the high weighted scores are composed of, it becomes apparent that in most cases both the ecological and social aspects of the project carried out are predominant. This underlines the fact that the success of a redevelopment project mainly depends on the ecological and social benefits that are created by the project itself.

5. Conclusions

For all the projects analysed in the present investigation the seven main criteria developed within the evaluation process proved to be appropriate as a means of judging the redevelopment measures adopted. Using the evaluation scheme, therefore, it is possible to assess the quality of each redevelopment. Most of the projects considered showed good weighted quality results in terms of sustainability, ecology, market acceptance and social benefit to both the users and the built environment. The results suggest that the success of a redevelopment project mainly depends on the ecological and social benefits that are created by the project itself. The sustainability of an area after redevelopment is dependent upon the contribution it makes to the social life of the users and residents of the area. The application

of the “quality factor” F_{qu} proved to be a helpful tool for investors, planners and other decision makers who are involved in the redevelopment of real estate properties. It is believed that the process of analysis based on the mathematical approach presented, rather than a vague rough estimation, can be employed in all phases before, during and after redevelopment.

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Construction Business with Innovative Cellular Structures, Modules and Buildings

Sorri, J.[1], Kähkönen, K.[2], And Rannisto, J.[3]

Abstract

Basically a cellular structure forms a fully functional part of building. A building can be constructed from cellular modules, which can be multiplied up to the full scale modular building. At the moment cellular structure technologies and their applications are well established and play a crucial role in particularly in aircraft manufacturing and marine industries. It is likely that large size cellular structures can have significant impact also on the building construction sector.

Because the cellular structures are relatively new solutions in construction sectors, wide variety of research questions have to be addressed before the technology will have wider impact in the commercial markets. The research needs in the field of cellular structures are very wide covering structural design and analysis, building physics, architectural opportunities, life-cycle economics and building processes. A research effort has been carried out to address all the named research needs.

This paper presents research results of the described effort that are addressing building processes and their management. Particularly, this includes partner network analyses and experiences from case projects. The used research methods included i) analysis of project data bases and ii) interviews about experiences of finalised cellular structure projects. These people were from the cellular structure factory, modular building factory and the actual construction sites.

Keywords: modular construction, cellular structures, supply chain management, business ecosystem, design principles

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1. Introduction

It was predicted in the early 20th century that housing would follow the development seen earlier in the car industry, where industrial production methods had revolutionized the business (Schnaars 2009). However, the production techniques and the productivity development of construction sector didn't follow car industry so quickly. On the other hand some Japanese housing manufacturers have developed industrialized housing solutions (Gann 1996). However, present building construction methods can be considered as industrialized ones merely regarding some special construction services. This seems to be the current status despite of major research and development efforts both by academia and industry itself, look at e.g. (Thuesen et al 2009 and Kazi et al 2009)

Construction sector is often considered very conservative and slow when it comes to diffusion of innovations (Sheffer 2011). One theme where the diffusion of innovations has been slow in practice is modular construction (Lovell & Smith 2010). Modular construction got a lot of attention in 1960s and 1970 s, at the same time when a modular building called Habitat at Expo 67 was built. However, the costs related to modular construction didn't fall as fast as expected, and the hype around modular construction decreased. (Schnaars 2009). Modular construction has gained its popularity, but less quickly than expected in 1960s and 1970s.

The term "modular" has many meanings, since forms and levels of modularity can have great diversity or variety (Starr 2010). In the case of building construction the term modular has also several meanings. For example, a prefabricated element such as a window can be classified as a module (Sheffer 2011). On the other hand, volumetric modules can be room size units (Lawson et al. 2011). Furthermore, modularity can have other types of appearances. Lennartson et al. (2009) have discussed not only about product modularity, but also process modularity and supply chain modularity, which both can have central roles in the production control of modular manufacturing. In this paper modular construction is understood to be a way where off-site construction is utilized widely in a way where dwelling sized modular units are produced.

Modular construction can be done either on-site or off-site. Bayd et al. (2012) have divided off-site construction into four categories: off-site pre-assembly, hybrid systems, panelized systems and modular buildings. In Europe the modular building industry has often resembled more an on-site construction production that has been moved into the interior conditions, than industrial manufacturing business (Linner & Bock 2012).

The published reviews about the advantages and challenges related to modular construction show evidence of numerous drivers towards and against modular and off-site construction. The identified key benefits include cost advantages (economies of scale and learning curve), time, quality, health and safety issues, productivity and predictability (Boyd et al. 2012; Pan & Goodier 2012). Moreover, compared with conventional construction modular construction seems to be more environmental friendly (Quale et al. 2012, Lawson 2010). It is also reported that modular construction can enable shorter on-site and overall project duration. Furthermore the quality targets of end products can be reached in more reliable manner

since the manufacturing can be done in the controlled circumstances (Boyd et al. 2012, Lawson 2010).

There may be cultural differences in the attitude towards modular construction. According to Linner and Bock (2012) an interesting difference between Europe and Japan is that in Japan the modular solutions are often seen as more reliable, customized and better designed buildings than its alternatives. In Europe modular solutions in the construction are possibly more often tried to justify by using cost-efficiency arguments (see Lovell & Smith 2010).

Also many barriers for modular and off-site construction have been reported. Even though a central argument for favoring modular construction has been (low) cost (Boyd et al. 2012; Lawson 2011), the cost issue has also been mentioned as a reason, why modular construction has not been more widely utilized than it in fact is (Schnaars 2009). As barriers have been reported to be for example difficulties in transporting manufactured products to site, restricted storage areas on the sites, the need for early done design specifications, limited capacity of suppliers and the lack of experiences (Boyd et al. 2012).

Modular solutions require deep collaboration between different designers, for getting truly modular and practical solutions. Traditionally challenging areas in modular buildings are for example noise management, vibration, heating, ventilation and air conditioning (HVAC) systems. It is seen that in modular construction there is a need for deeper collaboration between designers, manufacturing and construction personnel (Arif et al. 2012)

In the Japanese modular construction industry, automation and new process innovations are reported to be widely utilized, whereas it has been claimed that in Europe the critical mass needed for the most efficient production processes is not usually achieved (Linner & Bock 2012). According to Gann (1996) one key reason behind the success of Japanese industrialized housing might be in the ability to manage the whole supply chain in a way that takes into account the whole supply network, including manufacturing, sales and site erection. In proportion, one potential reason, why modular construction has not always been purely a success story, might be the challenges of supply chain management. Modular product architecture can require different kind of supply chain management solutions than on-site construction (see e. g. Doran & Giannakis 2011; Hofman et al. 2009).

Regarding the overall success industrial experiences over modular and off-site construction are uneven. For special purposes and with a novel business set-up such solutions have proved to be viable and seemingly have lasting operational chances. However, the combination of conventional business arrangements, its expectations and traditions with extensive modular construction seems to result in disappointments in many cases. It looks obvious that an extensive modular construction must be implemented in a way where “the weight of past” of traditional construction business is not present.

This paper presents some results of a joint recent research and development effort by four companies and an academic partner for forwarding modular construction in the residential building field. The overall solution is based on cellular structures, that form cellular modules

and completes modular buildings. The technology originates from the shipbuilding sector and provides an interesting opportunity for building construction.

2. Cellular structures, cellular modules and modular buildings

Modular construction as a concept is not a new idea. The motivation behind this movement is in the promise to gain advantages related to standard procedures. Different approaches of modularity can be identified. Main possible approaches are: i) manufacturing of identical modules (no customization), ii) mass-customization of modules according to the needs of project in question, iii) manufacturing of free-form unique modules. Architectural possibilities are naturally increasing when going towards higher variability of modules. However, all approaches share the production philosophy where industrialized and standardized production is targeted.

Traditionally, buildings have been constructed using practices where on-site methods have had a dominating role. However, many kind of prefabricated solutions have gradually become more popular. This has resulted in prefabricated production technologies where complete building elements are formed from prefabricated components. For example. building façade elements can be composed from prefabricated components (skeleton, insulation, windows). Modularity can go even further. Modular construction refers to the use of volumetric modules that are objects in three physical dimensions forming a complete space such as room or even a completed dwelling.

A cellular structure is defined as a structural component targeting the minimization of the amount of used material to reach minimal weight and minimal material cost. A honeycomb shaped structure is an example of such cellular structure. Modular construction represents a new kind of skeletal structure (compare Hong et al. 2011). The basic idea is that the modules can bear the load of the other modules, and thus separate supporting structures are not required. Modular construction is also a special case of modular construction where even multi-storey buildings can be made from volumetric modules, the size of which can comprise a whole dwelling unit (Figure 1).

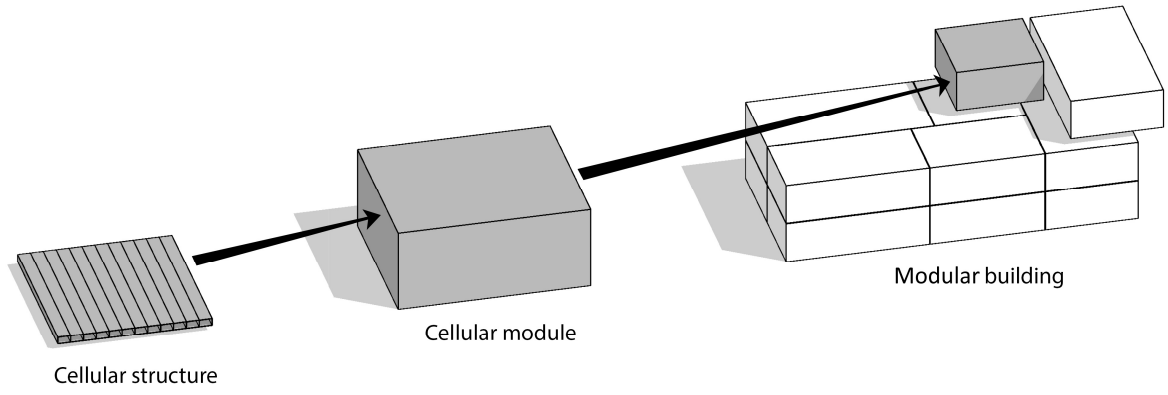

Figure 1. Concepts of cellular structures, cellular modules and modular buildings.

3. Concells research and development project

3.1 Research approach and methods

The Concells research project consisted of five work packages covering various knowledge gaps of cellular structures, modules and buildings. The research was carried out in collaboration of an academic research body and four companies, including engineering and architecture offices. As a leading company was a relatively new and innovative construction company, that has developed patented products related to modular construction. This company utilizes hot galvanized steel panels in its cellular structure products. Other firms involved were from the area sectors of architecture, engineering and HVAC.

The research and development effort within the Concells project has been particularly around technical and architectural questions related to modular construction. Because the core firm of modular construction supply chain is a part of the larger ecosystem of companies, also its partners are important in developing and learning. In this project we have studied things related to business networks.

The research itself included two case projects and one so-called virtual project that was designed and analyzed in co-operation with architects, engineers and researchers. Two case projects were residential building projects where the gained results and experiences were analyzed.

3.2 Case projects

Two modular building construction projects from Finland were under close evaluation in the Concells project. The both cases represent residential buildings where the apartments are built in a way where one module is a complete one dwelling. Later on in this paper the case projects are termed as case A and case B. The first case project (A) comprised three 2-storey apartment houses, altogether 53 dwellings. This project was originally designed as a concrete building but the engineering drawings were afterwards revised for modular apartments made from cellular steel structures. The client was a tenement company owned by the city in question.

Second case project (B) is a 5-storey apartment building. The building was designed as a modular solution from the beginning of the project. The size of apartments was between 37-73 square meters (Figure 2). Furthermore both dwelling and staircase shafts were manufactured and installed as factory made prefabricated modules. In this case also an underground garage made from concrete was built, due to the demands of the parking slot regulations set for the area’s buildings plan by the local city.



Figure 2. Installation of cellular modules for the case project B.

3.3 Research data

In the two case projects research data were collected in interviews covering the following three parts of the supply chain: at panel (cellular structure) manufacturer, module manufacturer and construction site (see the supply chain from the figure 3). Interviewed persons were project managers, production managers or other managers. Project managers had knowledge of their own projects (A or B) and the other interviewed had experience about both projects. The interviews were planned and discussed with purchasing experts in the core firm of the supply chain, thus also their perspective was notified.

The purpose of the interviews was to collect information especially about (1) what has been successful, (2) what kind of problems have appeared and (3) what kind of surprises have appeared in the modular building projects. Thus the basic purpose was to analyze earlier or current projects, and to document, what were the lessons learnt. So that the same failures are not repeated, and good things are reinforced in the future projects.

In addition to the interview a partner analysis was carried out. The data for this was provided by the supplies and procurement managers.

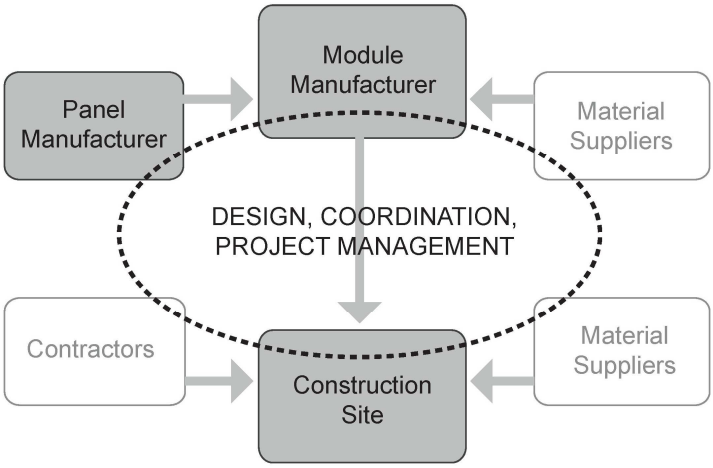

Figure 3. Supply chain in modular construction. The interviewed organizations are presented as gray.

4. Results

Clear differences between project A and B were identified regarding the logic of supplies and their management. In the project A even many basic small purchases were done by the core firm both in the case of module production and construction sites. In the project B there were many lessons learnt from the earlier project A related to the supply chain management. The content of the contracts was therefore developed, and also many suppliers and other partners were changed. In both cases the project management was in the hands of the core company, but many other tasks were outsourced to the specialized companies.

The following figure 4 explains the profiles of partners (other companies such as engineering companies, subcontractors, special contractors and suppliers) involved in the case project B. The total number of companies involved in both projects is noticeable. The project A included 140 partnering companies, and 26 contract relationships. The project B included 90 partners and 22 contract relationships. One should notice that the project A preceded the project B, and the number of partners was consciously reduced based on the gained experience.

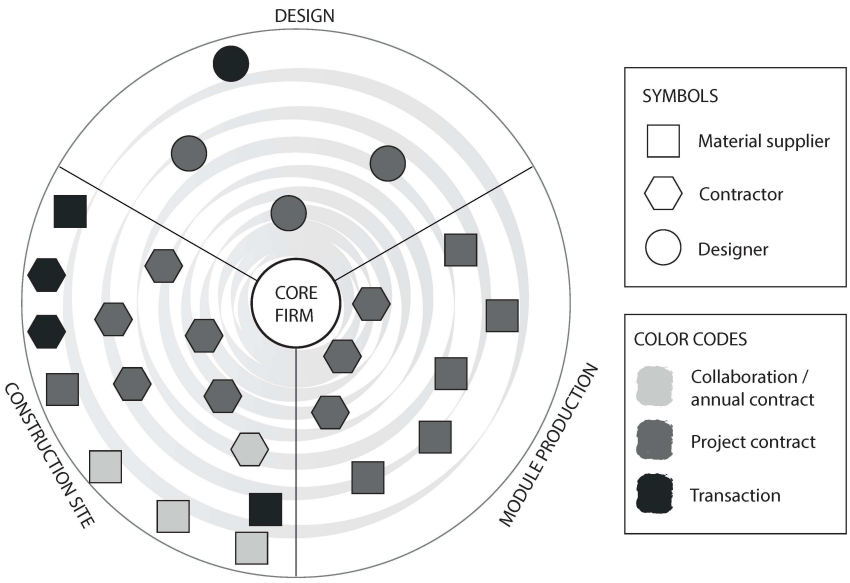

Figure 4. The most important partners in the project (B). Each figure represents a company. The nearer the figure is to the core firm the more revenue it had in the project. The subcontractors are not included in the picture.

From the construction site perspective the overall experience was that modular construction is rather similar to conventional construction operations, but installation phase is significantly faster. The most important differences are in the design phase and in the manufacturing process.

5. Significance of gained results for construction management

Some factory production related bottlenecks were identified in the case projects. This covered the organization and management of manufacturing processes themselves. The batch production type of factory operations can result in a situation where the site cannot have continuous flow of modules for installation. Apparently, this can be a significant cause for lower productivity and, finally, the total *project duration* is not in the target level. However, it seems clear that the construction process on site can be much shorter in modular construction than in conventional projects. The case projects included several waiting periods on sites due to the bottlenecks elsewhere.

Off-site and on-site constructability and its relations to design processes and their management turned out to be rather multidimensional and challenging viewpoints. The design philosophy in modular construction is clearly different than in traditional construction projects. In the modular construction the product design should be done in a way where modular feasibility is enabled in all phases from off-site manufacturing until the final stages of on-site construction operations. Generally, design management is an activity where the overall project objectives form the most importance reference point to evaluate outcomes of design processes and guide the actual processes further. In the case of modular

construction it is the manufacturing knowledge (off-site production, deliveries, on-site assembly) that needs to be incorporated within design management. Based on the studied case projects it seems possible that there will be always a good share of conventional on-site constructions activities in modular construction projects. For example, these can include earthworks, foundations, parts of load bearing structures, façade finishing and roofing. Thus, there will be a need to manage successfully the interplay between the results from off-site production and their assemblies on site together with some traditional construction operations taking place in an almost or totally overlapping manner.

Technical tolerances are a wide subject. In the modular construction the technical tolerance errors can be accumulated in panel manufacturing (including both own and tolerance errors of materials), module manufacturing, on site (including also the effects of weather) and dimensions transformations of modules during transportation. Such tolerances seem to be much more critical in modular construction than in traditional construction since chances to fix potential tolerance problems afterwards on construction site conditions are more limited in modular construction. In off-site manufacturing such fixing operations are possible, that errors will be copied many times (in several cellular modules) before the error is found. Therefore in the case of modular construction proactive supervising is important related to technical tolerances and also to other potential manufacturing defects.

Compared with traditional construction, modular construction requires more detailed and carefully designed solutions, e.g. complete shop drawings. *The management of information flows* is particularly important due to this reason. More detailed product and production data is also be needed in earlier phases than in conventional on-site construction. In the case projects several new kind of challenges were identified such as difficulties to optimize the purchases and their costs. This was due to the lacking or late arrival of material data from designers. Incompletely synchronized information flows caused notable rework and changes in the studied case projects.

Ability to avoid *moisture problems and their management* can be an advantage of modular construction, because most of the manufacturing process is done indoors where weather doesn't affect. However, in both projects there appeared to be moisture problems on sites. Thus even though the cellular modules are produced in interior conditions, it is possible to have water problems on site, if too little attention is paid on moisture management. However, in the case projects some solutions addressing moisture problems were identified in collaboration with module manufacturer. Thus the moisture problems don't seem to be unsolvable and lasting challenge for modular construction.

Spatial efficiency, in terms of the square meters that can be sold, can be currently a somewhat lower in modular buildings compared to traditional buildings. This is due to additional joints and their space requirements between modules. When using traditional performance indicators the spatial efficiency can prove to be a competitive disadvantage. Thus, it seems that this is then matter of presenting new kind of performance indicators that are highlighting the new kind of benefits provided by the modular construction.

Finding *capable and committed partners* can be very difficult when entering new business such as modular building construction. This is due to the lacking business ecosystem. As this modular building ecosystem we mean organizations and individuals which provide foundation for successful deliveries of such buildings from project initiation through the life-cycle of the delivery. Furthermore it is assumed that the ecosystem can provide knowledge and resources for the actual facility management as well. New companies have to market their technology and convince both the potential buyers and contractors in the situation where for example costing can be challenging, due to limited amount of reference projects related to modular construction in the building sector.

6. Conclusion

The cellular structures have their origins in the shipbuilding sector. Thus this emerging new business line has clear distance and differences to the traditional construction and its culture. It does not have its weight of past and it can be very interesting chance to create a significant impact to the building construction. However, challenges are notable. Our research observed several critical points, from which some are clearly different than in traditional construction. In particular, the overall process expectations are closer to manufacturing than construction. For construction management this presents another field of knowledge of importance. Based on this knowledge and relating observations from case projects several principles have been presented in this paper that needs to be incorporated within the management of modular construction projects.

7. Acknowledgements

The research effort forming the basis of this paper enjoyed a most fruitful and positive support and co-operation with Neapo Ltd., Suunnittelulinja Ltd, Hedman & Matomäki Ltd. and Ramboll Ltd. The main financing body of the Concells research and development project was Tekes (the Finnish Funding Agency for Technology and Innovation).

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High Rise Residential Building Quality: Residents Satisfaction Survey

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Abstract

It is widely recognized that the quality of design is crucial to the success of the construction or production process and fairly minor changes in design can often result in giving major effects on the cost and efficiency of production and construction as well as on the usefulness, constructability and marketability of the product especially in developing high rise residential property development. The purpose of this study is to figure out the critical perception of resident for property manager, considering the sustainable and building quality of property development in their high rise residential complex. This paper evaluates and examine the frequency of the building quality factors that affect the sustainability and comfort of living for the resident in the selected high rise residential complex in Malaysia. A total of 500 respondents consisting of 20 property managers participated in this study. The respondents were asked to indicate how important each of building equipments in giving them the comfort of living in the selected high rise residential complex. Accordingly, the living satisfaction by the framework model plays a meaningful role in preparing and developing sustainable and good building quality in Malaysia high rise residential complex.

Keywords: High Rise Residential, Construction, Resident, Quality, Building

1. Introduction

The increased in the number of complaints on service quality in the apartments are becoming more critical due to the lack of focus on the important service qualities that leads to residents' unsatisfaction. The firms are under increasing pressure to demonstrate that their services are customer-focused and that continuous performance improvement is being delivered (Zailan, 2001; Parasuraman, Zeithaml, and Berry, 1994; Hemmasi, Strong, and Taylor, 1994). The understanding of customer expectations is the key success because any gaps in service quality can be identified by referring the customer's perspective. By doing this, the firms will know their performance on delivering service quality and also can identify optimal costs of minimizing service quality gaps and of prioritizing which gaps to focus on.

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New regulations are intended to improve the sustainability of buildings especially high rise residential building in Malaysia. Whilst the main target is the more efficient operation of building services, initial construction makes a significant contribution to the lifetime costs and the environmental impact of a new development (Gruis, and Nieboer, 2004; Haksik, Yongki, and Dongkeun, 2000). The increase in demand for housing and the scarcity of land for development of landed residential properties in major urban areas in Malaysia such as Penang, Kuala Lumpur, Selangor and Johor Bahru, has resulted in the rapid development of high rise residential schemes in these high density areas. Viewed from the end of 2000, the property outlook suggests that with land prices experiencing an upward trend, strata properties, particularly affordable schemes, continue to receive encouraging demand in the local housing market. High rise living in urban centers is a logical response to soaring land prices. This has been successfully implemented in Singapore and Hong Kong where the traditional lifestyle is high density, high rise living.

The focus of property management at that time is often associated with maintenance job and rent collection (Singh, 1996). Property management in general is an activity that covers a wide range of activities such as property development, facilities management, project management, property portfolio management, human resources management, space management, risk management and also investment management. Historically property management has not been given priority in the property market since the focus of the property market is mostly on single or double storey landed property.

Nowadays people are beginning to realize that effective property management in high-rise living can sustain the property value and maintain high returns on their investment. The continuous growth of high-rise residential buildings indicates that there is a need for an effective ownership and property management system to instill a quality living experience among high-rise residents in this country. However, the current practice of property management in Malaysia poses numerous problems, which affect all parties involved: the developers, property managers, owners and residents of high-rise residential complexes.

The statistics as in figure 1 shows the increasing number of high rise residential buildings in Malaysia, which means the quality of every building constructed must be reached the customer requirement. Statistic collected from the Department of Statistic Malaysia (Department of Statistics, 2012) shown in figure 2 shows the number of new launches of housing in Malaysia since quarter 1 2003 till quarter 2 2012 based on the Logarithmic scale with the scale of 10.

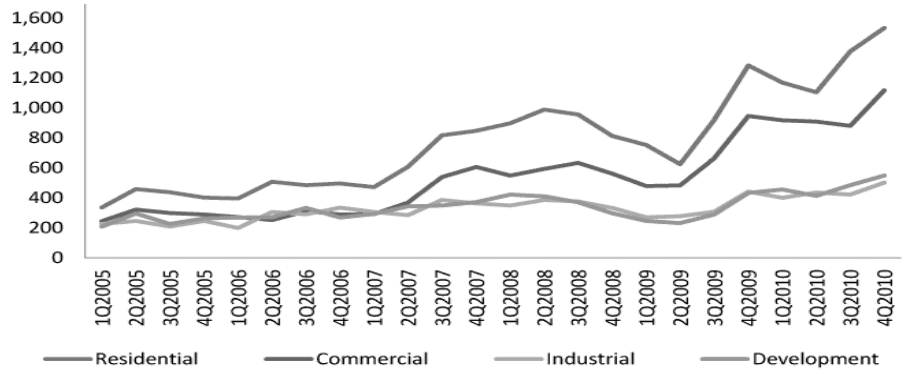

Figure 1. Malaysia Transaction Volume of Properties above RM1mil by Sub-sectors

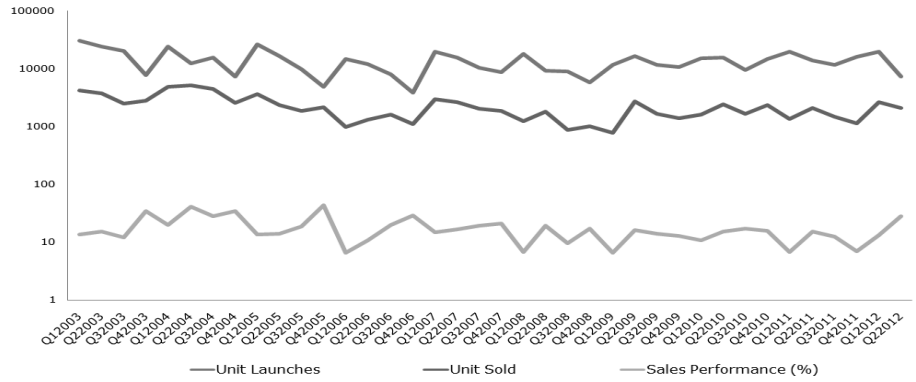

Figure 2. Malaysia New Launches of Housing from Q1 2003 till Q2 2012

2. Current Condition

Property management and maintenance are part and parcel of high-rise living but the standard of management service provided by most of the property managers and developers are questionable.Most are not professional, lacking in experience and to profit orientated and not knowledgeable in managing a residential complex. Property management was not taken into consideration during the early planning stage of development (Bebko, 2000; Liias, 1998). The emphasis is on the cost, location and aesthetics of the building that can attract buyers. Marketability of the building is the most important criteria for a developer. The numbers of units that can be sold are the most important in their marketing strategy. Property managers are not consulted in determining the maintenance fee that should be collected but it was solely determined by the developer themselves, some of which have no experience in property management (Caruana, Money and Berthon, 2000).

Owners are now knowledgeable in the proper property management practices for their unit and therefore good management is essential and will enhance the value of the property (Cui, Lewis, and Park, 2003; Dale, 2003). In the past owners might be satisfied with only the basic care-taking and cleaning service but current owners demand that housing management encompasses a variety of services from cleaning and security services to comprehensive maintenance (Bloemer, Ko de Ruyter, and Wetzels, 1999). Other than problems related to

parcel owners, the weakness in the property management system is also related to the unprofessional practice of property managers in the country.

Table 1 shows the volume numbers of report that have been submitted to the property manager (based on residents) meanwhile Table 2 shows report that property manager received from the residents in a month. Based on these tables, the volume number of reports submitted and report received are not tallied. This means further research on validating the data should be done to make sure the data are accurate.

Table 1. Report Submitted by Residents to Property Manager (in A month)

	N	Range	Min	Max	Sum	Mean		Std. Dev	Skewness		Kurtosis	
	Stat	Stat	Stat	Stat	Stat	Stat	Std. Error	Stat	Stat	Std. Error	Stat	Std. Error
RSDoors	500	2.00	1.00	3.00	666.00	1.3320	.02648	.59201	1.605	.109	1.481	.218
RSDoorKnob	500	2.00	1.00	3.00	822.00	1.6440	.02750	.61483	.398	.109	-.661	.218
RSDoorLock	500	2.00	1.00	3.00	697.00	1.3940	.02784	.62253	1.333	.109	.641	.218
RSWindows	500	2.00	1.00	3.00	615.00	1.2300	.02390	.53448	2.274	.109	4.130	.218
RSRoofing	500	2.00	1.00	3.00	818.00	1.6360	.03478	.77763	.734	.109	-.970	.218
RSPlumbing	500	2.00	1.00	3.00	776.00	1.5520	.03828	.85601	1.002	.109	-.883	.218
RSWall	500	2.00	1.00	3.00	590.00	1.1800	.02281	.51002	2.806	.109	6.666	.218
RSTelephone	500	3.00	1.00	4.00	930.00	1.8600	.04486	1.00320	.678	.109	-.937	.218
RSHVAC	500	2.00	1.00	3.00	803.00	1.6060	.03806	.85101	.851	.109	-1.080	.218
RSPainting	500	1.00	1.00	2.00	561.00	1.1220	.01465	.32761	2.317	.109	3.381	.218
RSFloor	500	1.00	1.00	2.00	595.00	1.1900	.01756	.39269	1.585	.109	.515	.218
RSLighting	500	1.00	1.00	2.00	681.00	1.3620	.02151	.48106	.576	.109	-1.675	.218
RSPowerSS	500	1.00	1.00	2.00	663.00	1.3260	.02098	.46922	.745	.109	-1.451	.218
RSLift	500	2.00	1.00	3.00	845.00	1.6900	.03427	.76621	.592	.109	-1.067	.218
Valid N (listwise)	500											

3. Methodology

Both quantitative and qualitative methods have been used as a research method to achieve the objective of this research. Under qualitative methods is concerned, this research is described to determine a quality and sustainable involved in performing the evaluation on resident's and property manager's intention at their high rise residential buildings. For the qualitative methods, about 20 property managers and 50 residents have been selected randomly for the interview session. The interview session took about 10 minutes for each person which total up to 700 minutes for gathering the qualitative data. This study carried out

with assistance from Research Assistants that have been appointed at the early stage of this research. All of the factors have been determined and the standard provision of the technical performance in delivering all the information of the selected high rise residential property is also analyzed. From this method and analysis, a proposed guideline of quality assessment as an evaluation tool is suggested to be used for high rise residential property residents with regards to the effect of quality and sustainability of the high rise residential property building itself in Malaysia.

Table 2. Report Received at Property Manager Desk (in A month)

Statistic	N	Range	Min	Max	Sum	Mean		Std. Dev	Var	Skewness		Kurtosis	
	Stat	Stat	Stat	Stat	Stat	Stat	Std. Error	Stat	Stat	Stat	Std. Error	Stat	Std. Error
RRDoors	20	3.00	1.00	4.00	42.00	2.1000	.23952	1.07115	1.147	.354	.512	-1.250	.992
RRDoorKnob	20	3.00	1.00	4.00	36.00	1.8000	.24709	1.10501	1.221	1.217	.512	.185	.992
RRDoorLock	20	2.00	1.00	3.00	34.00	1.7000	.20647	.92338	.853	.677	.512	-1.548	.992
RRWindows	20	1.00	1.00	2.00	26.00	1.3000	.10513	.47016	.221	.945	.512	-1.242	.992
RRRoofing	20	2.00	1.00	3.00	25.00	1.2500	.12301	.55012	.303	2.239	.512	4.657	.992
RRPlumbing	20	2.00	1.00	3.00	38.00	1.9000	.22827	1.02084	1.042	.218	.512	-2.183	.992
RRWall	20	1.00	1.00	2.00	24.00	1.2000	.09177	.41039	.168	1.624	.512	.699	.992
RRTelephone	20	3.00	1.00	4.00	34.00	1.7000	.23056	1.03110	1.063	1.319	.512	.589	.992
RRHVAC	20	1.00	1.00	2.00	25.00	1.2500	.09934	.44426	.197	1.251	.512	-.497	.992
RRPainting	20	1.00	1.00	2.00	24.00	1.2000	.09177	.41039	.168	1.624	.512	.699	.992
RRFloor	20	2.00	1.00	3.00	28.00	1.4000	.13377	.59824	.358	1.245	.512	.783	.992
RRLighting	20	2.00	1.00	3.00	37.00	1.8500	.19568	.87509	.766	.315	.512	-1.667	.992
RRPowerSS	20	3.00	1.00	4.00	33.00	1.6500	.19568	.87509	.766	1.321	.512	1.289	.992
RRLift	20	2.00	1.00	3.00	35.00	1.7500	.16018	.71635	.513	.418	.512	-.826	.992
Valid N (listwise)	20												

*based on the 10 different high rise building [500 respondents and 20 property manager]

Meanwhile, the quantitative method is referring to the questionnaire survey. The questionnaire survey was carried out as much as 500 forms for random residents and another 20 forms for random property manager within 2 months in the year 2011. The questionnaire survey forms are delivered through research assistant to the selected high rise residential buildings and the respondents are asked at the same time which approximately 5 minutes per respondents. The questionnaires include a brief introduction of the light well with layout image and the point of answer as a guide and simple questions relating to the following aspect;

a) Basic info regarding the residents and understanding of the issue.

b) Evaluation about quality of the environments in the high rise residential property building.

c) The frequency of the report that has been received and made.

4. Results

Table 3 and table 4 show the results of items factors and building quality in high rise residential. It shows the critical building quality in two different types of high rise residential building which is called the Private Housing and Public Housing.

Table 3. Resident's Perspective of Building Quality.

	N	Range	Min	Max	Sum	Mean		Std. Dev	Skewness		Kurtosis	
	Stat	Stat	Stat	Stat	Stat	Stat	Std. Error	Stat	Stat	Std. Error	Stat	Std. Error
Door	500	2.00	1.00	3.00	1084.00	2.1680	.03658	.81799	-.319	.109	-1.436	.218
DoorKnob	500	2.00	1.00	3.00	914.00	1.8280	.03939	.88089	.342	.109	-1.627	.218
DoorLock	500	2.00	1.00	3.00	809.00	1.6180	.03502	.78314	.786	.109	-.931	.218
Windows	500	1.00	1.00	2.00	715.00	1.4300	.02216	.49557	.284	.109	-1.927	.218
Roofing	500	2.00	1.00	3.00	787.00	1.5740	.03594	.80363	.921	.109	-.828	.218
Plumbing	500	2.00	1.00	3.00	1044.00	2.0880	.04332	.96857	-.177	.109	-1.916	.218
Wall	500	1.00	1.00	2.00	654.00	1.3080	.02067	.46213	.834	.109	-1.309	.218
Telephone	500	2.00	1.00	3.00	966.00	1.9320	.04339	.97018	.137	.109	-1.929	.218
HVAC	500	2.00	1.00	3.00	881.00	1.7620	.04057	.90719	.488	.109	-1.610	.218
Painting	500	2.00	1.00	3.00	878.00	1.7560	.03351	.74939	.432	.109	-1.112	.218
Floor	500	2.00	1.00	3.00	916.00	1.8320	.03993	.89296	.336	.109	-1.665	.218
Lighting	500	2.00	1.00	3.00	812.00	1.6240	.03847	.86029	.806	.109	-1.165	.218
PowerSS	500	2.00	1.00	3.00	893.00	1.7860	.04219	.94339	.439	.109	-1.736	.218
Lift	500	2.00	1.00	3.00	1034.00	2.0680	.04311	.96397	-.136	.109	-1.915	.218
OveralQuality	500	2.00	1.00	3.00	942.00	1.8840	.04158	.92966	.233	.109	-1.807	.218
Valid N (listwise)	500											

Based on the resident's perspective, it was detected that the results for windows and wall were really interesting. All the residents were very satisfied with both items. There are no bad results (ie not satisfied) has been selected for these items. The maximum selection for these two was 'neither'. Unfortunately, door, plumbing and lift are three major items that really critical based on the resident's perspective. Based on the rank, the door was at the top of the list, followed by plumbing and the lift was the last one.

Table 4. Resident's Perspective of Building Quality based on Type of Housing.

		OVERALL QUALITY			Total (%)
		Satisfied (%)	Neither (%)	Dissatisfied (%)	
RESIDENTIAL	PUBLIC HOUSING	92 (26.75%)	62 (18.02%)	190 (55.23%)	344 (68.80%)
	PRIVATE HOUSING	156 (100.00%)	0 (0.00%)	0 (0.00%)	156 (31.20%)
TOTAL		**248**	**62**	**190**	**500**
(%)		**(49.60%)**	**(1.24%)**	**(38.00%)**	**(100.00%)**

Eventhough, some indication arose in the previous table shown the movement towards the dissatisfied quality in both type of housing in Malaysia. But, overall quality result from a resident's perspective show that, more than 55% of the resident dissatisfied with the building quality of public housing meanwhile, 100% of the resident from private housing which total of 156 residents satisfied with their building quality. As a result, about 248 residents which the percentage total of 49.60% from 500 randomly selected residents in Malaysia, satisfied with their building quality and about only 1.24% put themselves in between of the satisfaction level (between satisfied and dissatisfied) on their building quality. Based on this survey, about 38% agreed that their housing building quality is in dissatisfied situation.

5. Way Forward

To strengthen this study, the author has also examined the condition of the building quality from the perspective of property manager. Most of them answered the survey by selecting either as the result of building quality in their place instead of satisfied or dissatisfied. Unfortunately, satisfaction has been chosen as a result of overall quality of their building. This result has been supported and shown in Table.5.

For sustainable development to become common practice, legislation is needed to ensure further measures are taken to safeguard the environment. While best practice and guidelines are helpful in raising awareness of opportunities for improvements, the bottom line is the dominant factor in procuring buildings. Property development is a market-driven business, and high rise residential buildings are financial instruments to most developers and clients.

6. Conclusion

Basically, the satisfaction on the environmental survey of these buildings shows that some improvements still need to be considered. The actual situation brought out in this paper has the possibility to indicate some guidelines for new development. Other factors such surrounding development should also be considered for the future development. The most important thing is the new development needs to take into account the satisfaction of the

residents when all the units have been occupied and the standards of sustainability to be followed as well.

Table 5. Property Manager Perspective of Building Quality.

	N	Range	Min	Max	Sum	Mean		Std. Dev	Var	Skewness		Kurtosis	
	Stat	Stat	Stat	Stat	Stat	Stat	Std. Error	Stat	Stat	Stat	Std. Error	Stat	Std. Error
Door	20	2.00	1.00	3.00	34.00	1.7000	.19331	.86450	.747	.663	.512	-1.347	.992
DoorKnob	20	2.00	1.00	3.00	36.00	1.8000	.18638	.83351	.695	.412	.512	-1.434	.992
DoorLock	20	2.00	1.00	3.00	34.00	1.7000	.19331	.86450	.747	.663	.512	-1.347	.992
Windows	20	2.00	1.00	3.00	35.00	1.7500	.19022	.85070	.724	.534	.512	-1.416	.992
Roofing	20	2.00	1.00	3.00	34.00	1.7000	.19331	.86450	.747	.663	.512	-1.347	.992
Plumbing	20	2.00	1.00	3.00	34.00	1.7000	.17918	.80131	.642	.627	.512	-1.108	.992
Wall	20	2.00	1.00	3.00	38.00	1.9000	.21643	.96791	.937	.217	.512	-2.035	.992
Telephone	20	2.00	1.00	3.00	45.00	2.2500	.17584	.78640	.618	-.496	.512	-1.152	.992
HVAC	20	2.00	1.00	3.00	30.00	1.5000	.17014	.76089	.579	1.195	.512	-.037	.992
Painting	20	2.00	1.00	3.00	35.00	1.7500	.19022	.85070	.724	.534	.512	-1.416	.992
Floor	20	2.00	1.00	3.00	31.00	1.5500	.18460	.82558	.682	1.071	.512	-.585	.992
Lighting	20	2.00	1.00	3.00	35.00	1.7500	.20359	.91047	.829	.552	.512	-1.632	.992
PowerSS	20	2.00	1.00	3.00	34.00	1.7000	.17918	.80131	.642	.627	.512	-1.108	.992
Lift	20	2.00	1.00	3.00	35.00	1.7500	.19022	.85070	.724	.534	.512	-1.416	.992
OveralQuality	20	1.00	1.00	2.00	28.00	1.4000	.11239	.50262	.253	.442	.512	-2.018	.992
Valid N (listwise)	20												

Typically, the assessment results by the property manager is better than the resident who occupy that place. This situation is indeed happening and no doubt it is critical. If analyzed in depth, this difference result occurs because, the property managers do not live in the house and just be in the area according to the hours of duty. In addition, the property managers don't own the house than residents who buy and own their homes. This is the clear and obvious differences.

It is clear that there is a pressing need to formulate and produce a set of practical guidelines for the management of high-rise residential buildings in this country. It is very important to note that extensive rules, regulations and guidelines must always go hand in hand with strict enforcement and monitoring to ensure their effectiveness in solving the problems of high rise residential living.

7. Acknowledgements

The authors would like to thank the anonymous referees for their helpful and constructive comments. The support of Centre of Real Estate Studies at Universiti Teknologi Malaysia is also appreciated.

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Concept of a quantitative project selection model for PPP projects

Stefan Weissenböck[1], Gerhard Girmscheid[2]

Abstract

Project selection decision-making in construction companies that deal with life-cycle oriented and equity-intensive projects (e.g. Public Private Partnership (PPP) projects) is still dominated by intuition rather than structured rational processes. At the same time, companies from related business fields, like infrastructure investors, have been successfully using quantitative models to support their decision processes for years. Hence, there is room for improvement in the project selection process of construction companies.

This paper proposes the concept of a new quantitative model to guide the project selection process of construction companies, using PPP projects as an example. The introduced PPP project selection model (PPP-PS-model) combines Modern Portfolio Theory (MPT) with multi-objective optimization. The PPP-PS-model is divided into three modules. Each module represents a self-contained part of the overall model. In a first step, the company's current PPP project portfolio is analyzed in order to determine the risk-return profile of every single project. To this end, quantitative parameters for the evaluation of both risks and return need to be identified in advance. Secondly, a target portfolio for the construction firm is calculated by applying MPT. Hence, this module quantitatively describes the future objective of the company's PPP project portfolio. Its evaluation is based on the analysis of the current portfolio (step 1) as well as the corporate strategy and economic constraints. Finally, a multi-objective optimization algorithm is applied. As a result, this algorithm provides a hypothetical optimal PPP project, which reduces the difference between the evaluated current portfolio (step 1) and the calculated target portfolio (step 2) as far as possible. This hypothetical optimal project serves as a reference, in order to select a new PPP project.

The authors are convinced that rational decision-making and project selection processes based on quantitative analyses will improve the performance of PPP project portfolios. As a result, the PPP project portfolios of construction firms will contain a higher number of suitable projects. To this end, the new PPP-PS-model supports construction companies to better meet their commercial goals.

Keywords: decision-making, **life-cycle orientation**, **Modern Portfolio Theory**, **operations research**, **project selection.**

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1. Introduction

Companies in demand-driven markets need to select the most appropriate projects out of all projects announced to be economically successful. The Public Private Partnership (PPP) market within the construction industry represents such a demand-driven market. Therefore, construction firms dealing with PPP projects rely on appropriate models which ideally support their project selection decisions.

Generally, project selection processes are predetermined by the corporate strategy, which defines e.g. business areas of interest for the company, and by the competitive strategy (Girmscheid (2010)). Nevertheless, decision-makers need to decide in their specific business unit (BU), for which project(s) they would like to apply. This project selection decision is particularly important, if the BU deals with PPP projects. This distinct type of project is characterized by immense bid costs in comparison to ordinary construction projects. In addition, PPP projects offer great potential regarding return on investments next to substantial risk exposure. Due to these facts, it is astonishing that PPP project selection processes in construction companies are still dominated by intuition rather than structured rational processes.

This paper proposes the concept of a new quantitative model to guide the ordinary project selection process of construction companies dealing with a PPP project portfolio.

2. PPP projects – Extended scope of service demands for an improved project selection process

2.1 Problem specification

The European Commission (2012) pointed out, that the “markets of the EU construction sector and the sector itself are highly fragmented…” (p4). Many different competitors with mostly small shares are determining the competitive market especially in traditional business segments (e.g. building construction). Furthermore, the composition of bidders, which are competing for the same contract, is commonly very heterogeneous. Companies of varying sizes and interests frequently applied and (still apply) for the same projects, which regularly leads to competitive disadvantages for bigger companies, as they need to cover higher overhead costs (Girmscheid (2000)). Consequently, many big construction companies both in Switzerland (e.g. Implenia, Marti, Priora) and abroad (e.g. Hochtief, Bilfinger Berger, Strabag, Vinci, Bouygues, Balfour Beatty, ACS, FCC) took actions against the ongoing price competition in the traditional business fields. These companies drift more and more towards becoming total service providers, trying to participate either in several project phases or the whole life-cycle of a building. According to the increasing life-cycle orientation, these companies offer a more comprehensive range of service. This range regularly includes construction, design, operation, maintenance and finance, having a positive impact for both the companies involved and the environment. These positive impacts are confirmed by a current study of the European Commission (2012), which points out that these distinct types of projects have „the potential to contribute to a competitive construction sector and to the development of a resource and energy efficient building stock…” (p12). On the other hand,

the extension of the range of service and the naturally longer contract duration of life-cycle oriented projects (e.g. PPP projects) lead to a significant increase in the magnitude of risks taken by the construction companies involved. As a consequence, construction companies that deal with these “high risk projects” increasingly emphasize considerations regarding risk management (Girmscheid (2007b), Girmscheid (2007c)), risk allocation (Girmscheid (2011a)) and risk diversification (Girmscheid and Busch (2008)) in their portfolio. However, there still is a lack of appropriate, quantitative instruments to support decision makers in selecting those PPP projects, which perfectly complement the risk and return profile of a company’s current portfolio. As a consequence, the actual process of decision-making in PPP project selection is mainly determined by the intuition of the company’s management rather than structured rational processes. Chapter 4 introduces a concept, which aims to improve the current project selection process of construction companies dealing with a PPP project portfolio.

2.2 The importance of an appropriate PPP project selection process

The reasons mentioned below have no claim to completeness, but stress the importance of an appropriate project selection process in construction companies dealing with PPP:

- **High bid costs:** Due to the fact that essential planning services are shifted from the tender authority to the bidders, notable costs arise for the private companies involved. These costs are further increased by the (mandatory) inclusion of several consultants. For instance, seven consultants were commonly mandatory due to specifications of the tender authority or specifications of lenders within the first stage of infrastructure PPP projects (A-models) in Germany. According to Stolze (2008), the average bid costs of all acquired PPP projects within the company Balfour Beatty added up to almost EUR 3,000,000 per project. This average amount can be largely exceeded in case of major infrastructure projects. Therefore, the success rate (i.e. the ratio between tender participations and acquired projects) is of considerable importance for construction companies dealing with a PPP project portfolio.

- **High equity investment:** The construction companies involved in PPP projects (usually) act as sponsors of the project and regularly invest a high amount of equity into a project. According to Weber and Alfen (2010), an “equity ratio (…) between 10 and 30% of the total financing volume of a project depending on its (perceived) risk profile…” (p199) is considered to be normal in this case. Thus, a lot of equity is tied up in one single project and is not available for other investments for a longer period of time.

- **Earnings depend on dividends provided by the SPC:** Usually, a special purpose company (SPC) takes the role of the private partner within a PPP contract. This SPC has to be financially equipped in order to fulfill its “special purpose”. Therefore, it receives debt capital from the lenders as well as equity capital from the sponsors, which are regularly the construction companies involved. If this is the case, the main earnings of these construction companies arise, according to Merna et al. (2010), from their “compensation for equity (which) is dividends (dividends are the amount of

profits paid to the shareholders)…" (p33). Dividends are only distributed, if the SPC makes profit. Furthermore, the debt claims of the lenders must be met, before the sponsors receive money from the SPC. Hence, construction companies that deal with PPP projects need to make carefully considered project selection (i.e. investment) decisions in order to be economically successful.

2.3 State of practice in arranging project portfolios in related business fields

When designing an applicable project selection model, it seems advantageous to make use of "best practice" solutions coming from comparable business areas by adjusting and enhancing the best suited methods to our specific problem. Furthermore, the participation of construction companies in PPP projects goes hand in hand with a broadening of the offered range of service. This offers the opportunity to learn from the experience of companies, which deal (or dealt) with comparable fields of action. Evaluations of related business fields have shown that the financial industry in particular successfully uses Modern Portfolio Theory (MPT) for quite a few years now to support their investment decisions. Furthermore, Wellner (2011) demonstrated that MPT can also be used for real estate investment decisions, which are highly comparable to PPP project investments. Wellner (2011) is convinced that "it is thus possible to implement the findings of the Portfolio Theory in practice and make investment decisions safer and more independent from subjective influences…" (p18). Viezer (2010) even goes one step further and proposes that private equity investors as well, such as construction companies that deal with PPP projects, "may someday find MPT as a useful engine of inquiry…" (p755). These recent findings demonstrate that MPT could contribute to an increase of rationality within the project selection process of construction companies dealing with a PPP project portfolio. Hence, the potential of MPT in construction has to be evaluated with further scrutiny, with special focus on its applicability to the PPP project selection process.

2.4 State of research regarding the applicability of MPT to the project selection in construction companies

The MPT was first developed by Harry Markowitz. Markowitz (1952) stated that the "hypothesis (or maxim) that the investor does (or should) maximize (…) return must be rejected…" (p77). He suggested instead considering both risks and return, where risks should be limited by optimal portfolio diversification. Markowitz' research concerned the security management in share portfolios and had no ambition of being applicable to other types of investment. Subsequently, most of the research related to MPT focused on implementing the basic findings on various industries and fields. Vergara and Boyer (1977) tried to implement MPT to construction bidding practices and generally stated that "bid decisions can be rationalized…" (p33) by applying this method. Kangari and Boyer (1981) calculated the return of a project by using the net present value (NPV) and compared the portfolio approach with a market model approach. Kangari and Riggs (1988) conducted a "probabilistic approach (…) to show a more realistic approach to the evaluation of correlation" (p168) within the project portfolio. Archer and Ghasemzadeh (1998) introduced a decision support system (DSS) for project portfolio selection, which utilized a computerized project database. Han et al. (2004) focused on big, diversified international construction

companies and provided a practical method based on NPV, return on investment (ROI) and value at risk (VaR) for the selection of new international construction projects. Ravanshadnia et al. (2010) added a fuzzy model, in order to determine the optimal project portfolio of a construction company.

The literature research showed that MPT is applicable for the project selection of construction companies. Nevertheless, two main problems in applying MPT to the project selection in construction companies have been identified. Firstly, the high correlation and therefore the limited diversification in the project portfolio of traditional construction companies have been criticized in several publications. This problem has less influence, if MPT is applied to PPP project portfolios of larger construction firms. The various types of PPP projects (e.g. hospitals, schools, highways, airports) show completely different risk profiles. In addition, the particular risk profile of each project changes over the life cycle. Thus, a PPP project portfolio offers a much bigger potential for diversification than an ordinary portfolio of construction projects. Secondly, many researchers used MPT by adding specific announced projects to the current project portfolio and then compared the risk and return profiles of these various potential future portfolios. These researchers faced the problem of a limited knowledge of the announced projects. The PPP-PS-model presented in this paper uses a completely new approach for identifying an optimal future project. This approach covers the identified problem of limited knowledge and additionally provides a bid strategy.

2.5 Objectives of the new quantitative PPP-PS-model

The objective of this paper is to present a new concept to support the PPP project selection process in construction companies. The PPP-PS-model has to be developed on a quantitative basis, in order to increase the currently limited rationality within the PPP project selection process. Furthermore, the PPP-PS-model aims to achieve the targeted return, while minimizing the risks within the whole PPP project portfolio (and not just for maximizing the return and minimizing the risks of a single PPP project). Therefore, the PPP-PS-model needs to consider the current portfolio and has to determine the specific project that improves the risk-return ratio of this current portfolio as much as possible. To meet this objective, MPT is applied. The practical applicability of MPT is bounded by the limited knowledge of a potential future project. This problem has to be solved by using a new and different approach. Furthermore, the model should provide a bid strategy. In addition, the model needs to include the corporate strategy so to enable a target oriented long-term development of the construction firm.

3. Research methodology

Putting the PPP-PS-model into a broader setting, this specific type of model can be seen as a decision model. Decision models are characterized by evaluating alternatives of action for a specific problem. According to Girmscheid (2007a), the derivation of a decision model follows the constructivist-hermeneutic approach, which has been developed by von Glasersfeld (1996). The quality of decision models is guaranteed by applying the principle of triangulation (Yin (2009)). The application of this principle ensures the (1) viable, (2) valid

and (3) reliable model development. Firstly, the viability of the PPP-PS-model will be guaranteed by designing the model logically deductively. The underlying theory is provided by systems theory (von Bertalanffy (1968)) and cybernetics (Wiener (1992)). Secondly, the validity of the model is ensured by using proven and target oriented mathematical methods such as MPT. Finally, the reliability of the model will be evaluated by conducting both simulations and practical tests.

4. Conception of the new quantitative PPP-PS-model

This new quantitative PPP-PS-model aims for the identification of the specific new PPP project, which achieves the targeted return of a PPP project portfolio while minimizing the risks. To reach this objective, MPT will be applied. Moreover, the practical applicability of MPT in project selection processes will be improved by solving the problem of limited knowledge of new projects at the beginning of the tender stage.

Fig. 1 displays the basic concept of the new quantitative PPP-PS-model. As illustrated, the model consists of three major elements:

1. analysis of the current portfolio,
2. evaluation of the target portfolio and
3. determination of the optimal next project for which a company should apply.

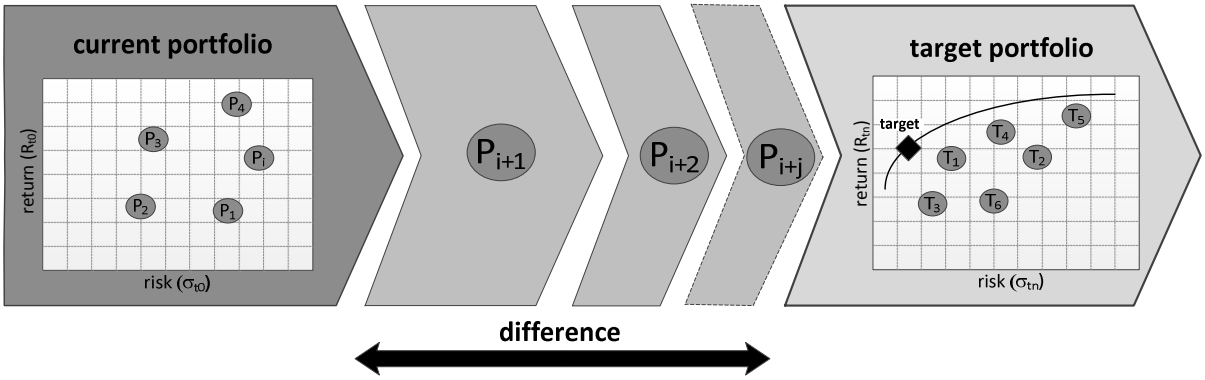

Figure 1: Basic idea of the new quantitative PPP-PS-model

The “current portfolio” symbolizes the actual PPP project portfolio within a construction company. It is characterized by the total return (R_{t0}) and the total risk (σ_{t0}) of every single project. Furthermore, the average percentage of return $R_{t0,m}$ [%] and the average risk $\sigma_{t0,m}$ [%] of the current PPP portfolio as a whole can be calculated.

The “target portfolio” symbolizes the optimal future PPP project portfolio within the same construction company. The target portfolio will be determined by the corporate strategy, taking into account the company’s specific constraints (e.g. risk bearing capacity and the availability of equity). It is characterized by the targeted return of the portfolio (R_{tn} [%]) and the corresponding minimal risk (σ_{tn}) of the PPP project portfolio. The target portfolio will naturally show a better risk-return ratio than the current portfolio:

$$\frac{R_{t0,m}}{\sigma_{t0,m}} < \frac{R_{tn}}{\sigma_{tn}}.$$

The determination of an optimal next PPP project ($P_{i+1} = P_{NEW,opt}$), for which a company should apply in a tender procedure, represents the third major element of the model. $P_{NEW,opt}$ is defined as the specific project, which minimizes the difference between the current portfolio and the target portfolio as far as possible. To meet this objective, the following formula needs to reach a minimum, where $R_{t1,m}$ [%] represents the average return and $\sigma_{t1,m}$ [%] the average risk of the PPP portfolio when adding one additional new project:

$$\min\left(\frac{R_{tn}}{\sigma_{tn}} - \frac{R_{t1,m}}{\sigma_{t1,m}}\right).$$

Each of the three major elements forms a separate module within the PPP-PS-model. Subsequently, these three modules are described in further detail.

4.1 Module 1: Analysis of the current PPP project portfolio

According to Busch and Girmscheid (2005), prior to "their acceptance, new risks to be assumed must be aggregated with the already accepted risks from, for example, other projects…" (p784). Consequently, a construction company needs to evaluate the accepted risks before applying for new PPP projects. As MPT constitutes the major instrument in the concept of the new quantitative PPP-PS-model, it is not just the risks that need to be identified but the composition of risks and return (Wellner (2003)). Therefore, every actual PPP project needs to be analyzed regarding its return (achieved + expected) and its associated risks. MPT defines the aggregated risks of every project as variance (σ) of the return. Referring to Girmscheid (2011b), the accumulated risks of a PPP project decrease over the contract period. Furthermore, the accumulated total return (achieved + expected) can be increasingly precisely determined with proceeding contract period because less parameters need to be forecasted (fig. 2). This time-related evaluation of both risks and return of every project allows for the comparison and aggregation of various projects at different stages. This makes MPT increasingly suitable for supporting PPP project selection.

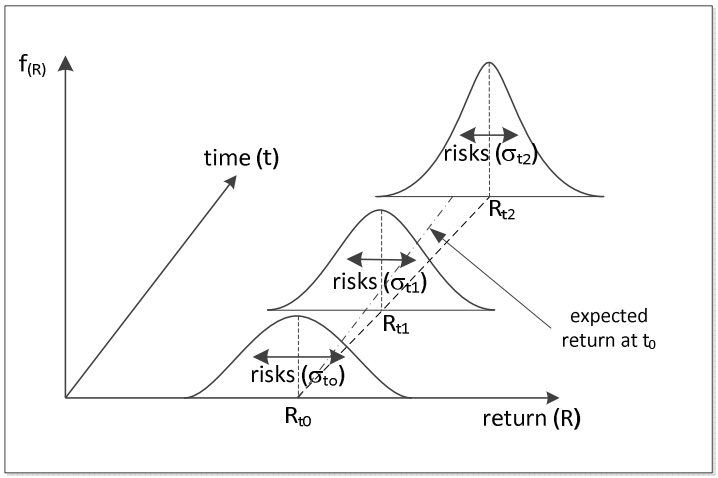

Figure 2: Time-related evaluation of risks and return

Supplementing the aggregated risks and the return (achieved + expected) allows for classifying each project by its current (t_0) risk-return ratio, as displayed in fig. 3.

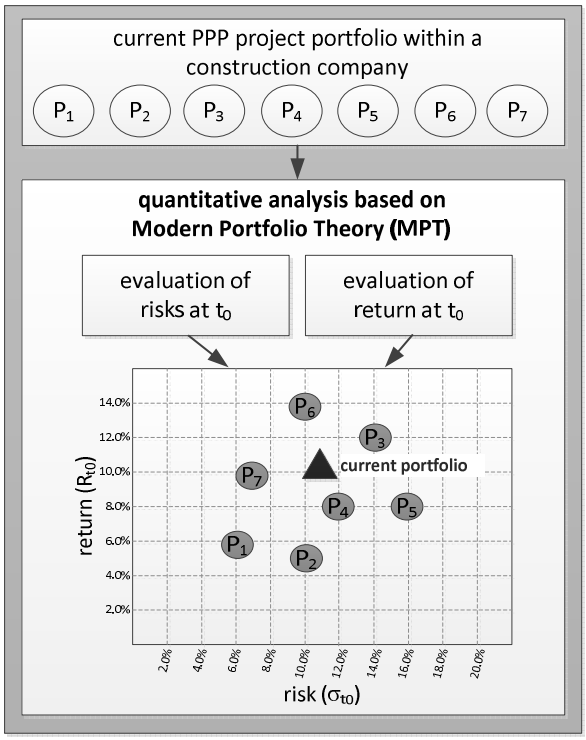

Figure 3: Analysis of the current PPP project portfolio

4.2 Module 2: Determination of an optimal target PPP project portfolio

Module 2 aims to determine an optimal target PPP project portfolio. Therefore, several steps, which refer to the market and to the resource based approach of Girmscheid (2010), need to be conducted. Firstly, the market based view represents the corporate strategy, which is important, due to the "linkage of the company's strategy and its project selection activities…" (Ravanshadnia et al. (2010), p1083). Developing a target oriented strategy results in the determination of potential target countries and potential types of projects. Secondly, the resource based view leads to constraints, which limit the development of the company in the future. These constraints are, amongst others, the company's risk bearing capacity, the available equity capital and the company's technical and economic performance. The market based view, under consideration of the resource based view, allows for the identification of potential fictitious target PPP projects as shown in fig.4. Every identified fictitious project T_n is described by the same characteristic parameters (respectively return and risks) as applied in module 1.

Subsequently, the application of MPT allows for the calculation of an optimal composition of various potential fictitious target PPP projects. To reach this target, an efficient frontier has to be calculated. This efficient frontier represents a curve of all possible compositions of projects that lead to the highest possible return at a specific level of risk (Elton et al. (2011)). The particular point of the curve, which represents the expected average return of the company, is named maximum sharpe ratio portfolio (MSRP). The MSRP represents the specific composition of potential fictitious PPP projects, whose combination bears the

smallest risks in reaching the return objectives. The obtained composition of PPP projects represents the optimal PPP project portfolio of the company.

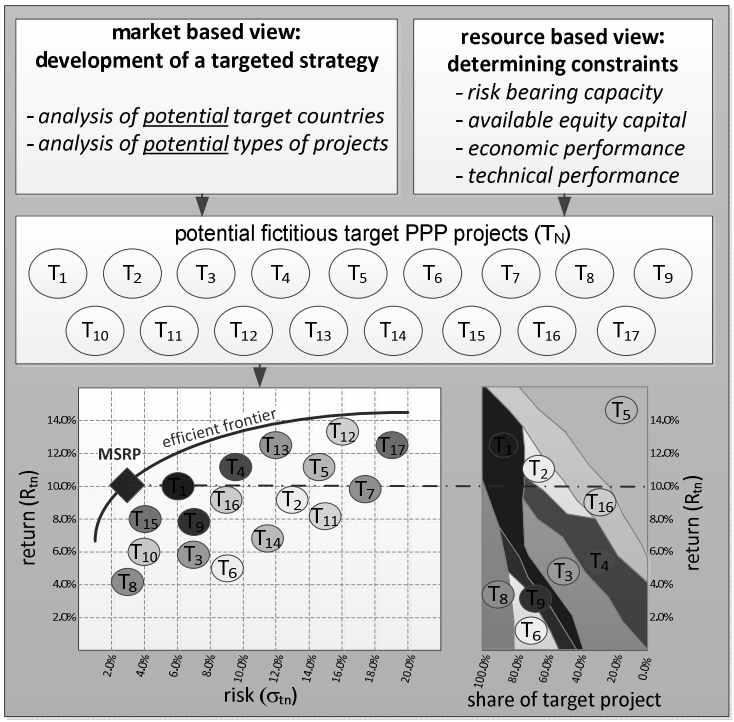

Figure 4: Determination of an optimal target PPP project portfolio

4.3 Module 3: Determination of an optimal new PPP project

Module 3 aims to determine an optimal new PPP project ($P_{NEW,opt}$) and is displayed conceptually in fig. 5. Firstly, the difference between the MSRP and the current PPP project portfolio is calculated. Subsequently, an optimization process based on multi-objective optimization is conducted. This process searches for the fictitious PPP project that reduces the difference between the MSRP and the current portfolio as much as possible. The result obtained is $P_{NEW,opt}$, which signifies the hypothetical next PPP project a company should apply for. Thus, $P_{NEW,opt}$ serves as a reference, in order to select a new PPP project.

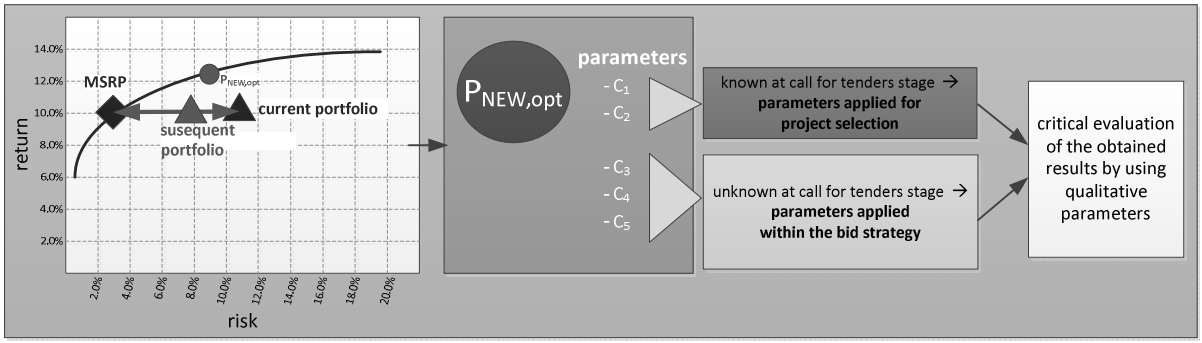

Figure 5: Determination of an optimal new PPP project ($P_{NEW,opt}$)

According to a holistic approach and in order to ensure the quality of the results, the parameters (return + risks), which determine $P_{NEW,opt}$ will be evaluated using qualitative parameters.

To solve the problem of limited knowledge of announced projects at tenders stage, the new PPP-PS-model distinguishes between two groups of parameters that describe $P_{NEW,opt}$:

- **Parameters that are known at call for tenders stage:** These parameters contain project information, which is commonly available when projects are put out for tender. Therefore, these parameters can be used to search for real projects that meet $P_{NEW,opt}$ as closely as possible.

- **Parameters that are unknown at call for tenders stage:** These parameters contain project information, which is commonly not available when projects are put out for tender. Notwithstanding this, these parameters are advantageous for designing and structuring the project in the bid phase. If applied, these parameters ensure that the bid strategy pertaining to the project is in line with the corporate strategy, which has been used to determine the optimal target PPP project portfolio.

5. Conclusion

The realization of this new PPP-PS-model will support construction firms in selecting and structuring highly suitable PPP projects for their specific strategy and their specific current PPP project portfolio. Furthermore, the problem of limited knowledge of projects at tender stage has been solved by following a new approach in applying MPT for project selection. This will allow for a more practicable application of MPT within the project selection process of construction companies dealing with a PPP project portfolio. Therefore, the authors are convinced that the realization of this concept will improve the performance of PPP project portfolios. As a result, the PPP project portfolios of construction firms will contain a higher number of suitable projects. To this end, the new PPP-PS-model supports construction companies to better meet their commercial goals.

The findings in this paper are restricted to large international construction companies that deal with a PPP project portfolio.

The current paper represents the first step of a research project at the Institute of Construction and Infrastructure Management, ETH Zurich. The next steps in the development of the new quantitative PPP-PS-model are the detailed determination of both an appropriate return measure and suitable risks as well as the mathematical formulation of the three modules. Finally, the model's reliability will be evaluated by conducting several simulations and practical tests.

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Managing the interface between work and study in a construction management program

Mary Hardie [1], Philip Love[2], Xiaohua Jin[3] and Swapan Saha [4]

Abstract

Many construction management students work in industry both before and during their formal tertiary studies. This often means that they have to balance conflicting demands on their time. Project managers in the industry often work very long hours and sometimes they expect the same of their building cadets and trainees. Flexible delivery of study programs can go some way to assisting with this problem. However, there are specific areas where universities are able to give a valid educational experience which is quite different from that of the workplace. It is desirable that working students are given sufficient time to participate in both the formal and informal aspects of university life. A statistical analysis of student evidence provided for a compulsory industry based learning unit in one university in Sydney has revealed that some students work as many hours as a full time employee, while at the same time attempting to study full time. The phenomenon of 'burn out' among such individuals has been identified by several researchers. This paper describes the situation at one Australian university. It concludes that the problem cannot be solved by the universities alone. Professional bodies and employer groups should take a lead in explaining the need for a reasonable time allocation for working students to study. A broader dialogue between industry and universities about how best to manage the competing demands on student time is highly desirable.

Keywords: Work integrated learning; working hours; experienced based learning.

1. Introduction

Most university students in Australia undertake some form of paid work while they study. Robbins (2010) reports that over 70% of full time Australian university students engage in an average of 14.8 hours of paid employment per week. Recent years have seen an increased concern about the impact on student performance of long hours spent in the workforce (D'Alessandro and Volet 2012; Hall 2010; Robbins 2010; Devlin et al. 2008; Lingard 2007; Jonkman et al. 2006; Lingard 2005). In some cases this work is low-paid and low-skilled and

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can be completely unrelated to the area of study that the students are pursuing at university. For construction and building students, however, the reported picture is somewhat different. Most construction management students find employment in the construction industry while they are studying at university (Lingard et al. 2003). This has both positive and negative effects. There are certainly many aspects of construction management that are best learnt through experience. Students are able to compare formal university education with on-site training. They may have the benefit of the best of both worlds. Many employers go to considerable effort to see that students are exposed to a plethora of different areas in construction in a structured and managed fashion. Nevertheless, there is considerable anecdotal evidence that some students are working very long hours and finding it difficult to manage their study workload.

There has been a general increase in the working hours of fulltime employees in Australia over the past ten years (Townsend et al. 2011; ABS 2012). The construction industry is widely recognised as a sector where long working hours are commonplace (Lingard and Francis 2007). This may stem from the competitive nature of construction procurement, job insecurity, strictly regulated time constraints and the complexities of project-based delivery. Lingard and Francis (2004) reported that the average number of hours worked by site-based workers was 63. 56 hours was the average worked by employees in site offices and 49 was the average among construction company head office employees. All these figures are well above the average weekly hours work by the general workforce which is 40.3 (ABS 2010). With these long hours becoming the industry standard, it is not surprising that there is pressure on those who are new to the industry to work long hours as well. In this context, some critical issues have been raised about the human impact of long work hours. These include: the 'burnout' phenomenon; family life deficits; workplace injury rates; mental illness; and even suicide among stressed-out workers.

1.1 Burnout phenomenon

Lingard et al. (2007) defined the burnout phenomenon among construction students as being described by three components: emotional exhaustion; cynicism and reduced personal efficacy. Research has also linked burnout to lower levels of worker performance, job satisfaction and organisational commitment (Maslach et al. 2001). At the same time, motivational issues have been linked to higher levels of absenteeism and staff turnover in construction businesses (Smithers and Walker 2000). Burnout can be regarded as the antithesis of engagement. Highly engaged people are said to have confidence in their own ability to act effectively and to deal with competing demands on their energy and time. Engaged learning is said to occur when students have the time, energy and the resources to devote to activities designed to enhance their learning at university. (Krause 2007). There is significant evidence to the effect that at least some construction students are working sufficiently long hours to make them vulnerable to potential burnout (Lingard 2007).

Family life issues

1.2 Family life issues

The long hours commonly worked in the construction industry mean that even for those individuals who do not succumb to burnout, there may be ongoing issues with balancing family life and work/study demands (Lingard and Francis 2007). This is an increasingly important issue for universities as the number of mature age students rises as a proportion of overall student numbers. At some Australian universities, many construction students enter tertiary study after some years working in industry in a trade or labouring capacity. These students often have existing family and work commitments which are difficult to balance with study requirements. In this respect, Brown et al. (2010) found that making provision for dedicated days off on weekends was more important than total hours worked. This is useful to note in the context of university pressure to schedule classes and examinations on weekends in order to make better use of capital resources.

1.3 Financial pressures

According to Curtis and Lucas (2001), there has been a fundamental shift in the youth employment market in recent decades. The young workers of the 1970s and 1980s were mostly school leavers. These have been replaced by students, trainees and the underemployed. Devlin et al (2008) has reported that student expectations and engagement with their university has changed significantly as a result of cost pressures stemming from the application of the 'user pays' principle to higher education. In a large national study, they found that students were making more money in industry than in the past but were also receiving less government assistance. In addition, one quarter of the undergraduates who were working reported regularly missing classes or equivalent activities because of employment commitments (Devlin et al 2008, p.118). Many students also reported that their courses did not provide for the flexibility that they needed to fit in with their paid employment. The shift away from public support to private support has a definite impact on student engagement. Krause et al. (2005) found that 16% of surveyed students felt that they did not belong to the university community. This disengagement does not stem entirely from financial pressures but there is a relationship between the two.

1.4 Workplace injury and serious illness rates

The negative impacts that long working hours have on student performance are increased when the potential for workplace injury is considered. Loudoun (2010) analysed injury rates of construction workers and found that young workers are at an elevated risk of injury. It was suggested that this may be due to their limited work experience, poor risk assessment, vulnerability to peer or work pressure and sensation seeking. Anecdotally, several academics have observed an increase in students needing time off from study to recover from workplace injury.

As well as physical injury there is some evidence to suggest that working in the construction industry can have severe mental health consequences for some people. Heller et al. (2007) studied the incidence of suicide in the construction industry in Queensland and found a

crude suicide rate of 40.3 per 100,000. This was significantly greater than the average working age Australian male rate. Young male employees were considered to be at excessive risk of suicide. Separation or divorce, relationship problems, and untreated psychiatric conditions were considered to be the likely major contributors to the problem. This is another factor which policy makers need to consider when making decisions about the structure of work and tertiary study linkages.

1.5 Role of professional bodies

Industry and professional bodies are well aware of the current situation with regard to the stresses created by long working hours. Many professional bodies have spoken out on the issue of construction industry suicide rates. Robert Hunt, Australian Institute of Building Chief Executive officer has declared that:

> "The fact that construction workers are six times more likely to die from suicide than an accident at work is a shocking statistic" and "Through a variety of events for professional builders, AIB tries to play its role to build morale and support networks in the construction industry." (AIB press release)

A similar emphasis may need to be given to the issue among future construction professionals.

1.6 Student profile from study

The research for this paper was undertaken at one Sydney university. The student profile in the construction management program consists of a high percentage of non-school leavers, articulating students from vocational training programs and a high level of 'first in family' at university students. As McLaughlin et al (2012) report, students enrolled in the construction management program at the subject university are more likely to come from low and medium Socio-Economic Status (SES) groups than other universities (The low and medium SEs rates at the subject university are 16% and 46% compared with the study group of five universities where the corresponding rates are 12% and 35%). For these reasons an analysis of the workplace hours for this one university is likely to present a useful window into the potential difficulties caused by student burnout, family life imbalance, financial pressures and workplace injury and serious illness. These issues if left unaddressed have the potential to cause considerable difficulty for the construction industry in the coming decade.

2. Methodology

An analysis of logbooks and employer letters from an Industry Based Learning subject was undertaken to find out what indicative hours university students were working in industry. Industry Based learning is a compulsory unit for graduation at the university concerned. Students are required at their own initiative to complete 1200 hours of industry experience during their period of study in the construction management program. They must provide documentation of this experience in the form of logbooks or employer letters. All such documentation for the years 2008 to 2011 was assessed for this study. The hours recorded were averaged and recorded in Excel spreadsheets under individual code names which de-identified the students. Statistical analysis was undertaken of the results for 230 students and these are presented below. In addition, the letters and logbooks were encoded using NVIVO9 software to classify keywords which described the industry experience of the construction management students.

3. Results and discussion

The average hours worked per week by students, most of whom were at the end of their four year program, was 35.92. The range of hours worked was between 14 and 60. The results are displayed in Figure 1. It should be remembered that these totals are average hours worked over several months or years. Many employer letters noted that students worked four days a week during semester time and five or five and a half days outside university term. The majority of these students were enrolled in a full time load. The university expects that this means that they will spend 40 hours per week in attending class and private study. For students at the high end of the scale of hours worked, this is clearly not sustainable.

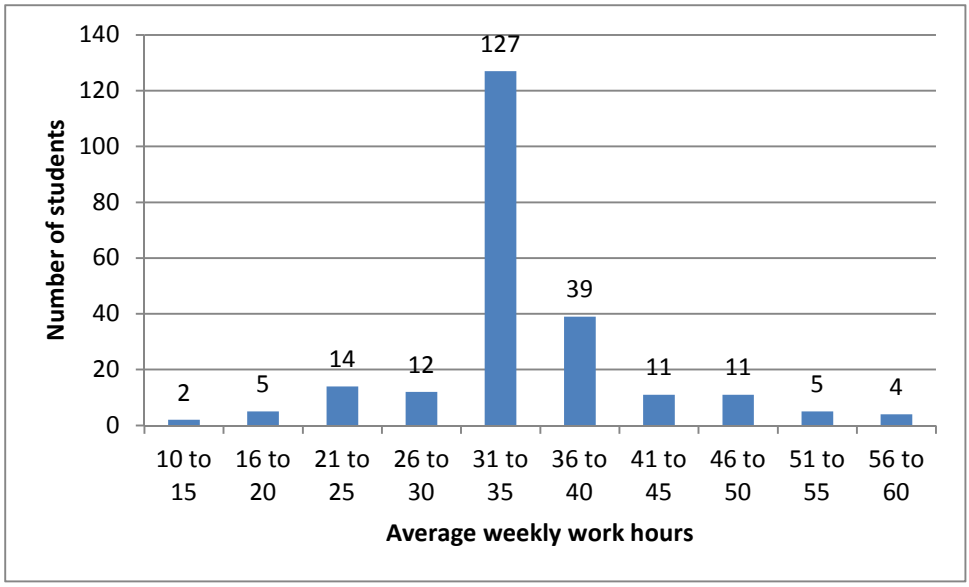

Figure 1: Average weekly hours worked in industry by construction students

Furthermore this pattern of many students working far more than what might be regarded as a reasonable number of hours was fairly consistent across the range of types and sizes of employer. Figure 2 compares the average hours worked in top tier construction companies (Dark coloured bar) compared with all other sizes of companies (Light coloured bar). Top tier companies were identified by using Construction Data lists and other market lists which identify high turnover construction and development companies.

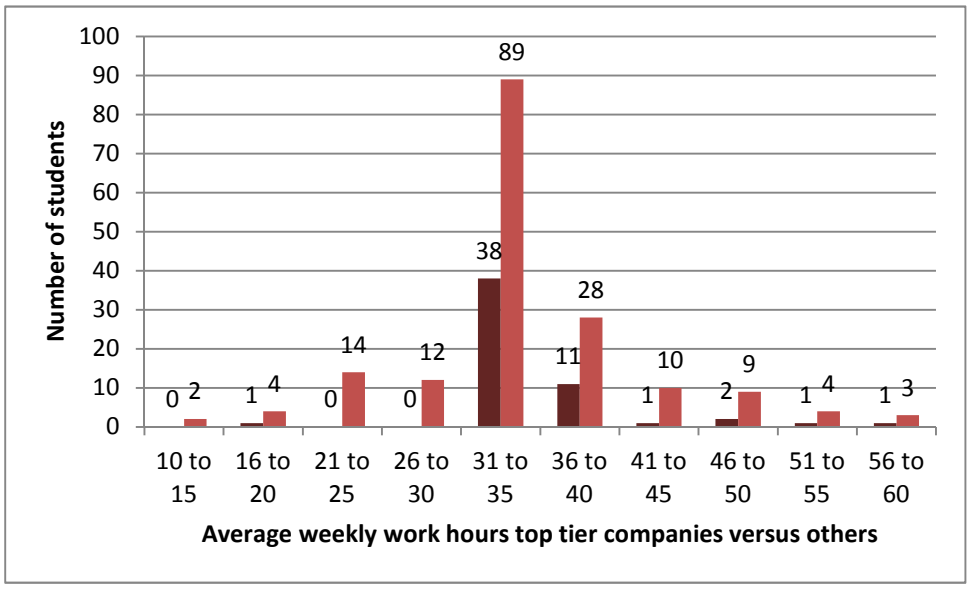

Figure 2: Average weekly hours worked by construction students with top tier employers shown in the darker shaded bars

The average hours worked was slightly higher for top tier companies at 36.56. Those students who worked very long hours (greater 45 hours per week) came from companies across the spectrum in size and turnover. They performed a variety of roles including: most commonly building cadet but also site manager, project coordinator and contracts administrator.

Employers were clearly aware of the hours worked while studying (identifying names have been removed from the quotations). One top tier employer wrote:

> "Working full time as a cadet, while completing his degree, *Student A* worked an average of 52 hours per week totalling well in excess of the 1200 hours required by the University to meet the degrees requirements for practical experience."

Another non top tier employer wrote:

> "During university semesters, *Student B* works an average of 4 days per week from 7am to 5pm, and during university breaks/holidays, he works 6 days per week from 7am to 5pm."

A similar employer wrote:

> "For *Student C* a normal working week consists of a 60 hour work week, starting at 7am and finishing at 6pm Monday *to* Friday, with a half day on Saturdays. During his study, *he* was given one day a week to attend to his study commitments at university."

While the total numbers involved in working very long hours is relatively small, it is indicated that some students are working excessive hours and that their employers are aware of this situation. It should also be noted that 30% of the students in the study worked more than 35 hours per week. It is difficult to see how this leaves adequate time for university study even in part-time mode.

3.1 Potential strategies

The problem of integrating work and university study is experienced in many discipline areas (Bates 2008; Barlow 2011; Brodie and Irving 2007; Curtis and Lucas 2001; Moore and Plugge 2008; Rhodes and Shiel 2007). Several possibilities are suggested as ways of dealing with the issue of excessive hours. The encouragement of online and blended learning is very much in favour at the moment. Capping the number of units that students can take if they are in full time employment is favoured by some academic staff. Compulsory attendance components have also been suggested in some cases. Such strategies are likely to fail without employer support. The professional bodies which cover the construction industry are supportive of the need to balance work, life and study. Yet despite this, long hours are still the norm for a significant percentage of workers in the industry. All stakeholders will need to be involved if a satisfactory solution is to be found.

4. Conclusion

Academics sometimes complain that student attendance at classes is less than it once was. Competing demands on student time go part to explaining this phenomenon. The pressure to work long hours in the construction industry is widespread and occurs at all levels of employment. An industry-wide strategy could potentially address the issue but will require accurate data on hours worked and a concerted effort to determine the optimum time that should be spent in the workplace while studying. The potential costs of ignoring this issue are considerable. Increased burnout rates of young employees, absenteeism, workplace injury due to fatigue and in the worst case suicide and self harm among those who cannot cope, are all possible if the current situation continues.

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Disaster resiliency measurement frameworks

State of the art

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Abstract

Since adoption of the Hyogo Framework for Action 2005-2015 “Building the resilience of nations and communities to disasters”, the concept of disaster resilience has gained a wider interest and has become more popular among academic researchers and practitioners. Although the literature on urban studies and also the practical planning documents recurrently refers to resilience concept as a managerial principle behind making resilient cities and regions, operationalizing this concept in urban and regional planning context raises critical challenges in terms of its determinants and assessment.

There exist a number of disaster resiliency frameworks and indicator sets in varying degrees of comprehensiveness, accuracy and validity which offer communities a set of indicators to measure and manage their resiliency in order to preserve their critical structures and functions in the face of disturbances and recover quickly to the desired pre-disaster conditions.

This paper presents a critical review of resiliency models in the international urban resilience literature. It starts by defining and individuating the resiliency concept from other similar related concepts in disaster literature. Then it defines a framework for evaluation of resiliency models for aligning it to urban studies discipline, using a number of criteria including comprehensiveness, structure of components and indicator building methods, scale and unit of analysis, dynamics, data requirements, validation and operationality, and actual and potential applications. The paper ends by speculating about the most promising opportunities to further improve the resiliency models in urban context by using a set of resilience attributes which already embedded in the discourse of urban theory to evaluate the resiliency of each city’s built environment and the way people have adapted to that built environment to recover following a disaster. The findings suggest that fostering these resilience attributes within different urban components, can potentially assist in the design and planning of resilient cities which have an enhanced capacity to absorb the shock and recover quickly.

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Keywords: disaster resilience, resiliency indicators, urban resilience

Introduction

More than a decade after starting attempts for quantifying community resilience, endeavors are still ongoing to refine and develop more applicable resilience models (Gilbert, 2010). There exist a number of centers which are investigating urban resiliency in different scales, mostly based in the US. They have developed a few disaster resilience models of varying degrees of comprehensiveness and sophistication, some of which have been and are being applied to real-life communities and places for purposes of research and/or policy analysis and/or education (Manyena, 2006, Renschler et al., 2010b).

This paper offers an overview of current disaster resiliency models. It starts by examining the general definitional issues of the concept and then presents eight resiliency models which will be evaluated later by criteria such as comprehensiveness, models structure and components, methods, scale and unit of analysis, dynamics, data requirements, validation and operationality, and actual and potential applications. The paper shows that most of the existing frameworks have not been fully operationalized and validated with real data yet, and ends with speculating about the most capable avenues to further develop effective and implementable planning and design strategies for increasing the resilience of cities to the potential future shocks.

Disaster resilience

The concept of resilience originated in the field of ecology, but it has been used within a wide diversity of disciplines from psychology, geography, social science to engineering and systems science (Klein et al., 2003, Manyena, 2006, Norris, 2008). Following the work of Timmerman (1998), many definitions of the concept of disaster resilience appeared in the hazard and disaster field in the last three decades. They are all roughly comprised of two common features for disaster resiliency: 1) the ability to resist and absorb disturbances, 2) the ability to reorganize and recover reasonably quickly (retain the same basic structure and ways of functioning) (Mayunga, 2009). Long-lasting concerns from the research community focus on disagreements as to the definition of resilience, whether resilience is an outcome or a process, what type of resilience is being addressed (economic systems, infrastructure systems, ecological systems, or community systems), and which policy realm (counterterrorism; climate change; emergency management; long-term disaster recovery; environmental restoration) it should target (Cutter et al., 2010).

The wide use of resilience is the recognition of its value but that some applications have stretched the concept beyond its original meaning to the point that the concept itself runs the risk of becoming meaningless and a source of theoretical confusion. There are a few linked terms and concepts such as resistance, vulnerability and sustainability, coping capacity and etc. in disaster studies which have to be defined carefully to avoid using them in incompatible ways. Norris et al. (2008) make a distinction between resilience and *resistance*. In their terminology resilient communities and people bounce back from disasters, while *resistant* communities and people do not suffer harm from hazards in the first place. Tierney

believes that community resilience acts to counter vulnerability. A high level of vulnerability does not necessarily mean that a community is not resilient; however vulnerability is often indicative of an inability to resist or respond to disaster (Tierney, 2009). In Cutter's adopted definition, vulnerability and resilience are not totally mutually exclusive, nor totally mutually inclusive. Vulnerability is the pre-event, inherent characteristics or qualities of the systems that create the potential for harm (Cutter et al., 2008b). Vulnerability is a function of the exposure (who or what is at risk) and sensitivity of system (the degree to which people and places can be harmed) (Adger, 2006, Cutter, 1996). In contrast, resilience is the ability of a social system to respond and recover from disasters and comprises those inherent conditions that allow the system to absorb impacts and cope with an event, as well as post-event, adaptive processes that facilitate the ability of the social system to re-organize, change, and learn in response to a threat (Tierney 2007).

The concept of sustainability is central in resilience studies since it is inseparably linked to the condition of the environment and the treatment of its resources. Sustainability, within the context of natural disasters is defined as the ability to ''tolerate—and overcome—damage, diminished productivity, and reduced quality of life from an extreme event without significant outside assistance''(Mileti, 1999) Unsustainable practice may cause more severe environmental hazards. Large-scale deforestation, for example, was a factor in increasing the flooding hazard in the 1998 floods in China, and loss of coastal wetlands is a contributing factor to the severity of impacts of tropical storms and hurricanes on coastal Louisiana (Wisner et al., 2004).

There are also diverse views about the relationship between the concepts of adaptive capacity and resilience which makes the actual linkage very unclear. As mentioned by Smit and Wandel (2006), some authors equate adaptive capacity with resilience and social resilience. Gunderson (2000) defines adaptive capacity as system robustness to changes in resilience; Carpenter et al. (2001) use adaptive capacity as a component of resilience that reflects the learning aspect of system behaviour in response to disturbance (Gallopín, 2006).

Methodology: Resilience models comparison

In order to bring together and evaluate the existing frameworks in disaster resiliency, and to answer the questions of what indicators can be used to measure community resiliency, we conducted a critical literature review including a wide range of disciplines comprising of environment, geography, planning and disaster, hazard and risk management. The eight most cited models and frameworks for measuring and assessing disaster resiliency were selected.

For the evaluation of disaster resilience models, an idealized disaster resiliency model has first been sketched out as a benchmark by which the existing models can be evaluated. Five types of resilience components are distinguished form literature for urban resiliency (See Figure1). The circles show the performance level of the urban system which in the event of a disturbance falls to a lower level depending on the resistance of the system. Each component of urban resiliency will have a particular level of resistance, transitioning period and recovery time to rebound to previous level of structure and functioning or to an upper

level of system's performance. The response to disturbance depends on different factors in each part of subsystems which are interrelated and this makes it more difficult to get quantified. It may vary from system to system and from one kind of disturbance to another. In the following sections, we will examine properties of the models based on eight criteria.
Since the principal motivation for understanding the drivers and processes of disaster resilience is to develop management plans to improve resiliency, assessments need to evaluate not only the baseline conditions but also adverse impacts, and factors that inhibit effective response (Clark et al., 1998). The transition from conceptual models to resilience measurement and assessment is challenging due to the multifaceted nature of resilience (Cutter et al., 2010).

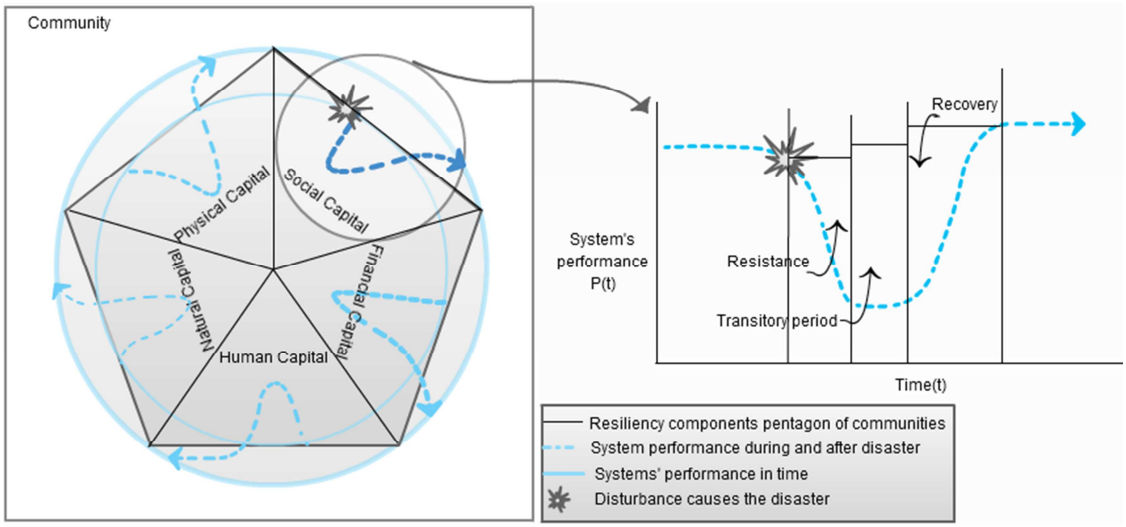

Figure 1: A model of disaster resilience models

The majority of assessment techniques are quantitative and use indicators or variables as proxies since it is often difficult to quantify resilience in absolute terms without any external reference with which to validate the calculations (Schneiderbauer and Ehrlich, 2006). As a result, indicators are typically used to assess relative levels of resilience, either to compare between places, or to analyse resilience trends over time (Birkmann, 2006). The selected eight models will be evaluated according to the following criteria: comprehensiveness, structure and indicator building methods, scale and unit of analysis, dynamic, data requirements, validation and operationality, and actual and potential applications.

Comprehensiveness

The comprehensiveness of disaster resilience models can be assessed based on different dimensions of resiliency included in the models such as built environment, economic, social, organizational and different temporal phases of disaster (mitigation, preparedness, response, recovery) for different types of disasters (such as geological, climatic,…). Yet it doesn't mean that the comprehensive model is necessarily better and more useful for policy making and planning purposes as it may result in too much complexity and serving too many purposes at one time.
PEOPLES stands for seven dimensions of disaster resiliency in this model: Population and Demographics, Environmental, Organized Governmental Services, Physical Infrastructure, Lifestyle and Community Competence, Economic Development, and Social-Cultural Capital.

As the third column of the Table 1 shows, DROP, CDRF and CDRI consistfive dimensions of aforementioned asset pentagon but DROP and CDRF disregarded the ecological resilience purposefully due to complexity or data inconsistency and relevancy (Mayunga, 2009).
DROP, PEOPLES, ResilUS, CDRF and Systems diagram are comprehensive in the sense that they address at least four dimensions of resiliency. They all encompass the technical, social, economic, organizational dimensions. NIRA focuses on the technical dimension of urban networked infrastructure. All of the models except for systems diagram and URF are multi hazard models whereas systems diagram is a seismic specific model and URF basically has been developed for climate change resiliency and thus not consider the risk as an abrupt change to urban systems but a slow onset challenge. All of the models have considered the pre and post disaster conditions but only CDRF has specifically emphasized preparedness and response phases, which are neglected by others (Mayunga, 2009).

Structure and indicator building methods

A proper resiliency index should identify the distinct dimensions and related key indicators and also aggregates the dimensions in ways that reflect community realities. PEOPLES seems to be the most successful model in this aspect. It uses a geospatial-temporal distribution within its influence boundaries to define components of functionality. And then uses the interdependencies between and among these components to determine the resilience indicators of communities (Renschler et al., 2010a, Gilbert, 2010). For example, the physical infrastructure dimension in PEOPLES includes both facilities and lifelines. In the facilities category, they include housing, commercial facilities, and cultural facilities. But for lifelines, they include food supply, health care, utilities, transportation, and communication networks (Renschler et al., 2010c). In this particular dimension, historical and continuously gathered information through remote sensing and also Geographic Information Systems (GIS) plays a major role in assessing the resilience of all integrated urban systems and feed a predictive resilience model (Renschler, 2010).The third and fifth column of table1 has summarized the main properties of models and comparison for the most important aspects of these criteria.

In DROP, two main qualities have been considered for resilience of communities: inherent (functions well during non-crisis periods); and adaptive (flexibility in response during and after disasters). Cutter's social vulnerability index, SoVI, in DROP has been used by PEOPLES to measure the social dimension of the resiliency. It integrates exposure to hazards with the social conditions that make people vulnerable to them to show the socioeconomic status of the community (Cutter et al., 2003, Cutter, 1996). They have also considered "Community competence" metrics in their index which represent how well the community functions pre-and post-disaster including a sense of community and ideals as well as attachment to place and the desire to preserve pre-disaster cultural norms and icons (Gilbert, 2010).

Metrics for measuring economic resilience have classically employed loss estimation models to measure the property loss and the effects of business disruption after disasters (Rose, 2004, Chang, 2010). PEOPLES, on the other hand, assesses both current economic activity and dynamic growth economic development (Renschler et al., 2010c).

ResilUS uses probabilistic methods within its loss and recovery modules. Each model state in ResilUS, is calculated through a comparison between a uniform random number and aggregation of all input variables which are stated as probabilities (e.g., the probability of restored water service in a neighbourhood) (Miles and Chang, 2011).

The key indicators in the Systems diagram are developed under the three complementary themes of resilience: ‘‘reduced failure probabilities’’, ‘‘reduced consequences from failures,’’ and ‘‘reduced time to recovery” which in conjunction with four aspects of resiliency: robustness, redundancy, resourcefulness; and rapidity have been organized in three horizontal layers. These layers are representatives of situations where in the bottom layer no intervention is made, in the middle first level of action and decisions and in the top layer multi attribute information is collected and used for decision making (Bruneau et al., 2003). On the other hand, the key elements of the urban resilience framework (URF) are urban systems and social agents(Tyler et al., 2010a)

Organizational dimension indicators include the number of available response units and their capacity. It means in addition to personnel and equipment, organizational resilience also includes elements that measure how organizations manage or respond to disasters such as organizational structure, capacity, leadership, training, and experience (Tierney 2007).

Scale and unit of analysis

Disaster resilience is often allocated to *technological units* and *social systems*. In smaller scales like when we consider critical infrastructures, the focus is mainly on technological aspects. And in larger scale like when we consider the whole community, the scope will be expanded to include the interaction of multiple systems – human, environmental, and others which together add up to ensure the resiliency of a community (Renschler et al., 2010c).
As column 4 of Table 1 shows, except from NIRA, which is only focused on networked infrastructures, all other seven models are at community level (Mayada, 2010). Systems diagram is developed for community level resiliency assessment and also for infrastructure networks systems. At community level, the human component is central, because in the case of a major disruptive event, resilience depends first on the actions of *people* operating at the individual and neighborhood scale. Community resilience also depends heavily on the actions of different levels of government and its agencies at the local and regional scales when a disruptive extreme event occurs.
In general PEOPLES *Resilience Framework* is based on basic community organizational units at a local (neighborhoods, villages, towns or cities) and regional scale (counties/parishes, regions, or states). Thus it can be considered as a multi scale model like ResilUS which is scalable to any number of neighbourhoods or socio-economic agents, and community. Among these community level models, URF and CDRI use city as their unit of assessment while DROP and CDRF model’s unit of analysis is county. They have chosen county as a reasonable unit of analysis mainly because of easy data availability and because it is where hazard mitigation plans and risk reduction programs are directed in the US (Mayunga, 2009).

Dynamics

Resilience can be considered as dynamic quantity that changes over time and across space. The conditions defining resilience are dynamic and ultimately change with differences in spatial, social, and temporal scales (Renschler et al., 2010a). A society may be deemed as resilient to environmental hazards at one time scale (e.g. short-term phenomena such as severe weather) due to mitigation measures that have been adopted but not another (e.g. long-term such as climate change). The temporal scale at which resilience is measured is an important issue, since it will affect the selection of variables and parameters in index construction. Although resilience is a dynamic process, but for measurement purposes, it is often viewed as static phenomena (Cutter et al., 2008a). In all eight models, there are signs which indicate the dynamic or quasi dynamic nature of the models. For example the post-event processes embedded within the DROP model allow the conceptualization to be dynamic, yet the antecedent conditions in this model can be viewed as a snapshot in time or as a static state (Cutter et al., 2008b). In PEOPLES model the community resilience indices are integral of the geospatial – temporal functionality of components of resilience. And it is supposed to continuously measure and monitor the functionality of the systems over time (Renschler et al., 2010a). The closed loops in systems diagram and iterative processes of diagnosing vulnerability, planning and implementation indicate the requirement for an iterative dynamic process to achieve a higher level of resiliency in systems (Bruneau et al., 2003). Dynamic of ResilUs is represented by pre/co-event and post-event models. For a particular dynamic (time-based) output, each model state is calculated as a comparison between a uniform random number and the aggregation of all input variables(Miles and Chang, 2011).

Data requirement

Researchers in this area often meet the difficulties in gathering data on resilience indictors for input into their models (Cutter et al., 2008a). However the availability and accessibility of the data has been one of the most important criteria for indicator construction (Mayunga, 2009). In general, data for these models fall into four types: case studies, insurance claims, direct measurements, and survey methods (Gilbert, 2010).

A huge part of the data for these models, particularly in DROP, URF,CDRF and CDRI primarily comes from the secondary datasets such as census (Cutter et al., 2008b, Tyler et al., 2010b, Mayunga, 2009, Shaw, 2009). The PEOPLES resilience framework requires the combination of qualitative (like pre/post disaster detection analysis; object oriented classification; change detection analysis of RS imagery) and quantitative data sources at various temporal and spatial scales (like voters registration, mortgage rates, saving rates, court reports, crime reports,..), and as a result, information requires to be aggregated or disaggregated to match the scales of the resilience model and the scales of interest for the model output (Renschler et al., 2010c). On the other hand, in ResilUS because of the large number of model variables and their interrelationships, the behaviour of this model is complex and it needs more simulated, aggregated and micro-data in addition to census data. However, its modularity helps to substitute a data source for a model reference. For example, rather than modelling lifeline restoration, actual lifeline restoration time-series data can be used (Bruneau et al., 2003).

Table1. Summary of the main properties of the models

Disaster resilience model	Developer/ Affiliation	Components	Scale/Unit of analysis	Methodology	Data sources	Application
DROP Disaster Resilience Of Place	Cutter et al. HVI- University of South Carolina/ 2008	Social Technical Economic Organizational	community/ county	Spatial mapping; Weighting; aggregation; Multivariate analysis; Sensitivity Analysis	Census; American community survey	Information gathering Comparison of the resiliency of different counties
PEOPLES MCEER's resilience framework	Renschler et al. MCEER- University at Buffalo/ 2010	Population &demographics Environment Organized governmental services Physical infrastructures Lifestyle & community competence Economic development Social cultural capital	Community (can be adapted to multi scale)/county	Spatial (time dependant community functionality maps); Visual inspection of RS imagery; quantitative and qualitative models for any or a combination of dimensions. E.g. SoVI for social resilience.	Census ; Quality of life surveys; Utility usage; Mortgage rate; Voter registration; Home price indices; Unemployment rates; SEC filings; Content Ground trothing interviews; pre/post disaster detection analysis; Object oriented classification; change detection analysis	Information gathering; Comparison of resilience between Counties; Empowerment of people; After complete development, it can be used as a geospatial and temporal decision support software tool
Systems Diagram Quantitative framework for seismic resilience assessment	Bruneau et al. MCEER- Univeristy at Buffalo/ 2003	Conventional systems System assessment and actions Resilience assessment	Community level, infrastructure networks	Scenario based resilience assessments	---	---
ResilUS A community-based disaster resilience Model	Miles & Chang et al. University of British Columbia & MCEER/ 2007	Recovery module Loss estimation module	Scalable to any number of neighbourhoods or agents/PUMA (Public Use Microdata Areas)	Spatial; probabilistic methods; Spread sheet-based Fragility Curves to model loss; Markov chain to model recovery; Survey based assessment	Poll results; general observations from previous studies; Zip Code Business Pattern data; Surveys from previous studies; some simulated data; Public use micro data series; USGS shake map data	Information gathering; education, training, public awareness; Resilience Comparison between different
CDRF Community Disaster Resilience Framework	Joseph Mayunga HRRC - Texas A&M University/ 2009	Human Capital Social Capital Economic Capital Physical Capital	Regional/ County	Spatial; GIS based Composite indicators; Correlational analysis; Regression analysis; Incremental validity	Census, Insurance datasets; County business patterns; Spatial Hazard Events and Losses database for US (SHELDUS); US Fire administration;; Centre for Disease control and prevention(CDC)	Information gathering; Enhance local community coping capacity; comparing disaster resiliency of communities; operationalize the disaster resilience concept to support planning, management and decision making
CDRI Climate Disaster Resilience Index	Rajib Shaw "Human Security Engineering for Asian Megacity" of Kyoto University/ 2009	Physical Social Economic Institutional Natural	City	Non spatial; Spreadsheet – based; Questionnaire survey	Surveys; Secondary data	Information gathering; Priority setting and policy recommendations based on level of resiliency in each dimension;
URF Urban Resilience Framework	StephenTyler Marcus Moench Jo da Silva ARUP + ISET/ 2009	Urban Systems (ecosystem, infrastructure, institutions, knowledge) Social agents	City/ Wards (communes)	Shared Learning Dialogues(SLD) workshops; GIS enabled sampling and aggregation method; Hazard, Capacity and Vulnerability Assessment(HCVA)	Identification of homogeneous socio-economic clusters by satellite imagery verified with rapid ground survey; Secondary data	Information gathering; Interpretation; Collaboration; implementation
NIRA Networked Infrastructure Resiliency Assessment	Omer, Mayada Stevens/Institute of Technology/ 2010	Urban Network Systems	Infrastructure networks	Spread sheet-based; System mapping; Network flow analysis; Disruption scenarios	State of New York department of Transportation; Highway capacity manual	Resiliency assessment; Resiliency strategy evaluation

Validation and operationality

Many researches in developing composite indices in resilience studies, fail to empirically validate the measures especially in terms of incremental validity. This is one of the major flaws of using composite indexes as there is no simple way to get scientific validation of a particular index (Davidson and Shah, 1997). The absence of validation is a major concern. In many circumstances, the index relies on empirical data that is far from perfect. Many assume that because numbers have been derived using some basic statistical procedure, the overall results of the index is valid and reliable. However, some qualitative methods such as in-depth surveys and case studies can be used to validate the index. Actually the best way that any sort of metrics related to the disaster field could be validated would be to continually test them after major events and refine them accordingly. This would take a considerable amount of time (Simpson and Katirai, 2006). Chang and Miles for example, have had several attempts like this to validate ResilUS (Chang, 2010, Miles and Chang, 2008). It has been applied for modeling recovery of Kobe after 1995 earthquake (Chang, 2010) and also1994 Northridge earthquake disaster (Miles and Chang, 2008) in order to calibrate several output variables with empirical data. ResilUS is currently being developed to better represent socio-cultural, personal, and ecological capitals to assist in modeling the resilience of the Gulf Coast area of Louisiana in association with the 2005 Hurricane Rita disaster (Miles and Chang, 2008).

NIRA, CDRI, URF have not been scientifically validated. However, NIRA has been applied to four types of critical infrastructure systems. These case studies probe the resiliency of the studied infrastructure systems in the face of specific disruptive events: telecommunication, transportation, maritime transportation and organizational networks. CDRI and URF has been applied to relatively 9 and 10 Asian cities for measuring their resiliency and providing some policy recommendations based on their expected level of resiliency (Shaw, 2009, da Silva and Moench, 2010).

Among all models, CDRF as a PhD project has had a full internal model validation process for its content by construct validity, predictive validity and reliability validity and plausible results were obtained (Mayunga, 2009). Based on our recent email contact, Cutter et al. are validating DROP through a case study from Mississippi Gulf Coast. PEOPLES has been partially applied for 2010 Haiti earthquake (Landscape-based Environemntal System Analysis and Modelling, 2012).

Actual and potential applications

Considering the range of issues facing communities in the event of disasters, the spectrum of applications which can be addressed by current models is not broad. These issues can be categorized into two major groups in loss reduction and quick recovery after disaster (Gilbert, 2010). The resiliency models can be utilized to assess the strategies, actions and policies for loss reduction and recovery acceleration through different scenario development or by modifying land use plans and building control arrangements. This can help to not only mitigate the exposure but also to maintain functioning of the urban system during and after a disaster (Coaffee, 2008, March et al., 2011)

PEOPLES, CDRF, DROP and CDRI by quantifying the disaster resiliency and generating hotspot maps or diagrams provide the ability to compare communities with one another in terms of their resilience, and determining whether individual communities are moving in the direction of becoming more resilient in the face of various hazards. In general, the disaster resilience determinants identified in these models, can be utilized to analyze the resiliency of each place and find the weaknesses and strengths to enhance the resiliency of place (Mayunga, 2009, Renschler et al., 2010a, Cutter et al., 2008a, Shaw, 2009).

However in ResilUS, the model's limitations make it more appropriate for education, training, and public awareness purposes rather than the actual planning purposes (Miles and Chang, 2011). On the other hand, URF seems to be more practical framework for resilience planning which in conjunction with SLD's (Shared Learning Dialogue) framework integrates resilience thinking into planning procedures in order to enable the vulnerable groups to anticipate, respond to and recover from projected climate change impacts. It will also provide resilience-related information to state and local mission partners that will support their risk-based resource decision-making process (Tyler et al., 2010a). NIRA by investigating the reaction of the networked infrastructure systems to disruptions, allow the decision makers to investigate the different resiliency strategies by adopting different scenarios.

Practicality of the resiliency quantification results depends on the level and scale of the assessment. At larger scale it is limited to public awareness and education. At regional scale, on the other hand, it can be more useful for disaster managers and policy makers to direct the resources to most vulnerable areas and where management and planning actions are needed. Resiliency models at local level by identifying more contextual determinants of resiliency of place can provide a tool for urban designers and planners to assess their designs and plans in terms of their resiliency. Several studies (Allan and Bryant, 2011, Bryant and Allen, 2011, March et al., 2011) suggest that the resilience is linked to the built environment indicators on spatial morphologies that encourage response and adaptation, such as a diversity of open spaces, redundancies in connectivity, self-sufficiency (food from urban gardens, multiple sources of water) and local urban spaces that can quickly be adapted to encourage communication and response. They note that recovery also has a spatial dimension and resilience theory suggests that design, form and space, as well as, process could influence recovery.

Conclusion

This paper has analyzed some of the most well cited and prominent resiliency models. Resiliency is a broad and complex concept which is very difficult to define and measure comprehensively. This review revealed that most of the frameworks for measuring disaster resiliency are generic and broader in the context of environmental hazards. Defining a proper context and scale for resiliency models seems necessary to take the most useful and applicable output of the model and also to provide a consistent basis for data development required for assessment. More specifically the variables and attributes of some of the frameworks are very broad and often not workable at the community level for measurement purposes. Therefore their application becomes clumsy at this level particularly where availability of data for certain indicators at the local level is a great challenge. The existing

indicators can also be criticised for difficulty of meaningful interpretation or the lack of causal linkages between the indicator values and the policy relevance of outcomes.

This critical review also points out a number of gaps in measuring disaster resilience literature. First, a large portion of the resiliency literature is mostly conceptual with excessive emphasis on resilience in socio-ecological systems. In this context, there remains a lack of robust case studies which can test or validate the models and their theories. Second is the lack of policy relevancy of the outputs. In this regard, the potential applications which were mentioned in earlier parts of this paper deserve more attention by researchers in this field including specific urban design and planning measures which can influence the resiliency of place such as incorporating flood attenuation as part of an integrated urban form. Open spaces, such as recreational parks and ovals to manage and reduce potential flood hazards and other applications such as improvement in construction practices, building codes, and mitigation of homes (retrofitting or elevating) are measures that enhance resilience as is the building of redundancy in critical infrastructure and also acting as a management or decision making tool are seem to be in reach by further developing and integrating the existing frameworks. To sum up, for making our communities disaster resilient we need tools for evidence-based policy making, analysis and evaluation of a large variety of issues and criteria. Existing experience shows that developing indexes, typology approaches and benchmarking can be of great help in research as well as for practitioners for making our communities resilient.

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Assessing the Influence of Cultural Issues on the Adoption of Life Cycle Management Tools

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Abstract

Among the industrial sectors, construction is probably the one with the highest 'human density', due to the great number of different actors involved in each phase of a project. It is acknowledged that cultural issues and cultural diversity impact considerably on the outcome of construction projects, due to the peculiar nature of contracting, procurement and collaborating with partners within the supply chain. In a traditional culture, the transfer and implementation of innovative philosophies and methods implies a radical modification of shared assumptions, values, and practices, which often results in a strong resistance to change. Life Cycle Management (LCM) tools (mainly Life Cycle Costing and Life Cycle Assessment) are an emblematic example of innovative approaches with a long tradition in theory but a rather complicated take-off in everyday practice. Literature has always reported on difficulties in finding suitable data, sharing standard methodologies, or choosing the most user-friendly tool. However, technical barriers cannot be overcome if culture within the organization hinders the decision process. This study adopted a structured and systematic research approach to analyze literature sources with the objective of understanding to what extent culture has an influence on the implementation of LCM tools. LCM literature has been studied by means of relational content analysis, performed with a multiple-software approach. The first phase, unsupervised concept mapping with Leximancer V4, was performed in order to enlarge the corpus, look for connections among concepts, and build the coding scheme of the following manual coding phase, performed with NVivo9. In the manual coding, four categories of actors (decision makers, clients, supply chain, and stakeholders), and four main categories of barriers (behavioral, organizational, financial, and technical) were identified as 'nodes'. Cluster analyses and matrix coding queries were used to investigate the connections between actors and barriers, organized in sub-nodes. The analysis revealed that organizational culture was the most coded barrier, and professionals were the most relevant actors. A strong statistical correlation between clients and decision makers can be considered as an indicator that these traditionally detached groups of actors perceive the same problems on the topic, such as unreliability and uncertainty of the tools.

Keywords: content analysis, organizational culture, LCC, LCM

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1. Introduction

Life cycle management (LCM) is a “flexible, integrated, framework of concepts, techniques and procedures to address environmental, economic, technological and social aspects of products and organizations to achieve continuous environmental improvement from a life cycle perspective” (Hunkeler et al., 2001: 385). Under this umbrella, Life Cycle Costing (LCC) and Life Cycle Assessment (LCA) are among the most discussed tools in the last decades. Numerous literature sources report on a scarce application of these tools despite their strong theoretical basis. This is particularly true in the construction industry, which is traditionally slow in innovating its products and processes. This paper reports on the obstacles encountered in the practical application of LCM tools in construction. Content analysis (CA) was chosen for this investigation because it allows to “read through the lines” of archival sources by assessing the presence of certain words, concepts, and themes in an objective way. CA enables to observe the latent content of a message, made of concepts that ‘cannot be measured directly but can be represented or measured by one or more indicators’ (Hair et al., 1998, cited in Neuendorf, 2002: 23). The objective of this work is to find evidence that cultural barriers hinder the process of accepting and adopting LCM tools in the construction industry. Where technical barriers may be seen as “perceived” obstacles (numerous software packages and databases are now available), cultural barriers may represent the “real” problem.

2. Literature review

2.1 Organizational culture in construction

Hofstede et al. (2010) define culture as ‘the collective programming of the mind that distinguishes the members of one group or category of people from others’ (Hofstede et al., 2010:6). The so called “software of the mind” represents the basic set of rules that are necessary to establish and keep the social order within a group. These “rules of the game” are habits of thinking, espoused values, underlying assumptions, shared meanings, and common practices that can be correctly interpreted only by the members of a specific group (Hofstede et al., 2010; Schein, 2010). Since culture derives from one’s social environment rather than genes, its strength and stability is due to the fact that it is group-based. Culture groups can be distinguished at different scales, from macro to microcultures: occupations that exist globally, such as medicine, law, engineering share the same occupational values despite national boundaries (Schein, 2010). The core of each culture is occupied by *values*, shared, abstract ideas about what is good, right, and desirable (Williams, 1970, cited in Sagiv and Schwartz, 2007). Cultural values, mostly learned during childhood, represent both the broad goals that the members of a collectivity are encouraged to pursue, and the justification for the actions taken to accomplish these goals (Sagiv and Schwartz, 2007). At the societal level, cultural values develop in order to respond to basic challenges, thus societies differ because of the different reactions to common challenges. Analogously, cultural values at the organizational level develop in response to two basic challenges: adaptation to the external environment and integration of their internal system (Schein, 2010). The relationship between society and organizations is twofold. Organizational cultures tend to develop compatibly with the societal culture, because organizations need to

get societal approval and justify their activities as expressing the societal culture in which they are nested (Sagiv and Schwartz, 2007). On the other hand, individuals affect organizational culture, both intentionally and unintentionally, through the promotion of values, personal views of what is desirable, practices and the design of physical settings (ibid.). Similarly, organizational culture shapes the behavior of its members, because they usually conform to the organizational culture in order to avoid problems in the workplace (Cheung et al., 2011).

According to Abeysekera (2002) culture in the construction industry is about the "characteristics of the industry, approaches to construction, competence of craftsmen and people who work in the industry, and the goals, values and strategies of the organisations they work in". In a few words, it is about what is done, how and when it is done, who is involved and why things are done in a specific way (Ankrah and Proverbs, 2004). The definition of all these elements is a potential source of conflicts in an industry that is well known for its adversarial and antagonistic aspects (ibid.), its strong masculine culture, a highly competitive and inherently unsupportive climate (Worrall, 2012). In this context, it seems clear that cultural issues at the organizational level are even more critical than in other industries. Moreover, the peculiarities of contracting and procurement phases, and the transfer and implementation of innovative approaches and practices from other sectors (Ankrah and Proverbs, 2004) call for a special attention to cultural problems. Unfortunately, for a long time, their importance has not been recognized, and culture has been kept as a "black box", used to justify the failures of the industry (Tijhuis, 2003). With regard to this, Ankrah and Proverbs (2004) advocate that understanding how culture affects the competitiveness, profitability and performance of organizations within the industry can help with the process of implementing changes in culture and organizational structures.

3. Research methodology

This section of the paper presents the research methodology designed to answer the research questions. The approach chosen for this research is based on the integration of two software packages, e.g., Leximancer and NVivo 9. Since the two packages perform the analysis with completely different logics, they have been employed for different aims, and in separate and sequential moments of the research process. The twofold content analysis approach was chosen as the most appropriate method to answer the following research questions: 1) How does culture, at the personal and organizational level, affect the application of LCM in construction? 2) Can culture be addressed as a relevant barrier for the widespread use of LCM? 3) Who are the main actors that hinder the adoption of LCM tools?

3.1 Content analysis as a research tool

According to Neuendorf (2002), CA is a summarizing, quantitative analysis of messages that relies on the scientific method (p.10). CA allows to acquire, summarize, and reformulate the information developed in a body of texts, in order to 'narrow the range of possible inferences concerning unobserved facts, intentions, mental states, effects, prejudices, planned actions, and antecedent or consequent conditions' (Krippendorf, 2001:25). Thanks to its flexibility of use, CA has been used in a vast array of fields, such as marketing and media studies,

literature, cultural studies, sociology, and psychology (Palmquist et al., 2005). Despite the numerous existing approaches, the general rules of CA are the same across all disciplines. Key factors in the evaluation of CA as a suitable research tool are the objectives of the assignment, the available data, the type of required data, the kind of analysis required, and the resources needed (GAO, 1996). The methodological rigor helps the researcher to give CA the conformity to the rules of good science: reliability, validity, replicability. The operative process of content analysis can be basically split into four phases (Neuendorf, 2002): 1) problem definition; 2) selection of the sample; 3) coding; and 4) analysis of results. Coding can be done either by one person (single-rater coding) or a team of people (multi-rater coding), and manually (pencil-and-paper approach) or with the aid of computer programs (CAQDAS). The coding is done according to a coding scheme, that has to be outlined by the researcher preferably before the activity starts (deductive approach). The scheme needs to be consistent with the formulated research questions, and has to be flexible and open to new ideas and patterns emerging from the analysis of the texts.

3.2 Content analysis in the research design

The four-phase approach proposed by Neuendorf was slightly modified to fit the research design of this study. First of all, 6 phases were identified. The coding phase was split into two sequential sub-phases, automatic concept mapping and computer aided coding. The combination of unsupervised concept mapping and manual text coding responds to the logic of mixed methods, and serves the following objectives: 1) clarify the relation between the two content analysis approaches; 2) find complementarity, similarity, or dissimilarity of the findings; 3) improve the research method by using one approach to inform the other; 4) obtain triangulation of convergent data, and 5) discover paradoxes and contradictions. Moreover, an additional phase was added, i.e., the classification of the sources according to different criteria. The ultimate goal of this task was to appreciate similarities and differences in the coding, with respect to the type of source, the research method, the main focus of the paper. An explanation of each phase is presented in this paragraph, while the last phase is presented in a separate paragraph to give relevance to the discussion of results.

4. Content analysis phases

4.1 Phase 1: Problem statement

The identification and discussion of the barriers for the implementation of LCM in construction is a fairly complex task, due to the number of actors involved and to the different aspects that involve them. Most literature sources indicate technical issues such as the inappropriateness of the existing tools, the lack or scarce quality of input data, or the lack of standard methodologies, as the most important barriers to the wide adoption of LCM. This may be absolutely true if only designers, managers or decision makers were responsible for choice of using LCM-based techniques or not. The coexistence of a wide variety of actors with their own cultural and professional background makes it clear that a deeper reading of what literature tells us about this topic is necessary. Thus, the use of content analysis seems appropriate for this purpose. According to Hofstede et al. (2010), individual and organizational culture are pivotal to understand why collaboration in projects does not

always work properly. Since culture derives from the social environment in which the individuals develop their personality, shared assumptions, values, and practices are often a matter of contrast between people coming from different cultural backgrounds.

4.2 Phase 2: Selection of the sample

The texts for CA were selected through searches in all the most common electronic libraries accessible from the University of Washington and Polytechnic University of Bari facilities, e.g. Academic Search Complete (EBSCO), Web of Science, ScienceDirect, Engineering Village 2, and so forth. Since CA is extremely time consuming, the selection of the sources was accurately planned. Firstly, a thesaurus dictionary was created for each main keyword: *LCM (LCC, LCA)*, *barriers*, and *use*. The thesauruses were successively enlarged thanks to the suggestions given by the automatic computed coding performed with Leximancer. Secondly, the search in all the databases was conducted using the Boolean connectors AND and OR to combine keywords. The keywords were searched, only in English, in all fields (title, abstract, keywords, full text, references). Besides digital literature databases, grey literature was searched on the internet: reports on European projects, Master's and PhD's theses were been included in the body of texts as sources of valuable information.

4.3 Phase 3: Unsupervised concept mapping with Leximancer

Leximancer V4 is a semi-automatic CA tool that analyzes textual documents and displays the extracted information visually in a conceptual map (or cloud). The maps provide a bird's eye view of the coded material, represent a means of quantifying and displaying the conceptual structure of text, and thus allow to explore interesting conceptual features (Leximancer, 2011). Leximancer V4 (online portal version) was chosen among others for several reasons. First, the resulting conceptual map is the combination of two CA approaches, i.e. conceptual and relational analysis, with words, concepts, themes, and relationships displayed in the same space. Secondly, it automatically extracts a dictionary of terms (thesaurus), which is constantly updated, for each concept. Third and most important reason, in Leximancer words that appear in the same circle (theme) indicate concepts that are frequently used together, thus are strongly correlated. This means that the program helps to figure out the relationships between concepts in terms of magnitude and direction, and thus draws the patterns among the different elements included in the text. To summarize, the aims of this phase were 1) to find keywords for the second and third rounds of search in literature databases and web search engines; 2) to identify the main concepts and the relationships between them (automatic relational analysis), and 3) to guide the coding scheme for the unassisted content analysis performed with Nvivo 9.

Figure 1 shows one of the concept maps developed by Leximancer, after setting 50% theme size and 70% visible concepts. The map settings can be changed anytime to suit the researcher's needs. In this case, this setting was chosen because it allows a comprehensive reading of the themes and concepts, without compromising the visibility of the picture. The map was studied with a top-down strategy, going from the themes through concept seeds words. First, the themes were studied in terms of color, size, position in the map space, and overlaps. Successively, the most interesting themes were studied by clicking on the

concepts in the map and analyzing the statistics used to create the map, mainly the co-occurrence rates and frequency ranks of concepts. As visible from the map, the most relevant themes were “Costs” and “Building”. This can be deducted by their red color (not visible in the picture due to editing reasons), their bigger radius (the radius indicates the connectedness of the concepts grouped into the theme), their central position in the map space, and the number of other themes they intercept. Furthermore, the 10 highest-ranked concepts in terms of co-occurrence were identified in the map, in order to understand the existing relationship between them. Ten combinations of concepts were identified. Besides the most predictable connections (the couples *Construction-Project* and *Life-Costs* remind the search parameters for the choice of the literature sources), some interesting patterns were observed. For instance, the couples *Building-Use*, *Cycle-Use* expressed the importance of buildings operational and use phase, while the couple *Design-Cycle* expressed the value of the design phase. These relations are reinforced by the mutual correlation among the concepts *Energy-Building-Use-Cycle-Design*, that can be read as the strong influence of the design phase on the performance of the building across the life cycle, especially in the use phase.

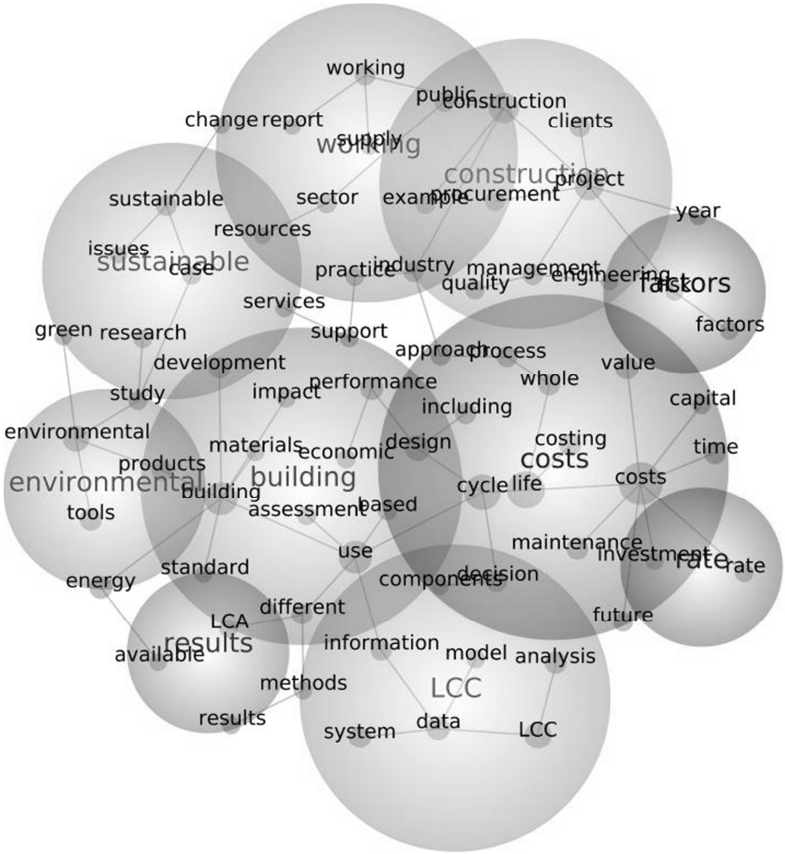

Figure 1: Concept map in Leximancer (Theme size 50%; 70% visible concepts)

Surprisingly, none of the emerging concepts addressed the term “barrier(s)” and its synonyms directly. This occurrence may be explained as follows. First, the sources are extremely dense in content, therefore the topic to be studied is often not central to the paper. Secondly, since the program creates concepts through the statistical evaluation of correlated words, there are few words expressing the concept “barrier”. This confirms the initial difficulty in creating the thesaurus for the literature search. Third, the concept of barrier may be

“nested” into other emerging concepts, such as “change”, “issues”, “risk”, “resources”, or “support”. This reinforces the consideration that the topic has numerous underlying issues, which were revealed thanks to automatic CA. All things considered, the use of unsupervised concept mapping was highly beneficial because: 1) it provided new keywords for the second and third stages of literature search; 2) it offered an overview of the main topics of the selected papers, 3) it highlighted the relationships among emerging themes and concepts, and 4) it confirmed that the topic requires a deeper level analysis that go beyond the semantic level of words. Without the use of Leximancer, the manual coding activity would have been done merely using the keywords “barrier(s)” or “obstacle(s)” as guides to identify the most important text passages, skipping the whole text (word search approach). This would have probably resulted in an incomplete reading and understanding of the text, and thus in an unreliable and ineffective content analysis.

4.4 Phase 4: Classification of the texts

In the fourth step, all the sources were uploaded in NVivo 9 (QSR International) and classified. The aim of this step was to distinguish the main features of each source, in order to use them as means of comparison in the analysis phase. The sources were classified according to a list of attributes: *Industry* (building construction, infrastructures, or both); *Inquiry* (literature review, survey, case study, interviews, or a combination of two or more); *Target of the paper* (LCC, LCA, or LCM approaches); and *Type of sector* (Private, public, or both). For each attribute, a value “Unassigned” was given when the attribute could not be explicitly defined. An emblematic case is the attribute *Inquiry*, which describes the research method that the author(s) adopted to report on the barriers to LCM in construction. For this attribute, the value *Unassigned* was given to the source when the references or citations were missing, and the barriers were simply listed. In this case, it was assumed that the discussion was the result of anecdotal evidence. The analysis of the sources revealed that about one third of the papers refer to previous literature as the main source of information. The papers based on anecdotal evidence covered 30% of the total, similarly to literature. Successively, text queries were used to find out how many sources reported key references and authors, in order to assess the independency of sources. Specifically, Flanagan (Flanagan & Norman, 1983; 1987; Flanagan, 1989; Flanagan et al., 1989; Flanagan & Jewel, 2005) was cited in 23 out of 50 sources; Kirk and Dell’Isola (1995) were cited in 15 papers, Clift & Bourke (1999) were cited in 12, and Bull (1993) in 9 sources. Moreover, these seminal pieces are often cited together in the same paper. Since most of the original sources were not available at the time of the analysis, it was not possible to find out if they had referred to other literature sources or, more likely, they relied on the considerable authors’ experience in the industry. This occurrence reinforce the idea that some ‘shared assumptions’ (Schein, 2010) on the topic may have negatively affected the industry’s ‘occupational culture’ about the topic.

Arguably, the interdependency of the sources may have influenced the results of the automatic concept mapping. Unfortunately, how Leximancer algorithm works is not fully known, therefore this condition cannot be disconfirmed. Nevertheless, a few considerations may help. Firstly, the variety of concepts is so large that the effect of reinforcing one concept to the detriment of others is probably insignificant. Secondly, the program considers the

relations of proximity between words to build the map, thus it is not just a matter of how many times a specific word is repeated, but how close and how far two words appear in the body of text. In third place, the interdependency of sources is an inevitable condition for the body of literature about the topic. There are seminal pieces that represent a sort of “Bible” for the researchers in this field, therefore a situation in which all sources are independent from each other would be unthinkable. Moreover, the unsupervised concept mapping was not used to draw conclusions, but to guide the successive phase. However, further research is needed to highlight this interesting and potentially controversial aspect of the study.

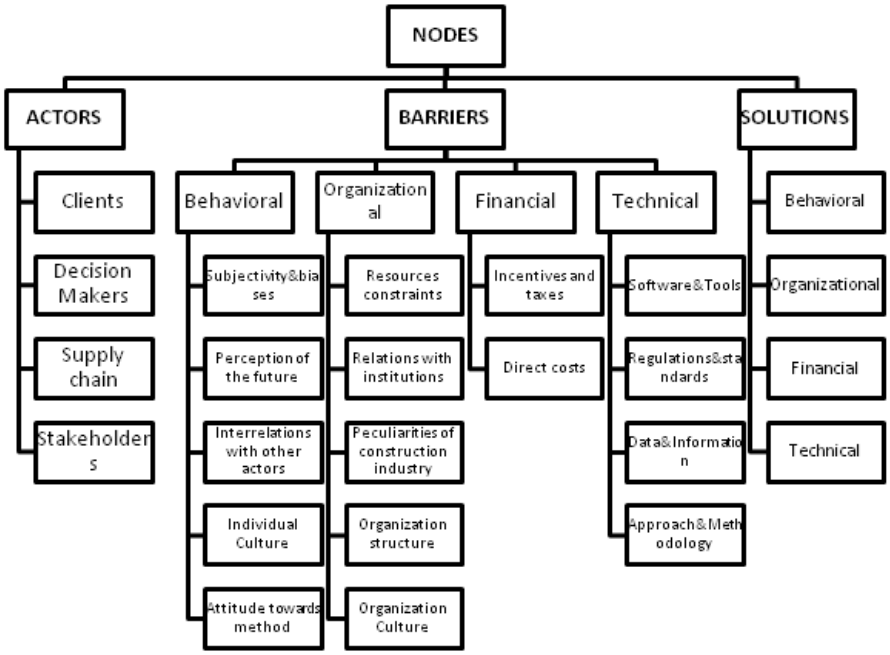

Figure 2: Coding scheme used for content analysis with NVivo9

4.5 Phase 5: Manual computer coding with NVivo9

In Phase 5 NVivo9 was used to perform the manual computer coding. The core of CA is the creation of the coding scheme, i.e., the classification system for describing the content of the text to analyze. The coding scheme adopted in this research was developed out of theoretical literature, with the aid of the conceptual maps provided by Leximancer, that were used to ensure a good level of “creativity” for the coding. The approach to the coding scheme was deductive in its ‘hard’ structure (definition of variables, coding rules, and coding scheme up to the second-level nodes), but inductive in the creation of lower level nodes, which were created, updated, and merged as the coding activity went on. Three sets of interrelated concepts were created and placed at the top of a hierarchical node structure, i.e., *Actors*, *Barriers*, and *Solutions*. As visible in Fig. 2, for each first-level node (e.g., *Barriers*), four second-level nodes were identified (e.g., *Organizational*), which were further split into third-level nodes (e.g., *Resources constraints*). Concepts were coded in the nodes at the lowest level of the hierarchy, therefore the higher levels worked as aggregators. The coding scheme and the coded material were continuously revised, in order to check if the principle of mutual exclusivity of the nodes was respected. As a rule, a concept can be coded at different nodes, but each node must not overlap the others. This condition ensures

the consistency of the coding. Additionally, since the coding has been performed by a single rater, the coding reliability was checked over time by re-reading the documents, randomly picked from the corpus, and coding them all over again (intra-rater reliability). Moreover, a set of explicit recording instructions were developed and eventually updated as the coding activity proceeded, in order to limit the artificial inflation of the reliability coefficient, due to the inevitable closeness to the coding (Krippendorff, 2004; Stemler, 2005).

5. Analysis and discussion of results

The coded material was studied through matrix coding queries and cluster analyses, available in NVivo. In particular, matrix coding queries were employed to analyze the interactions between different nodes (e.g, barriers and actors), and to study differences and similarities of the coding across the sources, according to their attributes (e.g., type of inquiry). On the other hand, cluster analyses were used to visualize relationship patterns, obtained by grouping the sources or nodes that share similar words, attribute values, or are coded similarly by nodes (statistical similarity). The bar chart in Fig. 3 shows the relationship between actors and barriers, as a result of a matrix coding query. As the bar chart reveals, the most relevant actors are decision makers (professionals who are in charge of the different phases in a construction project), with a total of 415 coded references, followed by clients (public and private), with 247 references. Organizational barriers were the most coded, with 43% of the total references, followed by behavioral (30%), technical (24%), and financial. These figures refer to the number of references that were coded both at the node *Barrier* and the node *Actors* (some text excepts were coded at one barrier but two actors).

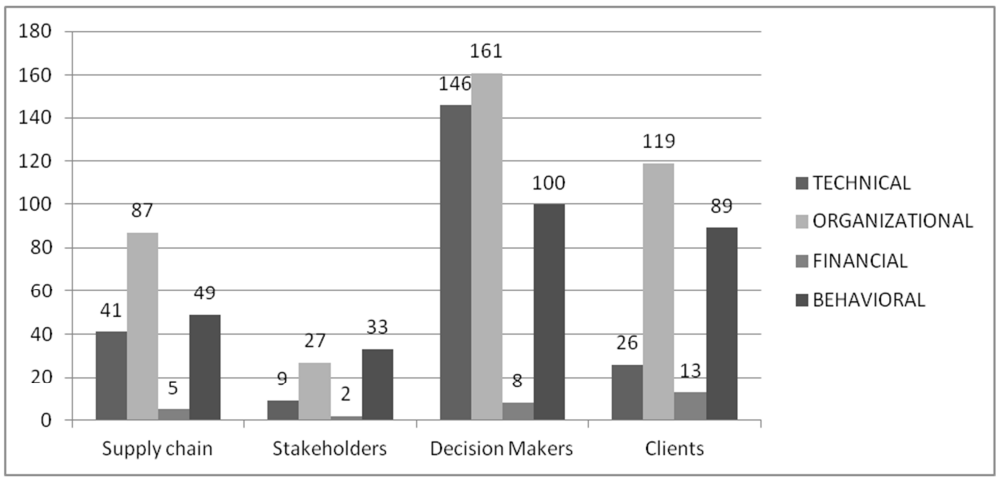

Figure 3: Actors and first-level barriers

Table 1 is displays the results of a matrix coding query between third-level barriers and the attribute *Inquiry type*. The table shows that *Organizational culture* (150 references) and *Approach and methodology* (151 references) were the most coded barriers. Therefore, it seems that technical issues prevail on over cultural problems. What is interesting is that while *Data and information* and *Approach and methodology* were mostly supported by anecdotal evidence and previous literature studies, *Organizational culture* issues mainly

emerged from mixed methods, which involve at least one direct inquiry method (i.e, interviews, case studies and so on). Anecdotal evidence is a valuable source of information if it comes from eminent researchers, but its scientific validity is controversial due to "cherry-picking", and confirmation and recall biases that manifest themselves at the subconscious level. On the other hand, construction industry can be recognized as a strong, universal macroculture, in which shared assumptions and value transcend national boundaries (Schein, 2010). Since "culture is not only all around us but within us as well" (Schein, 2010:9), and everything we think, perceive, or do is culture-bound, anecdotal evidence is also affected by the surrounding culture, thus inevitably biased. All things considered, organizational culture may be considered a "real" barrier, as it comes from a description of real situations, while technical issues, such as the inappropriateness of data or the difficult methodologies, may be considered "perceived" barriers, a sort of "telephone game" in which the origin of the message is no longer available.

Table 1: Inquiry type and third-level barriers

		INQUIRY TYPE						Coded refs/ node
		Anecdotal evidence	**Literature**	**Survey**	**Case study**	**Interviews**	**Mixed**	
Technical	Software&Tools	6	1	2	0	0	5	**14**
	Regulations&standards	3	4	1	0	0	7	**15**
	Data&Information	37	31	9	12	8	28	**125**
	Approach&Methodology	47	37	16	3	12	36	**151**
Organizational	Resources constraints	3	8	3	0	1	14	**29**
	Relations with institutions	1	6	2	0	0	4	**13**
	Peculiarities of construction industry	41	44	5	3	9	39	**141**
	Organization structure	3	6	3	1	3	9	**25**
	Organization Culture	22	34	24	7	8	55	**150**
Financial	Incentives and taxes	3	0	0	0	0	7	**10**
	Direct Costs	4	4	3	0	1	8	**20**
Behavioral	Subjectivity&biases	3	30	2	1	0	1	**37**
	Perception of the future	5	3	0	1	0	3	**12**
	Interrelations with other actors	8	6	1	5	2	8	**30**
	Individual Culture	6	35	1	0	4	19	**65**
	Attitude towards method	11	13	4	1	5	21	**55**
	Coded refs/inquiry	**203**	**262**	**76**	**34**	**53**	**264**	
	Coding density	**32,32%**	**41,72%**	**12,10%**	**5,41%**	**8,44%**	**42,04%**	

Finally, a cluster analysis was performed among the nodes *Clients* and *Decision makers*, and all the third-level nodes belonging to organizational and technical barriers. The cluster analysis indicated a strong correlation between *Decision makers* and *Approach and methodology* (Pearson's r=.82), *Organizational culture* and *Clients* (r=.81), and *Clients* and *Decision makers* (r=.79). Since the correlation indices are calculated from the co-occurrence and frequency of words coded at a node, here the high degree of similarity may indicate that

1) text excerpts were coded in both nodes, at simplest; 2) the barriers are strongly interconnected; and/or 3) the actors in the construction process share very similar views on the topic. The first occurrence is demonstrated by the strong correlation between *Decision makers* and *Approach and methodology* (r=.82, 80 common refs.). However, this relationship is weaker in the case of *Organizational culture* and *Clients* (r=.81, 61 common refs.), and reveals a contradiction, because *Organizational culture* and *Decision makers* share the maximum number of common references (85) but have a lower correlation index (.76). Moreover, *Attitude towards method* is equally correlated to *Clients* and *Decision makers* (.75), meaning that these two fundamental groups of actors in the construction process may share the same view on the topic, for instance they are both skeptical about its effectiveness and efficacy.

6. Conclusions

This paper briefly presents the results of a content analysis conducted on the barriers to the wide adoption of LCM tools in construction. The analysis showed that organizational and technical barriers were the first identified in the sources, and that decision makers and client are pivotal to the positive outcome of the process of accepting LCM into their mechanisms. What was striking (or probably, not at all), was that technical issues such as problems with data or methodology were less relevant than organizational culture. Organizational values and practices represent a source of richness but also a hindrance to the acceptance of what is "new". Construction industry is traditionally a sector in which the tolerance of risk is extremely low, but this may be less true in countries that feel less 'threatened by ambiguous or unknown situations' (Hofstede et al., 2010). It is not surprising that the first countries to accept and adopt LCC in public procurement score low in Hofstede's Uncertainty Avoidance Index (UAI), e.g. Sweden (29), UK (35), or US (46). Finally, a cluster analysis highlighted a strong correlation between elements that are usually considered detached, such as *clients* and *decision makers*, or *organizational culture* and *clients*. As suggested in the previous paragraph, different actors in the construction supply chain may face the same obstacles in pursuing their objectives, or the barriers are strongly interconnected, as in the case of *attitude towards method* and *organizational culture.* In any case, it seems that it is not merely a matter of how complicated the calculations are, or how difficult it is to find the suitable data to perform an LCC analysis. Cultural issues, at the individual and organizational level, constitute a barrier which cannot be easily overcome with the introduction of a new software tool or a new regulatory framework. Further research will investigate how organizations from different geographical contexts have addressed the issue, and how they have adapted their values, structures, and practices in order to integrate LCM tools into their processes.

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Applicability of Critical Chain Scheduling in Construction Projects: An Investigation in the Middle East

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Abstract

Many industries, including construction, have been using CPM scheduling for a very long time. However, due to the increasingly competitive business environment, tighter time constraints are becoming the norm of the industry. And as a result, more projects are slipping behind schedule. This led some to call for more efficient means to plan and schedule projects. Following to the introduction of the theory of constraints (TOC) by Eli Goldratt, a new and innovative project scheduling paradigm emerged; that is Critical Chain (CC). This technique is evolving year after another, with documented success stories in some of the biggest multinational companies in the world. However, it seems to be almost unknown within the construction industry, at least in the Middle East where the study was carried out. To better understand the potential of applying CC in construction, this study aimed to: (1) measure the readiness of construction professionals in two Middle East countries to adopt CC, (2) determine suitable project type(s) for its pilot application, (3) identify any technical obstacles to applying it, and (4) investigate means to overcome such obstacles. To this end, CC introductory seminars were organized in Egypt and Saudi Arabia. Questionnaire surveys were disseminated after these seminars to solicit feedback on these issues. One of the survey's findings is that linear projects, e.g., pipeline construction projects, were pointed out as potentially suitable for CC pilot application. An obstacle identified by construction professionals to hinder CC real life application is estimating the aggressive but achievable duration (ABAD). This term refers to fundamental parameter upon which the CC calculations are based. The paper briefly discusses how the intelligent capabilities of case-based reasoning are utilized to help facilitate the estimation of ABAD.

Keywords: project scheduling, CPM, critical chain, pipeline construction, case-based reasoning (CBR).

1. CPM scheduling for construction projects

The critical path method (CPM) and its underlying concepts evolved in the US back in the 1950s (Aguanno 2002). Today, CPM tools are the norm for planning and scheduling

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construction projects. According to surveys by Kelleher (2004), a staggering 98.5% of surveyed ENR's top 400 construction contractors were using CPM as the fundamental technique for project planning. The smaller size companies employed free-hand bar charts as well, while the larger size ones complemented their CPM planning with the use of Program Evaluation and Review Technique (PERT), 4D schedules, and others.

Many articles have been written about the importance of using CPM in construction planning and scheduling (Hansen 1994). The last decade, nonetheless, has witnessed a debate on the *real* effectiveness of such planning tools. Some even critiqued the construction planning process and argued that there was over-emphasis on the critical path terminology (Street 2000, Winch and Kelsey 2005). Among the arguments was the need to continuously update and revise the schedule, CPM becoming a ritual formality rather than a useful tool, among others (Baki 1998). Other opponents tackled the issue from a different perspective. Goldratt (1997), for instance, argued that there has been nothing really new in project planning and scheduling in 40 years. The traditional CPM inherited certain foundational philosophy in calculating activity duration, activity float, and the project total duration. However, with CPM, it is not uncommon to see projects failing to be completed as planned. There is a myriad of causes behind such failures, but one ought to think if the planning tools themselves are sometimes incapable of safely navigating a project to its end.

2. Critical chain and the need for this study

The critical chain (CC) method was first introduced in 1997 by Dr. Eli Goldratt in his book "Critical Chain" (Goldratt 1997, Raz et al. 2003). Since its inception, CC was realized to be a considerable deviation from the traditional CPM counterpart. Today, it is a well-recognized technique for project planning and scheduling in the literature (PMI 2008). Moreover, many success stories for its implementation have been reported in various industries such as defence, pharmaceutical, IT, research, and others (Leach 2005).

Despite this relative popularity in some other industries worldwide, there was no documentation of applying CC in the construction industry in the Middle East. Admittedly, there have been attempts at applying CC in the international construction industry, e.g., Balfour Betty (1998). Yet, this does not translate, by any means, into CC becoming a well-proven industry practice. The study in hand was initiated – back in 2008 – as an effort to:

1. Gauge the level of awareness of construction industry practitioners in targeted Middle Eastern countries about the CC technique.

2. Investigate the applicability of CC in construction projects, from the perspective of those industry practitioners. Also, investigate the type(s) of construction projects convenient for its pilot application.

3. Point out and possibly tackle an obstacle to its implementation.

To this end, the study proceeded in stages as follows:

1. Publications and earlier researches relevant to planning and scheduling techniques were thoroughly reviewed, particularly those addressing CC. Also, the CC awareness was informally investigated among industry practitioners (to better guide the following stages of the study).

2. CC awareness seminars in both Egypt (as a representative of North African countries) and Saudi Arabia (as representative of the Arabian/Persian Gulf countries) were conducted. The support of professional societies was sometimes sought in arranging the said seminars, to which industry practitioners were invited.

3. Following each awareness seminar, questionnaire forms were disseminated to the attendants to investigate CC applicability, potential construction project type(s) for its application, obstacles, among other aspects.

4. An obstacle to CC implementation was highlighted and a computerized tool was developed to help overcome such obstacle. The intelligent capabilities of case-based reasoning were particularly sought at this stage.

3. The critical chain terminology

The CC was born out of the theory of constraints (Goldratt 1997). The application of the theory of constraints in the area of project planning is based on the notion that task-time estimates are normally inflated, e.g., weather-related padding added to task estimates (Millhiser and Szmerekovsky 2012). Task owners typically incorporate these safety paddings to ensure as much as possible they would be able complete the work on time, regardless of uncertainties (Raz et al. 2003). In normal CPM scheduling, the safety paddings are inseparable from the activities durations. CC removes the safety paddings from the project activities and pools them to create safety margins for its different paths, figure 1, and eventually the project as a whole. The safety paddings/margin will hereinafter be referred to as the “buffer”. Also, it is to be noted that the durations in CC is frequently called *aggressive but achievable durations* (ABAD).

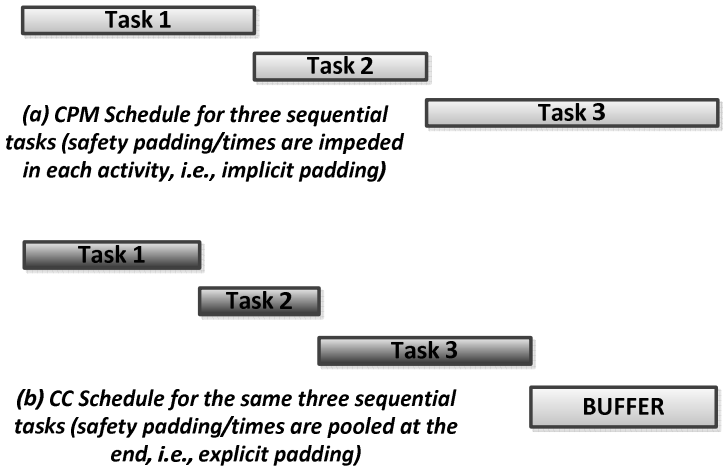

Figure 1: CPM schedule vs. CC schedule for a sample project

3.1 Activity durations and path/project buffers

The buffers which were hidden or impeded inside the activities in CPM schedules become explicit and pooled in CC schedules. Under CC, the buffers appear on the project bar chart (Raz et al. 2003). In other words, it is scheduled and managed. This can help visualize the level of uncertainty in the project. The lengthier the estimated buffer for a path/project, the riskier it is. Raz et al. (2003) further indicate that the combined buffer can be less than the sum of safety margins for the individual activities. This argument is supported by statistical theory that states that the standard deviation of the sum of a number of mutually independent random variables (in this case the duration of activities on the path) is less than the sum of the individual standard deviations. However, in practice, it may be easier to gain task owners' acceptance of polling their individual safety margins if the total is not reduced. This human-related factor needs to be taken into account as well.

The developer of the CC method, Eli Goldratt, suggested halving the durations of project activities under the traditional CPM schedules. Half of this "saved" time is then used to create a buffer for the path/project. Accordingly, the total planned project duration will drop to 75% of the original estimate. This method, which is called the 50% rule, is criticized by some. For instance, Herroelen and Leus (2001) argued that the 50% task duration estimate may be based on a loose ground. Further, the mechanism used for the estimating the task duration in CC will govern the created buffers for the paths and the entire project. Having an accurate buffer size and corresponding estimated completion date is of particular importance when projects must be won through bids that are evaluated, at least partially, based on the delivery date of the project (Millhiser and Szmerekovsky 2012).

Why does one need to account for the buffers of the different paths rather than the longest path alone? This is quite a reasonable question to ask when it comes to CC. After identifying the longest chain of activities based on the CC-estimated task times, the buffer for this chain denotes the project buffer. It is realistic to assume this will govern the actual project duration. Millhiser and Szmerekovsky (2012) claim that such notion simply undermines the significance of buffers on parallel paths. With the variability inherent in project activities, it is possible to encounter a non-critical chain, as per the plan, that leads to unrecoverable delays. The CC response is the insertion of feeding buffers where non-critical sequences join the critical chain, figure 2. Reason of such name is that it denotes where the non-critical chain feeds into the critical chain (Raz et al. 2003).

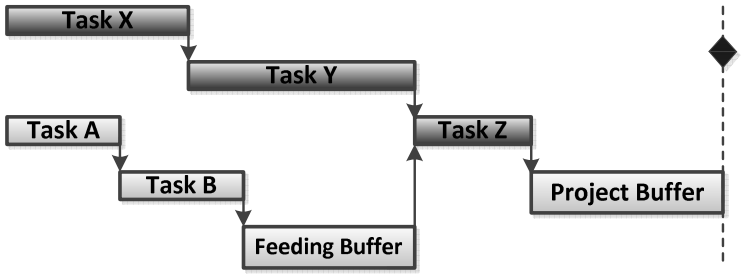

Figure 2: Use of buffers in CC schedules

A third type of buffers is used by CC is called a resource buffer, which is a virtual task inserted prior to the critical chain tasks that require critical resources. Its purpose is to issue a signal to the critical resource that a critical chain task to which they are assigned is due to start shortly (Raz et al. 2003). While working on the critical chain task, the resource is expected to work continuously on this task, so drawbacks of multitasking do not materialize.

3.2 Use of buffers

The buffer sizing is a topic that has been under scrutiny by researchers for some time now. There is no consensus yet on the best method to estimate the size of the project and feeding buffers. A review of many of these methods can be found in Geekie and Steyn (2008). But, assuming one of these methods is used to estimate the buffers, then they become not only protective means against variations but also transducers that provide vital operational measurements and proactive warning mechanisms on the project performance (Herroelen and Leus 2001). If activity variation consumes a buffer by a certain amount, a warning is raised to determine what needs to be done if the situation continues to deteriorate. These plans —expediting, working overtime, subcontract, etc.— are to be put into effect if the situation deteriorates past a critical point. Figure 3 illustrates a graphical tool, called fever chart, for the tracking of project performance as per the consumption of the allotted buffers (Leach 2005). This chart is particularly useful as it relates the buffer consumption to the project clock or completion of the critical chain activities. Three regions are identified and coded with the colours red, yellow and green. In this context, the red region signifies the most alarming scenario that induces proper intervention. Yet, the fever chart incorporates another dimension, which is the percentage of work completed to date, or alternatively said, the percentage of longest chain completion. Reaching the red region will not be as alarming in case of 90% completion as in the case of 10% completion. Only when the two dimensions are tied together, a more informative judgment can be made.

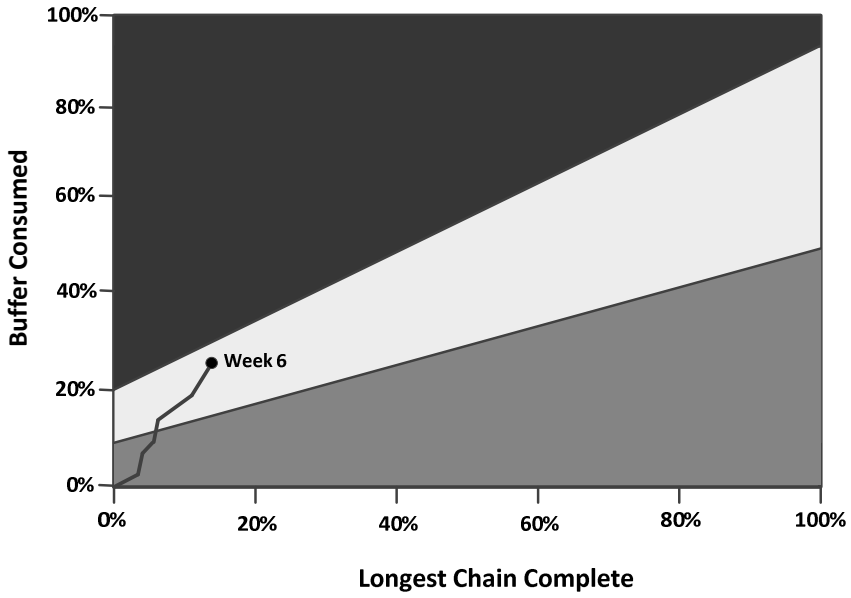

Figure 3: Illustrative fever chart for managing the buffer in CC schedules (Leach 2005)

3.3 CC vs. CPM Scheduling

CC planning seems different from the CPM counterpart. However, they still share some aspects in common. Both are represented by networks and bar charts, and both use forward and backward calculations to predict start and finish dates. However, unlike CPM, the CC terminology refers to the longest path as the critical chain, denote durations by ABAD, safety margins are pooled in the form of project/feed buffers, and the project health is evaluated via the buffer consumption.

4. Awareness sessions and surveys

Following to informal interviews with many industry practitioners in the Middle East, it was realized that the CC technique is, simply said, unknown to all. The exception was two Project Management Professionals (PMPs) who got acquainted with it while preparing for the PMP exam. However, they have not used it in reality or even investigated its use. This guided the research to arranging and conducting awareness sessions in Egypt and Saudi Arabia, followed by a survey to solicit the feedback of industry practitioners on the subject matter.

4.1 Venues and attendants

Three awareness sessions were conducted in three locations in Egypt: (1) an academic institution, (2) an authorized trainer for the Project Management Institute (PMI), and (3) a top Egyptian contractor with multitude of international projects. In addition, one awareness session was conducted in Saudi Arabia during a Quarterly Meeting of the Egyptian Association for Planning Engineers in Jeddah. All attendants of the latter session have many years of experience working in Saudi Arabia. After end of each awareness session, a survey was disseminated. Figure 4 shows the primary information of the participants in the awareness sessions and the surveys that followed. A total of 47 industry professionals took part in this research stage.

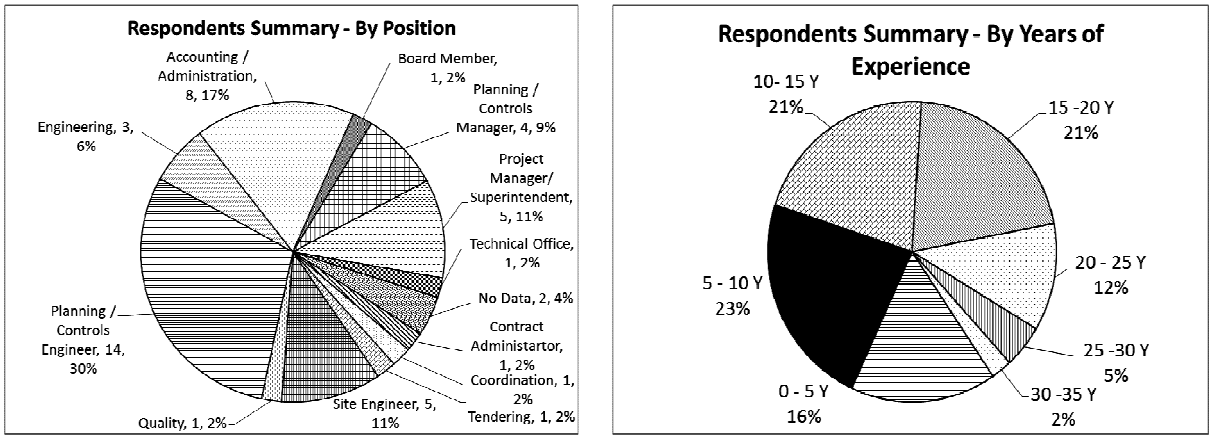

Figure 4: Summary of background and years of experience of participants

4.2 Survey structure and major findings

Survey had 19 multiple choice questions (with sufficient space for comments and out-of-list answers). After the conventional introductory section, two sections followed. First section investigated the current planning practices, including: (1) level of planning in company practices, and (2) the planning tools and techniques in use. The second section addressed CC in more specific details, including: (1) general perception of CC, (2) obstacles to practical implementation, (3) expectations for CC success/failure, (4) construction project type(s) most suitable for its pilot implementation, and (5) willingness of participant to engage in CC deployment in own company.

4.2.1 Current practices

All participants, with no exception, were found to use CPM for planning and scheduling in their companies. Eighteen benefits were identified for the use of CPM in such capacities, table 1. However, the significance of such benefits, denoted by the rank, differs between Egypt and Saudi Arabia. Both groups were in consensus, nevertheless, on "scheduling project activities" to be the top benefit.

Table 1: Benefits of CPM utilisation in construction industry (Middle East perspective)

Benefit	Rank (Egypt)	Rank (Saudi Arabia)
Improving team buy-in before work starts	13th	16th
Improved estimating/bidding	3rd	12th
Coordination of subcontractors	5th	5th
Coordination of own trades	17th	16th
Tracking shop drawings and submittals	7th	12th
Scheduling project activities	1st	1st
Reduces delays	7th	2nd
Tracking costs	2nd	7th
Calculating payment requests for work performed	10th	2nd
Faster response to problems	13th	5th
Improved understanding of the project	10th	7th
Improved communication among work force	12th	2nd
Helps train future project managers	13th	18th
Positive psychological effects on employees	18th	12th
Cost savings	5th	7th
Minimizes disputes between contractor and owner	7th	12th
Schedule impact analysis and tracking changes	3rd	7th
More control over risk and uncertainty	13th	7th

Survey investigated why the current CPM systems are deployed and will continue to be popular in the future, Figure 5. Construction professionals in Saudi Arabia cited such CPM

schedules to be a typical contract requirement, which enforces their use. Construction professionals in Egypt were rather perceptive of their significance in dispute resolution between the project parties. Familiarity of all contract parties about the CPM terminology cannot be overlooked. Among the other reasons is the validity of such technique (which was proven over the years), not needing high/sophisticated skills, and the time/cost savings associated with their use.

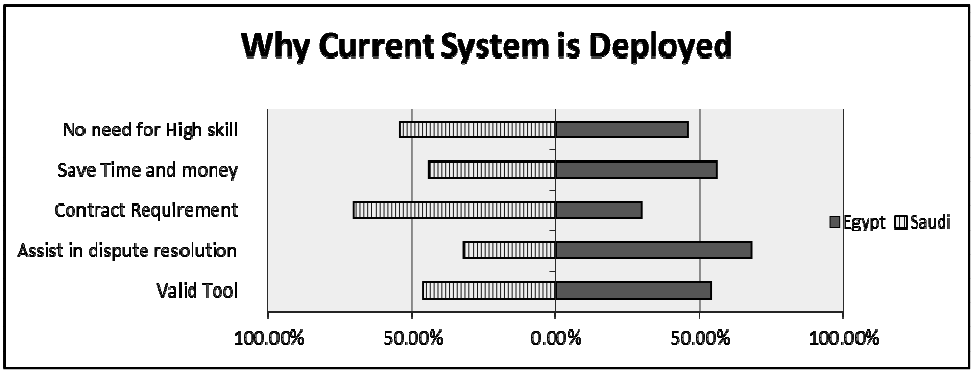

Figure 5: Reasons for adopting (now and in the future) of CPM-based Systems

4.2.2 CC potential and applicability

As per the survey, 10% and 44% of the surveyed industry professionals in Egypt and Saudi Arabia, respectively, had the opinion that CC adds no *real* value in project planning despite the new scheduling approach used. They see that using ABAD has a counterpart in CPM schedules via utilising aggressive activity durations. And then, having a buffer between the planned end date and deadline for completion is not atypical.

Construction professionals appreciated CC as a new and innovative approach, nonetheless. Yet, the majority of the surveyed professionals (68% and 62% in Egypt and Saudi Arabia, respectively) believed it was applicable in construction industry under certain circumstances/constraints.

To clarify the perception of CC applicability in construction practice, ten obstacles for its application were investigated, figure 6. Professionals in Egypt identified the inexperience of project parties, especially vendors and subcontractors, about CC terminology as the most significant hurdle. Among the other pointed-out obstacles is the software changes and reluctance to use new technique (i.e., it was not deployed before in construction projects). The professionals in Saudi Arabia were concerned primarily about the contractual context and the fact that CC application is not a contract requirement. They also showed concern about CC not being a “proven” scheduling and management technique.

Another area of great concern was the estimation of ABAD and the buffers. There are tied together. As per table 2, there was a complete rejection of applying the 50% rule in construction practices. All considered it to be unrealistic due to the nature of construction activities. Construction professionals in Egypt were divided as to which is the better approach for estimating ABAD and the buffer, where approximately half opted for expert

judgment and the other half preferred using analytical means to make the estimate. For the surveys in Saudi Arabia, there were more tendencies to use expert judgment as the primary basis for the estimates. The surveyed professionals conveyed an important point in this research; that is ABAD estimation is a main challenge for CC applicability in practice.

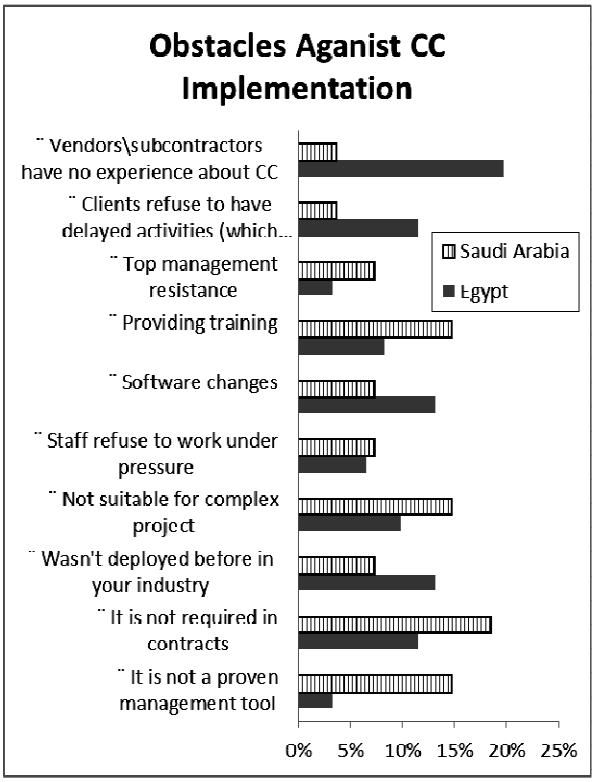

Figure 6: Obstacles to CC application in the construction industry

Table 2: Method for calculating buffers

Method	Preference by surveyed professionals (Egypt)	Preference by surveyed professionals (Saudi Arabia)
50% rule	0%	0%
Expert judgment	56%	74%
Analytical means, e.g., statistical analysis	44%	26%

An investigation of the project type(s) most suitable for the CC implementation in construction industry, professional in Egypt and Saudi Arabia preferred linear projects, e.g., pipeline/utility projects, over the traditional building counterparts. Other project types that are not construction oriented were presented to the participants. This allows those who feel less convinced about CC suitability in construction to convey their opinions. Results are summarized in table 3.

The choice of linear construction projects that are characterized by their repetitive nature should come as no surprise. Goldratt's theory of constraints, that is the theory upon which the CC method is founded, was developed for managing repetitive production systems (Raz

et al. 2003). Another reason is that, in more complex construction projects, it is typical to see paths splitting and merging again at various intermediate points. The resulting maze of paths in the network will make is difficult, if not impossible, to estimate the buffers, especially the feeding buffers (Raz et al. 2003). One ought to think of the scenario of various merging tasks and how much feeding buffer to use.

Table 3: Project types convenient for CC implementation

Project Type	Preference by surveyed professionals (Egypt)	Preference by surveyed professionals (Saudi Arabia)
Building construction	26%	19%
Linear projects, e.g., pipeline/utilities	32%	37%
IT/software	23%	25%
Research and development (R & D)	19%	19%

In conclusion, the majority of survey participants expected *partial* success for the CC scheduling technique in construction. None of those in management roles agreed to implement it immediately, but rather preferred to wait until implemented by others in the industry. Some even questioned the success stories of CC; they consider it the result of two types of changes, the first is the planning technique and the second is the working environment. Their perspective, which is shared by the authors, is that applying CC requires close supervision and better staff motivation and management. They raised a simple question; that is, *what if these changes in the work environment took place while using a CPM planning system? what will be the result then?*

5. Artificial intelligence tool for estimating ABAD

Building on the previous stage of the research, the development of a tool to help estimate ABAD was sought. As such, different statistical and artificial intelligence (AI) techniques have been investigated in light of studies such as Arditi and Tokdemir (1999) and Kim et al. (2004). Case-based reasoning (CBR) was finally identified as suitable for study implementation. CBR utilises case libraries to estimate parameters of a new case (Aamodt and Plaza 1994, Watson 1997). This section briefly describes this effort; however, the reader can refer to other publications by the authors for full details.

5.1 Preparatory work

Six work types were chosen for the ABAD estimation process; they are: (1) excavation, (2) bedding, (3) pipe laying, (4) cable laying/pulling, (5) cable jointing, and (6) backfilling. For each of the aforementioned work types, a survey was communicated to infrastructure experts to identify the primary factors governing activity duration. Based on the identified factors and with the help of a special-purpose form, data/cases for the six work types were collected and later analysed using SPSS.

5.2 CBR tool development and validation

A set of software tools was bundled together to develop the ABAD module in reference, figure 7. In this context, open database connectivity (ODBC) enables importing data (i.e., project cases) from Microsoft Access. Web interface capabilities and an underlying web server enable the search to be carried out remotely through customized web page. The latter facility allows the module to be used without the need for specialized experience in CBR.

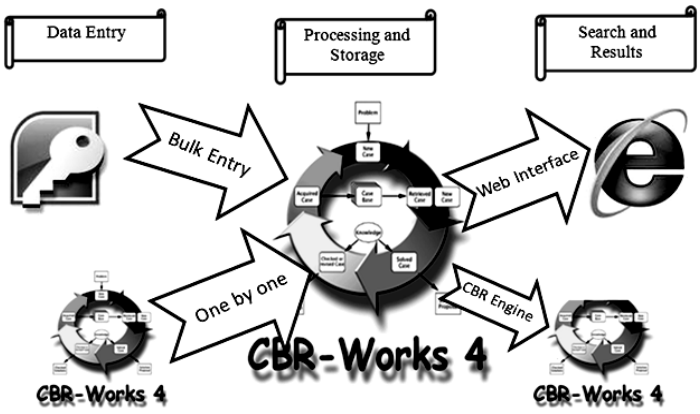

Figure 7: Obstacles to CC application in the construction industry

Similarity is a key notion of CBR. Estimating ABAD of a new target case is contingent upon its similarity to the cases stored in the case library. Similarity mechanisms in CBR can be reviewed in Watson (1997) and Georgy (2006). For quantifiably measurable parameters, e.g., length of pipe, a linear conversion function is used. Levels of qualitative parameters that have no implied relationships are treated as discrete points, i.e., similarity between these values is assumed to be zero. In case of qualitative parameters with implied relationships, similarity rules are established as per the parameter into consideration, figure 8.

Module performance was validated through test cases. With reference to ABAD, accuracy levels ranging from 84.8% to 91.9% were reported for the six work types.

	Gas	Telecom	LV	HV	Sewerage	Water	Storm Water
Gas	1	0.8	0.8	0.6			
Telecom	0.8	1	0.8	0.6			
LV	0.8	0.8	1	0.8			
HV	0.6	0.6	0.8	1			
Sewerage					1	0.7	0.9
Water					0.7	1	0.7
Storm Water					0.9	0.7	1

Figure 8: Similarity matrix for utility line type

6. Concluding remarks

CC may have its success stories in some industries. However, it is still unknown to the construction community in the Middle East. This study has got more of an investigative nature than drawing conclusions based on rigorous statistical analysis. Collecting industry feedback was quite challenging given the need to first educate the industry professionals, who accepted to commit time and attend the awareness sessions, about the CC terminology. The number of professionals/companies included in the data pool cannot be considered representative of the entire construction sectors in Egypt and Saudi Arabia. Yet, the study sheds some light on the potential of applying CC in companies of that region.

The study revealed some interesting thoughts. While several had doubts about having radically positive results in case of full-scale CC implementation, many still showed expectations of partial successes. They reckon that there are other contributing factors like change of management attitude, work culture, etc., that can together lead to the sought results. Also, it did not come as a surprise that linear construction projects were pointed out as potentially fit for the pilot CC implementation. This is in line with the nature of theory of constraints, which addresses the management repetitive production systems. However, industry professionals are rather reluctant to attempt the method in real practice, since it requires a change of project culture. Furthermore, the limited software support for CC scheduling, in comparison to CPM scheduling, can make the move rather difficult.

ABAD estimation, which governs the buffer management, was pointed out as hurdle to applying CC in real practice. All rejected applying the 50% rule claiming it to be unrealistic in the construction industry. Research adopted CBR for predicting ABAD in the project type of choice; that is pipeline construction. CBR creates analogies with available cases to estimate parameters for a new case. Success of the technique was promising, though estimating ABAD needs to be further researched in the future.

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Improving the reliability of environmental assessments of buildings

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Abstract

The assessment of environmental performances of building is now commonly based on a life cycle approach. The current studies comparing such performances highlight the problems related to uncertainties in the Life Cycle Assessment (LCA) results. The aim of this study is to identify the sensitivity and robustness of LCA models to these uncertainties in order to strengthen comparisons that can be done between building projects. The ultimate objective would be to implement sensitivity analysis in ELODIE software which is the life cycle assessment of buildings tool developed by the "Centre Scientifique et Technique du Bâtiment" in France. Calculation of building LCA conveys uncertainties due to: the calculation model; the data used into calculation and the LCA user's level of practice. This study is only concerned by the uncertainties related to the data used for calculation and is restricted to the data used for building components at the building scale. We have considered that the relative contribution of each material to the environmental impact of building is sensitive to three key points which are submitted to uncertainties: the service life of the building components; the environmental impact of this building component's production and the amount of material used in the building. In this study, statistical analysis allows to test the contribution of these three uncertainty parameters on the final impact for each building components at the building scale. Most sensitive parameters are identified. As a consequence, we are able to models buildings LCA throughout the main building materials as well as the potential variation of their impacts due to uncertainties on the three identified parameters. The first results are promising, although further work remains to be done to better quantify the uncertainties in the material scale.

Keywords: LCA of building, uncertainties, variability, contribution analysis.

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1. Introduction

Buildings are the largest energy consumers and greenhouse gases emitters, both in the developed and developing countries UNSTATS (2010). Li (2005) and Bribian (2010) cite that the building construction consumes approximately 40% of the total material use, 30-40% of the societies total energy demand, roughly 1/3 of the total CO2 emission. Urgent changes are therefore required relating to energy saving, production and application of materials, use of renewable resources, and to recycling and reuse of building materials. However to be able to focus on the pertinent and most sensitive aspects of the building sector, it is fundamental to accurately quantify which part of the life cycle, which part of the building industry, which part of the structural elements are the main contributors to environmental impacts and for which reason. To do so, and since more than 30 years, scientific community have developed and validate life cycle assessment (LCA) methodology Heijungs et al (1992), Fink (1997), Klöpffer (2006). Life cycle assessment "cradle-to-grave" approach, that begins with the gathering of raw materials from the earth and ends at the points when all materials are returned to the earth, is used to quantify the environmental impacts of a product on the environment Saic (2006). LCA methodology is based on ISO 14040 and consists of four distinct analytical steps: defining the goal and scope, creating the life-cycle inventory, assessing the impact and finally interpreting the results ISO (2006). Applying LCA to buildings has been done since a long time Fava (2006), but the reliability and robustness of results is even more complex than for the other industry sectors due to their very long service life, environmental database quality Weidema et al (1996), technological variation between materials' production plant Lewandowskaet et al (2004), Reap et al (2008). As a consequence, if we want to be able to assess the environmental impact of two building projects and be able to promote the choice of one rather the other we need firstly to quantify these uncertainties and in a second step, identify the main contributions in order to be able to constrain the constructor or to inform the stakeholder on the specific points on which they need to pay attention. For the moment, most of the LCA on buildings are comparing building designs without paying attention to the associated uncertainties. Other are using uncertainties associated with the pedigree matrix Weidema and Wesnaes (1996), Frischknecht and Rebitzer (2005) which inform only on the quality of the environmental data but not on the service life uncertainty. A few studies have tried to address the mixed question of environmental data quality and service life for building elements but these studies were limited to one specific building's element Aktas and Bilec (2012).

In our study, we want to assess these uncertainties at the two levels: the material level in order to identify which input parameter (lifetime, quantity or impact coefficient) has the most influence on the environmental performance of a material; and at the building scale to identify which material has the most influence on the environmental performance of building.

Furthermore, the objective of our study is to develop a method that can be easily used in order to use it at the project phase, when all the decisions have not been made and that stakeholders have to decide which project they want to fund and build. In that phase of the project, it is necessary to have a simple method that is able to highlight the main points of uncertainties in order that these aspects can be solved in a second phase of the project, and choose a project that will effectively be more environmentally friendly than the other one.

To do so, we proposed a methodology based on the statistical which is used to identify the most contributor parameters to the uncertainty of final results. The contribution analysis includes sensitivity and uncertainty analysis Imbeault-Tetreault (2010), as a parameter that has a small sensitivity but a large uncertainty may be just as important as a parameter with a larger sensitivity but smaller uncertainty Morgan et al (1990). Contribution analysis allows than to reach the goal of simplifying data collection and analysis without compromising the robustness of a result and to identify crucial data that must be thoroughly investigated. A general description of the method is resented in the next section before its application to buildings. Once the methodology described it is applied for the comparison of two single detached houses.

2. General theory of contribution analysis

The key purpose of sensitivity analysis is to identify the key data that have most influence on a result. But an input variable that has a small sensitivity but a large uncertainty may be just as important as a parameter with a larger sensitivity but smaller uncertainty Morgan et al (1990). Persuading a contribution analysis we must kept in consideration both analysis.
The contribution analysis which follows is mainly inspired by Ciroth *et al*. (2004), Morgan *et al*. (1990), Protassov (2002) and Taykir (2000). Consider a model represented as a function, f , with n uncertain inputs, and one output z .

$$z = f\left(x_1, x_2, ...x_i, ...x_n\right)$$

Proposing a Taylor series expansion of this function with respect to a chosen point $X^0 = \left(x_1^0, x_2^0, ..., x_i^0, ...x_n^0\right)$. If we can assume the independence of input parameters, the first order approximation of Taylor series expansion of function will be expressed:

$$\mathrm{var}\left(z\right) = \sum_{i=1}^{n} \mathrm{var}\left(x_i\right)\left(\frac{\partial f}{\partial x_i}\right)_{X^0}^2 \quad (1)$$

Where $\mathrm{var}\left(z\right)$ represent the variance of output and coefficients such as $\left(\frac{\partial f}{\partial x_i}\right)$ are referred to as sensitivity coefficients (Morgan 1990). The problem of determining the real value of a physical quantity (x_i) is inseparable by its uncertainties. The degree of uncertainty in each variable x_i can be expressed by its standard deviation σ_{x_i} .

$$\sigma_{x_i} = \sqrt{\mathrm{var}\left(x_i\right)} \quad (2)$$

More simply the equation (5) has the form: $\mathrm{var}\left(z\right) \approx \sum_{i=1}^{c} \Delta x_i^2$ (3)

Where: $\Delta x_i = \sigma_{x_i}\left(\frac{\partial f}{\partial x_i}\right)_{X^0}$ (4)

The relative contribution of each input parameter in output result is identified by equation:

$$RC_{M1}\left(x_i\right) = \left(\frac{\Delta x_i^2}{\mathrm{var}\left(z\right)}\right) \times 100 \quad (5)$$

A second method to identify the contribution of input data in output result is to study different scenarios of $f(x_i)$. In our case the output result is supposed to be a function of n input variables, so n scenarios will be performed.

First scenario is to fix all the input variable except one x_1 . Applying the Taylor series expansion in function will provide:

$$\mathrm{var}(z_1) = \mathrm{var}(x_1)\left(\frac{\partial f}{\partial x_1}\right)^2_{X^0} \Rightarrow \sigma_{z_1} = \sigma_{x_1}\left(\frac{\partial f}{\partial x_1}\right)_{X^0} = \Delta x_1 \quad (6)$$

Applying the Taylor series expansion with all other variables will have:

$$\mathrm{var}(z_2) = \mathrm{var}(x_2)\left(\frac{\partial f}{\partial x_2}\right)^2_{X^0} \Rightarrow \sigma_{z_2} = \sigma_{x_2}\left(\frac{\partial f}{\partial x_2}\right)_{X^0} = \Delta x_2$$

$$\vdots$$

$$\mathrm{var}(z_i) = \mathrm{var}(x_i)\left(\frac{\partial f}{\partial x_i}\right)^2_{X^0} \Rightarrow \sigma_{z_i} = \sigma_{x_i}\left(\frac{\partial f}{\partial x_i}\right)_{X^0} = \Delta x_i \quad (7)$$

$$\vdots$$

$$\mathrm{var}(z_c) = \mathrm{var}(x_c)\left(\frac{\partial f}{\partial x_c}\right)^2_{X^0} \Rightarrow \sigma_{z_c} = \sigma_{x_c}\left(\frac{\partial f}{\partial x_c}\right)_{X^0} = \Delta x_c$$

Uncertainty in the output result can then be calculated as a sum of the contribution of each input parameter's uncertainty in output result:

$$\Delta z = \sum_{i=1}^{c} \Delta x_i \quad (8)$$

The relative contribution of each input parameter in output result is calculated by equation:

$$RC_{M2}(x_i) = \frac{\Delta x_i}{\Delta z} \quad (9)$$

Both equation (5) and (9) can be used for identifying which input parameter has the most significant contribution to output result. The difference between methods is that the first method pushes up the input parameter with the higher contribution due to the square values. We underline that the hierarchy of the contribution inputs calculated with the two methods is the same.

3. Case study

In this case study we have applied the methodology presented above in order to compare two different projects of single-family detached house. The houses studies are fictifs and the are modelled by the Centre Scientifique et Technique du Bâtiment, France with a surface area of 100 m^2 and the lifetime of the house is considered to be equal to 50 years. One of the projects is a house with a reinforcing concrete structure (Project 1) and the second one is made with a wood structure (Project 2). The environmental performance of the building is commonly presented as a sum of the environmental performance of its building material plus the energy and water consumed during the use phase.

In the present paper, we will only consider the building materials used during all the service life of the building. Water and energy consumption during the use phase are not considered

but could be implemented in a further extension of the method. Equation (10) is used for evaluation of environmental impacts over the life cycle of the building. I_g , the value of the impact of the category g for the building, is calculated as the sum of the contribution of the impact of each building material (i).

$$I_g = \sum_{i=1}^{c} I_{g,i} \quad (10)$$

Where: c present the number of elements and material which the building is composed.

And the environmental performances of materials are calculated by the equation:

$$I_{f,i} = n_i \times k_{f,i} \times m_i \quad (11)$$

Where: $n_i = \frac{LB}{LM_i}$ (12)

LB -> lifetime of building;

LM_i -> lifetime of material;

$k_{f,i}$ is the environmental impact for the impact category f of life cycle of one unit mass of the building material i;

m_i is the amount of material i used for the construction of the building

n_i is the number of use of the material i during the service life of the building;

As shown in equation (11), uncertainties come from the mass, the service life and the elementary environmental impact of each material. To take them into account, we have introduced uncertainties. The variations in mass of materials are associated with waste on construction site ADEME (2001) and differences between provisional maps and the reality (Expert judgement). According to expert's judgements and ADEME (2001), uncertainties that are used vary from -5% to +10% of materials' quantities. In the case of knowledge of the minimum, mean and maximum of a physical quantity the normal distribution or triangular distribution is preferred to be used. In our study the standard deviation is calculated supposing that the distribution law for the quantity taken off is a triangular one.

Service life of materials has been calculated through the use of different references Lair (2000), in order to define a mean value and a standard deviation for each material.

The impacts coefficients, the environmental products declaration (EPD) of French database INIES (2012) are used. It means that all the life cycle of the product is considered (production, transport, use, demolition and end of life) and that the impact categories are the one from the NF P 01-010 standard AFNOR (2004). These standards are close to CML methods Guinée *et al* (2002). The standard deviations in this case are calculated using these EPDs.

When the EPD doesn't exist, environmental impacts have been calculated with Ecoinvent v2.2 database Kellenberger *et al* (2007). However, as Ecoinvent is a calculation from cradle to gate (production at plant), results need to be adapted to be compared to INIES. Previous studies have shown that this comparison was possible for most of the standard impact categories (GWP, acidification, energy) when some adaptations are made. For cradle-to-grave calculation, the other phases such as transport, use and en of life are added by talking

a given percentage of the production phase. Actually, previous works have shown that it was possible, without deteriorating too much the results, to consider the other phases of the life cycle as a given percentage of the production phase Lasvaux (2010). Concerning the standard deviation, the pedigree matrix of the process associated with the production of material in the Ecoinvent database is used. In the only case of reinforcing concrete elements, a further uncertainly concerning the amount of steel is added. More detailed the means and standards deviations for lifetime, quantity taken off and indicators of global warming potential (GWP) and atmospheric acidification (AA) are presented in table 1.

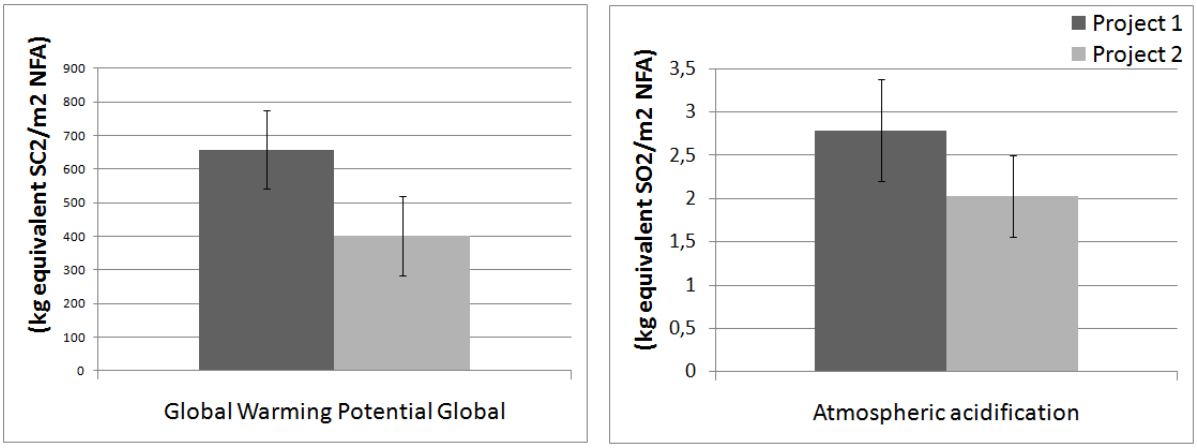
Table 1: Details of the technical data used for the life cycle inventory of both houses solutions

Projects / Decomposition of projects		Project 1	Project 2	
Materials	Elements	Qty	Qty	Unit
Non-structural clay	Tiles	130	IDEM	m^2
Structural clay	Wall	25727		kg
Gravel	Access road an drainage	33448	IDEM	kg
Non-structural concrete	Mortal	1530		kg
	Sill	347		kg
	Blinding concrete	1.44	IDEM	m^3
	Concrete layer/grout	4.94	IDEM	m^3
Structural concrete	Basement wall	9657	IDEM	kg
Reinforcing concrete steel	Beam	3.216		m^3
	Column	0,9821		m^3
	Foundations	11.31	IDEM	m^3
	Stairs	0,4935		m^3
	Floor	8,276		m^3
	Slab	15	IDEM	m^3
Non-structural steel	Garage door	4.8	IDEM	m^2
	Uprights and rails	54.5	IDEM	kg
	Valves	27.5	IDEM	kg
Non-structural wood	External and internal doors	13.45	IDEM	m^2
	Cabinet for sink	0.065	IDEM	m^3
	Shutter		15.63	m^2
	Panelling		54.54	m^2
Structural wood	Truss construction	3.82	IDEM	m^3
	Beam		1.13	m^3
	Column		0.32	
	Stairs		0.2657	m^3
	Deck		6	m^3

	Wall		6.8015	m^3
Glass wool	Thermal and acoustical insulation		809	kg
Rock wool	Thermal and acoustical insulation	1211		kg
PVC	Shutter	15.63		m^2
	Pipelines	519.5		kg
	Panelling	54.54		m^2
Bitumen	Waterproofing	159.25	IDEM	m^2
Plaster	Product for false ceiling/ suspended ceiling/etc	4643	IDEM	kg
Polyurethane	Thermal and acoustical insulation	243.5	IDEM	kg
Photovoltaic panels	Water heater	4	IDEM	m^2
Window	PVC	15.61		m^2
	Bois		15.61	m^2
Paint	Paint	166.6		kg
	Varnish		115.2	kg
Electrical installation	Light-switch/ consumption/indicator/etc	1	IDEM	u
Porcelain	WC	2	IDEM	u
	Sink	2	IDEM	u
Acrylic	Bathtub	1	IDEM	u
Enamelled sandstone	Kitchen sink	1	IDEM	u
	Shower plate	1	IDEM	u
Porcelain stoneware	Paving	72.13	24	m^2
Zinc	Gutter system	10.6	IDEM	m^2

Once all uncertainties are defined, we can use the analytical uncertainty propagation method based in Taylor series expansion (equation (1)), for assessing the uncertainty for the GWP and AA indicators. In figure 1 are presented the value for an interval of 95%.

Figure 1: Environmental impact of the life cycle of two houses solutions



Two types of results can be seen depending on the impact category. For impact categories related to GWP the results show that the project with reinforcing concrete steel structure has greater environmental impacts than the wood structure and we can conclude that the second project is better than first one. However for the other impact categories, uncertainties variations so that the two projects don't have significant differences. In order to reduce the uncertainties and choose the best project, we propose to identify the contribution of the different material in order to evaluate where are the easiest and most efficient improvements which can be done to reduce this variation and have finally a significant difference between the two projects.

Table 2: Relative contribution of different materials to the building life cycle assessment for atmospheric acidification indicator

Project / Materials	Project 1		Project / Materials	Project 2
Rock wool	11,97%		PVC	16,10%
PVC	11,87%		Bitumen	15,55%
Bitumen	11,44%		Non-structural wood	10,27%
Non-structural wood	7,56%		Plaster	8,72%
Porcelain stoneware	7,08%		Glass wool	7,1%
Plaster	6,4%		Photovoltaic panels	5,62%
Paint	6,28%		Structural concrete	5,01%
Window	5,02%		Polyurethane	4,47%
Non-structural concrete	4,98%		Reinforcing concrete steel	4,14%
Photovoltaic panels	4,13%		Window	3,8%
Structural clay	3,98%		Non-structural steel	3,36%
Reinforcing concrete	3,82%		Porcelain stoneware	3,2%
Structural concrete	3,68%		Porcelain	3,13%
Polyurethane	3,29%		Zinc	2,58%
Porcelain	2,31%		Structural wood	2,22%
Zinc	1,89%		Non-structural clay	1,98%
Structural wood	1,63%		Varnish	0,99%
Non-structural clay	1,45%		Non-structural concrete	0,74%
Non-structural steel	0,44%		Acrylic	0,48%
Acrylic	0,36%		Enamelled sandstone	0,38%
Enamelled sandstone	0,28%		Gravel	0,15%
Gravel	0,11%		Electrical installation	0,01%
Electrical installation	0,01%			
TOTAL	100%			100%

At the building scale, table 2 shows clearly that insulation rock wool, PVC and bitumen are the three materials which have the greatest contribution to variability of the buildings' environmental impact. It is due at a combination of the amount of material used of its elementary impact and lifetime as well as its uncertainty. Application of contribution analysis in this material will give the values presented in table 3:

Table 3: Relative contribution of different inputs to the material life cycle assessment for atmospheric acidification indicator

	Lifetime	Impact coefficient	Quantity taken off
Rock wool	86%	07%	07%
PVC	83%	14%	03%
Bitumen	63%	34%%	03%

For the three materials the highest contribution to uncertainties comes from the lifetime. It could then be possible to try to improve the knowledge on service life. For instance, a control on site work could be done, just after the rock wool has been fixed in order to certify that it has been done correctly (vapour barriers, humidity control, etc…). Similar work could be done for bitumen where it could for instance be mandatory to avoid an exposition to UV or high temperature in order to preserve the bitumen qualities. Finally, PVC tubes could be installed in a way that they can easily be check and only partially removed so that the majority of PVC tubes can have a given lifetime expectation. The methodology proposed here is then a tool for stakeholders to quickly evaluate in a project which aspects will induce a large variability on the expected environmental performance and take the appropriate decision to reduce the uncertainties on the environmental impact. For instance, if it is possible through design and quality control to be sure that service life of rock wool will be higher than 30 years, the one of PVC higher than 25 years and the one of bitumen higher than 30 years, and then uncertainties are reduced and presented in table 4. The two projects are now significantly different.

Table 4: Environmental impact of two houses solution

Indicators / Project	Atmospheric acidification (kg equivalent CO_2/m^2 NFA)		
	Minimum	Mean	Maximum
Project 1	2.132	2.52	2.91
Project 2	1.436	1.74	2.04

4. Conclusion

Analytic uncertainties propagation, using Taylor series expansion has quickly and easily permitted to calculate the uncertainty of environmental indicators. Previous studies have been working with Monte Carlo analysis which is time consuming when addressing uncertainties of each material. The contribution analysis using the second method allows identifying the highest contribution factors to the variability of output at material and then at building scale. In that situation, the developed method provides a very easy tool, which will give the relative contribution of each material to the variability of the building. In our case, we define Rockwool, PVC and bitumen as major contributors due to uncertainties on their

lifetime. It could then be possible to try to improve the knowledge on service life. For instance, a control on site work could be done, just after that the rock wool has been fixed in order to certify that it has been done correctly (vapour, barriers, humidity control etc). Similar work could be done for bitumen and PVC tubes. Once these certification and design controls have been implemented in the new project the comparison can be done again until it reached a position where the two projects are effectively significantly different. The relative contribution of environmental impact, lifetime and quantity taken off is essentially controlled by our hypothesis on the fact that structural material last as long as the house. This assumption where concrete, bricks or wood last as long as the house, could be discussed and probably improved. We think that the appropriate way of assessing this uncertainty would be to have uncertainty on the lifetime of the house rather than on the structural materials. Actually, it can be explained as the fact that if concrete is deteriorated through corrosion or that if bricks wall is fracture, it might reduce the lifetime of all the house, rather than just inducing the replacement of structural materials. This aspect should however be assessed in more details in further works. Thus, it is worthwhile to note that the methodology would be the same. Expect this strong assumption this fast identification is then a tool for stakeholder to constrain constructors or design offices to provide controls or design modification on specific aspect of the building throughout its service life. This first results presented here are encouraging as it has been shown that it is possible to choose which materials parameters has to be constrained in order to have significant difference between two projects that were initially to close to be distinguished. However further work is needed, in particular to improve the database on uncertainties at the material scale. Our study is actually based on an extensive bibliographic works; however variability on the environmental impact of materials' production as well on their effective service life needs to be better constrained to be able to apply our methodology to other case studies.

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Daylighting Design and Simulation:

Ease of use analysis of digital tools for architects

Konrad Panitz[1], Veronica Garcia-Hansen[2]

ABSTRACT

Good daylighting design in buildings not only provides a comfortable luminous environment, but also delivers energy savings and comfortable and healthy environments for building occupants. Yet, there is still no consensus on how to assess what constitutes good daylighting design. Currently amongst building performance guidelines, Daylighting factors (DF) or minimum illuminance values are the standard; however, previous research has shown the shortcomings of these metrics. New computer software for daylighting analysis contains new more advanced metrics for daylighting (Climate Base Daylight Metrics-CBDM). Yet, these tools (new metrics or simulation tools) are not currently understood by architects and are not used within architectural firms in Australia.

A survey of architectural firms in Brisbane showed the most relevant tools used by industry. The purpose of this paper is to assess and compare these computer simulation tools and new tools available architects and designers for daylighting. The tools are assessed in terms of their ease of use (e.g. previous knowledge required, complexity of geometry input, etc.), efficiency (e.g. speed, render capabilities, etc.) and outcomes (e.g. presentation of results, etc.).

The study shows tools that are most accessible for architects, are those that import a wide variety of files, or can be integrated into the current 3d modelling software or package. These software's need to be able to calculate for point in times simulations, and annual analysis. There is a current need in these software solutions for an open source program able to read raw data (in the form of spreadsheets) and show that graphically within a 3D medium. Currently, development into plug-in based software's are trying to solve this need through third party analysis, however some of these packages are heavily reliant and their host program. These programs however which allow dynamic daylighting simulation, which will make it easier to calculate accurate daylighting no matter which modelling platform the designer uses, while producing more tangible analysis today, without the need to process raw data.

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Keywords: Daylighting, Daylight simulation, Climatic base daylight metrics, Radiance, Daysim, Diva

Introduction:

Within the built environment, evidence-based design should be pursued either by looking at precedence works or the analysis of projects either physically (through observation and rules of thumb) or digitally (computer simulation) as they provide tangible information in terms of indoor environmental quality (IEQ) of the project. Research into the tools commonly used by architects has revealed that in terms of analysis, either digitally or physically, outputs, useability, efficiency and accuracy can be somewhat varied (Attia et al., 2009, Mardaljevic, 2001). The two main issues, as highlighted by Attia et al. (2009), are firstly the *usability and information management of interface, and secondly the integration of intelligent design knowledge-base* (Attia et al., 2009). According to a survey by Attia et al. (2009) the main software's used for building performance analysis are Ecotect, eQUEST, Energy Plus and Energy Plus for SketchUp (plug-in), and IES VE (Revit plug-in), etc.

Evidence based design is particularly important for daylighting design in buildings, especially in climates such as those present in Australia (tropical and subtropical). Main issues with building in these climates are overheating and glare, resulting in buildings with tinted glassed and/or overshaded openings which reduce daylight levels availability. Main decisions that affect dayligthing (availability, orientation, building context, shading, location and shape of windows, etc) are decisions made by architects, and therefore visualization and understanding of how these design decisions could affect daylighting performance is paramount. Thus the need for easy to use daylight simulation tools for architects. Galasiu and Reinhart (2008) survey of current daylight design practices of design teams (in the USA, and Canada), found that during the early design stage practitioners tend to rely on experience from previous work and rules of thumb and that computer simulations are increasingly being used during the design development stage. Participants reported the use of up to 39 different softwares for daylight analysis, although 62% were based on radiance.

With industry focus on Build Information Technology (BIM) design decisions can be changed quickly, effectively and verified within the digital model for costs, time and effectiveness. Any advancement in daylighting analysis needs to be integrated into BIM technologies so that architects and other professionals can easily integrate their models into the analysis software. Current analysis software for BIM has been designed as an add-on premise where a third party program or plug-in that supports a variety of file types performs the analysis of the building. Due to the many different file types within industry a universal file type such as an IFC (Industry Foundation Classes) has been developed. Conversion to IFC needs to contain the base information of the model such as, location, orientation and materials. Currently most IFC's do not contain this information (Lee et al., 2003). This leads to architects only using analysis software that's compatible with their proprietary modelling solutions or rely purely on rules of thumb for daylighting.

The purpose of this paper is to evaluate the usability of daylighting simulation software from the architect or designer's point of view in the particular context of Brisbane, Australia. This

paper will explore daylighting metrics, sky components, building rating/certification guidelines, built information modelling and IFC's while exploring the capabilities of digital analysis software. The development and understanding of all these components play a vital role in the future of daylight analysis in architecture. This paper highlights the need for evaluation of metrics using today's analysis software on a project, the capabilities and benefits of such analysis, as well as an exploration on the processes and issues that arise when architects use unfamiliar complex daylighting software.

The present state of daylighting and industry

The integration of light into a building is a fundamental part of creating space. Daylighting has numerous psychological and physiological effects on buildings' occupants; still, it can have an adverse effect (i.e. glare, overheating) on the indoor environmental quality of that space if special care is not taken into the daylighting design. Galasiu and Reinhart's survey on daylighting design practice among design teams with interest in sustainable design found out that rules of thumb and daylighting factor (DF) are the main prediction methods for daylight (Galasiu and Reinhart, 2008). However, DF has it short comings as proved by studies on post occupancy evaluations (Thompson, 2011, Mardaljevic, 2011, Lee and Guerin, 2010). These studies show a general disparity between what is considered acceptable between performance guidelines on daylighting and acceptable indoor illuminance by occupants.

Within the context of Brisbane there are currently 2 main documents that architects use that qualify daylighting design, National Construction Code (NCC): Building Code of Australia (BCA), and Green Star (GS) rating system (Australian Building Codes Board, 2011, Green Building Council of Australia, 2008, Standards Australia, 2006). These documents outline a set of performance standards and metrics which architects and professionals within industry should achieve usually based on DF. DF is defined as "the ratio of internal illuminance to the external illuminance under a CIE overcast sky." (MOON, 1942) It is a static metric measured on one day of the year as representation of the worst-case scenario. Nevertheless, there are new dynamic metrics (Climate based daylight modelling- CBDM) that predict luminous quantities using realistic sun and sky conditions derived from standardized meteorological data These metrics are Daylight Autonomy (DA), Useful Daylight Illuminance (UDI) and Daylight Availability (Dav) (Mardaljevic, 2001, Reinhart et al., 2006, Nabil and Mardaljevic, 2006) (Metrics are described under the assessment of daylighting simulation section).

New metrics for daylighting design could change the way in which architects and other professionals run analysis providing accurate legible data that could easily be applied to the design process by allowing more exploration and thus better designs. These new climate based daylight metrics (CBDM), are much more informative to professionals and disarmingly simple. Though, currently there is no consensus on targets let alone which metric should be used in standards (Nabil and Mardaljevic, 2006).

Methodology

This paper evaluates the usability of daylighting simulation software's from the designer's point of view. To this end, firstly, it identifies the simulation tools and methods most currently used by architects in Brisbane, to be selected for this study. Secondly, tests and compares their performance against real measurements from a real space (point in time simulations). And finally, qualitatively assess the "friendliness" of application of simulation software into the workflow of architects.

Selection of tools

A simple survey of architectural firms -within the greater Brisbane area- was performed to collect data on current technologies, services and methods used in design analysis. The firms were invited to contribute information on: 1- what methods they used to make models for design analysis, 2- if was daylighting considered in their analysis, 3- what programs methods or services were used to generate data on daylighting.

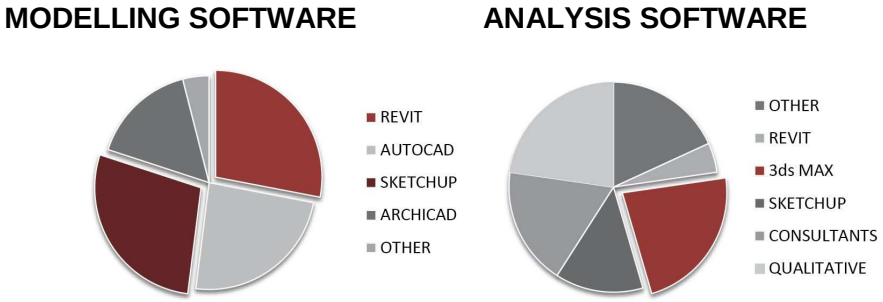

Figure 1. Greater Brisbane Architectural Firms Process and Method for design and analysis for daylighting

As seen in Figure 1, a significant portion of the firms surveyed use Revit and SketchUp for their 3D model making process, whilst the only industry recognized method for daylighting analysis used was 3ds Max. Due to the lack of recognised industry tools used within Brisbane firms, well known software's for daylight analysis such as Ecotect and Diva are added to the list of software's to be assessed. Ecotect is widely accepted as a method for analysis and Rhino/w Diva plug-in is currently leading the way for development of daylighting software overseas. In addition to Ecotect and Diva, a study by Reinhart and Breton (2009), compared two popular daylighting software packages, Daysim and Radiance alongside 3ds Max. The study found that Daysim and 3ds max were capable at achieving comparable results to radiance and therefore could be used for daylighting analysis (2009).

In summary, when considering the results of the survey and prior research, the software's used for digital model making for this research are SketchUp and Revit. The 3D models are then analysed using 3DS Max (Design Version), Ecotect (w/ Daysim and Radiance), SketchUp w/ Experimental Daysim Plug-in Su2ds and finally Diva through the use of Rhino (modelling making software).

Assessment of daylighting simulation tools

The assessment of the selected simulation tools has the following steps: 1- a real building is selected for analysis and 3d models of the building are constructed, 2- 3D models are imported to the different simulation tools for analysis. 3- DF, CBDM and point in time simulations are performed and 4- the results of point in time simulations are then compare to measured horizontal Illuminances taken of the real space for calibration.

1- A studio space on a university campus in Brisbane was recreated within both SketchUp and Revit for analysis and modelling. The room was selected based on the most equatorial facing room within the building with good daylighting. Dimensions were kept as identical as possible such as wall thickness, window heights and sizes, etc. to retain accuracy. The model was oriented from true north by +35 degrees to comply with aerial photos of the site. Neighbouring buildings were also added in the model. Reflectances for the building materials are 60% for ceiling and floors, 40% for walls, and 80% transmittance for windows. The geo-location, climatic data was gathered and imported into both Revit and SketchUp. The climatic data was IWEC (International Weather for Energy Calculation) weather data for Brisbane.

2- The model was altered and redrawn were necessary within software packages to correct for errors in the export/import process but also to effectively document to process of "build-ability". These programs are also run to produce annual data such as DA, continuous DA, UDI and DAv, as well as Point in Time illuminance measurements at 9am, 12pm, 3pm and 5pm (September 28th) as well as a DF for that day. These Metrics are as defined as follows.

1. **DF:** ratio of internal illuminance to the external illuminance under CIE overcast sky
2. **DA:** percentage of the year when an interior illuminance threshold is achieve by daylight alone
3. **UDI:** percentage of the year when a target range of illuminances (e.g. 100 to 2000lux), no too low (for visual task performance) and not high causing issues with glare or heat gain., is achieved.
4. **DAv:** is a variation of UDI accounts for partial daylight within its calculation and highlights areas within the room with thermal/visual discomfort (10 times the target illuminance).

3- Illuminance measurements of the studio space: A Minolta T10 illuminance meter with 9 sensors was set up in the studio to measure the internal horizontal illuminance (28th of September) at 1 minute intervals and diffuse and direct external illuminance at 1hr intervals. The placement of sensor in the space can be seen below in **Figure 2.**

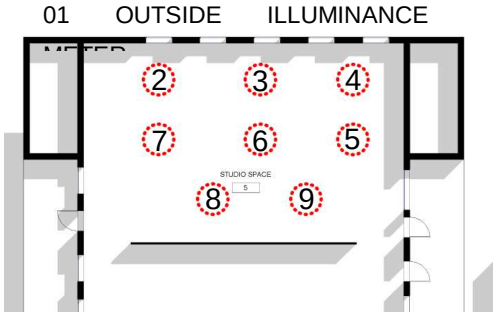

Figure 2. Sensor Grid, Light Meter Locations

4- Ease of use analysis of the different software was done via observations on legibility/output, speed, ease of use, and importing/exporting data capability with the aim to assess differences in workflow between programs.

Results

Measured horizontal illuminances and Point in time modelled illuminance for the studio space

Figure 3 shows measured average horizontal illuminance values for 9am, 12pm, 3pm and 5pm. These results are compared with simulations performed for the same day and times for the following tools and sky types: a) 3ds max with haze driven sky, with Perez sky and with , Perez sky tuned to mirror the clear sky (measured) on that day via controlling direct illuminance as well as diffuse horizontal illuminance, b) Radiance with uniform sky, sunny sky and intermediate sky and finally diva with sunny sky and sunny sky with no sun. , e) radiance with sunny sky. The results show that radiance simulations (through ecotect) with sunny sky most closely represent the internal illuminance levels and daylight distributions throughout the day obtained with the light monitoring. The curves from 3ds max with Perez sky simulations closely follow the measured values for half of the day, while direct sunlight is not present in the room. Diva simulations with sunny day do not follow the distribution pattern during the day, specially underestimating performance early in the morning and late in the afternoon. Because of the daylighting issues presented in the studied space (incoming direct sunlight in the afternoon), all the other simulations that use sky types with no sun, did not follow the illuminance distribution throughout the day or achieve similar lighting levels specially in the afternoon. It is not the aim of this paper to calibrate different simulation tools with measurements of real spaces, but rather to try to show, from the perspective of an architect how a simple step as choosing the sky type can have great implications on the overall results in the simulation.

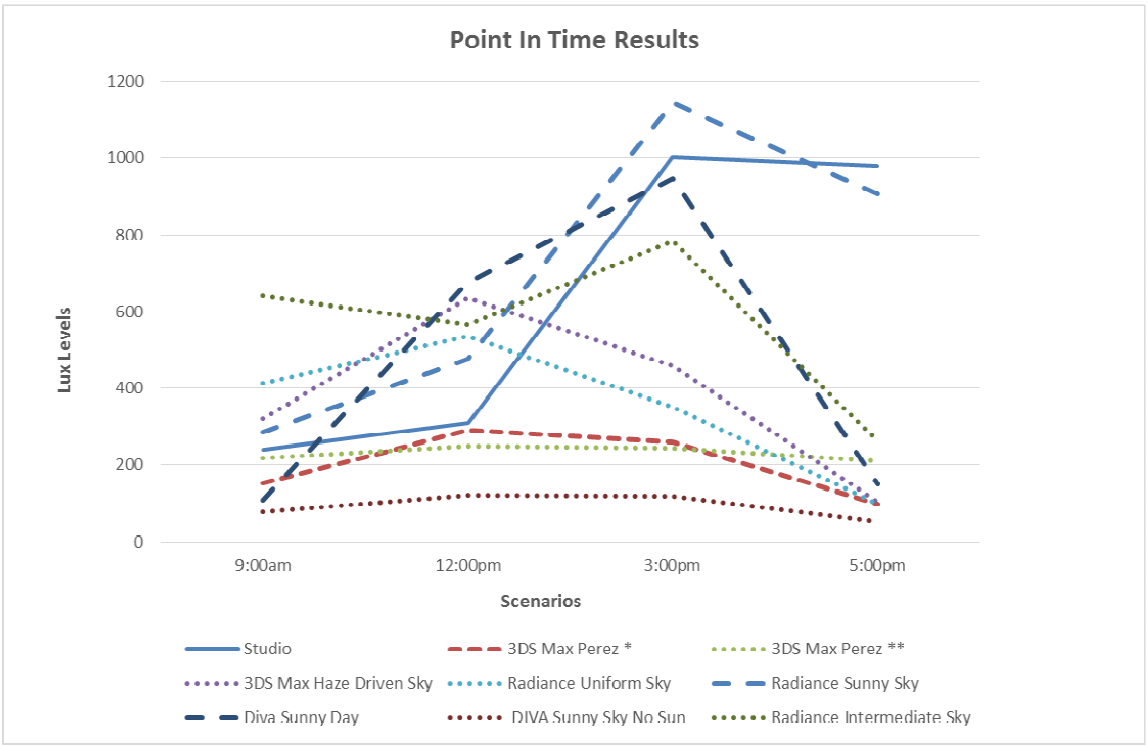

Figure 3. Comparison between measured illuminance levels in the studio space and modelled illuminance levels by different simulation tools for 28th of September

Climate base metrics and Daylighting factor simulations

Certain packages are able to perform more metric simulations than others, a list of which can be seen in Table 2 below. Rhino w/ Diva was the most comprehensive being able to generate data on, DF, DA, DAv and UDI. For the testing of DIVA the SketchUp model was used due to IFC issues when trying to import the Revit model into Rhino (host program for the DIVA plugin).

Table 1. Time Period and Annual Data Abilities within Selected Software

	3DS Max	Ecotect	Radiance	Daysim	Diva	Su2ds
DF	☑**	☑	☑***	☑	☑	☑***
DA	☑*	☑	☒	☑	☑	☑***
DAv	☑*	☒	☒	☒	☑	☑***
UDI	☑*	☒	☒	☑	☑	☑***
DAcon*	☒	☒	☒	☑	☒	☒

* Raw format requires processing through excel or other software.
** Prone to inaccuracy
*** Not able to be tested due to incompatibility with current software

For 3DS Max climate-based simulations like DA, DAv, UDI and DAcon are convoluted, and requited a lot of manual inputs. For this reason it was not included in the ease of use comparison analysis. While radiance, which is a rendering program, in its base form can calculated data over a time period but cannot calculate dynamic data, therefore cannot calculate climate based. However its algorithms are implemented into other analysis software's. Su2ds a direct plugin to Daysim for SketchUp required a complicated manual entering of analysis grid points via their x,y,z co-ordinates, making it easy for simple models, but impracticable for larger models so wasn't tested.

Table 2. DF and Climate-based simulation comparison within Selected Software

3d Model	Simulation Tool	DF	DA	UDI	Dav
Revit	Ecotect	5%	98%	-	-
	Daysim	-	71%	69%	-
SketchUp	Ecotect	4%	93%	-	-
	Daysim	-	62%	66%	-
	Diva	1%	28%	60%	24%

The simulations from the different software's show very different results. UDI $_{100\text{-}2000}$ shows some correlations between all the diva and Daysim plug in for Revit and Sketch up. While DA (with a target of 300lux) results do not compare closely between Daysim, Diva, and specially the results for Ecotect (Daysim plug in). The error in Ecotect could be related to the DA calculations being locality based the algorithm is only applicable at latitudes of 40-60 degrees +/-degrees from the equator. Brisbane is located at 25 degrees from the equator, so Ecotect cannot be used for DA calculations. Another issue is the skylights (present in the

space and modelled in the 3D models) seemed to be more effective in the Revit model, resulting in higher results. The differences between Diva and Daysim on the other hand, could be explained through the method used for Daysim analysis, which involved exporting data from Ecotect. Ecotect was used as a medium to generate data for Daysim. And then, painstaking imputing a sensor grid data manually using scripting (steps that are somewhat outside the skill set required from architects). To obtain more comparable results between all the software's, more testing, and further study of the models and simulations tools is necessary. However, for this research is a first step in analysis these tools, and from the architect/designer point of view (including skill sets).

Graphics

Within these programs, the viewports can also be quite ridged, often appearing in either as a fixed 2D image of a 3D space, as seen in the Radiance Image in **Figure 4.** Or a plane which hovers at the workplane within a 3d model as seen in **Figure 4.** Programs such as Daysim produce data mostly through spreadsheets as raw data, and 3ds max and diva have this same function for more in-depth analysis outside the parameters of what each program's view portal or false colour images can generate. Ecotect can input analysis data, however this data needs be in a .dat file type so Ecotect can interpret and create images, which was the case for Daysim/Diva, but not 3ds Max.

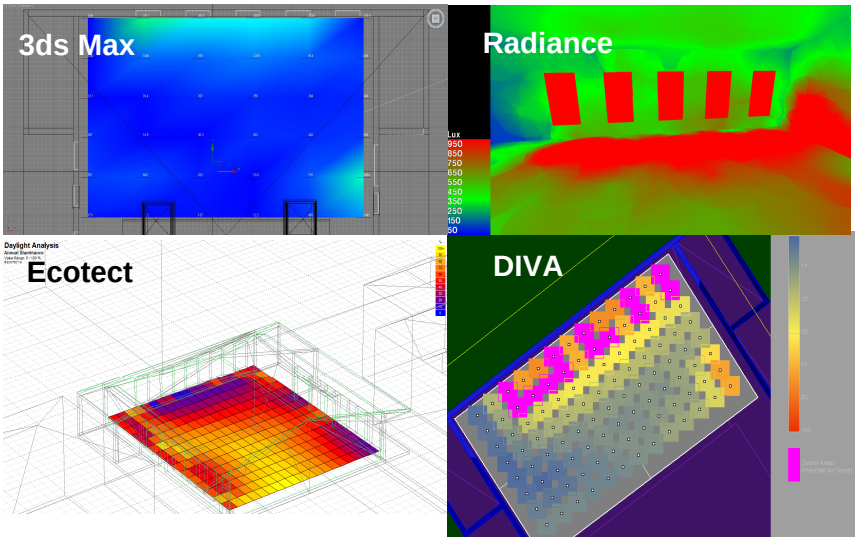

Figure 4. Examples of view portals from different softwares and different metrics/analysis

Analysis of ease of use

This section describes the analysis and observations of the process involved in the running of analysis for both point in time illuminance simulations and climatic data simulations.

Table 3. Modelling, Editing and Host Programs for Analysis: Observations

Software	Export Options	Import Options	Analysis Plug-Ins	Modelling Complexity	Required Familiarity	Notes:
3ds Max	.FBX, .3DS, .DWG, .DGN, .DXF, .SKP, .XML	.FBX, .3DS, .DWG, .DGN, .DXF, .SKP, .XML	Yes	High	Frequent Use	Complex program interface with multiple parameters to alter models requires prior experience
Revit	.FBX, .3DS, .DWG, .DWF, .DGN, .DXF, .XML, .IFC	.DWG, .DGN, .DXF, .SKP,	Yes	High	Frequent Use	Works well exporting to 3ds Max, complex program requires prior experience
Rhino	.3DM, .DXF, .DWG, .DGN, .SLDPRT, .FBX, .3DS, .RAW, .X, .SKP	.3DM.DXF .DWG.3DS .RAW.X .WMF.TXT .FBX.PLY	Yes	High	Infrequent Use	Not a common tool for modelling within Australia, simple program in terms of interface and usability
SketchUp	.FBX, .3DS, .DWG, .DXF	.3DS, .DWG, .DXF,.SKP	Yes	Low	Infrequent Use	Easy to use and install plug-ins. Exporting Directly into Radiance and Daysim requires experience with coding language and techniques.

Table 4. Analysis Software Observations Part 1 of 2

Software	Sky	Renderer	Raytracing	Metrics	Speed	Sky Models	Importability
3ds Max	CIE Perez Haze	Metal Ray	Forward and Backward	DF, DA, DAv, UDI.	FAST SLOW SLOW SLOW	Overcast Clear Perez	Triangulation, great at retaining surface integrity.
Ecotect	CIE Perez	none	Split Flux Method	DF, DA.	FAST FAST	Uniform Overcast	Triangulation, loses surface integrity.
Radiance	CIE Perez	Radiance	Backward	DF.	FAST	Sunny w/ Sun Sunny w/o Sun Intermediate w/ Sun Intermediate w/o Sun Overcast Sky Uniform Sky	Ecotect exports a dedicated radiance file for analysis. All model errors contained within modelling software.
Daysim	Perez	none	Backward with Daylight Coefficient	DF, DA, UDI.	FAST SLOW SLOW	Perez	As above due to Daysim being built upon radiance.
Diva	CIE Perez	none	Backward with Daylight Coefficient	DF, DA, DAv, UDI	FAST FAST FAST FAST	Clear Sky w/ Sun Clear Sky w/o Sun Cloudy Sky w/ Sun Cloudy Sky w/o Sun Uniform Custom (Perez) Perez	Some minor triangulation, North point data was lost on import. Most comprehensive Import options with fewest issues.

Table 4. Analysis Software Observations Part 2 of 2

Software	Editing Imported Geometry	Model Editing Interface	Analysis Interface	Analysis Viewports	Outcomes	Notes
3ds Max	Easy, Fast	Powerful, efficient, but complex	Complex	Full 3D & 2d Viewports & 3D	DF on Workplanes, Illuminance on Workplanes	Raw data needs to be calculated though excel spreadsheets. Unique communication

				images	and surfaces. Raw data False Colour images	methods available through animation tools within 3ds Max
Ecotect	Difficult, Slow	Difficult, unlike modelling software	Simple	Full 3d & some 2d Views & 3D images	Metrics and illuminance calculated on Workplanes	Imported data requires error checking, often large parts of the model needing to be redrawn or "traced" to fill missing surfaces.
Radiance	n/a	n/a	Simple within Ecotect, Complex Standalone	3D images	Illuminance on surfaces. (3D Image) False Colour images	Newer versions of radiance not compatible with Ecotect. Radiance own interface is limited. Direct importation from SketchUp through plug-ins still in Beta stages. Manual Method requires experience with coding language
Daysim	n/a	n/a	Simple within Ecotect, Complex Standalone	n/a	Metrics on Workplanes. In-depth PDF documents	Direct importation from plug-ins SketchUp still in Beta stages. Produces data that can be fed back into Ecotect to view the results effectively.
Diva	Easy, Fast w/ Rhino	Simple, but a lack of tooltips.	Simple	Full 3D & 2d Viewports & 3D images	Metrics on Workplanes In-depth PDF documents, False Colour Images.	Custom sky using direct horizontal irradiance can produces errors. Clear interface and comprehensive datasets from point in time calculations and climatic data.

Conclusion

The aim of this paper was to evaluate tools available (currently used and new tools) to architects for the analysis of daylight design and performance of buildings. To this end firstly the state of daylighting analysis in architectural firms within Brisbane was surveyed, and secondly the ease of use of the daylighting analysis tools was assessed. This assessment included: comparing modelled point in time simulations against a real scenario (studio space), climate based modelling of the studio space with different tools and observation of issues related to the process of creating models, adapting models and implementing for analysis.

The point in time illuminance calculations revealed that programs with common specific daylighting sky models that relate to realistic sky type lead to the most easily and realistic simulated results, furthermore, if the daylighting conditions can be recreated with direct and diffuse illuminance the results can be similar, however this leads to a variety of customizable options can easily confuse the user, which was seen with the use of Radiance and 3ds Max respectively. Radiance for indirect and direct were quite realistic, while 3ds Max for indirect results were realistic however, the direct component via the "Mr Sun" was difficult and produce inaccurate data without more specific data inputs. The simulations showed a direct correlation between the actual sky condition and the similar sky models used for analysis as seen in the Ecotect with Radiance and Rhino w/ Diva.

Climate-based simulations revealed that, Rhino as a modelling platform with the DIVA lighting analysis plug-in gives the most comprehensive data set when calculating daylighting metrics, being based on Daysim, DIVA, like Daysim generates documents that contains comprehensive data on illuminance measurements and glare ratings. Daysim as a plug-in through Ecotect, unlike diva requires manual import to create visual data. However, while it is possible for 3ds Max/radiance software to easily produce point in time data, climate based analysis requires a much more time intensive method, by illuminance data input via spreadsheet data analysis. This same method can be done with radiance, however the advantage of Daysim, Diva and Ecotect, is that the same can be achieved in a much simpler way through their respective interfaces.

The most adaptable method for daylighting analysis within architectural practice at this point in time, is using programs what integrate effectively with current BIM based or modelling solutions, and as seen in the poll the majority of firms report modelling with either Revit (BIM based) or SketchUp. Integration with Revit workflow is possible and efficient using Ecotect with the appropriate lighting analysis software (Radiance and daysim), while integration with SketchUp, is not as efficient, as a more manual approach is required due to the scripting based plug-ins. These methods aren't exactly architect friendly as advanced background in IT or scripting is required. Unless the users are looking to invest in either Ecotect, 3ds Max or Rhino w/ Diva. New programs are steadily being developed; existing plug-ins will likely be improved reducing the need to additional software.

Incompatibility between software is leading unknowing users to make design decisions on the assumption that these incompatibles are resolved within the software, and the results are correct. However this study has shown, they could be incorrect. More help features concerning input data, and simpler methods for creating analysis grids should help solve these problems as well as the expansion of what file types are supported for analysis. With the advancement of BIM and other analysis software packages such as DIVA and the upcoming Vasari, the software as well as plug-in compatibility should improve and enable architects to use the latest metrics within their analysis for daylighting.

The study findings agree with previous studies in that current lighting software isn't "architect friendly" (Attia et al., 2009). The processes and methods discussed within the paper reveals that some software could be more easily integrated into the current workflow of an architect than others. Although the process for daylighting analysis of 3d models using third party solutions is improving, to obtain more reliable results the user may need to purchase additional modelling software so they can gain access to the desired analysis software (i.e. Rhino and Diva). This issue may be resolved via the use of plugins, however, they are bounded by scripting and algorithms and can be troublesome for architects. Finally, the development of a method that can facilitate the understanding of how the data is processed could give architects an understanding of what a realistic result should look like. Ultimately giving architects the ability to overcome these shortcomings enabling them to use these complex metrics to benefit their design process and producing better outcomes for their clients, environment, profession and industry**.**

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Inter-municipal facility location-routing model

Lisa Koller[1], Gerhard Girmscheid[2]

Abstract

The planning of efficient and process-oriented inter-municipal street maintenance operations involve several decision making processes. Road maintenance for municipalities is an important activity to deliver value for money for the inhabitants and therefore has to be planned carefully. Nowadays Swiss municipalities have to deal with inefficient structures regarding the operational street maintenance in terms of cost, resources and labour which lead to high organizational costs. This paper is concerned with the planning of optimized multi-municipal facility locations in the field of operational street maintenance. The location of operation centres is one of the most important strategic decisions for municipalities performing inter-municipal street maintenance operations. Especially in times of declining public income, Swiss communities are trying to improve their efficiencies of operational street maintenance. In cooperation with the Swiss Federal Roads Authority (ASTRA), the Chair of Construction Process and Enterprise Management at the Institute of Construction and Infrastructure Management at ETH Zurich is developing an inter-municipal facility location-routing model in the field of operational road maintenance. It serves as a decision-making basis for street owners to improve the efficiency of operational road maintenance processes. This paper presents an inter-municipal facility location-routing and shows possible algorithms for optimizing global costs. Localization decisions present a very complex decision making problem that involve considerations of multiple criteria such as the minimization of build-up and installation cost of a new operation centre, transportation cost as well as an ideal availability to the municipal road network. The constructivist research approach will be applied to the development of the inter-municipal facility location-routing model. This research approach follows the hermeneutic research paradigm and aims to structure new socio-technical systems based on an intended input-output effect. The holistic facility location-routing model forms a basis for systematically developing operational street maintenance strategies. The aim is to ensure a high standard of street network quality, create a tool for local authorities, enabling them to cope more easily with challenging economic aspects and to provide good value to the customer and road users.

Keywords: operational street maintenance, facility location problem, cost optimization, inter-municipal cooperation, decision making tool for local authorities.

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1. Introduction

Nowadays Swiss municipalities have to deal with increasing financial pressure regarding the provision of public services. Increasing complexity and economic constraints, especially in the field of operational street maintenance, are the reasons why municipalities in Switzerland put more effort into cost savings and increasing efficiency, in order to ensure a high quality of communal infrastructure. In times where every municipality has its own operation centre with the corresponding equipment and team structure, inefficiencies in terms of cost, resources and labour can be observed. In cooperation with the Swiss Federal Roads Authority (ASTRA), the Institute of Construction and Infrastructure Management at ETH Zurich is developing an inter-municipal operational street maintenance model (I-OSMM). The aim is to motivate municipalities to collaborate regarding the execution of public tasks and to build inter-municipal structures to gain higher performance levels and to work more efficiently. Furthermore the equipment and infrastructure can be used more target-oriented and therefore organizational overhead costs savings can be obtained. This model is applicable where public services such as street maintenance operations, emergency services, fire departments, schools etc. need to be structured more efficiently to be able to cope more readily with challenging economic aspects. In the field of municipal street maintenance several research papers have been published which give direction to the following model (Girmscheid 2007a, Girmscheid 2007b, Girmscheid 2009, Fastrich and Girmscheid 2010a, Fastrich and Girmscheid 2010b). The Model serves as a basis in better decision making for inter-municipal cooperation, regarding the location of operation centres and optimizing cost and performance structures, with the aim of significantly improving efficiency in street maintenance, by using economies of scale.

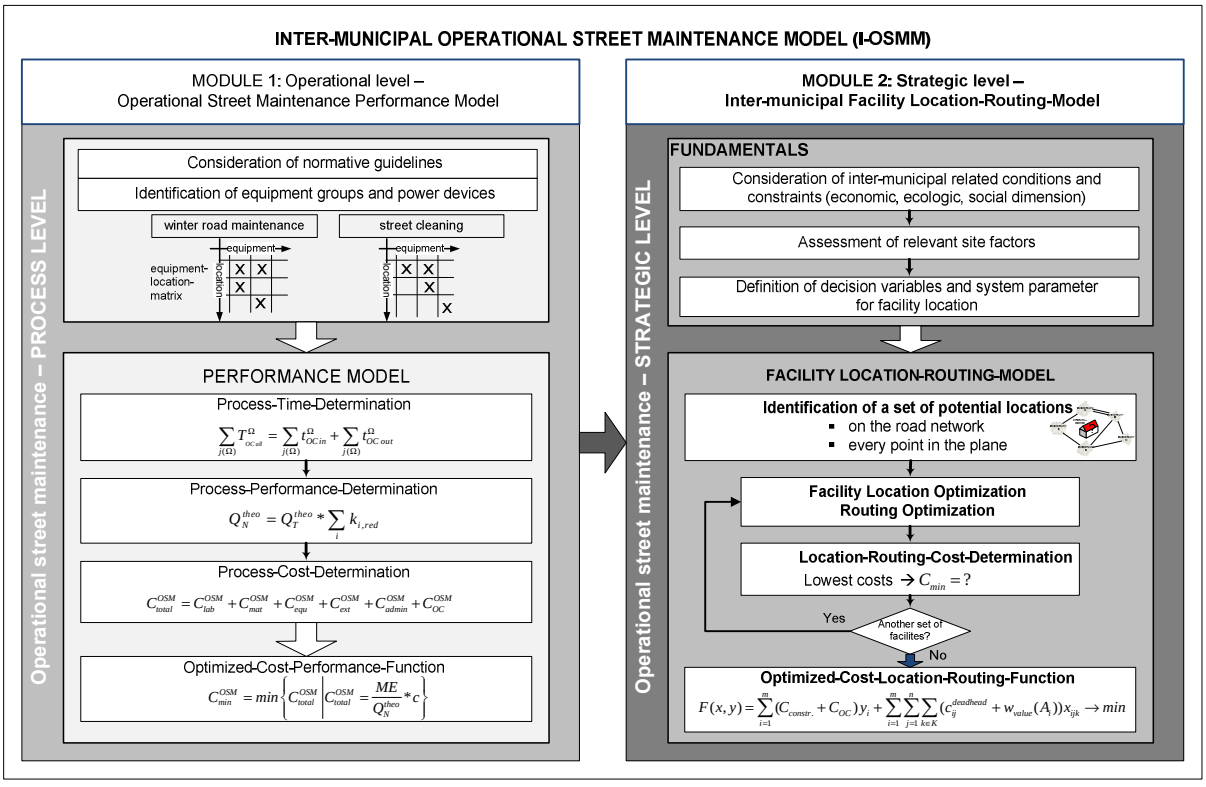


Figure 1: Overview – Inter-municipal operational street maintenance model

The I-OSMM consists of two modules – the operational street maintenance performance model on an operational level and the inter-municipal facility location-routing-model on a strategic level, as shown in fig. 1. Operational street maintenance contains, based on the Swiss Standard SN 640900a (2004), public tasks such as street cleaning operations, winter road maintenance and green area maintenance as well as the small rehabilitations of the street network (Girmscheid and Lindenmann 2008). To ensure a high level of street network quality, module one with its performance model of operational street maintenance shows a new approach of structuring and optimizing processes in the field of operational street maintenance, in order to increase the efficiency of public tasks in terms of scope, cost, resources and labour (Koller and Girmscheid 2012). This paper focuses on module two of an inter-municipal street maintenance model and shows how to locate operation centres when inter-municipal structures are used to optimize total cost. Furthermore, it provides a decision making tool for local authorities, enabling them to cope more easily with challenging economic and social aspects and to provide good value to the customer and road users.

2. Problem formulation and literature review

Road maintenance and asset preservation for municipalities is an important activity needed to deliver value for money for the residents. Decisions on where to locate facilities such as operation centres and satisfying the inhabitants' needs are a strategic issue for most Swiss municipalities and have a long-term effect on the operations of an inter-municipal street maintenance. The localization decision is a very complex decision problem that involves considerations of multiple criteria like the minimization of build-up and installation cost of a new operation centre, transportation cost as well as an ideal availability to the municipal road network.

Problems arising from the design and operation of street networks are especially complex. Facility location problems are optimization problems which follow the target of finding a subset of sites to establish a facility, by meeting all strategic and operational expectations of the service provider. Facility location problems and its variations have been widely studied in literature considering the field of operations research. Algorithms can be used according to the topography of the set of potential facilities as network locations models, models in the plane (Wesolowsky 1977) as well as discrete locations or mixed-integer programming models, respectively. Furthermore, objectives can be distinguished between minisum or minimax relations (Hakimi 1964, Klose and Drexl 2005). Minisum models are used to minimize the average distances of given networks, whereas minimax models are designed to minimize the maximum distance of the road network to the facility location. According to the type of work (winter road maintenance, street cleaning operations, etc.) in the field of operational street maintenance, the minisum model will be applied to gain a minimization of transportation costs between the demand points of the road network and the operation centre. While the classical location-allocation problem (LAP) only considers the optimized location of operation centres, the location-routing problem (LRP) also takes an optimal set of vehicle schedules and routing into account and therefore considers minimizing distribution costs (Salhi and Rand 1989). Several studies of LRP have been conducted, for instance, Golden (1977), Jacobsen (1980), Perl and Daskin (1985) have proposed LRP-algorithms with differing constraints, like capacity or tour-length limitations for example.

3. Research Methodology

The development of an inter-municipal facility location-routing-model of operational street maintenance is based on the constructivist research approach, which was developed by Glasersfeld (2008). The approaches' aim is to structure new socio-technical systems based on an intended input-output relation (Girmscheid 2004). The validation of the research project is based on triangulation. Triangulation ensures that the model is viable, valid and reliable. The modelling of the constructive-deductive process model is based on an intended input-output relation by using system theory (von Bertalanffy 1969). The viability will be ensured by using mathematical optimization methods like the graph theory and facility location problem. To ensure the reliability and validity of the model a realizability test will be conducted with eight municipalities of Switzerland to evaluate the current state empirically and to deduce the potential for efficiency improvement.

4. Inter-municipal facility location-routing-model

The purpose of the inter-municipal facility location-routing-model is to determine the optimized location of an operation centre, in order to satisfy the municipalities' needs and demands and to minimize the global costs incurred for each established facility. Furthermore it should motivate municipalities to collaborate and work together and therefore make it easier for them to cope with challenging economic constraints. With an inter-municipal cooperation, it strives to improve the efficiency regarding the cost and performance structures, by using economy of scales. The aim of an inter-municipal operation centre is to use resources (equipment, buildings, labour, etc.) more efficiently by benefiting from synergistic effects and know-how transfer, as well as the financial risk sharing regarding new expenditures and saving, due to optimized operation centre locations and vehicle routing. The model is especially applicable in questions where to locate facilities that are used collaboratively for the execution of public tasks. As shown in fig. 2 the first procedure starting the facility location-routing-process is the determination of inter-municipal related conditions and constraints regarding the economic, ecologic and social dimension.

Eiselt and Laporte (1995) show how to classify objectives in location models. These objectives can be manifold according to the municipalities needs, but mostly identified as the minimization of total construction, building and annual operation costs as well as the minimization of routing distances together with the maximization of the public service level provided for the municipalities. Recently, social and environmental aspects and objectives based on energy cost, pollution and noise, use of ecologically friendly de-icing techniques for example become increasingly important. Based on these constraints relevant site factors must be defined. After the assessment of site factors, decision variables and system parameters can be derived. According to Arinze and Banerjee (1992), possible system parameters are for example the topology of the municipalities, distance and travel time from the operation centre to the municipalities, number of possible facilities as well as the necessary capacity of the facility.

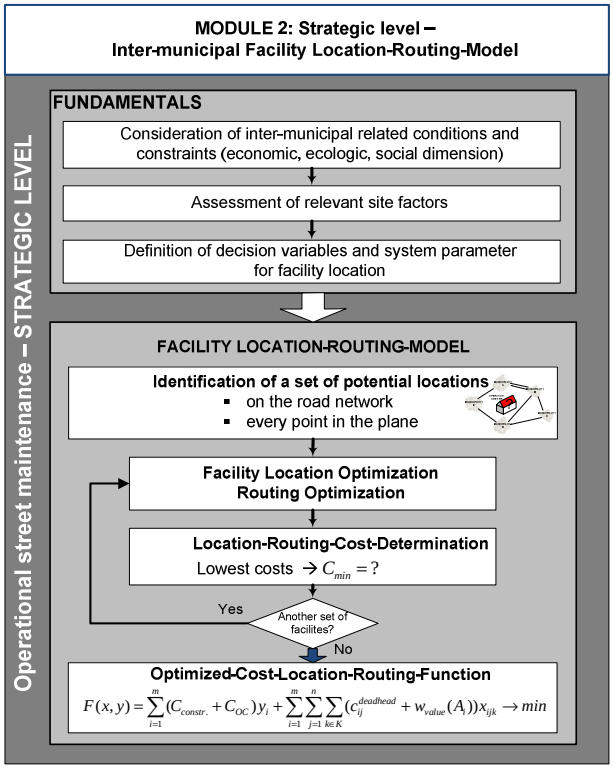


Figure 2: Inter-municipal facility location-routing-model

After defining the necessary decision variables and system parameters, potential operation centre locations must be defined. It should be noted that potential locations can be existing buildings which are suitable for the execution of tasks as well as new land where the new operation centre has to be build up. The inter-municipal facility location-routing-model therefore classifies the problem into two alternatives:

1.) **ALTERNATIVE 1:** Consideration of the facility location only
   a.) Formulation as warehouse-location problem (WLP) with one or more depots
   b.) Location in the plane with Euclidian metric

2.) **ALTERNATIVE 2:** Consideration of facility location and routing simultaneously
   a.) Location-Routing-Problem (LRP)

Fig. 3 shows possible alternatives (alternative 1a, 1b and alternative 2a) to locate an operation centre on a given street network or in the plane formed by five cooperating municipalities working together.

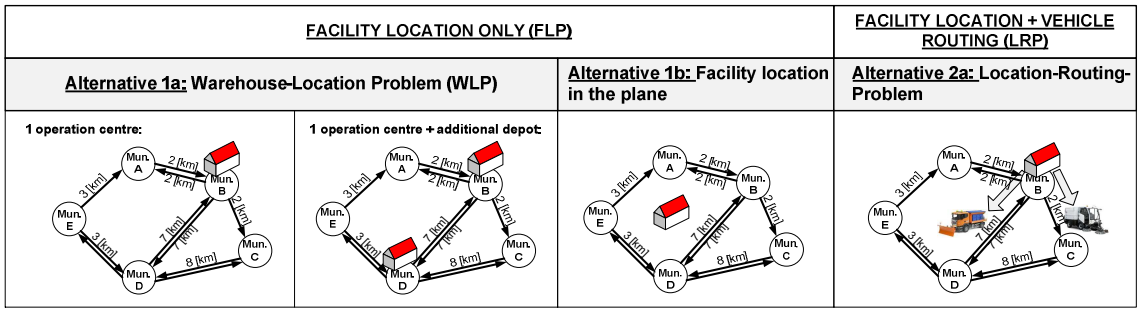


Figure 3: Alternatives for operation centre location and vehicle routing

The main difference of the proposed alternatives is the decision whether the operation centre will be located on a given street network or in the plane. These circumstances especially affect the cost structure, because of different requirements regarding new expenditures of establishing new roads and connecting supply ducts to the operation centre on the chosen “green field site”. Alternative 2 also takes account of an optimal set of vehicle schedules and routing which isn’t considered in alternative 1. In many cases in the field of operational street maintenance assumptions of linear costs regarding the warehouse location problem are not appropriate. Domschke (1996) for example, proposes to expect concave build-up costs for the operation centre. These costs are not constant, because usually they are dependent from the capacity of inventory. Therefore, doubling the capacity of space of the operation centre doesn’t mean doubling the build-up costs. In the following, alternatives as proposed in fig. 3 will be discussed.

4.1 ALTERNATIVE 1: Facility location problem

Alternative 1 only considers facility location without vehicle routing. Alternative 1a can be formulated as a warehouse location problem (WLP). On a given street network one or more operation centres and depots can be established, depending on whether the total cost will be minimized by using one or more depots. Alternative 1b takes advantage of a “green field site”, where every point in the plane can be seen as potential facility location.

4.1.1 Alternative 1a: Uncapacitated facility location problem (UFLP)

An uncapacitated facility location problem is a discrete problem, where a set of potential locations has to be allocated over a set of costumers with their specific demands and service requirements. The optimization problem is to find the subset of locations that will minimize the total fixed construction and operation costs and the variable transportation costs to satisfy the demand of public services in the municipalities. Considering the problem, let m be the number of potential operation centres, n the number of customers.

The decision variables for the optimization problem can be formulated as:

$$x_{ij} = \begin{cases} 1 & \text{If point i precedes point j on route} \\ 0 & \text{otherwise} \end{cases}$$

$$y_i = \begin{cases} 1 & \text{If the operation centre is located at site i;} \\ 0 & \text{otherwise} \end{cases}$$

The mathematical problem can be designed as:

$$F(x,y) = \sum_{i=1}^{m} (C_{Constr.} + C_{OC}) y_i + \sum_{i=1}^{m} \sum_{j=1}^{n} c_{ij} x_{ij} \rightarrow min \qquad (1\text{-}1a)$$

$C_{Constr.}$ … construction costs of the building yard
C_{OC} … operation centre costs
c_{ij} … transportation costs for the execution of street maintenance operations

The objective in constraint (1-1a) is to minimize the total costs including the construction and operation centre costs as well as the variable transportation costs for the execution of street maintenance operations from the municipalities to the operation centre.

$$C_{OC} = C_{vh.maint.} + C_{coord.} + C_{operation} \qquad \text{(2-1a)}$$

Constraint (2-1a) shows that that the costs for the operation centre consist of costs for vehicle maintenance, cost for coordination and organization (overhead costs) and operational costs of the building itself.

$$\sum_{i=1}^{m} x_{ij} = 1; \qquad j = 1,...,n \qquad \text{(3-1a)}$$

Constraint (3-1a) ensures that each municipality is served by only one operation centre.

$$x_{ij} \leq y_i; \qquad i = 1,...,m; \quad j = 1,...,n \qquad \text{(4-1a)}$$

To ensure that the demand requirements of the municipalities will be met, constraint (4-1a) is invented. It ensures that the operation centre can satisfy the demand of public services (such as winter road maintenance, street cleaning operations etc.) of the municipalities.

$$y_i \in \{0,1\} \qquad i = 1,...,m;$$
$$x_{ij} \geq 0 \qquad \forall i, j \qquad \text{(5-1a)}$$

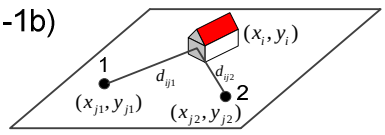
In constraint (5-1a) the 0/1-decision variables regarding the operation centre will be defined.

4.1.2 Alternative 1b: Continuous location model

Models in the plane are characterized by the fact that it is feasible to locate an operation centre at any point in the plane. The distance between two points can be measured by suitable metrics, in order to minimize the sum of distances between the operation centre and the points of demand. As Klose (2005) stated the subject of the so called Weber problem is to determine the coordinates (x, y) $\in R \times R$ of a single facility such that the sum of the distances to given demand points will be minimized.

The optimization problem can be formulated as:

$$F(x,y) = \sum_{i=1}^{m} (C_{dev.} + C_{constr.} + C_{OC}) y_i + \sum_{j=1}^{n} d_{ij}^2 x_{ij} \rightarrow min \qquad \text{(1-1b)}$$



$C_{dev.}$ … development costs regarding the new operation centre

d_{ij}^2 … Euclidean distance metric [km]

The target function (1-1b) aims to minimize the cost for development, construction and operation of the building yard together with the minimization of the Euclidean distance from every possible point in the plane to the new operation centre.

$$C_{dev.} = C_{road\ constr.} + C_{land} + C_{connection} \qquad \text{(2-1b)}$$

As shown in constraint (2-1b) the costs for development of the operation centre consist of the costs for the establishment of new connecting roads to the existing road network, costs for land use as well as connection costs for electricity, drains, water etc.

$$d_{ij}^2 = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} \qquad \text{(3-1b)}$$

Constraint (3-1b) shows the Euclidean distance from every possible point in the plane $R \times R$ to the new operation centre which needs to be minimized to reduce transportation costs.

4.2 ALTERNATIVE 2: Facility location problem and routing

Location-routing problems (LRP) consist of two linked subproblems: the facility location problem and the vehicle routing problem. Fig. 4 shows a flowchart of the heuristic design of the LRP for inter-municipal street maintenance (adapted from Lin and Kwok (2006); Tavakkoli-Moghaddam, Makui et al. (2010)). The two subproblems – facility location and routing – are tackled repeatedly for a predefined minimum number of facilities, until the total cost reach the optimum.

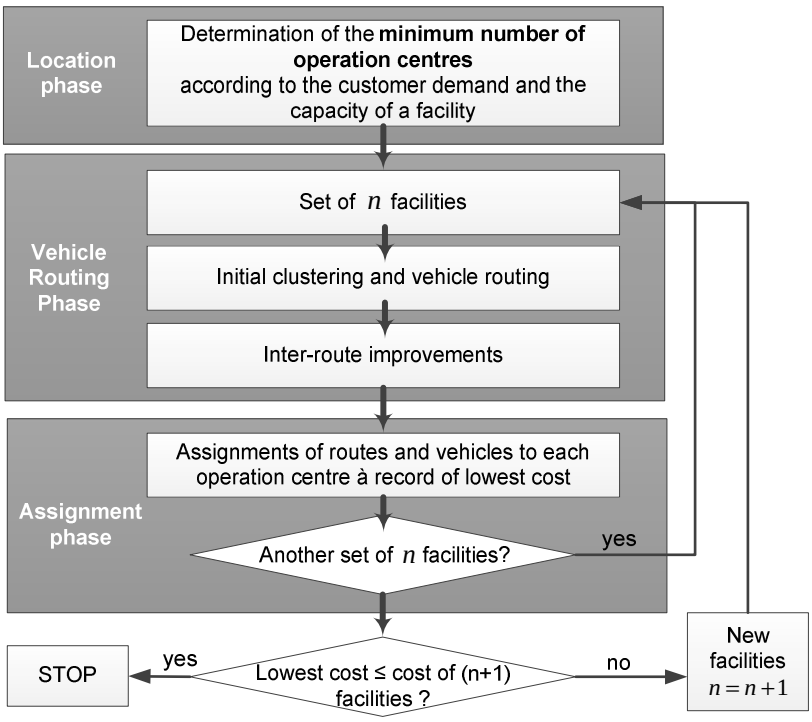


Figure 4: Heuristic design for the operation centre location-routing-problem (LRP) (Lin 2006; Tavakkoli-Moghaddam, Makui et al. 2010)

The first step – the location phase – starts with defining a minimum number of potential facilities, in order to fulfil the municipalities work requirements. For every set of potential sites the vehicle routing process will be applied. With a given set of potential operation centres, an initial clustering and vehicle routing will be conducted. This can be done by either using the saving algorithm by Clarke and Wright (1964) or the traveling salesman algorithm (TSP). In the routing phase Clarke Wright's saving algorithm will be applied for optimizing

each objective function with the aim to achieve local optima. Inter-route improvements can be solved by applying the TSP. In the last assignment phase assignments of routes and vehicles to each operation centre or depot will be done in order to record the lowest cost. The approach will be terminated when the set-up cost with an additional facility exceeds the lowest total cost calculated.

The mathematical problem can be designed as:

$$F(x,y)=\sum_{i=1}^{m}(C_{constr.}+C_{OC})y_i+\sum_{i=1}^{m}\sum_{j=1}^{n}\sum_{k\in K}(c_{ij}^{deadhead}+w_{value}(A_i))x_{ijk}\rightarrow min \qquad \text{(1-2a)}$$

$c_{ij}^{deadhead}$ … deadhead costs to and from the operation centre

$w_{value}(A_i)$ … variable costs for value-adding work in relation to the worked area

The aim of constraint (1-2a) is to minimize the total costs including the construction, building and operation centre costs (containing costs for vehicle maintenance, management costs and operational costs). The transportation costs can be divided into deadhead costs to and from the operation centre which can be seen as fixed costs as well as variable costs for value-adding tasks (such as winter road maintenance, street cleaning operations,…) in relation to the worked area in the municipality.

$$\sum_{i=1}^{m}\sum_{j=1}^{n}x_{ij}=1; \qquad i=1,...,m \qquad j=1,...,n \qquad \text{(2-2a)}$$

Constraint (2-2a) ensures that each municipality is served by only one operation centre and each vehicle is assigned to only one route.

$$\sum_{i=1}^{m}\sum_{j=1}^{n}b_j(S)x_{ij}\le V_C; \qquad \forall k\in K \qquad \text{(3-2a)}$$

$b_j(S)$ … demand of public service required in the municipality in relation to the required service level

V_C … vehicle capacity; e.g. loading volume, mechanical dimensions (width of snow plough, etc.)

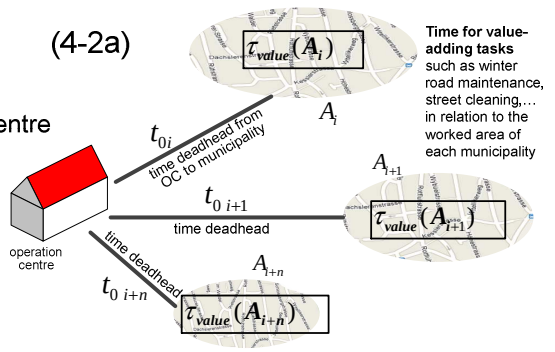
Constraint (3-2a) takes account of a technical vehicle influencing factor V_c, in order not to exceed the demand of public service in relation to the required service level (S) in the municipality.

$$\sum_{i=1}^{m}\sum_{j=1}^{n}t_{ij}+\sum_{i=1}^{m}\sum_{j=1}^{n}\tau_{value}(A_i)\le T_K; \quad \forall k\in K \qquad \text{(4-2a)}$$

t_{ij} … deadhead time to and from the operation centre

τ_{value} … time for value-adding tasks

$A_{i,...,i+n}$ … worked area of municipality i,…,i+n



Constraint (4-2a) guarantees that each vehicle route doesn't exceed the maximum allowable duration T_k according to the legal working hours per day. Variable t_{ij} shows the time of

deadhead (non-value-adding) from the operation centre to the site of operation. With τ_{value} the time for value-adding tasks can be described in relation to the worked area in the municipality.

5. Results

Results that can be obtained by using the inter-municipal facility location-routing model are schematically shown in fig. 5. The result of the optimization process regarding the facility location and vehicle routing show different cost-functions $C_{total}^{(1a,1b,2a)}$ in relation to the facility location, using alternatives 1a, 1b or 2a. The result is an optimized cost-location-routing-function which shows (under economic and operational constraints) where to locate new facilities. A prerequisite for this is the establishment of an inter-municipal cooperation. Variable $C_{fix}^{(1a,1b,2a)}$ denotes the amount of total fixed cost of the operation centre, regarding the land cost, development cost, construction and building costs of the operation centre as well as operation costs. Every inter-municipal merger has different demands in public services in relation to the required service level. Therefore, $y^{(1-3)}$ will be integrated in the model to show the overall demand of public service. The last step will be the calculation of an envelope (shown as thick line in fig. 5) which shows optimal solutions by connecting fixed costs of the operation centre and depots and demands of every cost function on the envelope (Schumann, Meyer et al. 2011). Therefore, for every demand y, an optimal solution regarding minimum costs can be found on the envelope.

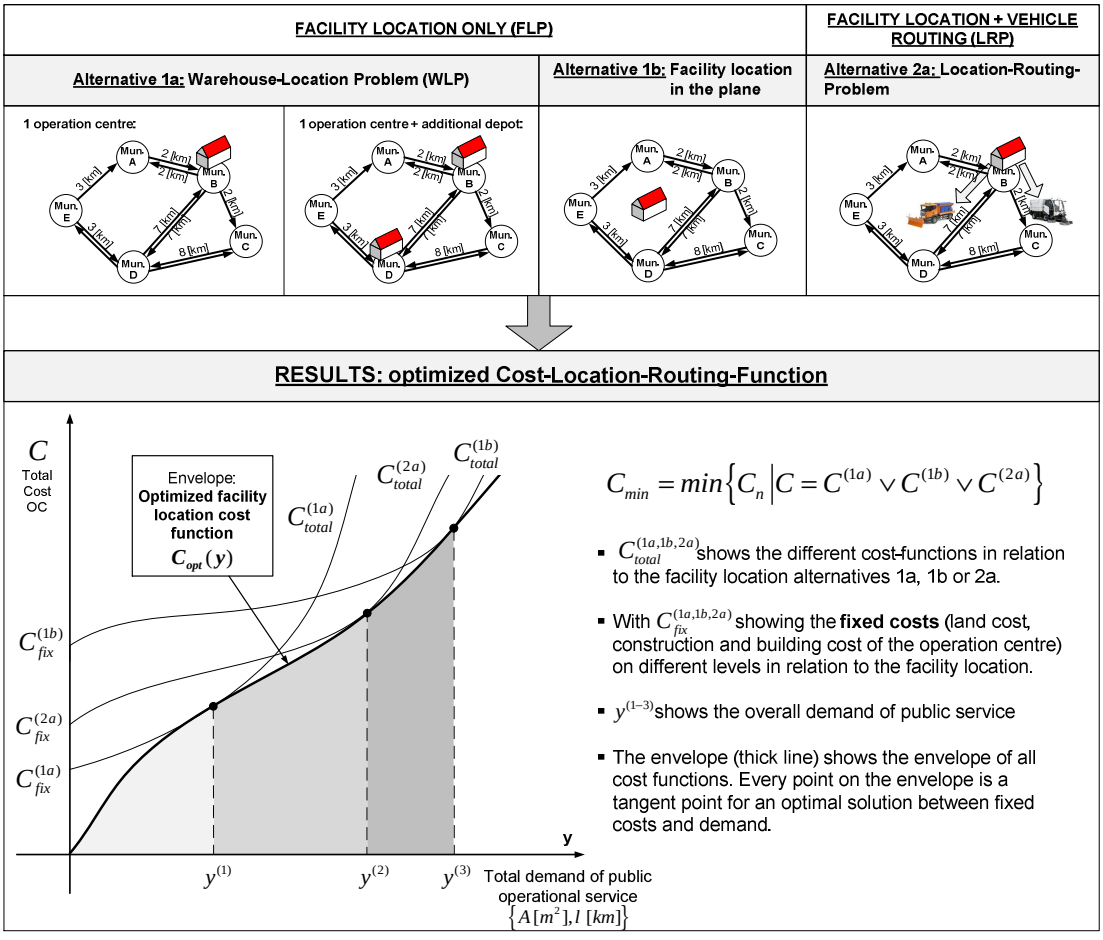


Figure 5: Results – Optimized Cost-Location-Routing-Function

6. Conclusion and outlook

This paper focuses on module two – the inter-municipal facility location-routing-model - of a holistic model of an inter-municipal street maintenance within the framework of the development of a research project on behalf of the Swiss Federal Roads Authority. The aim of this paper is to set-up an inter-municipal facility location-routing model in the field of operational street maintenance, aiming to make a valuable contribution to the process-oriented execution of public tasks. It shows how to locate operation centres, in order to minimize global cost by providing a high-quality inter-municipal street network and to use equipment and team structures more efficiently. Furthermore, the inter-municipal facility location-routing model provides a decision making tool for local authorities, to be able to cope more readily with challenging economic aspects and to provide good value to the customer and road users. The subsequent step in the development of the model will be the calculation and comparison of the proposed facility location and vehicle routing alternatives, so to provide recommendations for local authorities and therefore to increase the efficiency of public inter-municipal tasks.

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Social resilience in the context of South African cities: Exploring the interdependencies of urban and social resilience

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Abstract

Urban areas as socio-ecological systems can be seen as consisting of an urban environment created by biogeochemical processes (including those originating from human activities) and governed by natural laws and an interior noosphere created by and experienced through the human psyche and social interaction to give rise to social and cultural structures. These two spheres interact to create the dynamics of a city and therefore urban resilience needs to consider not just biophysical or social resilience, but also the interactions between them. To date, most work on urban resilience tends to focus on the exterior aspects of the city, while work on social resilience tends to ignore the city and its biophysical aspects. This paper explores the interdependencies between resilience in the social and biophysical systems of the South African city. From the scenarios based on real events in cities in South Africa we can see the relationships between the social and biophysical resilience of an urban environment.

Keywords: Resilience, interdependencies, urban resilience, social resilience

1. Introduction

The notion of urban areas as socio-ecological systems is becoming more widely accepted (Alberti et al. 2003; Moffat and Kohler, 2008; Du Plessis, 2009a). As such they can be seen as consisting of an urban environment created by biogeochemical processes (including those originating from human activities) and governed by natural laws, and an interior noosphere created by and experienced through the human psyche and social interaction that give rise to social and cultural structures (Haberl et al., 2004; Du Plessis, 2009b). These two spheres interact to create the dynamics of a city and therefore urban resilience needs to consider not just biophysical or social resilience, but also the interactions between them. To date, most work on urban resilience tends to focus on the exterior aspects of the city, while work on social resilience tends to ignore the city and its biophysical aspects.

This paper explores the interdependencies between resilience in the social and biophysical systems of the South African city through the use of scenarios constructed from an

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individual's perspective of three recent events in South Africa. These scenarios are based within the City of Tshwane as a model apartheid city.

2. Approach

The approach used to explore the interdependencies of urban and social resilience is formative scenario analysis. Formative scenarios can be a useful tool to guide one towards a differentiated and structured understanding of a case's current state and its dynamics. Comprising of a sufficient set of impact variables and the linkages of these variables to gain a valid description, scenarios are useful tools to gain insights into a case and its potential developments and dynamics (Scholz and Tietje, 2002 pp80-85).

The three scenarios constructed in this paper are based on real events and conditions experienced by citizens of the City of Tshwane as a typical South African city and are formulated from an individual perspective. These scenarios were based on news articles, interviews and engagement with the subjects involved. In the next section we examine the literature on resilience. Both social and urban resilience are examined to see whether there is a juncture between them or not.

3. Resilience

Resilience was first used as a term in engineering in the field of material sciences to describe the ability to store strain energy and deflect elastically under a load without breaking or being deformed (Plodinec, 2009).The Resilience perspective grew in the 1970s and 1980s to include ecological as well as psychological interpretations of resilience. In terms of the ecological resilience perspective the term was used to describe the capacity of ecosystems to recover from environmental stresses (Holling 1973; Abel and Stepp, 2001; Resilience Alliance, 2006; Jentsch et al, 2011) and emerged due to the dissatisfaction with other existing models of ecosystem change (Cote and Nightingale, 2012). However, this equilibrist model of resilience has been questioned, as in practice ecological recovery does not inevitably entail a return to the system's original state. The understanding of resilience has subsequently been expanded to a more evolutionary model that acknowledges the ability of the system to adapt and transform to a new state of being while still maintaining previous functions (Kirmayer et al., 2009 pp64; Zolli and Healy, 2012 pp13). The main characteristics therefore of ecological resilience are adaptation, transformation and continued functioning (Waller, 2001).

From this point of departure, it is suggested (Carpenter et al. 2001:766) that the resilience of social-ecological systems has a three part definition: the amount of disturbance a system can absorb and still remain within the same state or domain of attraction; the degree to which the system is capable of self-reorganisation; and the degree to which the system can build and increase the capacity for learning and adaptation.

In psychology the concept of social resilience developed in parallel, with focus on the strengths that people and systems demonstrate that enable them to rise above adversity (DuPlessis Van Breda, 2001; Masten and Obradovic, 2006). As with ecological resilience, it

developed out of dissatisfaction with the distorted focus on vulnerability and deficit models and not on strengths and adaptability. The concept of individual resilience expanded to include family resilience, community resilience, as well as broader social resilience. However, there is as yet little integration between the work on social resilience and the resilience of social-ecological systems.

In the following sections we will discuss the emphases that urban resilience (focussing on climate proofing, disasters etc.) and social resilience (focussing on the individual, family, community and society) has taken in practice.

3.1 Urban resilience

The development of assessment systems or planning guidelines for urban resilience introduces concepts such as diversity, redundancy, modularity and interdependence of system components, feedback sensitivity and capacity for adaptation to the planning lexicon. However, there is still no consensus about what these and other resilience thinking concepts actually mean when applied to cities.

Urban resilience research has been centred on climate proofing (see Muller, 2007; Tomkins and Adger, 2004 and Newman et al, 2009), disasters such as flooding (see Lamond and Proverbs, 2009), oil spills (see Dow, 2010), terrorism (Coaffee, 2009; Coaffee and Wood, 2006) as well as sea level rise (see Muller, 2007). These are very specific disturbances to the urban system and fail to take into account the complexity and interdependence of all the social, ecological, economic, political and physical aspects of an urban environment that contributes to its general resilience. These studies also tend to focus on the vulnerability of the exterior or physical aspects of the city such as its infrastructure or ecosystem services and the concomitant strengths and vulnerabilities in the economic or political structures of the city. They rarely look at the relationship between the systems of the city (whether institutional, biophysical or economic) and social resilience.



Figure 1: Components of broader social resilience

3.2 Social resilience

Social resilience can broadly be grouped into four strata consisting of individual resilience at the base, family resilience, community resilience and then broader social resilience of communities incorporating towns, cities and even entire nations (Kirmayer et al., 2009). Figure 1 describes the components of broader social resilience that will be discussed in this section.

3.2.1 Individual resilience

Individual resilience or personal resilience could be seen as the basis of societal resilience building the upper strata of social resilience (Kirmayer, et al., 2009). Individual resilience focusses on an individual's personality traits and capabilities (personal abilities and cognitive strategies) of adaptability and transformation (Lemay and Ghazal, 2001; Rutter, 2007; Tugade et al, 2004; Kirmayer et al., 2009; Hefferson and Boniwell, 2010).

When considering individual personality traits there is an abundance of literature on various different sets. We therefore focus on certain key traits that have reference to several others: self-efficacy, confidence, hope and optimism. Confidence can be defined as the "individual's conviction…about his or her abilities to mobilize the motivation, cognitive resources, and courses of action needed to successfully execute a specific task within a given context". Confidence can be seen as a positive psychological capacity (Luthans et al., 2004 pp47).

Hope is also seen as an indispensable trait for both individuals as well as communities. Hope is the capacity of an individual to conceptualise goals, develop pathways to achieve these goals; and initiate and sustain the motivation required to achieve them (Snyder et al. 2002; Morrow, 2010; Braithwaite, 2004). Optimism is another individual resilience trait in positive psychology that comes from Seligman's theory of learned optimism. Seligman's (2002) definition focuses on permanence of events and pervasiveness. Permanence, in this case, refers to the perceived permanency of events in terms of time. Pervasiveness has to do with significance. For bad events, "optimists make specific attributions, while pessimists make universal attributions" (Luthans et al., 2004 pp45; Hefferson and Boniwell, 2011 pp117).

Resilience in terms of personal capabilities depend on mental operations and mediating processes that reflect personal agency, self-efficacy, idiosyncratic habits, coping mechanisms, mental sets, and the ways that people deal with challenges (Bandura, 1982; Rutter, 2007; Kirmayer et al., 2009).

3.2.2 Family resilience

Resilient individuals influence the resilience of a family system and the inverse is also true. A family unit can be seen as a self-regulating system that interacts with a larger community, social system, ecology or urban environment (Kirmayer et al., 2009, pp70-71). As with individual resilience, a family unit adjusts its roles, goals, values, rules, and priorities according to external changes in order to achieve and maintain certain levels of balance and harmony, as well as to transform or bounce back. In terms of general family resilience great emphasis is placed on a supportive environment for the individuals within the family unit as well as the support the family receives from outside such as schools, community members, religious institutions, government and others (Kirmayer, et al., 2009).

Culture and ethnic identity is another important support to enhance family resilience. It is a grounding element that supports families in times of rapid change and could be a source of stability. Protective factors like cultural knowledge and practices allow for both flexibility and

consistency, which are key components of both individual and family resilience (Kirmayer, et al., 2009, pp71). Key steps towards creating resilient families would be to establish supportive communication networks, build emotional capacity, support spirituality, foster community relationships and to cultivate collective objectives or goals (Kirmayer et al., 2009).

3.2.3 Community and broader social resilience

Individuals and families do not exist in isolation and are part of a complex web of relationship within their environment. Community resilience accentuates assets or resource adaptability, collective processes such as collective hope and strengths such as social cohesion and trust (Kirmayer et al., 2009).

Resource adaptability (asset based resilience) focuses on the quality and quantity of resources accessible to the community and the extent to which these resources can be modified to meet changing social environments and adapt to breakdown in the system, and build on the strengths of such a community (Adger, 2003). These resources take account of not only physical resources but also social resources such as the individuals, networks and other associations that individuals or families would not necessarily have access to if they were not included in this community. However this view is over simplified, only taking stock of resources but failing to consider the interactions between these resources as something of consequence.

Collective processes linked to resilience incorporate visioning and collective hope. Visioning give both individuals and communities an opportunity “to express how they wish the world to be” and therefore make allowance for collective hope (Morrow, 2010, pp6). Sustainable collective action requires individuals to genuinely buy into the collective hope process with a shared vision of desired social change and a belief that change can happen (Braithwaite, 2004). Collective hope has to provide a framework for understanding how individual hopes are coordinated into a common aspiration and then into collective action (McGeer, 2004). It is therefore essential that all involved recognise that “others care about their well-being; that the society will help deal with the desired goals; that resources are available; and that the goal is worthy” (Braithwaite, 2004). If their goals are not reached it is also important to review and build onto these aspirations to keep the collective hope operating (McGeer, 2004).

Social cohesion is linked to the collective processes and is also an important element of social resilience. Social cohesion is a set of social processes that focuses on the feelings of solidarity between citizens, development of shared values, equal opportunity, feelings of involvement within the community, cooperation with other people as well as institutions and place attachment (Jenson, 1998). This also links to aspects of trust in one another, as well as trust in the government’s capabilities and integrity.

As with urban resilience, social resilience has thus far focussed mainly on interrelations between social strata with few linkages to the properties in the urban environment and when it attempted such linkages (e.g. asset based resilience), the complexity of the interactions

were disregarded. In the next section we elaborate on the linkages with the urban resilience of South African cities.

4. Reciprocity of South African urban and social resilience

To explore the possible reciprocal relationships between urban and social resilience, we will discuss a few scenarios in which the interdependencies between urban and social resilience are illustrated. These scenarios are based on real events and conditions experienced by the City of Tshwane as a typical South African city and are discussed from an individual perspective.

Illustration of urban-social interdependency – Soshanguve train

Nombeko is a 39 year old single mother who lives in the dormitory township of Soshanguve with her four children. She travels to inner city (35km from the train station) to work as a domestic worker. She leaves home at five in the morning to be at work at seven. Walking 8km to the Mabopane station she arrives to find the train late, at the arrival of the train 50 minutes later she gets onto the train. Ten minutes later the train unexpectedly stops in the middle of nowhere. In the confusion she gets out of the train to see a train support vehicle stopping next to the train and a minute later dash away with the train driver. She stands back hopelessly as her fellow commuters, outraged by the continued poor service delivery, set fire to the train. She has to walk home and let her employer know that she will not be able to come to work as taking a minibus taxi would equate to her day's pay. The next morning she hears that Metro Rail has discontinued services to Mapobane in the face of severe threats to the safety of their personnel, damage to infrastructure and losses of rolling stock due to a number of similar incidents in the past couple of years. This leaves only the unaffordable taxi as an alternative means of transport.

If we consider the factors at hand, the low adaptive capacity of the physical environment maintains the isolation of Soshanguve and the failure of the urban environment to provide the urban poor with equal access to economic opportunities within the city. Current development by the metro council according to national guidelines situates affordable housing infrastructure predominantly in the old townships located on the city periphery.,A a practice which further entrenches the spatial segregation of the poor in isolated areas far from any economic opportunities (Vanderschuren and Galaria, 2003:268). It is unfeasible for the private sector to invest in Soshanguve as the area has low connectivity and low economic opportunity. The inhabitants then become dependent on work elsewhere in the city. However, Tshwane's spatial structure necessitates long travelling distances and with the low densities of the city, this makes public transport unaffordable and limited viable public transport options are available to the people in these isolated areas, lowering the adaptive capacity of the transport system.

This physical rigidity then influences the social resilience as these poor communities are fixed in an area with low opportunities, increasing their vulnerability to factors such as increased transportation costs or the failure of transport systems. The social resilience of these communities falters as their assets (such as their transport system) fail. When the

transport infrastructure, like the train, comes to a stop there are not sufficient or cost-effective alternatives for people like Nombeko to continue functioning as she did previously. People lose trust in their government's ability (or willingness) to provide for them or care about their well-being and their personal goals, and feel exploited. The social cohesion weakens as the cooperation with other people and explicitly government institutions weakens and people lose their attachment to place (Jenson, 1998). They then respond from a place of anger, resulting in social unrest and even mob justice through actions such as burning trains and threatening train drivers. This then in turn influences the ability of the physical environment to function as infrastructure is damaged or destroyed. Replacing and repairing infrastructure place a further economic burden on the city and displace funds from other service delivery programmes such as the provision of affordable housing.

Illustration of urban-social interdependency – Plastic View squatters

Alakhe is a 36 year old man who settled with his family in an informal settlement on a vacant plot within walking distance of the work he acquired as a gardener in a prestigious golf estate. It was a tossup for the family between living in the outskirts of the city with low probabilities of finding employment and staying close to work but with no running water or electricity. They opted for proximity. Their shack (informal built structure) made of corrugated sheeting wasn't much but it was home. His wife and he could easily get to work and shops however their children could not go to any schools nearby and stayed at home. Coming home from work one day he arrives at a mess of smoke and bewildered occupants. Anguished over the safety of his family he starts negotiating his way through the huddle and finds his wife and kids settled atop a pile of their belongings in the field adjacent the burning settlement. Perplexed he listened to his wife's account of how the police came into their home and chased them out with just enough time to grab their belongings before they set their shack alight and started to burn shack after shack. They slept in the field that night as they were rendered homeless. The next morning he hears that the home owners' associations in the adjacent affluent (and influential) areas were putting pressure on the council to move them and that the Metro wants to relocate them to some far off area.

After this disruption in the community the informal settlers stood together and took the government to court with the help of a local NGO. Six years down the line, after standing together as a community, the 865 households were given the right to stay, and Plastic View will be formalised.

If we reflect on the dynamics in this scenario, the urban poor communities are adapting to the existing state of affairs, as described in the Soshanguve scenario. The result is an infiltration of the informal into the formal settlement areas. As the government fails to provide them with affordable housing close to job opportunities, the poor locate themselves close to job opportunities at the cost of other social amenities and access to basic services.

The ability of the political environment to resolve this issue is restricted due to the rigidity of strict policy and land use management systems and larger economic forces that effectively prohibits a diverse range of housing options. Additional forces in terms of land markets and

social pressures demand that government take action, and eventually the Metro respond to these pressures by forcefully removing illegal squatters.

The community's social resilience is tested by the actions taken by government as their shacks are destroyed. However this community's solidarity and cooperation with each other and institutions like the NGO, cultivated the community's resilience. They took action toward a collective goal and confronted the council in court and won. Which in turn influenced the physical environment, as the council now has to provide formal low cost housing. By formalising Plastic View, the community may now have access to job opportunities, but these are still lowly paid and the costs of formal housing (rates and taxes, basic services) will place a heavy demand on disposable income. There are also no public health facilities or affordable schools in the vicinity which greatly reduces the personal resilience of people staying in these informal settlements. Furthermore, Plastic View is located on a floodplain, making it vulnerable to (and contributing to) the documented increases in flash flooding as a result of hardening of urban surfaces and the increased rainfall and strong storm events some are attributing to climate change (Cox et al., 2004). Thus an intervention which aimed at resolving one pressing issue may actually reduce the broader economic resilience of the individual and the small community.

Illustration of urban-social interdependency – Backyard shacks

Msizi is a 45 year old male, who stays in Mamelodi Township which he has made his home with his wife and two children. He has been on the waiting list for a free government provided house in Mamelodi for almost ten years now. With the cost of formal rental accommodation disproportionately high in terms of his income, he lives (like many other locals with little income)in a backyard shack. Dissatisfied with waiting for government to provide him with a house, he feels no remorse at the illegal connections of electricity to his backyard shack or the hosepipe they run from the public tap. However, the shared ventilated improved pit latrine cannot cope with the sixteen people living on the stand, resulting in a number of health problems for his family.

If we reveal the dynamic forces, the political and economic environment retains low capacity for providing housing for the poor. The delivery of subsidised housing units has time and again failed to reach the annual target of 300,000 houses per year, with for example only 161,854 housing units and 64,362 serviced sites delivered in 2009/10 (Khumalo, 2012. pp15), while a large young and unemployed populace continue increasing the backlog. According to recent statistics approximately a third of the youth (15-24 years) were neither employed, nor in education or training (StatsSA, 2012).

The social resilience is then affected as poor communities have no alternative formal housing. The community's resource adaptability focuses on the quality and quantity of resources accessible to the community and the extent to which these resources can be modified to meet changing environments (Adger, 2003). These backyard shacks build onto the existing infrastructure and resources to fulfil a housing demand (Poulsen and Silverman, 2012), thereby encouraging the infiltration of informality into the formal settlement. Unlike the informal settlements, backyard shacks reduces the housing demand in areas demarcated for

residential use, which are serviced and have access to social amenities. However, this informal social intervention then places additional pressures on the resilience of the physical environment, especially municipal services, as these areas were not serviced to accommodate these numbers (Poulsen and Silverman, 2012). This could ultimately lead to poor service delivery which could subsequently lead to other social dilemmas such as outbreaks of diseases such as cholera or social unrest such as described in the Soshanguve train scenario.

5. Conclusion

In the literature on social and urban resilience we have found a disjuncture between the two aspects of the social-ecological system. To date, most work on urban resilience tends to focus on the exterior aspects of the city, while work on social resilience tends to ignore the city and its biophysical aspects. The formative scenarios illustrated how resilience of both the biophysical system (spatial segregation), as well as the social structures (housing subsidy schemes) leads to the rigidity of these systems, which in turn impacts on the resilience of smaller scale systems. These scenarios illustrated how the biophysical system's resilience can influence social resilience and similarly how social resilience at smaller scales can influence the resilience of the larger system. With the rigid biophysical and institutional system, individuals are forced to self-organise. However this self-organisation then place pressures on the biophysical system, as well as the larger social system. These pressures could lead to a breakdown in the urban system and the social response then impacts the system in other ways. It is suggested that researchers in urban resilience should incorporate social resilience in their study of the biophysical aspects and social resilience should consider the influence of exterior aspects of the city on social resilience. It is the interdependencies of these systems and their ability to work together and adapt when other systems falters, that strengthen or reduce urban resilience.

Acknowledgements

The authors are grateful to the National Research Foundation who supported the production of this paper through NRF Grant no 78649.8

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Modelling, Collaboration and Integration: A Case Study for the Delivery of Public Buildings

Keith Hampson[1], Judy Kraatz[2]

Abstract

An evolution in the use of digital modelling has occurred in the Queensland Department of Public Works Division of Project Services over the last 20 years from: the initial implementation of computer aided design and documentation (CADD); to experimentation with building information modelling (BIM); to embedding integrated practice (IP); to current steps towards integrated project delivery (IPD) including the active involvement of consultants and contractors in the design/delivery process. This case study is one of three undertaken through the Australian Sustainable Built Environment National Research Centre investigating past R&D investment. The intent of these cases is to inform the development of policy guidelines for future investment in the construction industry in Australia. This research is informing the activities of CIB Task Group 85 R&D Investment and Impact. The uptake of digital modelling by Project Services has been approached through an incremental learning approach. This has been driven by a strong and clear vision with a focus on developing more efficient delivery mechanisms through the use of new technology coupled with process change. Findings reveal an organisational focus on several areas including: (i) strategic decision making including the empowerment of innovation leaders and champions; (ii) the acquisition and exploitation of knowledge; (iii) product and process development (with a focus on efficiency and productivity); (iv) organisational learning; (v) maximising the use of technology; and (vi) supply chain integration. Key elements of this approach include pilot projects, researcher engagement, industry partnerships and leadership.

Keywords: **digital modelling, Building Information Modelling (BIM), Integrated Project Delivery (IPD), Queensland Project Services, Australia**

1. Introduction

This case study investigated the incremental adoption of digital modelling technologies and processes in the Queensland Department of Public Works Division of Project Services (QPS). Implementation has occurred over the last 20 years from: the initial implementation of computer aided design and documentation (CADD); to the experimentation with building information modelling (BIM) from the mid 2000's; embedding integrated practice (IP); to current steps towards integrated project delivery (IPD) including the active involvement of

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consultants and contractors in the design/delivery process. Improved productivity has been the key driver for this initiative.

This illustrative case study is one of three undertaken through the Australian Sustainable Built Environment National Research Centre (SBEnrc) investigating past R&D investment to inform the development of policy guidelines for future investment in the construction industry in Australia. Major challenges exist for the Australian construction industry in effectively leveraging R&D investment due to: the disaggregated nature of this industry (DIISR 1999, Hartmann and Fischer 2008, Eastman et al. 2008); the predominance of small to medium sized enterprises (the Australian industry employs some 950,000 people through 250,000 firms); intense competition; a history of limited investment in R&D and new technologies; and a project-based culture focussing on short-term business cycles (Newton et al., 2009).

In 2004 Engineers Australia established a Task Force to investigate the problem of poor documentation and its causes (Engineers Australia, 2005, p1). This showed: declining standards of project documentation correlated with a 24% decrease in design fees over past 12 to 15 years; the majority of variations were due to poor design and documentation; and that there was strong industry support for a solution. They also found that poor documentation practices have led to: an inefficient and non-competitive industry; cost overruns, reworking, extensions of time; high stress and low morale in the industry; adversarial behaviour impacting on reputations; and a decline in safety standards (p3). The Task Force identified that the cost of 'leaving things as they are' included: poor documentation 'contributing an additional 10 - 15% or more to project costs in Australia' and estimated costs of substandard project documentation equating to financial losses 'exceeding AU$2 billion in the Queensland construction budget every year – and probably six times this or AU$12 billion nationwide' (p4). One solution identified by this report was the 'adequate and effective use of technology' (p5). Complementing this report, the CRC for Construction Innovation (the predecessor to SBEnrc) through its Construction 2020 initiative identified a series of eight "visions" for the future of Australia property and construction industry. Vision 5 *Information and communication technologies for construction* addressed the use of communication and data transfer technologies within construction to improve efficiency and effectiveness. Vision Six *Virtual prototyping for design, manufacture and operation* was to facilitate the *try before you buy* opportunity across the project life-cycle (Hampson and Brandon, 2004).

This paper investigates how digital modelling and IPD can provide productivity and other benefits throughout the project supply chain through: design visualisation; improved documentation; enhanced supply chain collaboration; more effective cost estimating; and improved building performance.

2. Conceptual framework

Implementation of digital modelling in QPS has been achieved through an incremental learning approach driven by a strong and clear vision with a focus on developing more efficient delivery mechanisms through the use of new technology coupled with process change. Through this approach, QPS has been able to build the capacity for knowledge

uptake, assimilation and exploitation in both their own organisation, and that of their supply chain. In addition they have sought input from external sources of innovation and knowledge, and shared this knowledge openly throughout their supply chain.

2.1. Organisational capabilities

Academic theory used to contextualise gathered data includes: (i) dynamic capabilities; (ii) absorptive capacity; and (iii) open innovation. Teece, Pisano and Shuen (1997) discuss *dynamic capabilities* 'as the firm's ability to integrate, build, and reconfigure internal and external competencies to address rapidly changing environments' (p516). Criteria used to code and analyse data have been drawn from papers in this field including Lawson and Samson (2001), Teese and Pisano (1994), Eisenhardt and Martin (2000), and Davis and Walker (2009). Cohen and Levinthal (1990) introduced the concept of *absorptive capacity* as a 'firm's ability to recognise the value of new, external information, assimilate it, and apply it to commercial ends' (p128). Zahra and George (2002) propose absorptive capacity is a dynamic capability and discuss four dimensions of this capability, namely: knowledge acquisition, assimilation, transformation and exploitation (p186). Measures of absorptive capacity used to code and analyse data have been derived from Cohen and Levinthal (1990), Zahra and George (2002), Nieto and Quevedo (2005), and Flatten et al. (2011). Chesbrough (2004) defines *open innovation* as the use of external and internal ideas and pathway to market to advance their technology and general value. Chesbrough proposes that this approach better enables an organisation to deal with the unknowable, and manage the risks associated with experimentation. Chesbrough (2005) defines a series of features of 'open innovation' which have been used in the analysis of case findings. Additionally Huizingh (2011), Ling (2003) and Bossink (2004) have been used to derive categories for the nature of open innovation; deriving the benefits of open innovation; and the drivers for construction innovation respectively.

2.2. Digital modelling

BIM has been identified as one answer to current industry fragmentation and inefficiencies as it 'incorporates a methodology based around the notion of collaboration between stakeholders using ICT to exchange valuable information throughout the lifecycle.' (Jordani, 2008 in Arayici et al. 2009, p2). Such implementation however requires 'an examination, and potential reengineering, of all impacted processes and a reassessment of the role of practitioners in each of those processes' (Owen et al. 2010, p233). Benefits of BIM implementation are being continuously defined and evaluated. McGraw Hill (2008, p42) highlights benefits including: (i) competitive advantage; (ii) cost, quality and schedule control; (iii) potential to focus on the building owner's life-cycle; (iv) enhanced opportunities for off-site manufacture (including pre-fabrication); and (v) greater opportunities for collaboration across and throughout the building life-cycle, by way of IPD' (pp42-43). Integrated project delivery (IPD) requires greater team collaboration across the supply chain, including design consultants, contractors and sub-contractors (CRC CI 2009a). Cohen et al. (2010) describe characteristics of IPD as: early involvement of key participants; shared risk and reward; multi-party contract; collaborative decision making and control; liability waivers among key participants; and jointly developed and validated project goals' (p5). Figure 1 illustrates the

evolving stages of BIM and IPD implementation as described by the CRC for Construction Innovation (2009).

However, substantial challenges exist to the uptake of BIM. These include lack of awareness of life cycle benefits; lack of relevant training and a lack of industry data standards (DIISR 2010).

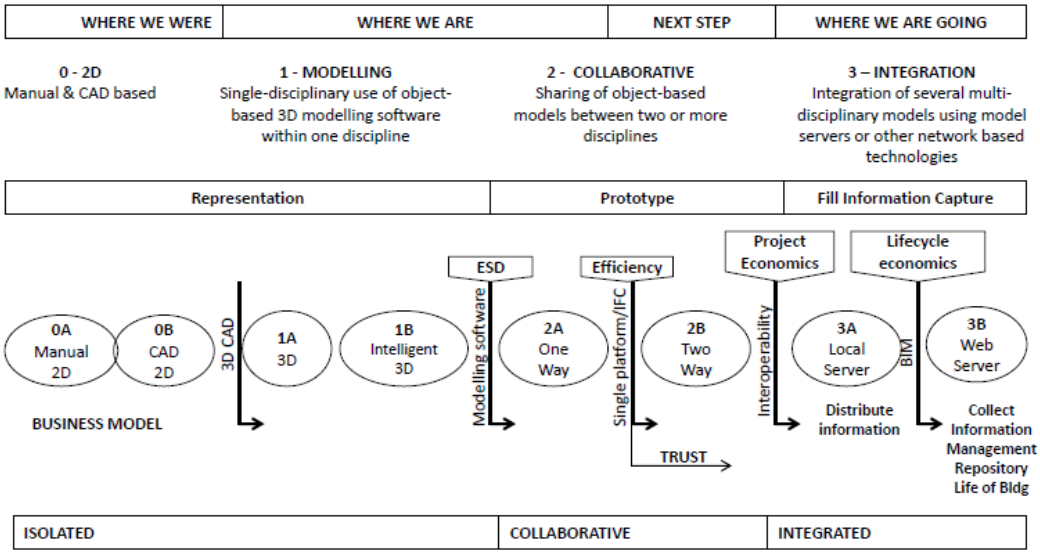

Figure 1 - Implementing BIM (adapted from CRC CI 2009)

Cohen (2010) identified further challenges including the need for project team members 'step outside the boundaries of traditional roles into a more fluid, interactive, and collaborative process' (p7) which impacts on traditional roles, project sequencing and the blurring of lines between design and construction and traditional project delivery. Owen et al. (2010) in the concept of 'Integrated design and delivery solution' (IDDS) identify the need for 'a team approach; support for innovation and tolerance of failure in a team; strong lateral linkages and decentralized decision making; networks of commitment; and new forms of contracting, transparency and risk management (including insurance models)' (p233).

Measuring benefits is also the subject of much literature (Dawood and Sikka 2005, Eastman et al. 2008, McGraw Hill 2008, Arayici 2009, and Coates et al. 2010). An important issue to highlight is to understand benefit aligned to various parties at different stages in the project life cycle (British Standards Institute 2010, p2).

3. Case study method

Multiple sources of information were used to inform this case study including: (i) meetings with key agency staff; (ii) project, program and organisational documentation; (iii) formal interviews; (iv) academic literature in the field; and (v) industry reports and presentations. The primary source of data was the formal interviews. Eleven interviewees were identified from within QPS and from those external to the organisation but with a high level of awareness of the initiatives undertaken by QPS. People from each of the following categories were selected including: internally an executive, champion, project leader, and

implementer; and externally a supplier, contractor, consultant, industry representative and a researcher. Formal interviews carried out from August to November 2011.

Data from interviews was subsequently coded by a research team member to build an understanding of the organisational capabilities evident in the implementation of these initiatives (and highlighting those not evident which may contribute to enhance outcomes in the future). Thematic coding and analysis was undertaken in two parts. Firstly key themes were established based on an analysis of the interviewees' direct responses to each question identifying drivers, barriers and successes for each of the cases. Secondly, responses were coded against criteria derived from dynamic capability, absorptive capacity and open innovation theory. The thematic grouping and coding was verified (via random sampling) by an alternate research team member to ensure the reliability and trustworthiness.

4. Findings

The incremental adoption of digital modelling technologies and processes within QPS (Figure 2) has been driven by the key champions from both the executive and delivery levels within QPS, based on experience and sensitivity to the needs of the industry.

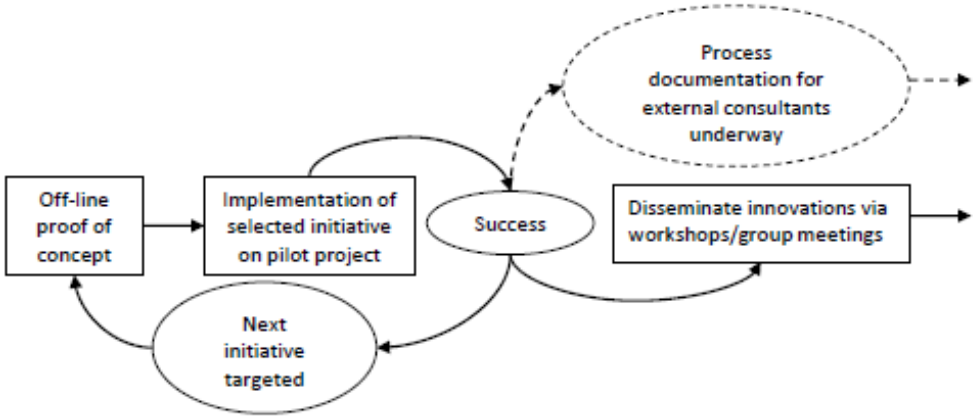

Figure 2 – Incremental implementation process

Both strategic and day-to-day issues have been addressed throughout the development cycle. Strategic support was provided by Departmental executives, with project delivery support provided by a team of CADD and BIM managers, discipline leaders, principal consultants, project directors and superintendents and selected IT consultants/contractors, suppliers and vendors. An integrated practice approach has been critical, with QPS able to promote integrated decision making across the project team leading to more productive collaborative decision-making. This has laid the ground-work for current steps towards IPD in which the consultant/contractor also becomes an integral part of the design team. The ongoing role of internal working groups has provided an important forum for internal discussion and knowledge dissemination. This approach was implemented on selected projects from 2005 (Table 1).

Table 1 – Project implementation time-line

Mareeba Court House and Police Station	2006	BIM approach first piloted.
Queensland State Archives , Brisbane	2006	4D model consultancy novated to contractor. Benefits included ability to rehearse construction sequence improving construction productivity.
North Lakes Police Station	2008	BIM approach further developed. Structural steel design provided directly to the fabricator improving fabrication productivity.
Dandiiri Contact Centre, Brisbane.	2008	Use of a model for energy modelling. Building awarded highest environmental rating of any Australian building at that time. Structural steel detailing for carpark photovoltaics resulted in no Requests for Information.
Toowoomba housing	2009	Use of 3D modelling on a smaller scale. Models provided to a select tenderers, who where coached in their application and use. Guaranteed Schedule of Quantities was provided

The establishment of collaborative working relationships with contractors, subcontractors and consultants willing to participate in the development and implementation of new work processes and practices has been critical. Relationships with external research organisations including the CRC for Construction Innovation, and universities QUT and RMIT (via Australian Research Council (ARC) Linkage projects) have also contributed to the pathway of success. Of importance also has been the relationships established with national industry organisations such as NATSPEC, and industry associations including buildingSMART and the Australian Mechanical Contractors Association. Engagement in forums such as the 2007 Australian Institute of Architects national conference has also contributed to driving developmental milestones within QPS and as forums for dissemination. These initiatives have been further recognised through winning industry awards for innovation (including the 2011 Australian Institute of Architecture, Queensland - Award for Sustainable Architecture and 2010 Engineers Australia Excellence Awards, Queensland - Hawken Award for Engineering Excellence).

4.1. Analysis of the implementation

Key **drivers** of these initiatives include: (i) increased production and process efficiency providing additional project value for same fee while maintaining timelines; (ii) better communication and collaboration through the development of effective supply chain networks; (iii) improving market share through demonstrating to government clients the added value that this service (such as environmental modelling, potential for facilities management); (iv) creating a stimulating and smart working environment to maintain skilled professionals in a public sector environment; and (v) providing industry leadership as demonstrated through: Australia's national building specification NATSPEC (http://www.natspec.com.au/); broad industry recognition of this national leadership role; and active engagement with vendors, suppliers, and contractors to enhance outcomes.

Key **implementation activities** included an incremental approach to improvement building on a strong, shared vision for implementation (Figure 3) supported by all levels of management. These efforts (particularly since 2005) have helped highlight the benefits of BIM to the wider industry. An investment in both training and technology underpins this advancement, with associated process improvement. Links with researchers were important to underpinning these developments as they moved beyond the *proof of concept* stage.

New **processes** required to deliver on these initiatives included the use and sharing of building information models, and ensuring a shared vision across the delivery team. This enabled new activities such as high level clash detection, energy modelling; and rehearsals of the construction sequence with both programming and safety benefits. A significant number of **required new processes** were also identified including the need to: (i) embed IPD into business and procurement mechanisms (the UK Cabinet Office (2011, p16) highlights the tension between 'seeking a more collaborative, integrated model' which at the same time maintain competitive tension and value for money) including new procurement methods; (ii) develop new methods of training; develop new industry standards such as National BIM Guidelines (CRC for Construction Innovation 2009 and NATSPEC 2011); and (iii) develop product libraries (such as those being developed by AMCA and SBEnrc) and applications which support this new collaborative and integrated environment.

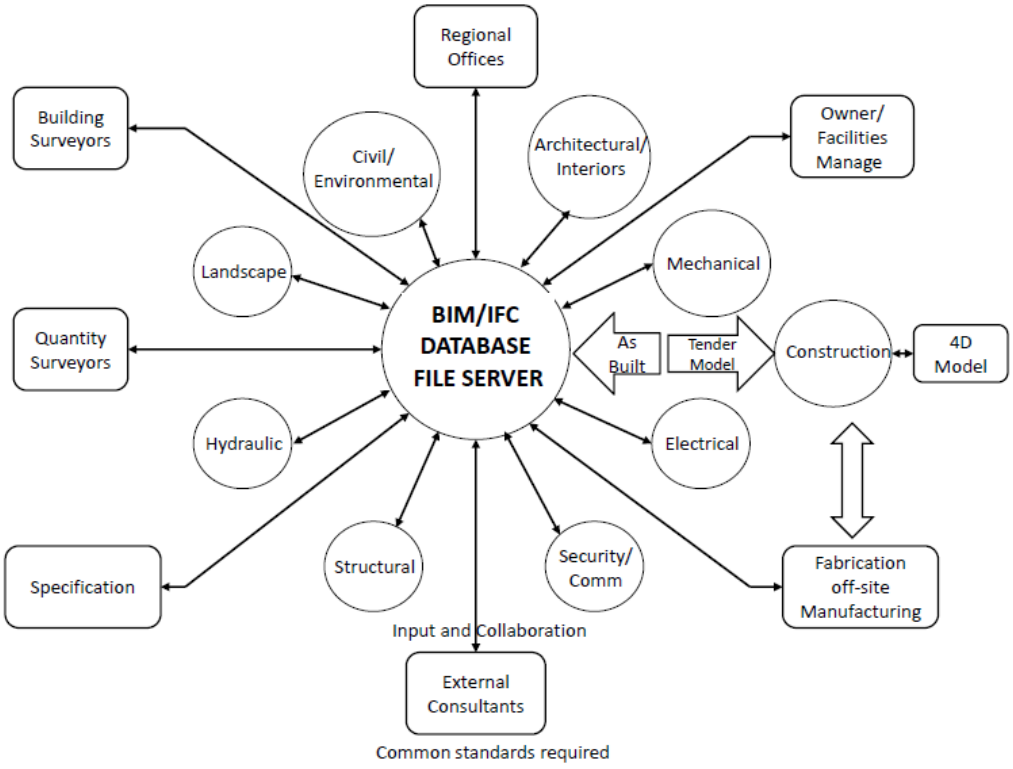

Figure 3 – The Vision (Project Services 2005)

Impacts were felt both internally on organisational culture and values; and externally on the supply chain. McGraw Hill (2008, p5) note that 'seven in 10 users say that BIM has had at least a moderate impact on their internal project practices; and two-thirds of users say that BIM has had at least a moderate impact on their external processes. Impacts felt by QPS included: the need for changes in delivery processes such as the shift from engaging an individual consultant to engaging a consultancy team; having contractors as a part of project team; and ensuring shared vision and trust between this larger team. This still requires: new forms of contracts; that legal and copyright issues and concerns are addressed; and new methods for on-site operations (see also Allen Consulting Group 2010, pxiii). Key **supply chain impacts** have thus arisen due to these changing relationships include the sharing of models with an integrated project team. Feedback mechanisms across the supply chain have been important in order to achieve these industry-wide standards.

Key **successes** include the incremental change approach, with process improvements targeted on a project-by-project basis. A key part of this has been the preparedness of QPS to take the risk associated with the use of digital models by contractors and suppliers (for example on North Lakes, the State Archives Project, Dandiiri Contact Centre and the Toowoomba housing projects). McGraw Hill (2008, p33) highlight some of the key risks including: errors and accuracy issues; liability and legal issues; inexperience; and the ownership of the model. The establishment of a *collaborative environment based on openness and trust* has been critical. This is essential to IPD, and QPS, as a multi-disciplinary design office, have been able to take on this approach as part of their on-going leadership in this field. This has led to a motivated team of individuals with a commitment to quality outcomes. Additional successes include: (i) 'green' outcomes leveraged through the use of the 3D model; and (ii) the ability to rehearse the construction sequence to maximise on-site efficiency and construction safety (Queensland State Archives Building), and facilitating off site manufacture (North Lakes Police Station).

Potential **barriers** identified range from indifference and a lack of knowledge, to a resistance to change along with entrenched business practices. This has been a challenge in terms of establishing a shared vision. A lack of political engagement is also evidenced, especially when compared to that which has grown for green buildings. Also acknowledged is the need for pressure to be brought to move beyond a 'promising early start' with BIM technology. Software and technology capabilities have also inhibited development, along with suppliers' focus on graphics rather than object data. Associated skills gaps still need to be addressed. The commercial realities of associated costs such as technology, training, and process improvement especially suitable procurement mechanisms (see Hartmann and Fischer 2008) have also impacted development. Each of these barriers, identified in interview reflect the findings of the Allen Consulting Group report (2010, pxii) and challenges identified in the international literature (McGraw Hill 2008, Eastman 2008).

R&D activity can be described as *informal and integrated*. Proof of concept was achieved using their own resources through an on-going series of pilot projects, where innovation was achieved within the project budgets, and with existing resources, and outcomes disseminated via an informal mechanism. They then established a number of formal research links to further realise the potential of BIM, IPD and visualisation. Collaboration has occurred with: the CRC for Construction Innovation; the SBEnrc; the International Alliance for Interoperability (now buildingSMART); and through a series of ARC Linkage projects (in conjunction with QUT and RMIT). Additionally links with contractors, vendors and suppliers; and industry-wide organisations such as NATSPEC, have been an important part of the integrated approach to R&D.

4.2. Analysis of associated organisational capabilities

Evidence of **inbound absorptive capacity** is apparent in the exploitation, assimilation and transfer of knowledge, and its acquisition from external sources. The capacity for technological development is demonstrated in the evolution from CADD to BIM to IP including leveraging broader potentials through digital model development; environmental modelling; brief development; and model server development. This capacity is also

evidenced in its ability to adapt knowledge through a high level of technological specialisation – as evidenced in the specialists engaged within the QPS's CADD team, and through links with key external specialists. QPS have also taken advantage of noteworthy economies of scale being a fully commercialised business unit within the Queensland Department of Public Works with a strong multi-disciplinary team delivering much of the State's building infrastructure.

Regarding **features of open innovation** the majority of interviewees shed light on an abundant underlying knowledge landscape and outbound flows of knowledge and technology. Regarding **the nature of this open innovation**, inbound innovation is evident in: (i) knowledge acquisition and its exploitation - through informal, formal and integrated R&D activity which is actively embedded into project outcomes and translated into broader industry benefit; and (ii) the enhanced effectiveness of this technology. **Benefits of an open innovation approach** for the workplace are apparent in the capabilities of the people involved (including software-specific specialists and discipline leaders with the ability to integrate new techniques into project delivery process); and the level of interest of team members (enhanced through alpha and beta testing new products and methods).

Base on these findings the following pathway to innovation has been identified (Figure 4).

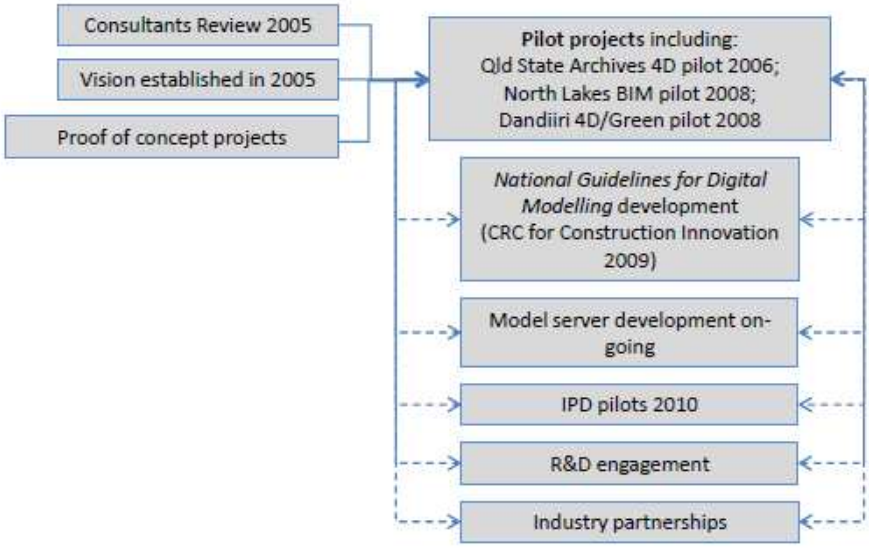

Figure 4 – Pathway to innovation

5. Conclusions

Findings of the analysis are two-fold. Analysis of the implementation revealed several key drivers including a central focus on productivity with the coupled requirement for new implementation activities and processes. This included a number of drivers yet to be implemented such as embedding IPD into business and procurement mechanisms. The incremental adoption approach was validated with beneficial outcomes on several projects on which specific aspects of BIM were implemented. Significant barriers were experienced in line with barriers and challenges identified in current literature in this field, including a lack of knowledge and an indifference or even resistance to change. This was countered within

Project Services by the establishment of a strong vision which guided implementation from 2005.

Analysis of organisational capabilities reveal an organisational focus on several areas including: (i) strategic decision making including the empowerment of internal innovation leaders and champions; (ii) the acquisition and exploitation of knowledge; (iii) product and process development (with a focus on efficiency and productivity); (iv) organisational learning; (v) maximising the use of technology; and (vi) supply chain integration. Key elements of this approach include pilot projects, external researcher engagement, industry partnerships and leadership. Additional areas where there was a high level of focus on several criteria including: clients with innovative demands; industry push; and supply chain integration. Together this provides a powerful cross-section of mechanisms through which benefits of innovation can continue to be maximised.

Queensland Project Service's adoption of BIM and important formative steps towards IPD has been a long-term commitment driven by key champions and leaders within that organisation, with executive support. The criteria discussed above illustrate areas in which this activity has been successful and areas from which potential future benefit could be obtained. These findings are reinforced by industry and academic literature including (Allen Consulting 2010, UK Cabinet Office 2010, and Owen 2012).

Whilst QPS have not formally tracked performance the following criteria can be considered as important, based on case study findings: reduction in RFIs; ; improved client understanding through visualisation; improved productivity (delivery on time, enhanced product for same budget); integrated practice (reduction in clashes); supply chain collaboration; staff retention (through skills enhancement and workplace satisfaction).

The leading initiatives undertaken by Queensland Project Services over the past decade may be considered as providing a proof-of-concept of this direction. This leadership has established the basis for industry reform that is advancing towards more productive delivery of public buildings in Australia.

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Concept of a Holistic, Life-Cycle Oriented Yield, Cost Planning and Controlling Process Model

Magdalena Proyer[1], Gerhard Girmscheid[2]

Abstract

In times where high competition, low profit margins, tight time project schedules and cost overruns dominate the construction industry, life-cycle oriented design as well as holistic yield and cost planning in combination with controlling processes are the crucial factors for project success. Project modifications often cause cost overruns and a decrease in yield during late design stages and construction. This is due to the fact that in the early design phases, where the project strategy is developed and modifications can still be carried out with low effect on the actual costs and the actual schedule, project targets and building requirements are not yet clearly defined. This paper presents the concept of a holistic, life-cycle oriented yield, cost planning and controlling process model, targeting the planning process of building projects. The model is built on a mathematical basis covering all project phases, where life-cycle oriented income, cost and yield planning is adjusted according to the system standard, the system targets and requirements by means of multi-criteria system optimization. The holistic, life-cycle oriented yield, cost planning and controlling process model is directly interfaced with the customer targets and system requirements to enable a sustainable financial success of the project in all planning phases, while supporting the decision makers in deciding between “must have” and “nice to have”. At each project phase, following procedures are carried out: the determination of system requirements and integration into the system, the life-cycle oriented estimation of income, costs and hence the net present value and yield, a system optimization by multi-criteria decision analysis and a target check. A holistic and cybernetic approach allows the controlling of life-cycle costs, yield and target accomplishment, at each project phase, as well as the application of steering measures in case of deviations. The holistic, life-cycle oriented yield, cost planning and controlling process model is an important support tool for decision-making, within a life-cycle oriented approach. The model enables the determination of sustainable system requirements as well as cost planning, reporting and controlling, through all stages of the project with a continuous system optimization.

Keywords: construction management, life-cycle cost planning, cost controlling, requirements-engineering, multi-criteria system optimization.

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1. Introduction

Today's construction practice is characterized by continuous cost overruns, time and time again. Frequently, investment targets, initially defined by the client, are continuously exceeded during the planning and construction process. In many cases, the influence or rather the endangerment on the project's outcome and yield isn't analyzed and considered early on. This can be observed not only in small projects, but also in large-scale projects in the private as well as in the public sector. Particularly, when concerning large-scale projects, although there may be a high concentration of specialists working on those projects, cost overruns are all too common. Nevertheless, there are professional clients and project managers, who have the means next to the formal and intuitive ability to manage projects, according to a target oriented cost controlling process.

Looking into the field of construction management research, there aren't any holistic and cybernetic concepts for the yield and cost controlling process, which control the investment costs through the whole planning and construction process, based on a life-cycle oriented income, yield and cost prediction, in accordance with a well-grounded requirements engineering. Considering the above in conjunction with the current situation in construction practice, there is a high potential for system requirements optimization, interactive cost optimization and cost controlling, regarding the building's system requirements based on the customer targets for all stages of planning and construction.

Taking up this issue, the concept of a holistic, life-cycle oriented yield, cost planning and controlling process model (LYCPC-model) will be presented in this paper. The LYCPC-model uses the methodology of multi-criteria decision analysis to evaluate qualitative and quantitative criteria at each phase of the project, allowing the project planner to control the system requirements, based on the customer targets, and costs by making corrections, if necessary. Using the approach of the LYCPC-model, costs and system requirements of a building project can be optimized ensuring a successful investment and a predefined yield.

2. Life-cycle oriented cost planning and requirements engineering

A well-grounded life-cycle oriented cost planning and cost controlling has to be implemented right at the beginning of a project and has to be pursued systematically with adequate tools for each project stage. Girmscheid & Motzko (2007c) describe the cost planning and controlling process very detailed for Switzerland and Germany, including a detailed cost calculation. In practice, there are clear structure systems to build upon a mathematically oriented cost controlling process model. These are often published in national standards. In Switzerland for example, the Swiss Center for Rationalization in Construction CRB (2009) provides standards, which enable a systematic and hierarchic classification and a stepwise subcategorization of construction costs in the planning process. The published standards also comprehend corresponding cost values from reference projects. In Germany, the construction cost information center of the German architects' chambers BKI (2012) releases a comprehensive collection of statistic cost values for buildings, building elements and positions with the correlating cost structure. Meyer-Meierling (2010) describes the tasks and levels of cost planning according to the Swiss project phases [SIA (2001)]. Girmscheid

(2007a; 2007b) proposes a cost model with a project phase related procedure and the implementation of life-cycle costs. The model controls the fulfillment of the customer stipulated targets with regard to the system requirements and the investment costs as a function of the life-cycle oriented yield.

A life-cycle oriented yield and cost approach is becoming more and more important. This is largely due to the efforts in more energy efficient building practice and a correlated reduction of energy costs. In a calculation model, Pelzeter (2006) describes the influence of geographic location, design and environmental aspects on the paying structure during the life cycle of a building. In correlation with a life-cycle oriented approach for the reduction of energy costs, Weizsäcker et al. (2009) mention that a shifting of the planning process to earlier project stages is crucial for a successful project outcome. Girmscheid (2010a; 2010b) has widened the approach to monitor and actively control the customer targets at each design stage by developing the system requirements interactively with the cost budgets of the customer, with regard to the life-cycle return on investment. The LYCPC-model is built on the target and system requirements process model [Girmscheid (2010a; 2010b) and Krönert (2010)], which implicates an early definition of targets as well as requirements and therefore an integration of the requirements-engineering process into the planning process of construction projects. The LYCPC-model ensures that the minimum system standard will always be targeted in case of cost correction due to overruns, to secure the attractiveness of the target rent. Additionally, during the advanced detailing of the planning, it enables the decision maker to differentiate between nice to have and must have, in case of divergence between system standard and target cost. Due to this holistic approach the LYCPC-model differs from pure target cost control.

3. Research Methodology

The Research Methodology of the presented holistic, life-cycle oriented yield, cost planning and controlling process model is based upon the hermeneutic research approach according to Girmscheid (2007d). Building on Popper's "Three-World-Theory" [Popper (2002)], the construction management sciences have to be classified as world three, products of the human mind. Constructivism [Glasersfeld et al. (2007)] is used for the development of the theory and logic driven deductive model. System theory according to Bertalanffy (1973), cybernetics according to Ashby (1971) and Wiener (1991), and methods from operations research [Winston (2004)] build the theoretical reference framework.

The holistic, life-cycle oriented yield, cost planning and controlling process model is developed in a generic, logic driven and deductive way, over the life-cycle phases of construction projects. Its structure is theory-driven and based on a mathematical approach. The system theoretic modeling concept consists of

- the project phases,
- a cybernetic requirements management,
- a life-cycle oriented approach to income, yield and cost planning and
- a multi-criteria system optimization.

Besides the system theoretic modeling and demarcation of the contents, a dynamic and iterative controlling mechanism is carried out, in form of control circuits. This cybernetic process is repeated at all phases of the project and provides target oriented balance and steering between the intended value, the benefit and costs.

4. Concept of the holistic, life-cycle oriented yield, cost planning and controlling process model (LYCPC-model)

The concept of the holistic, life-cycle oriented yield, cost planning and controlling process model enables project developers/planners/managers, total service contractors, system providers and so forth, to counsel the client in all his decisions, with a clear, transparent and holistic yield and cost steering process. This includes the identification of consequences regarding the yield as a function of the required system standard (requirements), to achieve a sustainable yield and related investment costs. In particular, necessary requirement modifications have to be distinguished in reference to the yield, effecting the whole life cycle of a building.

4.1 Cybernetic cost controlling and its effect on cost compliance

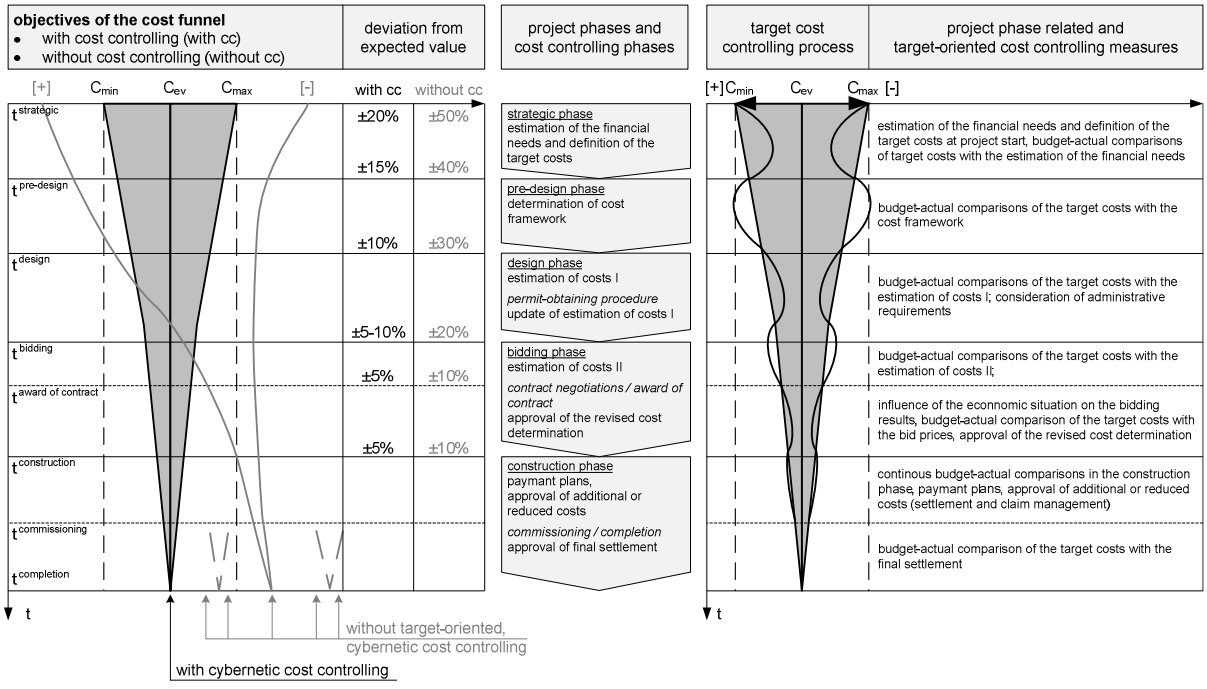

Figure 1: Cybernetic cost controlling and its effect on cost compliance according to the project phases [referring to Girmscheid (2007a)]

Figure 1 shows the effect of target-oriented and holistic yield and cost controlling on cost compliance, according to the various project phases. The cybernetic procedure, which contains control circuits (budget-actual comparisons) at each project phase, guarantees that deviations from the cost target and their triggering causes can be detected in good time. Especially in early project stages, the decision bandwidth is still broad. This gives the client, respectively the project manager, the option to develop the project in accordance with the

target cost margin and requirements. According to the cost funnel (figure 1) the influence possibilities on the development of costs, according to the system standard, become smaller with the project's progress, where major changes cause additional costs.

4.2 System theoretic structure of the LYCPC-model

In order to provide an adequate and clear application in practice, according to project progress, the holistic, life-cycle oriented yield, cost planning and controlling process model (figure 3) is composed of two process levels:

- the primary project developing process and
- the LYCPC module processes.

The primary project developing process describes the model over the course of time and consists of the different project phases, namely strategic phase, pre-design phase, design phase, bidding phase, construction phase and operation phase. They allow for a holistic and cybernetic connection over time. Hence for each of them, a milestone, which contains specific targets concerning costs, time, quality and so forth, must be achieved, in order to progress to the next project phase. In this primary project developing process, the LYCPC module processes are embedded. They are linked with each other, so that each LYCPC module process requires the output of the previous one, while providing the input for the following one. The linkage and dependencies mentioned above provide a structured procedure during the primary project developing process, i.e. during all the project phases.

The LYCPC module processes (figure 2) are either assigned to the target oriented planning phase, which includes requirements-engineering, estimation of income, costs and yield, or to the controlling and steering oriented planning phase, which comprises multi-criteria system optimization and a target check.

LYCPC MODULE PROCESSES	PHASES
• determination of system requirements and integration into the system, • prediction and estimation of income, • prediction and estimation of costs, • estimation of the net present value and the yield,	target oriented planning phase
• system optimization by multi-criteria decision analysis and • target check.	controlling and steering oriented planning phase

Figure 2: LYCPC module processes

In figure 3, the holistic, life-cycle oriented yield, cost planning and controlling process model is shown with the detailed primary project developing process and the detailed LYCPC module processes.

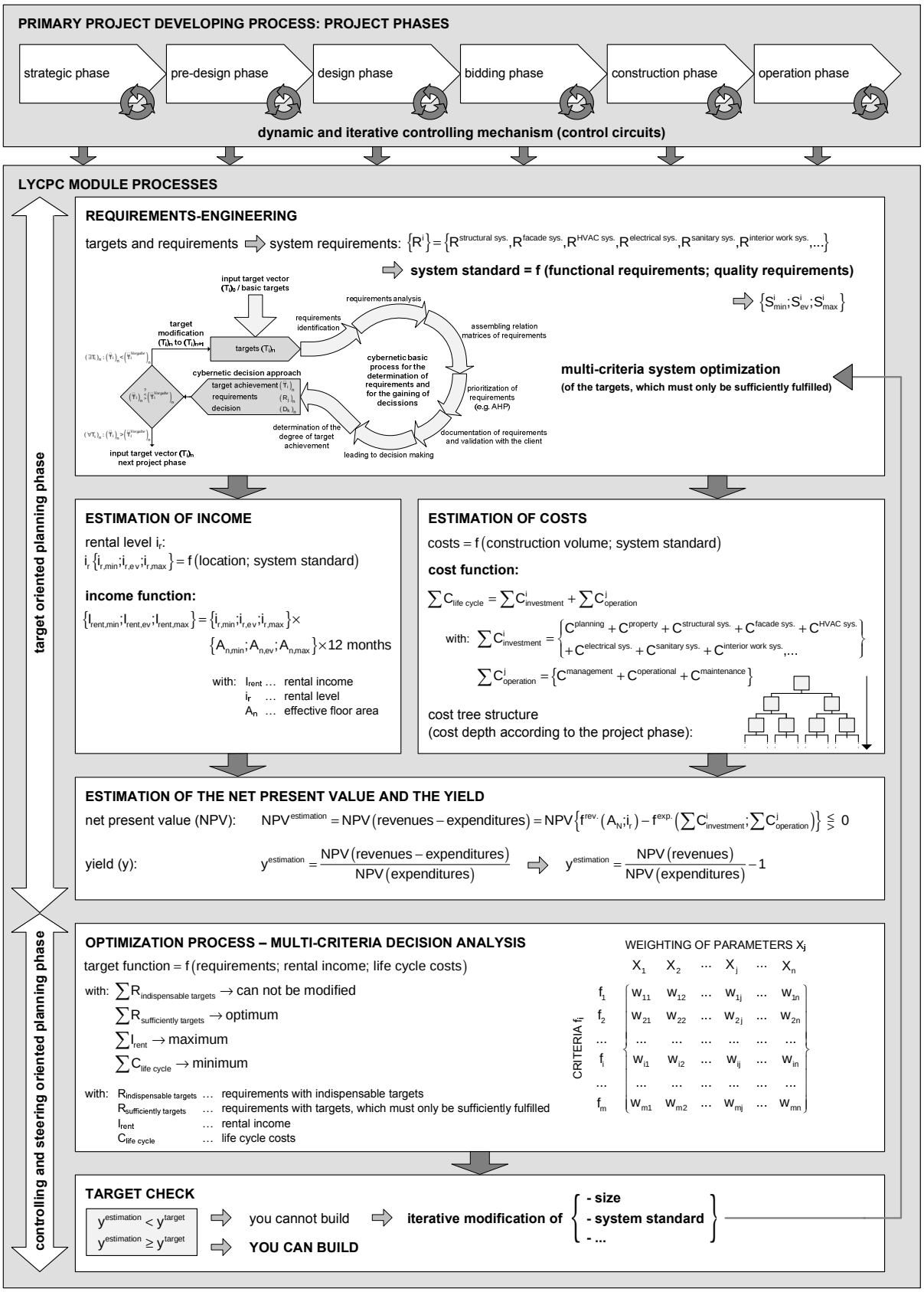

Figure 3: Holistic, life-cycle oriented yield, cost planning and controlling process model (LYCPC-model)

4.3 Contents and procedure of the LYCPC-model

In the strategic planning process, the client or rather the project manager has to define the project portfolio, including geographic location and project type, as well as the target yield. Based on these criteria, a target level is defined and compared to an ascertained market demand. The investigation results must be evaluated and positive development potential needs to be identified. This constitutes the basis for adequate property acquisition. Furthermore, the system standard and the rental level for the potentially to be developed property, result from the geographical location of the property, the life-cycle oriented attractiveness for the user and the segment of demand.

Already at this project stage, targets and requirements have to be defined with a generic and axiomatic requirements-engineering. Girmscheid (2010a; 2010b) defines and differentiates between user requirements, client or investor requirements, environmental requirements, site and building-ground requirements, regulatory requirements (standards and laws), design requirements and construction requirements. Having obtained them, they have to be transferred into system requirements $\left(R^{i}\right)$:

$$\left\{R^{i}\right\}=\left\{R^{\text{structural sys.}},R^{\text{facade sys.}},R^{\text{HVAC sys.}},R^{\text{electrical sys.}},R^{\text{sanitary sys.}},R^{\text{interior work sys.}},\ldots\right\}.$$

These are classified into functional requirements and quality requirements, for instance architectural, technical, HVAC (heating, ventilation and air conditioning) and finishing quality, which consequently determine the system standard. Thereby, it is important to note that the system standard fluctuates in a certain range:

system standard = f (functional requirements; quality requirements) → $\left\{S^{i}_{min};S^{i}_{ev};S^{i}_{max}\right\}$.

To obtain a sustainable requirements-engineering, the target achievement $\left(T_{i}\right)$, the requirements $\left(R_{j}\right)$ and the decisions $\left(D_{k}\right)$ have to be determined and verified in a cybernetic requirements-engineering development process at each project phase. [compare Girmscheid (2010a; 2010b)]

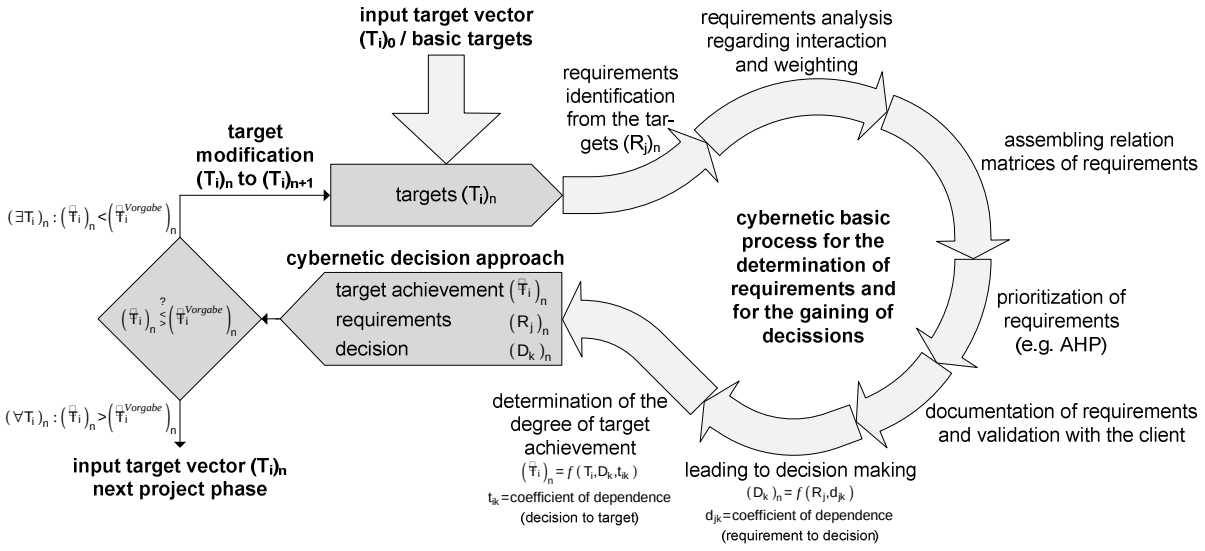

Figure 4: Module process "requirements-engineering" [referring to Girmscheid (2010b) and Krönert (2010)]

In the next step, building on the system standard and the geographical location of the building project, the rental level (i_r) can be assessed and the future rental income predicted, at the time of observation:

$$i_r \{i_{r,min}; i_{r,ev}; i_{r,max}\} = f(\text{location; system standard}).$$

Much in the same way as the rental level, the size of the effective floor area (A_n) can fluctuate in a certain range, corresponding to the range of the defined system standard. Hence the rental income per year (I_{rent}) can be calculated:

$$\{I_{rent,min}; I_{rent,ev}; I_{rent,max}\} = \{i_{r,min}; i_{r,ev}; i_{r,max}\} \times \{A_{n,min}; A_{n,ev}; A_{n,max}\} \times 12\,\text{months}.$$

Utilizing these interval approaches, the client and project manager gain the decision spectrum, in which target-oriented decisions can be made, implementing a cybernetic controlling process.

For the calculation of the net present value, concerning the life cycle of the building and hence the yield, costs for the construction phase $(C^i_{investment})$ as well as for the operation phase $(C^j_{operation})$ need to be calculated. The cost prediction is, similarly to the income prediction, bound to some uncertainties and moves within a certain range. The client and project manager must realize that the cost values for cost calculation need to be adapted to the system standard of the building and subsequently multiplied with the exact quantities:

$$\text{costs} = f(\text{construction volume; system standard}).$$

The life-cycle oriented cost calculation contains the calculation of investment costs for the construction phase and operation costs for the operation phase:

$$\sum C_{\text{life cycle}} = \sum C^i_{investment} + \sum C^j_{operation}.$$

Looking at the calculation of investment costs, the cost structure follows the structure of the building system and can be arranged as follows:

$$\sum C^i_{investment} = \left\{ \begin{matrix} C^{\text{planning}} + C^{\text{property}} + C^{\text{structural sys.}} + C^{\text{facade sys.}} + C^{\text{HVAC sys.}} \\ + C^{\text{electrical sys.}} + C^{\text{sanitary sys.}} + C^{\text{interior work sys.}}, \ldots \end{matrix} \right\}.$$

Quantities of the different construction units need to be determined and then multiplied with cost values obtained from reference projects. While doing so, it is essential to investigate cost values according to the system standard and geographic location of the project in order to achieve meaningful results. When calculating the investment costs in the LYCPC-model, a cost tree structure according to the building system has to be followed, in order to support a holistic and cybernetic project progression. This allows cost tracking at every project stage and in case of deviations, the identification and analysis of cause and effect. With the mentioned holistic and cybernetic approach, cost deviations are detected early and consequently regulatory measures can be initiated accordingly. The cost tree structure for the calculation of an exterior wall, as well as the correlation between cost depth and project phase, is shown in figure 5.

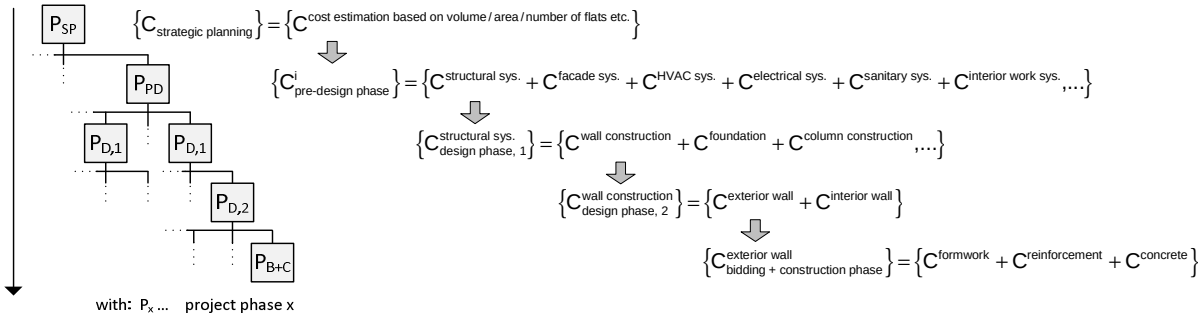

Figure 5: Cost calculation according to a tree structure

In a further step the costs for the operation phase $\left(C^{j}_{\text{operation}}\right)$ have to be calculated. They contain management costs, operational costs and maintenance costs and have to be discounted to the time of observation:

$$\sum C^{j}_{\text{operation}} = \left\{C^{\text{management}} + C^{\text{operational}} + C^{\text{maintenance}}\right\}.$$

Management costs (for example costs for administration) and operational costs (for example costs for cleaning) arise continuously. Additionally to these, costs for maintenance incur at different points of time. They include costs for smaller measures, which recur in certain time intervals like painting walls, window frames and doors or sanding parquet floors, and costs for significant measures like the renewal of the roof, the windows or the heating installation. Significant measures should be carried out at the same time in order to realize possibilities for a system optimization, to use synergy effects and consequently to achieve cost reductions.

Based on the results from the life-cycle oriented income and cost prediction, the net present value can be estimated by discounting the predicted costs and the predicted income to the time of observation.

$$\begin{aligned} NPV^{\text{estimation}} &= NPV\left(\text{revenues} - \text{expenditures}\right) \\ &= NPV\left\{f^{\text{rev.}}\left(A_N; i_r\right) - f^{\text{exp.}}\left(\sum C^{i}_{\text{investment}}; \sum C^{j}_{\text{operation}}\right)\right\} \ \begin{matrix} < \\ > \end{matrix}\ 0 \end{aligned}$$

If the estimated net present value $\left(NPV^{\text{estimation}}\right)$ is higher than zero, the yield $\left(y^{\text{estimation}}\right)$ can be calculated:

$$y^{\text{estimation}} = \frac{NPV\left(\text{revenues} - \text{expenditures}\right)}{NPV\left(\text{expenditures}\right)} \quad \longrightarrow \quad y^{\text{estimation}} = \frac{NPV\left(\text{revenues}\right)}{NPV\left(\text{expenditures}\right)} - 1$$

Having obtained these results, the system can be optimized by using the methodology of multi-criteria decision analysis. While doing so, the project targets, especially the indispensable targets (for example the defined yield) must be achieved. The application of multi-criteria decision analysis into the planning process of a building project offers new possibilities to optimize qualitative as well as quantitative criteria, while a certain cost margin can be assured. The system can be optimized for instance either by using other materials, changing the floor plan or by making changes in the architecture. In case of cost deviations, the targets, which must only be sufficiently fulfilled, need to be modified and optimized in order to reach the indispensable targets, such as a certain yield or a defined system standard. The existing influencing opportunities, utilized for controlling the system standard

and the cost development, are identified and then formulated mathematically using functional dependences. Hence, possibilities for design and action including their effect over the life-cycle of a building are shown, beginning in the strategic phase up to operation. The process of a cybernetic controlling process model is provided by control and iteration circuits, which ensure target control by considering higher level information pertaining to the progress of the project.

As mentioned above, the cybernetic procedure of the model demands a target check before advancing into the next project phase. Therefore, if the calculated yield is higher than or equal to the target yield of the customer $\left(y^{estimation} \geq y^{target}\right)$, the project can be carried out successfully, which means passing on to the next project phase. If the calculated yield is lower than the initially target yield of the customer $\left(y^{estimation} < y^{target}\right)$, the project cannot be carried out successfully and consequently, a system optimization must be conducted alongside a repetition of all LYCPC module processes. The process repetition must be carried out until the yield is higher than or equal to the initially determined yield $\left(y^{estimation} \geq y^{target}\right)$ in order to ensure the client or rather investor a sustainably successful investment. Otherwise, the project must be terminated or retargeted.

By following the above described module processes during all phases of project, the project manager can build upon a solid basis. The LYCPC-model enables the identification and implementation of requirements at early design phases, so as to optimize the correlation with the cost and income side. In combination with a holistic controlling process, the model ensures the detection of target deviations in good time and offers the option to initiate steering measures.

5. Conclusion and outlook

This paper has presented the concept of the holistic, life-cycle oriented yield, cost planning and controlling process model (LYCPC-model), a new holistic approach to cost management and requirements engineering. A major good of the model is to optimize the relation between the requirements of a building and its investment and maintenance costs to achieve a specified yield. Based on the holistic, cybernetic cost controlling process model [Girmscheid (2007a; 2007b)] and the target and system requirements process model [Girmscheid (2010a; 2010b) and Krönert (2010)], the LYCPC-model consolidates cost planning and requirements-engineering by means of optimization methods. The LYCPC module processes, as described in this paper, will be developed in further detail. Thereby, the focus will be laid on the optimization process. For this purpose, the methodology of multi-criteria decision analysis will be used, as it allows the consideration of quantitative and qualitative criteria at the same time. Furthermore, the linkage, dependencies and interaction among the LYCPC module processes will be discussed, as, for example, a modification of requirements always causes cost changes. The presented concept of a holistic, life-cycle oriented yield, cost planning and controlling process model is an important step concerning target achievement and cost control, especially when considering the realization of large-scale building projects. The model enables cost controlling during all project phases and the identification of cost or quality divergences at early stages and makes timely steering measures possible.

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The Brazilian Design Manager Role and Responsibilities after the BIM Process Introduction

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Abstract

The introduction of Building Information Modelling (BIM) in the Brazilian construction industry has raised a discussion about various topics through forums organized by professional associations, unions and universities. The design management topic has been discussed by a group led by researchers of the University of Sao Paulo and senior professionals. This group verified the growth in the number of interfaces between players and tasks related to design production in BIM, which have generated an increase in management responsibilities for the design coordinator. These realizations raised questions regarding the current management and communication practices, required to evolve to a collaboration scenario with the implementation of BIM.

In this context, we present the development of "The Design Manager Responsibilities Guide" (DM Guide) and its structure. The guide is based on IDDS four pillars: Collaborative Process; Enhanced Skills, Integration and Automation Systems and Knowledge Management. The design manager responsibilities are approached in the context of the Real Estate Developer. The development methodology for the DM Guide is a discussion by a panel of specialists comprising construction players, facilitated by the academy through regular meetings.

Keywords: Design Management, Building Information Modelling, BIM initiatives.

1. Introduction

In the last 10 years, papers and discussions about BIM (Building Information Modelling) and its associated technologies have increased significantly, both in academic and industry contexts. However, most of the discussions and references have focused on technological aspects, such as software and interoperability tools, information flow, strict language, parametric objects, etc. Even though all of these themes are relevant, the discussion about process and design management in the BIM context has been set aside.

According to Fox and Hietanen (2010), several researchers focused their studies on interoperability issues for BIM software and tools. However, more recently, there has been a number of researchers realizing the relevance of design process improvement, especially

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inter-organisational work handbooks, in order to make technology application more feasible. Owen, Palmer et al. (2009) advocate that technology exists to support processes, which exist to support the creation and maintenance of coherent and important information, which in turn supports the collaboration in the project team. Therefore, the definition of process protocols and standards is required to achieve full collaboration and BIM highest potential.

To illustrate this discussion, a review is made of BIM implementing initiatives in countries such as USA, Finland, Norway, Denmark, Singapore, Hong Kong and UK. Regarding Brazil, the discussion focuses on the importance of defining policies and strategies to implement BIM in the construction sector.

According to Wong et al. (2010), in Finland, AEC researches found that companies are disappointed with technology adoption due to the high costs of investment and the low immediate benefit return. For the authors, this is verified in contexts in which project processes were not reviewed for the adoption of BIM. In this sense, they conclude that, for achieving a successful BIM implementation, efforts towards technology, people and processes should be equivalent. Another aspect emphasized by these authors is the importance of discussing processes and work handbooks preferably in inter-organisational environments, involving most of the project players throughout the project lifecycle.

In this context, this paper reports the process of writing a “Design Manager Responsibilities Guide” (DM Guide). The aim of the guide is to define all the design manager’s responsibilities and tasks throughout the building project life cycle with BIM application. The guide is currently being developed by the Design Management Workgroup of Escola Politécnica, University of São Paulo, and it is a part of the PhD research named “Guidelines to the Design Management area of Real Estate Developer Companies - structure, people, technology and processes” as of the Master’s research named “Models of Collaborative Contracts for Integrated BIM Projects”. The workgroup comprises AEC professionals from architectural firms, construction firms and clients as well as software developers that discuss the BIM project process as it has been implemented in Brazil, under the coordination of this paper authors.

2. Literature Review

2.1 Integrated Design and Delivery Solutions

For Owen et al. (2010), due to the construction sector inefficiency, from product development to construction and building operation, concepts and tools issued from Lean Construction, Lean Design and Information Technology have been undertaken to improve processes and add value to construction projects. Nevertheless, according to the authors, these practices and technologies have been applied singly, and until 2010, initiatives to integrate them had not been proposed.

As an example of low integration, BIM introduction practices have been similar to the introduction of CAD (Computer Aided Design); however, BIM could change the current practices, since its associated technologies improve building project management practices

along its life cycle. In this context, to potentiate the use of BIM, a critical analysis to the current implementation practices should be performed.

Aiming at integrating actions and good practices, such as Lean, BIM, IPD and others, the International Council for Research and Innovation in Building and Construction (CIB) elected the IDDS (Integrated Design and Delivery Solution) as a priority theme, through the framework for an integrated and coordinated merge of people, process and technology issues in order to conduct a radical and continuous transformation in the construction industry.

According to the authors, several elements of the IDDS are currently being explored in largely isolated parts of the academy and of the industry. The IDDS approach also challenges traditional industry structures and contractual process, as it both highlights current inefficiencies and facilitates their resolution, making the most of the workforce collaborative intelligence. The implementation of IDDS will move the industry towards an ongoing and iterative way at each of the projects phase: conceptual planning and making business case, all the design parts, supply chain management, construction, commissioning, operation, retrofit, and decommissioning.

For Gray and Hughes (2001) and Hjelseth (2010), design management complexity increases as the number of specialists grow. Analysing the design process from the information exchanged point of view, the greatest design manager challenge is to provide timely information and within the requested quality, aiming to meet the design team needs and the final client demands, through collaborative approaches and tools throughout the project life cycle.

As an example of low integration in the construction sector, Nederveen and Ridder (2010) emphasize that due to the construction sector fragmentation, building projects are characterized as multifunctional structures, with high level of risk tied to cost management, inefficiencies in communication processes, among others, which often trigger stakeholders' dissatisfaction. To Hjelseth (2010), information exchange in the construction sector has been conducted with a low level of formalization, once in general the building information is scattered in various documents, such as descriptive memorials, blue prints, contracts and legal documents, which raises questions on information quality and availability.

In this context, Nederveen and Ridder (2010) proposed LBC (Living Building Concept) as an approach to the requested paradigm shift. In most cases, the construction product development occurs through demand-driven supply approach conduct, since the initial contact occurs between the client and the architect, who is responsible for translating the clients' needs into construction information. In the LBC approach, the suppliers are active players during the construction product development, since clients choices must be met within the library of components and systems previously developed. These components must be organized into a parametric object library, since the condition to apply LBC is the similarity between virtual and real world. From the components and system choices, a building information model should be built aiming to evaluate the performance and design solutions quality, from the clients' point of view.

3. METHODOLOGY

For the development of this paper, the authors conducted a literature review based on the IDDS (Integrated Design and Delivery Solutions) agenda. Also, having Succar's (2009) BIM Initiative field model in mind, a research through papers and publications in these themes that classified initiatives around the world was developed, and the same classification concepts were applied to Brazilian and the UK scenario.

The second part of the paper presents the work by the Design Management Workgroup from the University of Sao Paulo, on one of its current research themes, the production of a Design Manager Guide for BIM in Brazil. The workgroup methodology is presented in item 3.1.

3.1 Design Management Workgroup Methodology

This research group was an initiative of the design process management research group from the University of Sao Paulo, and consisted in regular meetings with the participation of the researchers and market players, such as designers, design coordinators, software industry representatives, and members of construction building companies.

The meetings took place every two weeks and the discussion was based on the Brazilian Design Manager Scope (2006), and on several international BIM guidelines and handbooks as references, as well as on the participants' experiences. The discussion involved the Design Manager tasks and responsibilities, and the analytic process was guided by a division of management tasks domains in four different fields: product management; design process management; communication management and modelling management.

At a second stage, specialists in specific AEC themes (planning, sustainability, constructability) will be invited to discuss the group production and evaluate its results; workshops in different Brazilian regions and with the academic community are going to be organized by the workgroup.

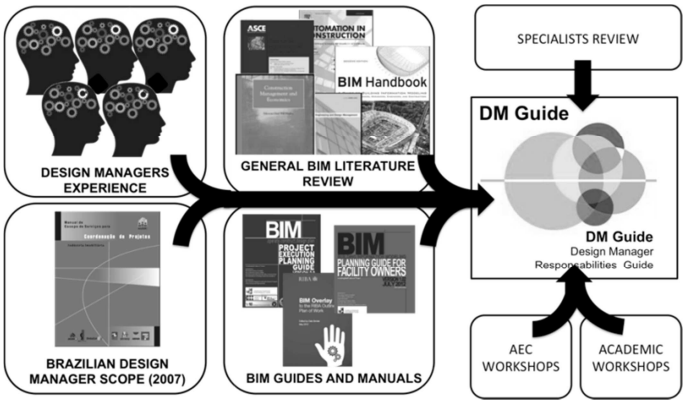


Figure 1: Workgroup Method

4. BIM SECTORIAL INITIATIVES: STRATEGIES AND MOBILIZATION

According to Wong et al. (2010), the BIM knowledge domain is expanding with its implementation in various countries. The authors present a review of BIM implementation process in six different countries (USA, Finland, Norway, Denmark, Singapore and Hong Kong), and classify their initiatives into the fields of policy, process and technology (Succar, 2009), where they identify the players and deliverables for each field. The six countries evaluated have developed more initiatives in specific fields (Wong, 2010), shown in Figure 2.

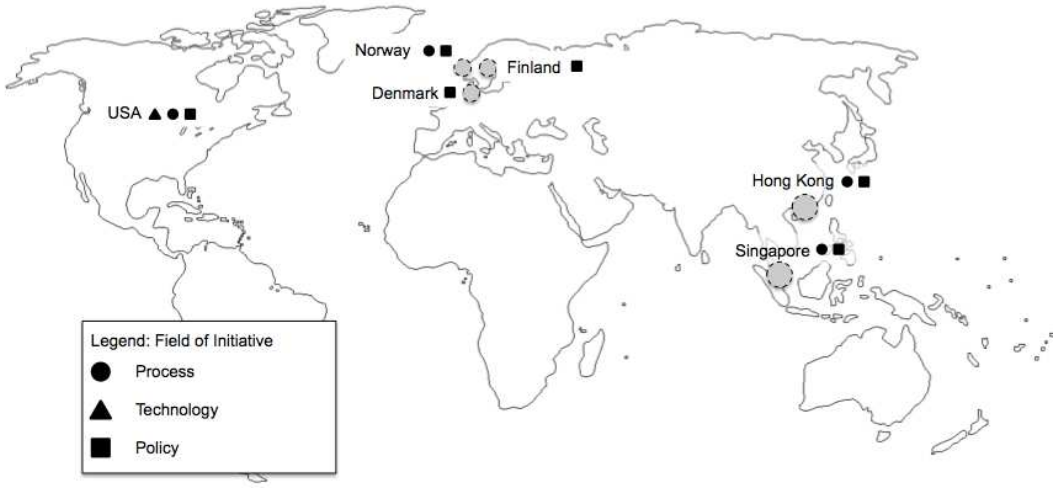


Figure 2: BIM Initiatives in the USA, Norway, Denmark, Singapore and Hong Kong according to Wong, 2010.

The USA have developed BIM initiatives within the three fields, which can be explained by the players from different sectors, such as government associated institutions, such as GSA (General Services Administration, responsible for BIM implementation in the public sector), NIST (National Institute for Standards and Technology) and many others, including research institutes, organizations and associations from the private sector.

In Denmark, public sector clients defined specific modelling standards and guidelines; in Finland, the effort dedicated to the development and use of IFC standards stands out in government initiatives. Also, BIM guidelines emerged as the result of an R&D project developed within industry players, ProIT.

Norway also developed BIM guidelines from a state client pilot construction project using BIM, and also has strong initiatives along the implementation of IFC standards and the definition of information exchange requirements. Within the process field, the building SMART initiative has a number of cross department projects working on converting and implementing BIM in building projects.

In Singapore, the use of an automated code checking system that reads IFC for project approvals has a strong influence in Policy initiatives, and also process initiatives have been implemented since 2007. In Hong Kong, the public sector have applied BIM technology for design, sustainability studies and construction coordination of its public housing projects. In

the process field, several companies have implemented BIM in their projects and have been using the technology for clash detection, design visualisation and evaluation, and also have a number of consultants providing implementation services.

Succar's classification model used in the six countries above, allows the identification of each countrie's strategy for BIM implementation, the probable responsible players and deliverables, and, by exclusion, helps identify the fields that are not being developed equivalently. This review methodology is used in this article to evaluate UK and Brazilian BIM initiatives, as follows.

4.1 BIM INITIATIVES IN THE UK

In 2011, the United Kingdom Government, through its Plan for Growth, highlighted the critical importance of an efficient construction industry for the economy. According to the Cabinet Office Report (2011), the construction industry in UK is highly fragmented, with over 300.000 businesses, of which 99.7% are SMEs and over 2 million workers. The sector has contributed, on average, with 7% of GDP and is worth about £110 billion per annum, through three main sub sectors:

a) Commercial and social infrastructure: (45% - public: 18%, private: 27%): projects are typically traditional construction with a mix of new building and refurbishment;

b) Residential (39% - public:13%, private: 26%): the public sector has a relatively small new building program compared to repairs and maintenance;

c) Infrastructure (16% - public: 6%, private: 10%): is typified by civil engineering works, long overall project durations and major programs are renewal/ maintenance.

As the scenario which forced the UK Government to rethink the construction sector strategies were based on studies which highlighted that the construction sector activities usually under-performs in terms of its capacity to deliver value, and that there had been a lack of investment in construction efficiency and growth opportunities, the prevalent inconsistent procurement practices, particularly in the public sector, aligned with low level of standardization and fragmentation of the sector had led to waste and inefficiency. As a solution, the UK Government proposed a four-year program to modernize the Construction Sector with two key objectives: reducing capital cost and carbon burden from the construction and operation of the built environment by 20%.

One of the strategy objectives was related to Building Information Modelling and was detailed in the Building Information Modelling Working Party Strategy Paper (March, 2011), which recommended a strategy to deliver a structure Government/ Sector capability to increase BIM adoption over a five-year horizon. For this, a Client BIM mobilisation and implementation group to drive the adoption of BIM across government was established to meet the requirement to attain fully 3D BIM collaboration (with all project and asset information, documentation and data being electronic) as a minimum by 2016. This group was named Building Information Modelling (BIM) task Group.

The working group recommended the “Push-Pull” as the strategy to adopt, supporting the “push” supply side of the industry to enable all players to reach a minimum performance in the area of BIM use, balanced by a “pull” from the client side to specify, collect and use the information derived in a value-adding way. The working group team was formed by construction player representatives, academics and software manufacturers. Its objectives were related to adopting BIM methodology benefits in construction as post-occupancy management, identifying the UK Government as a client who would need to encourage a number of BIM approaches as well as assess the potential of the government policy regarding BIM.

4.2 BIM INITIATIVES IN BRAZIL

The Brazilian AEC sector has only recently started BIM implementation , and the companies which have invested in this initiative in the past few years belong to the private sector. A number of Brazilian institutions have been developing study and workgroups aiming to discuss the implementation of BIM, and to promote its concept within the AEC community by promoting events and courses, but the concept of BIM is still not widely spread in the market.

Figure 3 shows a map identifying a number of BIM initiatives per region, identified in Brazilian research institutions with publications on BIM initiatives, some of them connected in a knowledge network for defining parameters and promoting BIM in the country. The data refers to papers published by Brazilian researchers on BIM in the Brazilian Information Technology Conference (TIC) in 2009 and 2011. The papers were organized into the following subjects: Design Process, Academic Diffusion, Technology and AEC Sector Diffusion. A total of 46 papers were analysed and 8 papers (16,7 %) were classified as Design Process, 7 papers (14,6%) as Academic Diffusion, 28 (58,3%) as Technology and 5 (5,4%) as AEC Sector Diffusion.

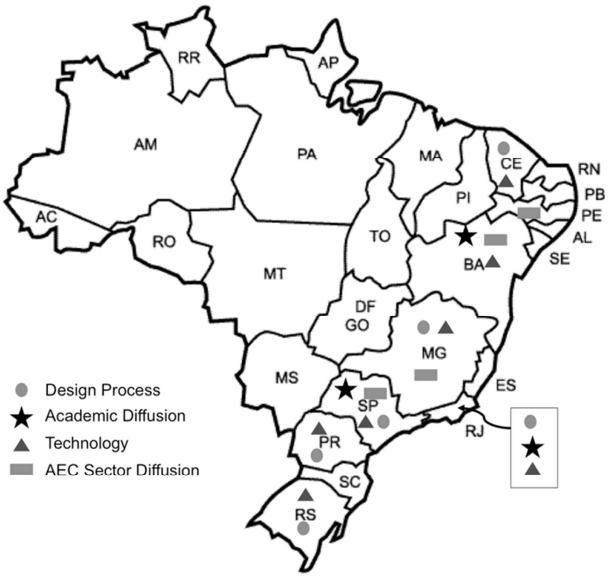


Figure 3: BIM initiatives in Brazil

There are five specific initiatives which have connected a significant number of researchers and AEC associations with specific purposes of BIM development in Brazil. They are described in Table 1.

Table 1: BIM Initiatives in Brazil

BIM Initiative	Initiative Description
BIM Interdisciplinary Group	In 2009, a regular discussion group was created on the initiative of AEC associations, opened to research institutions participation, AEC associations, institutions and private companies. This group was responsible for the development of those private companies knowledge of BIM and its processes, which led to the first real BIM project cases known in Brazil, further developed within the companies with consulting from members of the Interdisciplinary group.
BIM BRASIL NETWORK	This network is financed by CAPES, the Brazilian Federal Agency for the Coordination for the Improvement of Higher Education Personnel, and counted on the participation of four Brazilian Universities (USP, UFF, UFBA and UFPR). It was responsible for the inclusion of BIM disciplines in those universities graduate programs, and for promoting BIM research projects through scholarships. The production related to this group will be available for public access in their website, redebimbrasil.org.br.
SINDUSCON – SP (Sao Paulo State Contractors Union)	Sinduscon - SP is responsible for the annual BIM seminars, hosted in their headquarters since 2010. This event is known for bringing together representatives of all roles in the AEC chain, from designers to suppliers, clients and construction companies, investors and consultants. Its themes are compatible with the BIM scenario in Brazil, and companies implementing BIM often present cases with results, the positive and negative aspects of their implementation processes. The participation of international researchers and BIM consultants is also regular. These seminars are considered an annual event for every company and professional interested in BIM, a valuable opportunity for creating connections and sharing knowledge, and also discussing real case studies of implementation, preventing them from making the same mistakes as the companies who started the innovation curve.
BIM Standard Committee	The growing discussion and dissemination of BIM concepts led AEC institutions to identify the need of developing national standards, leading to the formation of a committee for developing BIM first standard in Brazil, NBR 15965-1 – Construction Information Classification System – Part 1.: Terminology and Structure, and Part 2.: Construction Objects Characteristics. These Standards define the vocabulary, the principles of the classification system and groups of classification for planning, design, management, construction, operation and maintenance, and should be observed in the elaboration of other standards which may rule and concern Building Information Modelling. The first part is in force since August, 2011, and the second part since August, 2012.
FINEP's TICHIS	FINEP – Project and Research Financer is a public company associated to the Brazilian Ministry of Science, Technology and Innovation (MCTI). In December 2010, a cooperative research network was formed with seven of the largest public universities in Brazil (USP, UNICAMP, UPM, UFRGS, UFPR, UFBA and UFC), financed by FINEP, called TICHIS: Information Technology and Communication Applied to Social Housing. The cooperative research network aims at developing innovative solutions for improving the quality and productivity of social housing constructions, focusing on BIM solutions, comprehending six main themes: (1) Web management, (2) Open standards for interoperability, (3) Digital design and conception, (4) Information technology and communication in construction management, (5) Integrated project management and IPD and (6) Information technology and communication for usage. These themes are reflected in the research subprojects, described in Table 2 herein and classified into BIM fields.

There are also isolated BIM implementation and development initiatives identified in professional associations and private companies. These initiatives, despite having a minor range, have helped the formation and shaping of Brazilian AEC professionals and, therefore, the implementation of BIM in the country. In this category, there are a few professional associations such as Agesc (Association of Design Managers and Co-ordinators), AsBEA (Brazilian Architectural Firms Association), SindusCon (Contractors Union), and software developers, such as Autodesk, Bentley and PINI. These associations and companies are responsible for several initiatives, such as BIM workshops and courses, promotion and sponsoring of BIM congresses, and contributing to the development of BIM national practices.

Table 2: Brazilian university research themes and BIM fields

University	Research project themes	BIM Field
USP – University of Sao Paulo	Construction site prototyping, multi-dimensional performance analysis, masonry modulation generative techniques for BIM, handbook for creating BIM components, BIM project management and collaborative contracts	Process, Technology and Policy.
UNICAMP - State University of Campinas	Augmented Reality, 4D simulation, project cost vs. performance analysis model, participatory design, BIM technology for decision making, design prototyping, model control parameters.	Process and Technology
UPM – Mackenzie Presbiterian University	Digital fabrication, model for multi-dimensional analysis of risk areas occupation, generative systems for design modulation, components library production, collaborative process methodologies	Process and Technology
UFRGS – Federal University of Rio Grande do Sul	Modelling of client requirements, augmented reality, construction control automation, 4D simulation implementation	Process and Technology
UFPR – Federal University of Paraná	Multi-dimensional performance analysis, environmental performance tool analysis, semi-immersive collaboration environment development, handbook for construction of BIM components by suppliers, augmented reality for simulating construction site, BIM and Lean for public projects, communication management through BIM.	Process and Technology
UFBA – Federal University of Bahia	Business model/project management model for social housing, procedures for complex geometric shaping in BIM, thermal performance analysis methodology development, laser scanning, collaborative project methodology model.	Process, Technology and Policy
UFC – Federal University of Ceará	Post-occupancy evaluation through BIM models, strategies for improving integrated management in social housing.	Process and Technology

4.2.1 Design Management Workgroup

The Design Management Workgroup is an initiative of the Research Group on Construction Technology and Management of Escola Politécnica (USP). It is an integral part of the PhD research named “Guidelines to the Design Management area of Real Estate Developer Companies: structure, people, technology and processes” as of the Master research named “Models of Collaborative Contracts for Integrated BIM Projects”. The workgroup gathers AEC professionals from architectural firms, construction firms and clients, as well as software developers, aiming to discuss the BIM process as it has been implemented in Brazil, under the coordination of this paper authors.

The first meeting was held in March 2012 and aimed to discuss the responsibilities of the Design Manager in the BIM context with a panel of design management specialists. Aiming

to attain the Design Management Workgroup objective and its context, the Brazilian Design Manager Scope (2006) was chosen to base group discussions.

This Scope service had been part of an initiative to develop a set of Design Services Scope, in the context of Brazilian Construction Policies which had aimed to improve the services quality into the construction chain as well as to maintain an ethic and reliable relationship in design contracts.

Since the first meeting, the Design Manager Workgroup has met 10 times and developed a document called “The Design Manager Responsibilities Guide” (DM Guide). The guide is structured throughout the Building Project Life Cycle and uses the four IDDS pillars to define design managers’ tasks. It is worth emphasizing that the DM Guide structure is addressed to the context of Real Estate Development projects.

5. The Design Manager Responsibilities Guide in Brazil: DM Guide

Before presenting the DM Guide, it is important to understand The Brazilian Design Manager Scope (2006) development context and its structure. In this handbook, BIM is slightly approached, since when it was developed, there had been few discussions about BIM in Brazil, most of it only in the academic field.

The Brazilian Design Manager Scope (2006) is a handbook structured upon design building life cycle phases: a) Product Conception; b) Product Definition; c) Design Interfaces Identification and Solution; d) Post-Design and e) Post-Construction. Each phase was divided into three services categories: i) essential services, which are applicable to all types of building projects; ii) specific services – applicable only to some specific building projects; iii) optional services, which are not part of the design manager basic responsibilities, but can be hired in order to add value to the project.

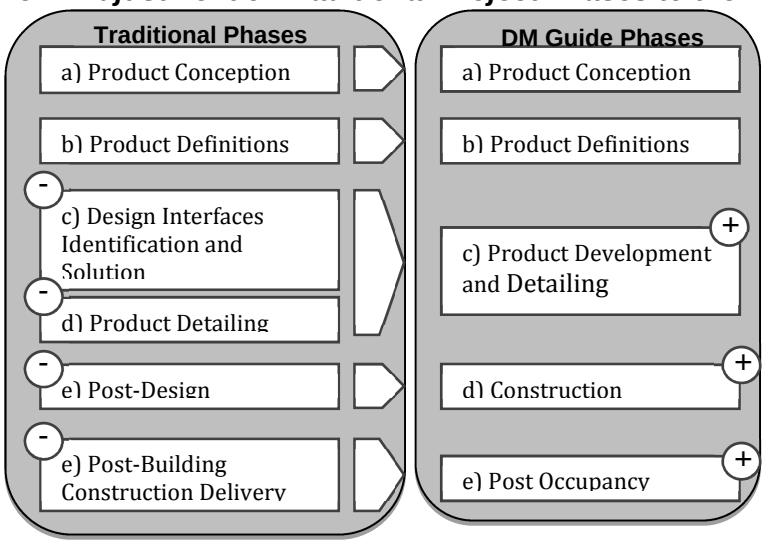
The development of the DM Guide is not a review of the Brazilian Design Manager Scope (2006). It is the result of a research that re-organises the Design Management tasks based on practitioners’ experiences, BIM literature review, and the analysis of international guides, such as the BIM Project Execution Plan Guide and BIM overlay to the RIBA outline Plan of Work.

5.1 DM Guide Structure

The DM Guide aims to define and to organize the Design Manager responsibilities in a context in which the design is developed by modelling processes. Additionally, the tasks are structured for planning and organizing the necessary information to design activities, making it available in time and with the quality required. It also aims to maintain information integrity along the building project life cycle. The guide is structured into 5 phases: a) Product Conception; b) Product Definition; c) Product Development and Detailing; d) Construction; e) Post-Occupancy.

Considering the design process evolution, some of the design phases proposed by the Brazilian Design Manager Scope (2006) were supressed (Design Interfaces Identification and Solution and Product Detailing), as demonstrated in Figure 4.

Figure 4: Adjustment of Traditional Project Phases to the BIM context



Product Conception tasks aim to support the Real Estate Developing Company to conceive the Building Design. For this, the Design Manager must understand what the developer's resources and needs are, including performance, quality costs, time and sustainability objectives, among others. This phase tasks help define product briefing and support the multidisciplinary design team conceptualize physical and occupational characteristics through geometric conceptualization. The identification of stakeholders as well as their demands and expectations is part of the design manager responsibilities.

After Product Conception, Product Definition tasks aim to support the feasibility studies. Once the Business Plan is approved, it supports modelling development to extract documentation for legal approval purposes, since the Brazilian government agencies responsible for building design and construction approval still work on a paper/document basis. Also, tasks referring to multidisciplinary design management support technological analysis and building construction system choices, considering cost, time, risk, quality, communication, sustainability and procurement.

In the Design Product Development and Detailing phase, the tasks aim to consolidate all the information required for building execution through the model and to support the modelling process in decision making as to construction strategies and methods. For the Preparation for Construction Execution phase, the Design Manager must support the construction team at operational and production plans, procurement process, and quality process plan, defining the resources and team responsibilities.

During the Construction phase, the DM Guide tasks support resolving construction managers' doubts, management of design changes and production simulation. The Preparation for Operation tasks aims to support the model preparation for facilities management.

Finally, Post-occupancy tasks support the post-occupancy evaluation and allow the feedback for the knowledge management system of the Real Estate Developer Company as well as the knowledge asset of the AEC players involved.

In each phase, management tasks were organized into four categories: a) Product Management; b) Design Process Management; c) Collaboration and d) Modelling Support.

Product management tasks aim to support the decisions referring to the building product from the aesthetic, functional and technical point of view, based on the developer and stakeholders constraints and cost requirements, time, quality, usability, operation, sustainability and constructability criteria. As to design process management, the tasks refer to the setting, contracting and evaluating the multidisciplinary design team, managing the design team activities, following costs and quality controls and other KPIs (product and management).

Collaboration tasks must enable communication and provide information integration for the decision-making marks along the design process and among all the agents from the design team and real estate developing company to the construction and facilities managers.

Design knowledge management tasks are part of the collaboration process along the project life cycle; even in the post-occupancy phase, the design manager must collect and organize the lessons learned through post-construction research, involving all the teams who participated in the project cycle different phases. The knowledge accumulated along the design phase must be fed into the Real Estate Developing company knowledge system. Modelling Support tasks aim to provision the BIM manager with all the necessary information for the modelling process.

At this point, the development of the Design Manager Responsibilities Guide is still in phase 1, and the tasks and process workflow defined so far are available at (http://www.iau.usp.br/pdconhecimento/melhorespraticas/?categoria=3).

The workgroup intends to continuously publish its results and production in academic meetings and scientific journals.

6. DISCUSSIONS

Analysing the BIM initiatives in Brazil, it is verified that there is low articulation among them. The discussion about BIM in Brazil, both in the Academy and in the Industry, started less than 10 years ago, and the existence of isolated initiatives is reasonable. However, it is important to highlight that, although the initiatives are not articulated, they are all relevant. Compared with the data presented by Wong et al. (2010) and the UK Government Strategy, the approach of these countries started with construction policies establishment as well as government requirements - as a major client of BIM implementation -, which does not correspond to the Brazilian reality.

The second interesting aspect of BIM initiatives in Brazil refers to academic researches. According to data shown in Part 4 and Figure 3, the Brazilian academic production in BIM is concentrated in the South, South-West and North-West states, and in four priority themes: Design Process, Academic Diffusion, Technology and AEC Sector Diffusion. Most of the papers (58.3%) published by TIC (2009 and 2011) were about technology.

For Fox and Hietanen (2010) and Owen, Palmer et al. (2009), processes and technology are co-dependent. In the BIM context, process protocols and standards are fundamental to achieve collaboration. Following this logic, it is important for the Brazilian Academic Community to re-evaluate their research strategies to include processes as well as AEC Sector Diffusion and Academic Diffusion themes.

The DM guide was developed under these assumptions and that in Brazil the BIM Manager and Design Manager responsibilities and skills must be better understood and defined. Through the DM Guide development, we perceived that both professionals are part of the Project Building Manager staff and they should work together in the BIM context process management to comply with stakeholders and clients constraints and requests.

7. CONCLUSIONS

The development of the Design Manager Responsibilities Guide is an important BIM initiative in the Brazilian scenario, given the few cases in which processes have been approached for the implementation of BIM in this country. As discussed in item 4, most Brazilian initiatives are towards the implementation of BIM technology, creating an unbalanced score for process and policy initiatives, recreating the Finn experience, which has shown high levels of disappointment by AEC companies.

Both academic researches that incited the creation of this workgroup emphasized the importance of defining the role of the design manager in the design process. They also emphasized the definition of project phase tasks and of the players involved, proposing a detailed workflow for the design process that can be used as a generic model for BIM implementation by Brazilian AEC companies.

Aiming to apply the DM Guide as a resource for BIM process implementation in Brazil, the next steps of the workgroup grow in importance, as they will validate the document as a referential set of guidelines for the AEC sector. After the discussion and first draft of the design process and design management tasks (Phase 1 of the DM Guide), the workgroup will promote three other phases for analysis and validation of the Design Manager Responsibilities Guide: Phase 2) Discussion with AEC specialist at each process phase; Phase 3) Promotion of workshops in different Brazilian regions; Phase 4) validation of the reviewed Guide with the academic community.

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Moisture risks arising from retrofitting – The safest technical solution is not always the best solution

Eva B. Møller[1], Niels-Jørgen Aagaard[2]

Abstract

In the coming years insulation in buildings will need to be retrofitted to save energy. The article focuses on the difficulty in choosing the best way of retrofitting the insulation as e.g. safety, aesthetics and costs are often prioritised differently in each project, depending on the context for the building and the building owner. As an example, the paper describes risks arising from retrofitting with emphasis on moisture safety, as high moisture levels may lead to health problems for the building users. The example illustrates the difficulty in obtaining moisture safety and energy savings at the same time when retrofitting by internal insulation.

However, moisture-related health risks are mainly personal, as they depend i.a. on age, gender and medical history. This raises the question of whether the building owner should be allowed to choose whatever he wants, with the risk of extreme prioritisations, or whether society should ban some solutions, because they may be too risky for some building users. On the other hand, can society afford to make all retrofitting safe also for the weakest? Based on a review of literature, the paper outlines how these dilemmas are described and handled in Denmark today. The aim is to operate with a combination of information on why some solutions pose more risks than others and descriptions on how the risks are reduced. The best solution is found by weighting potential energy savings, costs, aesthetics and health risks. Consequently, the best solution is not necessarily the safest technical solution; it depends on an evaluation by the building owner or user.

However, the risk is not quantified. To make the decision more objective in the future, a more quantified prioritisation might be possible by defining moisture safety classes for buildings, describing which buildings should only be used by people who are not prone to moisture-related health problems and which can be used by more sensitive users.

Keywords: Retrofitting of insulation, prioritising, moisture safety level, health, costs

1. Introduction

In Denmark, the expected life time of buildings is 70-100 years (de Place Hansen, 2010). Consequently, most buildings are retrofitted at least once during their life time. There are

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many reasons for retrofitting and they are often a combination of factors: a need of repairs, a desire for improved comfort and indoor climate, handling of social problems or improvement of energy performance (Møller et al., 2011). Retrofitting can be executed in many ways and typically differs on costs, aesthetics, structural design, robustness and moisture risk. One solution is rarely optimal on every parameter and therefore a building owner must prioritise. A solution can be unacceptable in one case, but be the best solution in another case. Consultants often suggest the safest solution. However, that solution may be expensive or change the appearance of the building and the solution would therefore be unacceptable to some building owners, while other building owners would prioritise safety more. Furthermore, authorities may have limits as regards what is acceptable from an aesthetic, economical and health point of view.

The paper outlines these issues with examples of moisture risk arising from interior insulation. In principle, most of the issues also apply to other risks and methods of retrofitting.

2. Designing moisture safe buildings today – acceptable solutions

Most countries have standards for structural design based on probabilistic modelling of loads and capacities (CEN, 2000), which include the level of acceptable risk. Moisture design, on the other hand, is in its infancy. WHO (2010) concluded: “Building standards and regulations with regard to comfort and health do not sufficiently emphasize requirements for preventing and controlling excess moisture and dampness.” There are standards describing humidity loads e.g. EN ISO 13788 (European Standard, 2001), but this standard is not referred to in the Danish Building Regulations and moisture safety is only described in very broad terms, e.g. that retrofitting must be moisture safe. However, it is not defined what is meant by moisture safe retrofitting. Consequently, an acceptable level of moisture is not defined.

Therefore, risk assessment today is based on professionals assessing different materials properties and measurements e.g. humidity levels and ventilation rates in existing buildings. By combining this with guidelines, experience, calculations and knowledge of the future use of the building, the professionals propose what solutions they believe to be acceptable.

Pietrzyk & Hagentoft (2008) proposed a method for estimating the probability of a design providing proper conditions in the building under various conditions. This was followed up by new initiatives such as IEA-ECBCS Annex 55 (2012) to develop and validate probabilistic tools for hygrothermal performance of energy retrofitting measures. The aim is to use probabilistic methods to provide reliable ranges for the outcome (e.g. humidity) making moisture risk assessment quantifiable.

3. Moisture risks arising from retrofitting

Some retrofits solve one problem but create another one, and some retrofits are ineffective or inadequate (Møller et al., 2011). Some retrofits are safer than others, e.g. repairs that only restore the performance of the building without adding new value can be relatively safe. If no changes of a building physical nature are made, the building performs like it did before the

repair was necessary. Major repairs are often only one part of retrofitting; when major repairs are necessary, the building has probably reached an age when its original performance no longer complies with modern standards. Especially energy performance, comfort and layout are areas where an existing building often needs modernisation.

3.1 Retrofitting through additional insulation – the theoretical understanding

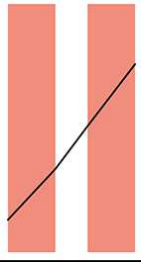
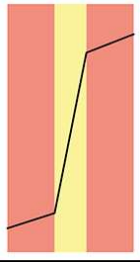
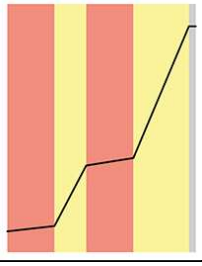
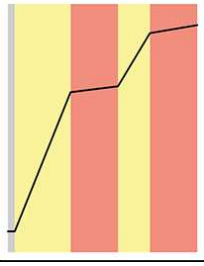
Buildings account for approximately 40 % of the energy consumption in the EU (European Parliament, 2010). It is therefore to be expected that retrofitting will in the future include measures to reduce the energy consumption in existing buildings. However, practice shows that sometimes moisture problems arise from retrofitting. These problems might be further aggravated as requirements to energy performance are tightened.

When buildings are retrofitted to reduce energy consumption, it is necessary to increase focus on moisture transport as heat and moisture transport is connected:

- Heat can dry out moisture; consequently, the potential for drying out is reduced if the heat flow is decreased.
- Hot air can hold more water vapour than cold air; consequently, decreasing the temperature will raise the relative humidity

The location of the insulation material is decisive for the temperature distribution and therefore for the moisture behaviour of the wall. Table 1 shows a cavity wall with different kinds of additional insulation. In the insulated examples, the cavity is filled with mineral wool (λ-value: 0.044 W/m·K). The interior insulation consists of mineral wool and battens (combined λ-value: 0.045 W/m·K), vapour retarder and a 2 x 13 mm gypsum board. The exterior insulation material is mineral wool (λ-value: 0.038 W/m·K) with exterior rendering. The calculation is made by a simple Glaser calculation according to EN ISO 13788 (European Standard, 2001), based on outdoor climate according to the Danish Design Reference Year (DRY).

Table 1: Temperature distribution through a cavity brick wall depending on where the added insulation is placed. Outside is on the left.

	No insulation	Cavity insulation	Cavity insulation + interior insulation	Cavity insulation + exterior insulation
Section of brick wall: Cavity: 70 mm Interior and exterior insulation: 150 mm Outdoor temp.: -1.1 °C Indoor temp.: 20 °C				
Outdoor surface	- 0.5 °C	- 0.8 °C	- 1.0 °C	- 1.0 °C
Inside inner leaf	18.1 °C	19.1 °C	8.1 °C	19.6 °C
Indoor surface	18.1 °C	19.1 °C	19.6 °C	19.6 °C

If the vapour retarder is intact in the example of the added interior insulation, there is no problem with diffusion through the insulation material. However, if the vapour retarder is defective, humid indoor air will pass through the mineral wool and reach the former inside of the wall (inside inner leaf), then condensation will occur with a risk of degradation of the battens.

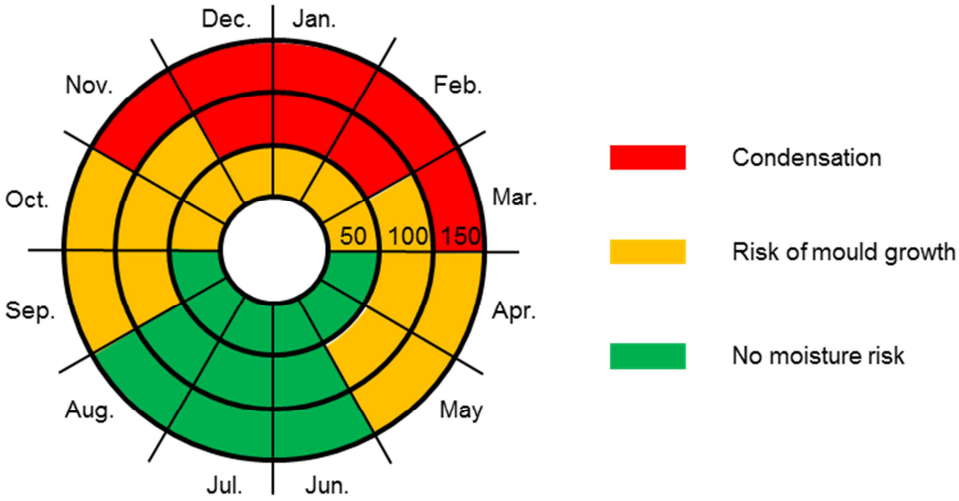


Figure 1: Moisture risk behind interior insulation with different thicknesses, over a whole year. Inner circle: 50 mm, middle circle: 100 mm, outer circle: 150 mm

Avoiding condensation is not enough; condensation might result in degradation of organic materials, but mould growth can occur at lower humidity levels; 75 % RH at 25 °C is considered the lowest humidity level on easy accessible materials like paper and cardboard (Sedlbauer, 2001). At lower temperatures, the limit is higher. In Figure 1, the example of interior insulation in Table 1 has been repeated for every month, showing how condensation and risk of mould growth increase with increased insulation; tightness of the vapour barrier becomes more critical with improved insulation.

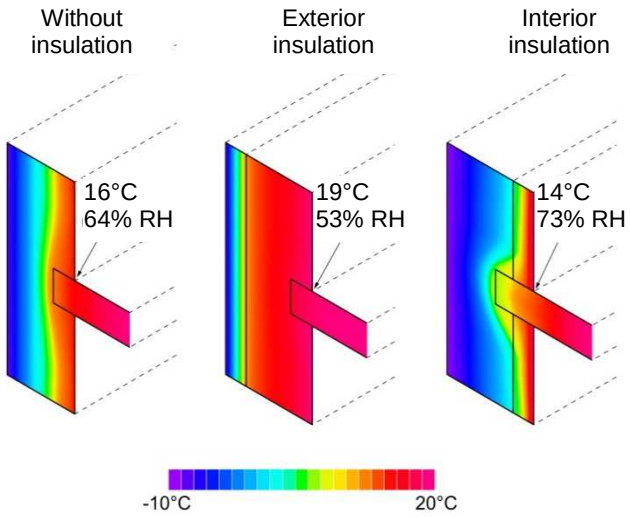


Figure 2: Temperature and relative humidity at thermal bridges depending on where insulation material is installed (Møller, 2012).

Even if the vapour barrier is tight and other prerequisites are met, interior insulation can still be risky from a moisture point of view. Figure 2 illustrates the effect of a thermal bridge in a solid brick wall with a suspended concrete floor, where 100 mm mineral wool is added both at the exterior and the interior side, the outdoor temperature is – 1.1°C and the indoor temperature is + 20 °C.

The lower temperature at the thermal bridges results in high relative humidity. In buildings with a wooden joist system, the thermal bridge at the beam ends will be less extreme. However, wooden floors are not airtight, so humid indoor air will reach the cold area at the beam ends, resulting in condensation or mould growth. In order to prevent this, the temperature in the area must be raised. Morelli et al., (2010) showed that this can be achieved by finishing a 200 mm interior insulation material at approximately 300 mm above and below the floor division. This will reduce the moisture risk but also the energy savings.

3.2 Retrofitting to save energy – controlling the airflow

Ventilation is responsible for 20-30 % of the total heat loss in existing dwellings in Denmark (Wittchen, 2004). Reducing the airflow is therefore also a way of reducing the heat loss. Many older buildings have a high natural air change rate as a result of air leakages in the building envelope. Tightening the building will reduce this. As a consequence, the airflow will be more controlled, the air change rate will no longer depend on the weather and the humid air will no longer find its way through random cracks in the building envelope in places where condensation may occur. The air change rate will be reduced and thereby the heat loss. However, it is necessary to have a minimum air change rate as the relative humidity in the indoor air will otherwise become too high because of the moisture produced by human activities. It is therefore necessary actively to provide sufficient ventilation. It is normally sufficient to open windows to make a thorough airing a few times a day for 10-15 minutes. However, experience shows that for some users this is difficult to accommodate.

Some users do not ventilate as much as recommended, while other users do ventilate, but have a high moisture production and should therefore ventilate more than usual. Figure 1 would change with user behaviour that is different from what is considered normal. Ventilation rates can be mechanically controlled so that users no longer have to open the windows themselves. Unfortunately, many mechanical ventilation systems have to be adjusted and maintained, which practice has shown to be difficult for the ordinary user to do. As a result many ventilation systems in single-family homes do not function optimally (Knudsen et al., 2012).

4. Considerations of the building owner

When a building owner decides to retrofit a building, his reasons for choosing a specific solution is influenced by the way he uses the building. Whether he himself uses it, or whether he rents it out, will to some degree influence his view on costs, aesthetics, comfort and health risks. The best solution is found by weighting the different parameters and the best solution might change over time as energy prices, construction costs, demands for comfort, climate and fashion change.

4.1 Cost efficiency

If the building envelope is to be retrofitted, the Danish Building Regulations (Danish Enterprise and Construction Authority, 2010) stipulate that cost-effective thermal insulation must be applied if it is moisture safe. Moisture safety is not defined, but energy-saving measures are cost efficient if:

$$\frac{(\text{Annual savings}) \cdot (\text{lifetime of measure})}{\text{Investment}} > 1.33$$

This is considered unproblematic by society and the building owner who uses his own building; as savings and costs end up in the same place. However, if the building is rented out, the user benefits from the annual savings while the owner must pay the investment.

4.2 Aesthetics

The appearance of a building is not always just a question of the cultural and personal preferences of the building owner. Especially in older urban districts, some buildings are listed, considered worth preserving or are otherwise subject to strict district plans. In such cases, the architectural freedom will be limited and interior insulation is often the only way to reduce the heat loss through the facades of buildings. In areas where buildings or the building stock have little or no architectural value or there are very few restrictions by the municipalities, it is up to the building owner to decide if and how the appearance of a building is to be changed. Some owners want to preserve the architectural expression, and interior insulation is therefore the only option for reducing the heat loss. Other building owners may have a wish to change the appearance of the building, and in such cases exterior insulation is a good solution.

4.3 Technical and economic barriers

The actual building morphology has a strong impact on the level of energy savings and the cost of retrofitting and consequently what type of additional insulation to choose. In some cases, balconies, exterior staircases or the like make it very complicated to retrofit the building envelope by exterior insulation, either because severe thermal bridges from the outside are introduced or it becomes very expensive to remove and re-construct such ‘extremities’. In some cases, technical installations in or close to the outer wall would have to be moved, which can be expensive. The floor area will be reduced and in some rooms this can limit the options for decorating. In such cases, indoor insulation might be preferable. Under other circumstances exterior insulation might be preferable, e.g. on numerous inner walls or suspended floors, which means thermal bridges from the inside resulting in decreased potential energy savings.

4.4 Ownership

In theory, the building owner’s considerations may be the same whether he uses the building himself or rents out, but in practice his views on the different parameters may be different in the two situations.

4.4.1 Building owner = building user

If the building owner uses the building himself, then he knows directly what is important for the building user. At some point, he will probably sell his building and must therefore take into consideration, how much the value of his building will change as a result of the retrofitting. Improved comfort is difficult to price. However, as a building user and an owner he knows how important it is to him personally that furniture does not have to be placed 10 cm from the outer walls, that the building is not draughty and that children can play on the floor without feeling cold.

Building dampness is strongly suspected of causing health problems e.g. respiratory symptoms and infections, and atopic and allergic people are especially susceptible (WHO, 2010). Health risks are therefore personal and depends i.a. on age, gender and medical history. All these factors will be known to the building owner, who can decide, whether he is willing to take a health risk, because his health is at low risk of being affected by a damp building, his ventilation habits are sound, moisture production is low and he can gain other benefits.

4.4.2 Building owner rents out the building

If the building owner rents out the building, he often focuses on economy as the value of the building depends on how much the tenants are willing to pay. Location is an important factor, but it cannot be changed by retrofitting. However, retrofitting can change how popular a location is; this is why retrofitting is used to change areas with social problems into more attractive areas (Danish Ministry of Refugee, Immigration and Integration Affairs, 2004). Retrofitting may include changes to the architecture, so the building owner must consider how the appearance of the building can attract economically advantaged tenants.

When it comes to health risks, there is a difference between taking risks yourself and taking risks on behalf of tenants. Some buildings are prone to high humidity levels and some buildings have high humidity levels due to user behaviour. Whether high humidity levels will cause health problems depends on how sensitive the building user is. Tenants may include persons ranging from healthy and robust persons in their best age to asthmatic babies, sensitive to health problems caused by damp buildings. User behaviour is just as wide-ranging. Normally the building owner will make sure his building can be rented out to a broad variety of people; therefore, he will have to choose a solution that is robust against user behaviour and sensitivity. He cannot be as specific in his risk assessment, as if he himself is the building user.

4.5 Prioritising solutions and risk assessment

In general, the building owner should chose a solution with a reasonable balance between the relevant parameters; e.g. architecture, building physics, durability, indoor climate, robustness of operation and costs. In practice, he should only chose a technically less safe solution if he gains more on other parameters by choosing that solution. He needs to assess the risk and compare it with the benefits of the solution. Assessing the risk includes:

- estimation of likelihood of defects (e.g. the probability of exceeding the level of acceptable relative humidity)
- consequences of defects (e.g. deterioration, chronic health problems or lower energy savings)
- costs of correcting defects (e.g. rehabilitation costs, discomfort and inconveniencies for users)

Especially the estimation of the risk of defects is difficult. The risk can be influenced e.g. by choice of material and extended quality assurance.

5. In practice – Danish guidelines and risk assessment

At present there are only few tools available to help the building owner to prioritise. In Denmark, guidelines describe principles for designing safe solutions. For new buildings, it is often possible to give examples of solutions that are generally considered to be safe for most uses. Where retrofitting is concerned, many factors are unknown and not everything is possible due to existing constructions. As a result, guidelines have to be pragmatic and describe not only the technically safest solutions, but also other possible solutions with a description of the prerequisites for each solution and a description of why the solution could be problematic and how the risk is diminished.

As retrofitting must cover many types of construction, guidelines (e.g. Møller, 2012) contain descriptions with thorough illustrations of typical situations and associated solutions as well as more general statements about solutions that are not standard or are compromises. However, there is no quantification of the moisture risk, because it depends very much on the specific case.

Today risk assessment is primarily based on guidelines and the experience of professionals. It is not mandatory to follow the guidelines, but if they are followed and a problem occurs anyway, the planner or contractor cannot be held responsible. This means that if the guidelines advise against specific solutions, these are de facto banned. Most professionals probably tend to recommend solutions that are on the safe side; it might be more costly, but in the end it can make life easier for the professional, the building user and the building owner.

6. Discussion - acceptable risks in the future?

It is not possible to construct new buildings or retrofit buildings without moisture risks. The question is what the acceptable risk is and how to assess the moisture risk.

6.1 Limit values

The reasons for not defining a moisture risk could be the difficulty in defining limit values based on scientific results. When it comes to defining the moisture limits to prevent degradation of materials, traditional experiments can show when degradation (e.g. corrosion

or rot) starts, and materials-based limits can be found. However, when it concerns humidity causing indoor climate problems, it is unlikely that dose-response limits based on scientific knowledge will be defined in the near future. Specific knowledge of why moisture causes health problems is still lacking (WHO, 2010). Mould growth is strongly suspected of causing health problems. However, the connection between mould growth and moisture level is indirect, as materials, temperature and time are also decisive factors for mould growth (Sedlbauer, 2001). Another reason is the difficulty in measuring the exposure; should it be moisture or mould measurements? To this can be added the difficulty of finding suitable measuring methods.

One of the reasons why it is difficult to establish dose-response knowledge is that the dose-response limits are very personal; some people are more susceptible to health problems caused by dampness than others, e.g. children, asthmatics and allergic persons are especially sensitive (Danish National Board of Health, 2009 and WHO, 2010).

6.2 Moisture safety class

When IEA-ECBCS Annex 55 is finished, it could change moisture risk assessment from assessing a solution to be acceptable or non-acceptable, based mostly on experience, to a more refined risk assessment with a scientific approach where several parameters specific to a given case are taken into account. Until then, it could a realistic approach to introduce “moisture safety classes”. Ideally, the classes should be defined by how many per cent of the population that, with normal use of the building, would not statistically experience health problems. Until more specific knowledge about dampness and health is available, a simpler less quantifiable method could be used.

An operational method for defining moisture safety classes could be to combine the hygrothermal load with the robustness of the solution against dampness and the resulting risk of mould growth. This would be equivalent to how structural design uses design loads and performance (load-bearing capacity).

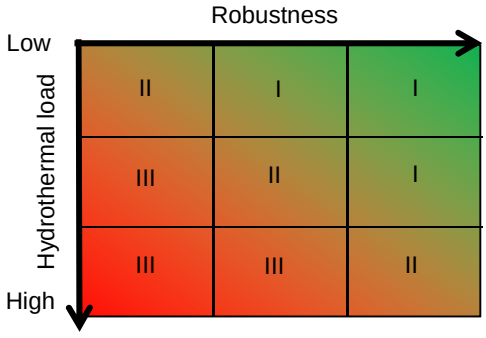


Figure 3: Example of how three moisture safety classes could be described based on robustness against dampness and hygrothermal load. Class I is the moisture safest.

In Figure 3, three moisture safety classes are proposed that are formed by subdividing robustness against moisture and moisture load into low, middle and high. Class I ‘High Moisture Safety’ is the best as it combines high robustness and low hygrothermal load and Class III ‘Low Moisture Safety’ is the worst as it combines low robustness and high loads. To reduce the number of classes, the two adjacent groups are also defined as Class I and

Class III respectively. Class II ‘Medium Moisture Safety’ covers situations in between Class I and Class III.

In this way, it would be realised that in certain buildings some people will have difficulties in obtaining an indoor climate that does not cause them problems. People who know that they are sensitive to higher humidity levels could choose to live in buildings with a High Moisture Safety classification. The costs would probably be higher, but so would the safety. This could be a way to accept e.g. interior insulation in older buildings; the moisture risk would be higher, but only people who are less prone to moisture-related indoor climate problems would choose to use these buildings. This could be an argument for the building owner who uses the building himself, and who has an idea of whether he or his family are prone to moisture-related problems. This solution would not be possible for office buildings.

The “moisture safety classes” could also be used the other way around; buildings with a low moisture safety classification can be used by more people, if the moisture level is kept low. This means low moisture production, no cold areas and good ventilation. In practice, this would be the same recommendations as used today when people experience moisture problems in existing buildings. This illustrates that today’s buildings are not built for everybody; their moisture safety class is just not defined.

6.3 Ban or explain risky solutions

As long as there are no moisture safety classes or methods of risk assessment, risky solutions must be handled in another way. The simple approach is to ban solutions that are risky, but on what grounds can a solution be judged to be risky? Another way is to guide building owners so that they are themselves able to make an informed choice and prioritise between several solutions. To assess whether a solution is risky from a moisture point of view, it is necessary to understand how the building physics of the solution works. Guidelines with different solutions must therefore not only describe how the retrofitting can be executed but must also explain the prerequisites and pitfalls of the solution.

Interior insulation is an example of a solution that is judged to be risky by many professionals, (Møller, 2012); the pitfalls are known (see section 3.1) and have been pointed out for years. Nevertheless, new examples of interior insulation with moisture problems still turn up, sometimes because neither the planner nor the contractor was aware of the problem, in other cases problems occur despite various precautions. Unfortunately, it is not known how often the solution fails and the reasons for failing are not always analysed. However, it illustrates how difficult it is to make it right.

Maybe interior insulation should be banned. In some cases, this would mean that additional insulation would in practice be impossible, thus blocking retrofitting of buildings to improve their energy efficiency. Instead, the awareness of the problem can be strengthened by describing the problem and emphasising that the solution is known to result in moisture problems and is therefore judged to be risky.

7. Conclusion

In an ideal world, all buildings have an indoor climate after retrofitting with no restrictions on moisture and temperature conditions. However, this would mean strict regulations regarding what solutions may be used. Some solutions would be too risky and should therefore be banned with the result that some buildings would not be retrofitted. This scenario would counter the need for lower energy consumption in existing buildings and would be very costly and therefore unrealistic. On the other hand, no regulations, where building owners are to decide what constitutes an acceptable risk, can result in solutions where only few people can use the building without developing health problems or where the building's use is very limited. This is especially problematic when buildings are rented out.

Instead, moisture safety classes should be defined. The classes could be based on a combination of hygrothermal load and robustness against dampness. In this way, building owners and users know the limits of the building. However, to define moisture safety classes, more knowledge about moisture is needed regarding:

- how often do constructions that are generally judged to be risky from a moisture point of view actually cause moisture problems
- how moisture or mould exposure should be determined including appropriate measurement techniques.
- dose-response relationship between moisture level and health effects, although a direct connection is probably very individual
- reliability-based modelling of building physics including parameters for moisture/mould loads, resistance, consequences of defects and acceptance criteria

Until this becomes known, society must operate with a combination of information on why some solutions are more risky than others and descriptions on how the risk is reduced. In Denmark, guidelines describe the best technical solutions as well as more risky ones; no solutions are banned, but some are judged to be risky. The idea is to help the building owner to decide what solution is the best in his particular case, because the safest technical solution is not always the best solution.

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Contribution for Integrating Energy Simulation into the Building Design Process

Nathália de Paula[1], Vanessa Gomes da Silva[2], Silvio Burrattino Melhado[3]

Abstract

Building energy simulation is a new topic in the Brazilian civil construction market. Therefore, it is important to investigate how to integrate this new activity into the building design process. A necessary step to advance in this direction is to map the building energy simulation process. For that purpose, a literature review was carried out on concerns regarding energy conservation, energy simulation and challenges in the building design process in the Brazilian market. An exploratory research was then developed, including semi-structured interviews with the energy and mechanical/electrical/plumbing (MEP) manager of a consulting firm in São Paulo city and the analysis of documents related to a commercial building. Energy simulation process mapping can help designers to understand: the relationship of simulation and design disciplines; simulation as a process (input – processing – output); the responsibilities involved in data simulation and how to organize them to other players; the importance of providing simulation data input.

Keywords: Integration, process, mapping, environmental requirements.

1. Introduction

In Brazil, actions related to energy conservation began to be taken, motivated by the 2001 Brazilian energy crisis, when the first energy law was approved. In 2003, the National Program for Energy Efficiency in Buildings (PROCEL EDIFICA) was established to promote electric power rational use. PROCEL EDIFICA contributed to the development of reference parameters for checking the level of buildings energy efficiency, which originated the Quality Technical Regulation for Energy Efficiency Level of Commercial, Services, Public and Residential Buildings (RTQ-C) and the Conformity Assessment Requirements for Energy Efficiency Level of Commercial, Service, Public and Residential Buildings (RAC-C), both published in 2009 (FOSSATI, MORISHITA and LAMBERTS, 2011; MELO et al., 2012; SCALCO et al., 2012).

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RTQ-C specifies the technical requirements to classify the buildings energy efficiency level in order to label them. The buildings can be classified into five levels – from “A” (most efficient) to “E” (least efficient) – based on two approaches: simulation or prescriptive method. The building labelling process is composed of two stages specified in RAC-C: design assessment, whereby a design label can be issued; building inspection, whereby the building can obtain the label (FOSSATI, MORISHITA and LAMBERTS, 2011; SCALCO et al., 2012). According to Inmetro (2012), one in thirty-five commercial, services and public buildings labelled at the design stage was assessed by the simulation method, and the prescriptive method was utilized in all residential buildings and multifamily buildings (twelve design labels were issued).

As stated by Mendes et al. (2005), building simulation use in Brazil is still concentrated in educational and research institutions with little technology transfer to the private sector. Nevertheless, there is a trend for change since there is the market demand for buildings labelled or certified by LEED (Leadership in Energy and Environmental Design), AQUA Process (High Environmental Quality of Buildings, an evaluation and certification methodology of sustainable buildings of French origin used in Brazil), among others. Cavalcante (2010) says that ASHRAE 90.1 Energy Standard for Buildings Except Low-Rise Residential Buildings, referred in LEED, has gained acceptance in recent years in Brazil, specifically in São Paulo city, and consulting activities have been hired to demonstrate building compliance through simulations.

Energy simulation is a new topic in the Brazilian civil construction market. As a consequence, the energy simulation process is not yet mapped; information used in simulation is dispersed and the sustainability consultant needs to seek data in the several design disciplines. Moreover, simulation is also a new activity in the designer sphere, which had not been previously required. Hence, it is important to investigate how to integrate this new piece into the puzzled building design process. For that purpose, it is necessary: (1) to map the energy simulation process (input – processing – output), (2) to map the design process (input – processing – output), (3) to identify interfaces and difficulties between the design and the simulation processes, (4) to define strategies to integrate the new activity into the design process, (5) to test the strategies and (6) to validate them.

In Brazil, there is lack of a building design process reference. Although there are some standards related to design and free design scope manuals created by Brazilian entities that represent the design professionals, they are not applied by them. It is important to highlight that the standards are outdated. Melhado (1994) emphasizes that the standards should be reviewed in order to add some concepts, such as multidisciplinary approach, constructive rationalization and buildability. New demands should be inserted in the standards and manuals: building integrated design, building environmental sustainability, building performance standard and Building Information Modeling (BIM).

The Brazilian reality is different from other contexts. In the British case, for example, the building design process was mapped, resulting in a document called Outline Plan of Work, which was reviewed with BIM and Green Overlays. These documents can be downloaded for free (RIBA, 2012); they are references to the players involved in the building production.

Paula and Melhado (2012) state that the effects of environmental sustainability demands on the building design stage are: consulting firm participation in the project team, to promote the inclusion of environmental requirements at the design stage; inclusion of new players in the design team, such as acoustic and sanitary engineers; changes in contractual requirements, as designers should be aware that there are sustainability requirements in the project; inclusion of environmental requirements into the design, which should be coordinated also with that specific focus; use of new technologies, both incorporated to the buildings and to the design stage, such as use of BIM and simulation tools; and recognition of the importance of the design stage and integrated design.

In addition, Paula e Melhado (2012) present the challenges and questions: the design process is not defined - there is a lot of rework in the design tasks; the scope of the players involved in the project is not defined - what are the responsibilities of each player and the scope of the designers?; should new competences be developed according to the demand for environmental sustainability?; the time of the use of simulation tools and their results should be defined to facilitate decision making; current demands and their interrelation should be considered in the design process, such as environmental certifications, PROCEL EDIFICA, performance standard and BIM.

All of this is complex as a whole; it is necessary to break this context down into parts that allow understanding of the design process, the new demands and the relationship among them. Thus, our aim is to map the building energy simulation process, one point necessary to integrate it into the design process.

2. Research method

The research method used was the exploratory research. According to Gil (2008), this type of research provides more familiarity with the problem studied, making it more explicit and allowing hypotheses delineation. The main purpose of exploratory research is to allow ideas to be improved or insights to be had. The planning for data collection is very flexible, making it possible to consider various aspects related to the fact studied.

Two semi-structured interviews were conducted with the energy and MEP (Mechanical Electrical Plumbing) manager of a consulting firm in the São Paulo city. In addition, the documents related to building energy simulation– a commercial building seeking LEED certification - were analyzed. The aim was to understand the energy simulation process followed by the consulting firm. As shown in Figure 1, this paper contributes to the first stage towards integrating energy simulation into the building design process.

A literature review was carried out regarding the Brazilian concerns about energy conservation, energy simulation in the Brazilian market and challenges in the building design process.

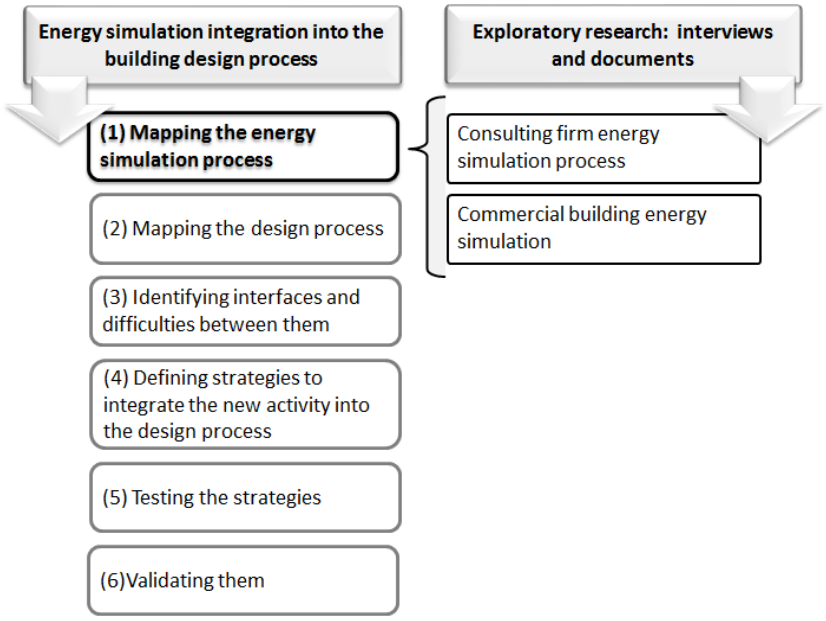

Figure 1: Stages to the energy simulation integration into the building design process

3. Exploratory research

3.1 Building and consulting firm characteristics

The consulting firm characteristics were obtained through the interviews and its website. This firm was chosen due to its relevance in the Brazilian market. It has been in the market since 1990, has approximately 130 employees, and is also ISO 9001, ISO 14001 e OHSAS 18001 certified. Nowadays, it works in six areas: business consulting, sustainability, management, real estate, events and courses and web applications. Its clients are investors, developers, construction firms, design firms, material manufacturers and government agencies, among others.

The building of reference, currently at construction stage (building foundation), is inserted in the commercial market segment and aims at LEED Gold certification level. Its built area is 61.240 m², distributed in 4 underground parking, ground floor, 2 mezzanines, 31 floors type, engine room and attic. The project team was composed of the following players: real estate developer, construction firm, design firms and consulting firms.

3.2 Energy simulation in the building design process

The interviews allowed obtaining a set of considerations that are summarized as follows. As stated by the energy and MEP manager, his team usually uses the software Energy Plus. However, he is analyzing the possibility of using the software IES <VE>, because its graphical interface is more intuitive than that of EnergyPlus. EnergyPlus was the first tool used in the company and because of the large number of contracts aimed at LEED certification, its professionals have created an extensive database of this software.

According to the interviewee, regarding the moment for the energy simulation team to participate in the design process, in most cases the firm is contracted at the beginning of the design. The client hires the consulting firm to guide the design team to adequately consider environmental requirements in the building conception. The interviewee highlighted the importance of the architectural conception stage, a moment at which important decisions are made, such as building orientation and geometry, which greatly influence subsequent decisions.

In most cases, the consulting firm is hired by a developer, but construction or architectural firms also play this role. In the past, when the firm started the certification-related works, some clients hired it at the detailing design stage or with the construction in progress. In these situations, the consultants perform a diagnosis to analyze the possibility of the building obtaining the certification and the potential contribution of the simulation to evaluate alternative design solutions is rather limited. The interviewee exemplified two building cases in which the consulting firm was hired at an unsuitable time: in one case, based on the diagnosis, the certification could not be granted and the client opted to desist of the certification process; in the other case, the consulting firm was hired late at the design stage, which caused a lot of rework to finally achieve certification.

According to the interviewee, when the energy simulation occurs at beginning of the process, the consulting firm can provide an appropriate feedback to the design team. Currently, he has observed that designers await input from simulation results (feedback from consultants) to specify equipment, fixtures etc. Also, he highlighted other important points to the design stage success: design process management, activity planning and design coordination.

3.3 Energy simulation process mapping

The consulting firm suggests three energy simulations per building: preliminary, at the end of the preliminary design; intermediate and final simulation. At least two simulations must be performed: a simulation for the preliminary analysis of the building energy performance and proposition of improvements to the design, and the final simulation, as required by the environmental certification process. Simulation yield is defined in contract, and depends on the building complexity and the client requirements; some clients may require two, three or four simulations.

Figure 2 presents the energy simulation process mapping composed by inputs to perform the simulation, data processing in the design disciplines – architectural design, air conditioning design, lighting design and electrical design along with general data – and outputs from the process.

In the preliminary design stage, the designers are able to provide inputs for preliminary energy simulation. Regarding the information level, the interviewee said that the design information in a given stage varies greatly across design practices. The consulting firm receives the designs from different specialties and fills a, Energy Efficiency Simulation Data Form, normally used for commercial buildings, but adaptable for residential buildings and hospitals. As explained by the interviewee, filling the form was required from designers, but they did not carry out this activity.

The consulting firm just sends the form to the designer in case it needs specific data and, if necessary, designers perform some calculations and estimates. Therefore, when concluded, the form is validated often by e-mail by all professionals, including the clients, since they must be aware of the input data used in the simulation.

Energy Simulation Process	Inputs	What to considerar...	Design Disciplines					Outputs/ Activities
			1. ARC	2. AIR	3. LIG	4. ELE	5. Gen. Data	
1.1	Facades	Ground plan and sections of the building and facades						Annual consumption and cost of energy Building performance analysis Proposition of energy efficiency strategies Energy Efficiency Technical Analysis Report [Simulation]
		Solar protection devices						
		Specification of the facades and exterior wall materials						
		Specification of the facades glazing						
1.2	Roof	Specification of the roof						
		Zenithal daylighting or skylights						
2.1	System composed of Chillers	Chillers circuits						
2.2	Direct expansion system	Condensing units						
2.3	System for distributing air conditioning	Fan-Coil equipment						
		Thermal zoning by VAV boxes						
		Thermal zoning by raised floor system						
2.4	Mechanical ventilation systems	External air intake						
		Bathroom exhaust or purge (central or individual)						
		Garages exhaust						
		Stairs pressurization						
2.5	Energy efficiency strategies for air conditioning system	Enthalpy wheel (sensitive and latent heat)						
		Individual heat recovery (sensitive heat)						
		Control of external air intake in relation to CO_2						
		Control of garage exhaustion in relation to CO						
		Chilled water thermal storage						
		Ice thermal storage						
		Use of gas absorption chillers in peak shaving						
		Pretreatment of outside air (cooling/ dehumidification)						
		Saving cycle						
		Free-cooling						
		Co-generation with absorption chillers and gas generators						
		Night-cooling						
3.1	Indoor lighting	Lighting power density considered (W/m^2) or total power considered per area (W)						
3.2	Exterior lighting	Lighting power density considered (W/m^2) or total power considered per area (W)						
3.3	Energy efficiency strategies for lighting	Lighting dimerization for daylight use						
		Automatic shutdown of lighting by photoelectric relay						
		Presence sensor in all indoor areas						
		Presence sensor in garages						
4.1	Lifts	Number of lifts (social, service etc.)						
		Nominal power unit (KW or CV)						
4.2	Escalators	Number of escalators (social, service etc.)						
		Nominal power unit (KW or CV)						
4.3	Hydraulic pumps	Number of operating pumps of cold water, rain water, waste water, water for irrigation, water for ETE / ETA						
		Nominal power unit (KW or CV)						
4.4	Energy efficiency strategies for electric	Lifts with regenerative braking						
		Lifts with early call system						
		Escalators activated by presence sensor						
5.1	General data	Climate file (temperature data of dry bulb and wet bulb, atmospheric pressure, wind, solar radiation and nebulosity)						
		Electricity rates						
		Occupancy and use patterns of the building						

(1) Architectural Design, (2) Air Conditioning Design, (3) Lighting Design, (4) Electrical Design, (5) General Data

Figure 2: Building energy simulation process mapping

Energy simulation, building performance analysis and energy efficiency strategies propositions are carried out resulting in the Energy Efficiency Technical Analysis Report [Preliminary Simulation]; it is composed by: (1) introduction, (2) data common to both models, (3) baseline data, (4) design data, (5) performance data and (6) concluding remarks. The form Data Form for Energy Efficiency Simulation is an appendix of this report. All data contained in the form, in compliance with the standards and from estimates and calculations, are necessary to perform the preliminary simulation. As a consequence of design evolution, there are changes and the data, previously estimated, needs updating. Thus, the difference among the simulations – preliminary, intermediate and final – is the refinement degree of the information inserted. The preliminary report simulation assists in data refining and closing, and provides feedback to designers, who can improve proposed solutions toward the detailed design stage.

3.4 Building energy simulation

Three energy simulation were predicted to the building – preliminary, intermediate and final simulations. The first simulation occurred at the end of the preliminary design.

According to the Energy Efficiency Technical Analysis Report [Preliminary Simulation], the building design was not complying with the goal of reducing 10% in annual energy cost as compared against the baseline model, required by LEED ® for Core & Shell (2009). For this reason, the consultants identified the items that influenced the building's performance and proposed a set of potential energy efficiency strategies. The main items were the window wall ratio in the facades and the glazing's solar factor, both above the ASHRAE 90.1 (2007) baseline.

After that, scenarios were created with the adoption of energy efficiency strategies, considering the same architectural design condition and keeping the facades and glazing options; technical options were inserted in relation to the air conditioning and lighting designs. The strategies were: (1) insertion of heat recovery in the HVAC system, in which the purged indoor air pre-cools the incoming external air; (2) variation of external air intake in each floor, depending on the CO_2 concentration in the spaces; (3) automated and motorized blinds implementation to reduce direct solar radiation gain; (4) fixture circuits dimerization next to the facade in order to use daylight and reduce energy consumption.

The report concluded that the conditions for improving the facade architectural design, along with specifying more efficient glazing would certainly contribute to the improvement of the building overall energy performance, due to the direct impact on reducing the power consumption of the HVAC system.

Subsequently, a facade study was ordered, also conducted by the consulting firm, but contracted separately. Study specifications were simulated (intermediate simulation). As demonstrated by the Energy Efficiency Technical Analysis Report [Facades Study], the evaluation of two types of laminated glass applied to the facades and atrium roof, and the use of automated blinds applied to the North facade was carried out, and the final glazing specification was provided by the architectural design practice.

Nonetheless, according to the report, the design was still not in compliance with the minimum goal of reducing 10% of the annual energy cost; there was the need to maintain the adoption of the strategies listed above. It was concluded that only with the adoption of North facade blinds, along with the use of heat recovery system as well as the dimerization next to the facade was it possible to comply with the minimum goal of 10%.

4. Results and discussion

As seen from exploratory study, there seems to be a growing demand by LEED certification in Brazil and, consequently, of interest in demonstrating building compliance with ASHRAE 90.1 through energy simulations. It also corroborates Cavalcante (2010) and Paula and Melhado (2012) statements regarding consulting firm participation in the project team promoting the environmental requirements inclusion at the design stage.

Paula e Melhado (2012) discussed the suitable time to perform energy simulations. Based on the interviewee experiences, the moment for the first simulation is right at the beginning of the design process (preliminary design), when the consulting firm can provide appropriate feedback to the design team. Otherwise, there will be a lot of rework or the building will not be certified. Simulation yield is provided in contract, but new organization forms of the design team could be discussed, in which the consultant works directly with the architectural firm in order to provide simultaneous and continuous feedback instead of three simulation times – preliminary, intermediate and final simulations.

Energy simulation is required by most environmental certification schemes. Despite the requirement, simulation should be discussed concerning building performance. Thus, designers, especially architects, could discuss the need of some studies with the use of software or not in the design conception, such as building geometry study, attempting to anticipate the concerns about energy efficiency and environmental requirements as a whole. In this way, it seems the consultant presence should be anticipated, too.

Energy simulation process mapping (Figure 2) is the first step toward definition of strategies to integrate energy simulation in the design process, which needs to be tested and validated. As demonstrated by Inmetro (2012) and Mendes et al. (2005), the energy simulation is a new activity in the Brazilian market. Thus, mapping can help designers to understand the relation of design disciplines with simulation; the simulation as a process (input – processing – output); the responsibilities involving data simulation and how to organize them with other players; the importance of providing data for the simulation.

As stated by Paula and Melhado (2012), there is a major challenge towards integration of energy simulation in the design process, as the building design process itself is not mapped in Brazil. Moreover, the standards are outdated and the manuals are not used. The interviewee recognized the importance of design process management, activity planning and design coordination. As a whole, this, therefore, presents a research opportunity.

5. Concluding remarks

The suggested procedure of mapping, identifying, defining, testing and validating strategies contributes to integration of new activities or requirements into a given process. In other words, it can be used to integrate energy simulation or environmental requirements in the building design process. This paper focused on the first step (Figure 1): the barriers that needed to be studied. The research will be continued, as the design process and the energy simulation process need to be discussed with the players involved in building production, in order to develop guidelines transferable to the market.

BIM has widely been discussed and one of its premises is integrated design. The mapping procedure is a stage until the time when there will be the expected maturity in the application of this concept.

6. Acknowledgements

The authors thank the interviewed consultant for his kind participation and CAPES for the financial support granted.

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“Sustainable Campus”: a starting point for a Building Sustainable Refurbishment. Energy-Efficiency Upgrading and Thermal Comfort

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Abstract

During the last year Politecnico and Università degli Studi di Milano have been launching a project in order to transform the university area into a sustainable and quality campus, which could become a model for the rest of the city, sharing experiences and results into the International Sustainable Campus Network (ISCN).

Various interventions are needed within that project, in order to improve the quality of life, environmental, economic and social aspects, not only on a large scale but also at each building level. For this reason some activities have been already carried out and others have been planned on a number of representative buildings inside the campus. More specifically, the first aim is the assessment of the current condition in terms of thermal performance of the building envelope, heating and cooling systems functioning and indoor comfort. It has been done by micro-climate measurements, statistical surveys, energy consumptions monitoring, modelling and simulations, after having established the specific methods, standards and protocol to follow. Some BIM models have been created to support analysis and design phase.

In this study the ultimate goal is the proposal of different solutions to improve the energy efficiency and thermal comfort of the existing buildings, acting both on the envelope and on the plants. The best project alternative choice is based on the calculation of the sustainability level of each one, determined through a multi-criteria choice method, based on the existent AHP (Analytic Hierarchy Process) comparison method, able to consider simultaneously environmental, economic and social aspects, following the standards EN 15643 relating to the sustainability assessment of buildings. The best alternatives obtained have been compared with the current situation of the building, showing a large performance increase in

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terms of environment, economy, and internal performance level. These results have also been confirmed by changing into the BIM model the boundary conditions based on the best refurbishment interventions and comparing them with the actual state.

In conclusion, that evaluation system could be a tool useful during the decision phase, able to guarantee the maximum quality level and upgrading within a sustainable building framework in the project alternatives design stage.

Keywords: Sustainability, energy efficiency, thermal comfort, multi-criteria method, BIM

1. Introduction

The “Sustainable Campus” project started in 2011 and it has been promoted by two Universities in the “Città Studi” district of Milan. The aim of this project is to transform the whole area in a sustainable quarter thanks to the active participation of students, researchers and whoever lives in the district, suggesting idea and specific projects.

The project is organized into different thematic areas: “people, energy, environment, accessibility and city” and for each of them a discussion group is active. In order to achieve the general results it is important to act also at each building level. So, from a building point of view the main purposes are related to environment and energy because of the necessity to reduce its impacts in terms of emissions and resources and energy saving.

Nowadays the attention for sustainability issues has increased, along with the calculation methods to evaluate it, based on the Life Cycle Assessment (LCA) as expressed by the European guidance (2010). In recent years we are witnessing a thriving standardization by Technical Committee ISO/TC 59, Building construction, Subcommittee SC 17, Sustainability in building construction, and by CEN/TC 350, at European level, in order to define the principles and the procedures for assessing the sustainability of both products, ISO 21930 (2007), and new and existing buildings, ISO 21931-1 (2010) from environmental, social and economic point of view, related to ISO 15392 (2008) and ISO 21929-1 (2011).

On the basis of what has been outlined in the reference standards, a preliminary evaluation activity on some existing buildings has been carried out within the project “Sustainable Campus”. This project is aimed at assessing the real conditions and proposing solutions to improve the environmental performance, the life cycle cost performance, the health and comfort performance of the buildings.

2. Conditions survey

The university campus consists of a series of buildings of different construction periods and therefore they have different characteristics from plants and structures point of view. For this reason, the first step of the analysis was to select the more representative buildings on which to perform the investigation in terms of thermal performance of the building envelope, heating and cooling systems and indoor comfort, for evaluating the energy consumption and

consequently the environmental, social and economic impacts. Among others a significant building ("Nave"), that will also soon undergo heavy refurbishment, has been chosen and monitored.

The “Nave” (see Figure 1) was built in the late sixties by Gio Ponti, it is a 7-storey building, which is L-shaped and divided into two blocks with different functional uses: a block for the offices, extended in the north-south direction, with a concrete bearing structure in beam and pillars and a floor area of about 732 square meters; and a second block, which extends west-east, with a mixed concrete - steel structure and a floor area of about 1242 square meters, for the classrooms. The building has a radiator heating system and no air conditioning ventilation system.

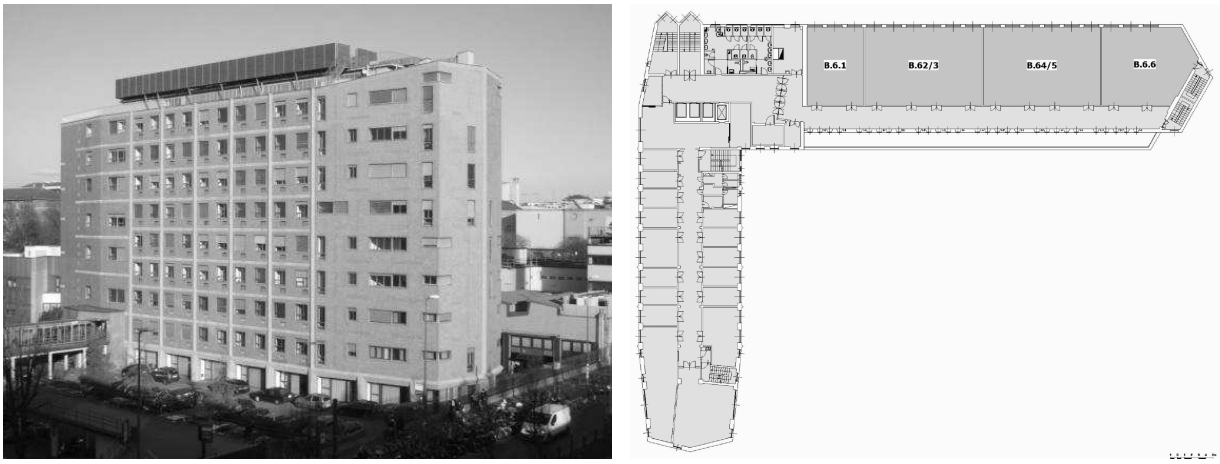

Figure 1 – “Nave” building: picture and sixth floor map.

2.1 Thermal comfort and measurement protocol

The first activity was related to the monitoring in terms of heating and cooling demand and environmental comfort: the goal of the surveys is to improve the comfort avoiding the equipment of rooms with air conditioning (not present today in those building) and to propose more efficient and energy-saving solutions that initially explore the redesign of the building envelope.

The survey of the current situation is performed by instrumental measurements, statistical surveys and calculation of indicators to evaluate the deviation from the thermal comfort ideal conditions. According to the definition, the thermal comfort is “condition of mind derived from satisfaction with the thermal environment”. An environment is considered acceptable if it meets a certain percentage of occupants. The comfort sensation is governed by the subject-environment thermal exchanges, determined by the combined thermal effect of environmental parameters including air temperature, vapour pressure, air velocity, mean radiant temperature (fixed factors) and clothing and activity level of occupants (variable factors).

A detailed measurement protocol has been drawn up with the aim to define a survey procedure which may be valid and applicable in all the cases the assessment of the actual thermal comfort in existing buildings is needed.

2.1.1 Calculation model

Two different calculation models, described in the reference standards and to be used for monitoring and displaying the indoor environment, as recommended in the Energy Performance of Buildings Directive (2010), can be applied to obtain the comfort index, depending on the data input and the boundary conditions. The two models are the Fanger Method and the Adaptive Method.

The Fanger method, as shown in UNI EN ISO 7730 (2006), allows us to calculate the Predictive Mean Vote (PMV) of a group of people related to a 7-point thermal sensation scale (+3 hot, +2 warm, +1 slightly warm, 0 neutral, -1 slightly cool, -2 cool, -3 cold), based on measured indoor climatic parameters and with assumed typical levels of activity and thermal insulation for clothing. The other parameter, calculated on the base of PMV, is the Predicted Percentage of Dissatisfied (PPD). For different categories there is a list of recommended value to be respected. The model is mainly valid for moderate environments with conditioning system.

The Adaptive Method, as shown in ASHRAE standard (2004) is valid mainly for non-conditioned environment and represents an individual's ability to adapt to the prevailing climate (seasonal and local) depending on physiological conditions and by acting directly on the surrounding environment. The reference parameter is the Optimal Operative Temperature for which a maximum number of the occupants can be expected to feel the indoor temperature acceptable. It is calculated starting from Outdoor Air Temperature and has got upper and lower limits of acceptability, which the measured Indoor Operative Temperature should fall within. The acceptable ranges are higher than the Fanger model.

2.1.2 Instrumental monitoring

In order to map and assess the building thermal fluctuations over time according to the different contextual conditions, some continuous measurements of temperature and relative humidity were carried out using mini-logger (thermo-hygrometric probes) installed in more than one room per floor (for minimum 30 days) at the middle of the inner wall and at the height of 70 cm from the floor. Other measurements were performed for monitoring the environmental parameters, as shown in ISO 7726 (1996), for the calculation of the comfort indexes, using probes sets (micro-climate station) installed in some representative rooms, also for a shorter period of time (7 days). The station is composed by: psychrometer to measure relative humidity and air temperature (dry and wet bulb), globe thermometer to measure mean radiant temperature, and hot wire anemometer measuring air speed. This micro-climatic station was installed in the centre of the room.

2.1.3 Data collection

A survey (thermal sensation questionnaire) on a cross-section of users was carried out to evaluate statistically the subjective experience and individual feeling, preferences and acceptability of the thermal environment, based on UNI EN ISO 10551 (2001). The goal is to obtain an Actual Mean Vote of thermal sensation comparable to Predicted Mean Vote calculated from direct measurements in order to validate the model. External Temperature and Humidity (outdoor climatic data) were gathered from a data base, measured by the nearest environment monitoring station in order to compare the trends of internal hourly values with the external ones and to calculate the acceptability limits for the Adaptive Model.

2.1.4 Data processing and results

The monitoring activity has been carried out for two periods in 2011-2012, in summer and winter conditions, in order to have enough values to evaluate seasonal discomfort based on the calculated indices. Thanks to the continuous measurements by mini-datalogger it was possible to see the different trend of temperature on the building area, (for instance a difference of 1 °C for each floor as shown in Figure 2).

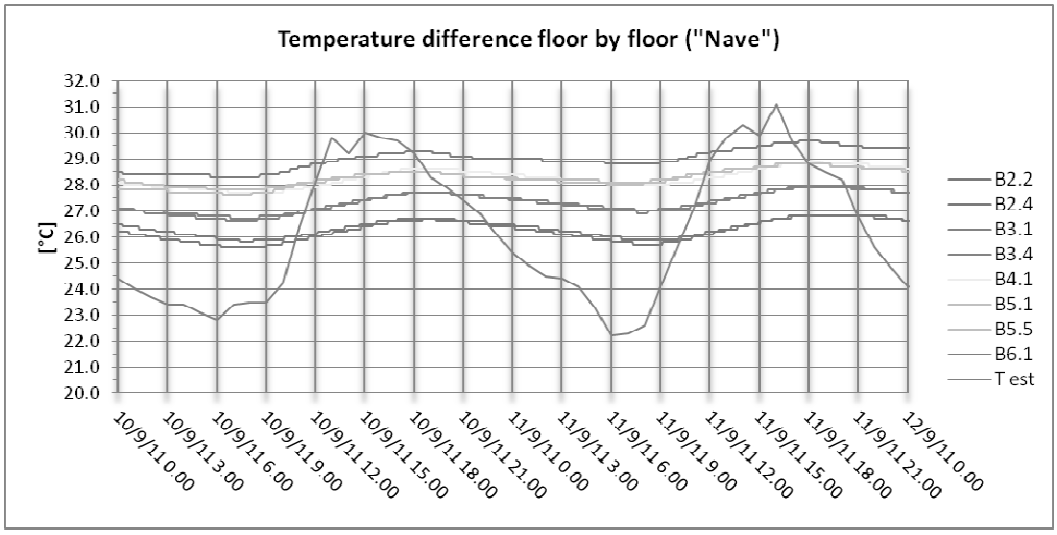

Figure 2 – Trends of temperatures in summer conditions

In summary an evident discomfort is shown in summer conditions in case of application of Fanger Model with much higher values than limits for the category III of existing buildings (PMV > 0,7 and PPD > 15%) during the occupation hours, from 8:00 a.m. to 6:00 p.m. In the case of Adaptive Model the results are not so critical considering the physiological, psychological or behavioural adjustment of building occupants to the interior thermal environment in order to avoid discomfort. In winter condition, with the heating system turned on, there are no critical values of discomfort. In fact, PMV and PPD values are slightly above the acceptability limits in the “Nave” building. The Figure 3 represents an example of “footprint”, seen as the percentage distribution of hours that the building falls within each of the four categories based on PMV-PPD reference limits and gives us an overall evaluation of the thermal environment. This evaluation is an useful tool for “mapping” the building and highlighting the most critical area where an intervention is necessary.

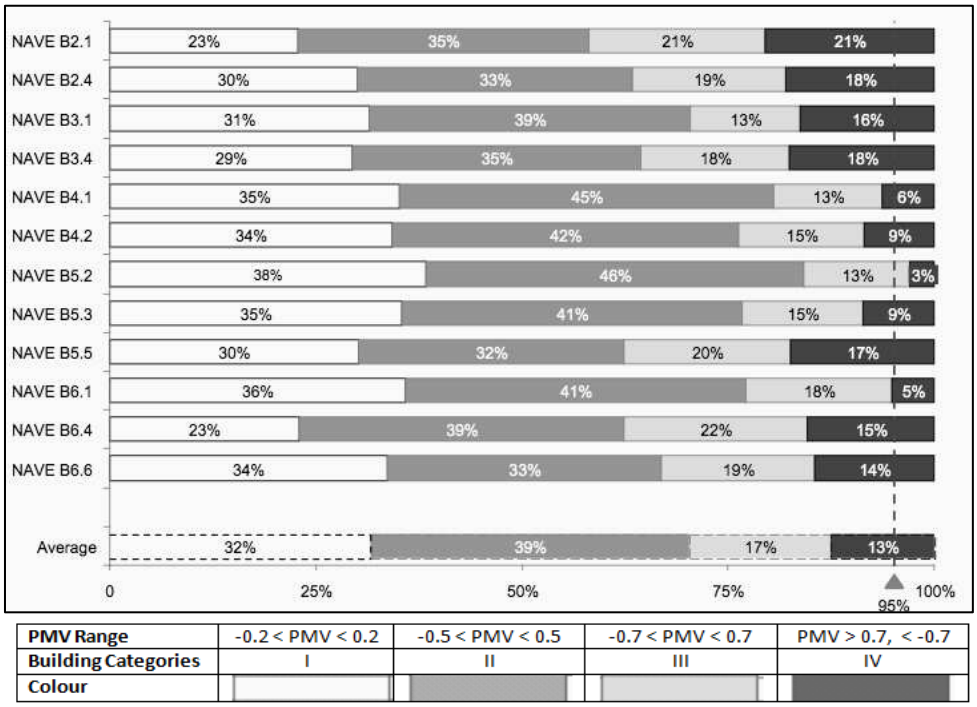

Figure 3 – "Footprint" of PMV value for the monitored rooms in winter conditions

2.2 Thermal Comfort related to Energy Consumption

Simultaneously to the comfort assessment some fact-finding analysis on the building envelope were performed in order to reconstruct the technical solution and evaluate its thermal performance (Figure 4).

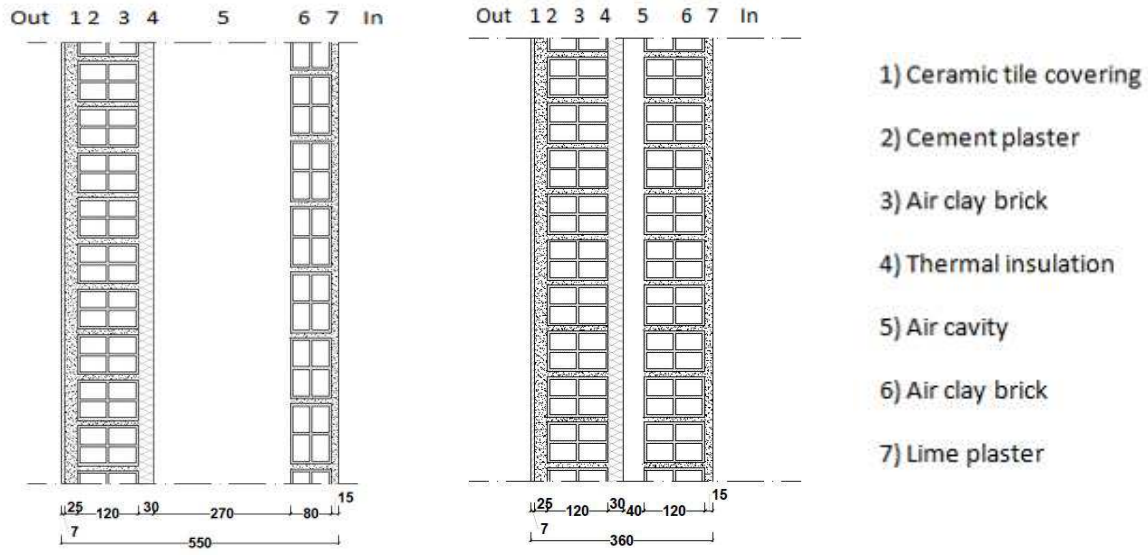

Figure 4 – Main sections of the South facing wall

At the same time, energy monitoring on the heating plants has been initiated, using probes such as temperature detectors and flow-meters. This activity may allow us to make a comparison among the thermal comfort level, the real energy demand and energy consumptions. For instance, through the thermal comfort measurements in winter condition,

it was possible to learn that there are acceptable levels of comfort and sometimes the value is upper than the superior limit (too warm). This means that the heating system is oversized and mismanaged. In fact there is a poor regulating and controlling system. In order to ensure comfort and decrease the energy consumption some solution are needed and simulations should be performed in order to evaluate the advantages.

2.3 Simulations and BIM modelling

The building "Nave" energetic assessment has been done through a fully interoperable BIM model (Figure ~~Figure 5~~), useful both for energetic analysis and for managing the project alternatives in the refurbishment design phase. This BIM model has been also inserted inside the much bigger 3D model of the Politecnico di Milano Campus to assess its interoperability.

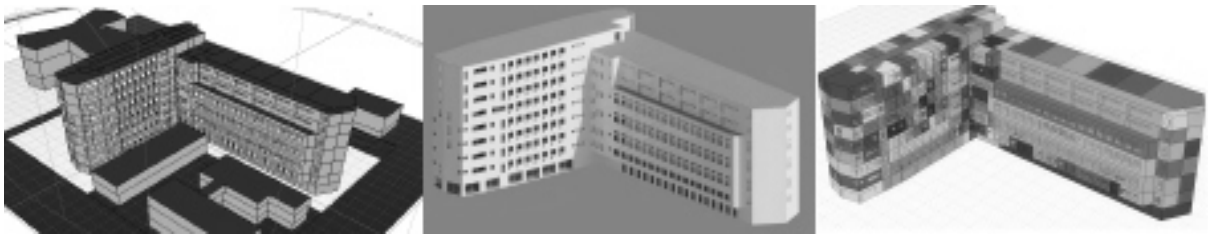

Figure 5 – BIM model of the case study

The model contains data about surfaces, volumes, thermal zones, time schedules (both for plants and users habits), technologies and plants; all gathered from the survey previously done. The simulations results show numerically what has been already noticed during the assessment of the building: there is a great consumption caused mainly by the lacks of the regulation systems of the heating plant and the low insulation level of the envelope, both opaque and transparent. The overall consumption of the heating system, evaluated with the BIM model, is around 130 kWh/m^2 y. The results will be fully checked next fall because the Politecnico is currently implementing a new system of consumption monitoring.

3. Multi-criteria method

After the inspections and analysis of the current state of the building, both in term of internal comfort and degradation of the components, some project alternatives for a sustainable refurbishment have been proposed and evaluated. To do this, a multi-criteria decision support system has been created to help the designers during the decision phase. The multi-criteria method allows evaluating interventions of different categories, regarding both plants and building components, sorted in groups or alone. A large amount of parameters has been evaluated, starting from the International Standards and other research projects with the same theme Open House (2011), Akadiri (2011). These parameters are divided into three major categories, as written in the UNI EN 15643 (2010). In this study the social sustainability has been converted into the internal performance, measured in terms of internal comfort perceived by the occupants. All the parameters, divided in the three major categories of sustainability, can be seen in the Table 1~~Table 1~~. The method is built according to the AHP selection process Kaklauskas, Zavadskas, Raslanas (2005) and Sonmez,

Ontepeli (2009). The first phase consists in the creation of the hierarchic scale, made by three levels.

The project alternatives are in the bottom of the hierarchic scale, out of the three levels. In this study the normalization method with equally distributed scale has been used, both for parameters that need to be maximized or minimized. In this method a weighting system able to consider the relative importance among parameters seemed to be convenient, so a pair comparison among the elements of the second and third level of the hierarchic scale was conducted; the comparison was performed among elements of the same category (the three fields of sustainability) to get three series of weights. First of all, the relative importance of the field of sustainability has been calculated, with the following results: a) environmental sustainability 55%, b) economical sustainability 21% and c) internal performance 24%. Then the relative importance of the parameters has been calculated with the same method. The results are shown in the Table 1~~Table 1~~.

Table 1 – Parameters relative importance and references in the UNI EN 15643

Sust.	Category from UNI EN 15643	Building phase (from A to C)	Parameters evaluated	Weight [%]
Environmental	UNI EN 15643-2 §6.2 - Indicators for resource use (environmental aspects)	B6	Consumption of energy primary	37%
		B1	Consumption of energy and resources	23%
		B7	Water consumption	17%
		from A1 to C4	Embodied energy	11%
	UNI EN 15643-2 §6.2 - Indicators for environmental impacts (LCIA impact categories)	from A1 to C4	CO_2 emissions	13%
Economical	UNI EN 15643-4 §5.4.2.1 - Economics impacts and aspects at the Product Stage	A4 - A6	Construction cost	33%
	UNI EN 15643-4 §5.4.3.1 - Economic impacts and aspects at the Use Stage	B6	Cost of energy primary	27%
	UNI EN 15643-4 §5.4.3.1 - Economic impacts and aspects at the Use Stage	B1	Cost of energy and resources	19%
	UNI EN 15643-4 §5.4.2.2 - Economic impacts and aspects at the Use Stage	from B2 to B5	Maintenance cost	13%
	UNI EN 15643-4 §5.4.2.3 - Economic impacts and aspects at the End of Life	from C1 to C4	Disposal cost	7%
Social	UNI EN 15643-3 §6.2.2.3 - Health and Comfort	B1	Thermal comfort	46%
		B1	Acoustic comfort	24%
		B1	Internal Air Quality	19%
		B1	Internal visual comfort	12%

The evaluation of the parameters was carried on by an online survey sent to a great amount of people, consisting mainly of professionals, professors, students of Architecture and Engineering. After the comparison, the alternatives could be analysed by collecting the data

and calculating the related parameters. The method really helps in the decision phase because it allows the comparison at the third and the second level of the hierarchy scale; so the user can compare both the final and the partial ranking (environment, economy and internal performances) to better understand which solution fits best the objectives.

4. Solutions for a sustainable refurbishment

Several possible solutions have been designed to solve the major criticalities encountered in the inspection phase (thermal losses of the envelope, plants regulation systems and electric high consumptions mainly). These alternatives have been studied also because there is the possibility to concretely implement these solutions inside the activity of the project "Campus Sostenibile". For each alternative all the fourteen parameters described above have been calculated with different techniques, depending on the degree of precision required and the data available. The phase after the calculation of the various parameters is represented by the correct application of the multi-criteria method, as described in §3**Error! Reference source not found.**. So, the alternatives have been normalized and weighted using the weights of the Table 1~~Table 1~~ to get the rankings, that can be seen as sustainability indexes of the alternatives. Five alternatives have been selected among the fortyfour according to these criteria: the most sustainable alternatives overall and the necessary alternatives (which means alternatives connected to components with really low performances, not depending on the improvement of sustainability). The selected alternatives are listed in the Table 2~~Table 2~~.

Table 2 – Sustainability indexes for the selected alternatives

#	COMPONENT	CODE	ENVIRONMENTAL S.	ECONOMIC S.	INTERNAL PERFORMANCE	GLOBAL S.
1	Windows	A.01	0.3647	0.1251	0.0838	0.5737
2	Illumination	A.02	0.3728	0.1481	0.0471	0.5681
3	Heating system	A.03	0.2515	0.1430	0.0192	0.4138
4	Concrete panels	A.04	0.1844	0.1285	0.0192	0.3322
5	Concrete-framed glass panel	A.05	0.1788	0.1269	0.0192	0.3250

The first three alternatives bring serious improvements to the building; on the other hand, the last two are necessary because the concrete panels and the concrete-framed glass panel show really low performances and they require prompt replacement. The five alternatives have been aggregated to make a final comparison with the current situation of the building. The Table 3~~Table 3~~ shows a large performance increase in terms of environment and economy, and also a good upgrade in the internal performance level. The initial cost is obviously high but the five selected interventions should be distributed during years.

Table 3 – Comparison with the actual situation

PARAMETER	CURRENT STATE	SELECTED ALTERNATIVES	Δ [%]
EPH [kWh_{term}/m^2 y]	141.59	33.55	-76.31%

EPC [kWh_{term}/m^2 y]	36.15	33.6	-7.06%
ELECTRICITY [kWh_{elet}/m^2 y]	63.94	52.43	-18.00%
CO2 [kg CO_2/m^2 a]	45.15	27.04	-40.11%
EE [MJ/m^2]	1,137	1,399	23.07%
INITIAL COST [€]	0	604,882	-
MAINTENANCE COST [€]	2,774,435	2,492,588	-10.16%
EP_H COST [€]	2,433,234	576,534	-76.31%
EP_C COST [€]	299,687	278,535	-7.06%
ELECTRICITY COST [€]	2,955,131	2,423,208	-18.00%
LCC [€]	8,690,734	6,375,746	-24.66%
THERMAL COMFORT [degreehour hot]	97,147	103,869	6.47%
THERMAL COMFORT [degreehour cold]	404,564	385,182	-5.03%
ACOUSTIC COMFORT [dB]	39.33	45.21	-13.01%
IAQ [PPD]	54.90%	54.90%	0.00%
VISUAL COMFORT [PPD]	30%	10%	-66.67%

The good piece of news is that two of the previously analyzed alternatives (windows replacement and implementation of the illumination system) are actually in the construction phase. The other alternatives will be evaluated in the next months.

4.1 Model validation and thermal comfort comparison

A comparison between the thermal indexes obtained by the monitoring activity and the ones obtained by simulation with the BIM model has been carried out in order to validate the model itself. As shown in Figure 6 the courses are very similar, so it is possible to highlight that the created model approximizes well enough the building actual condition.

Moreover, thanks to comparison with the PPD value obtained changing into the BIM model the boundary conditions based on the alternatives of refurbishment interventions, it is clear that the thermal index remains within the ranges but a decrease of energy consumption occurs.

PPD_A_Sim
PPD actual value obtained
by modelling and simulation

PPD_P_Sim
PPD expected value after refurbishment
obtained by modelling and simulation

PPD_A_Measured
PPD actual value obtained
by direct measurement

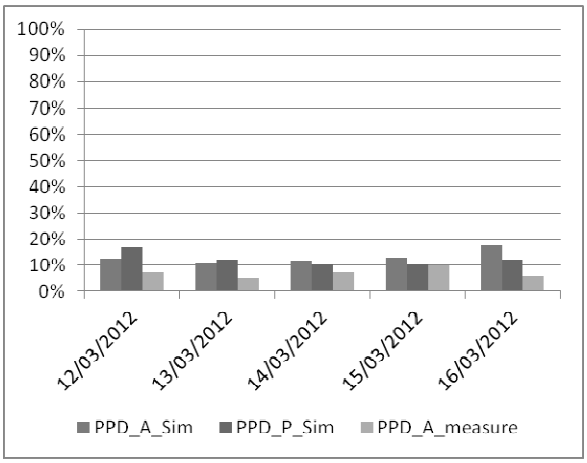

Figure 6 – Comparison among PPD values obtained by measurements and by simulation (actual and expected values after the refurbishment)

5. Conclusion

Through this case study has been demonstrated the applicability of the principles and methods for assessing the sustainability in construction sector in case of existing buildings, starting from the actual situation.

The thermal comfort assessment, performed according to a measurement protocol developed ad hoc, is a useful tool and it is aimed at assessing the actual sustainability level from the environmental and social point of view. Thanks to its wide applicability and the creation of standardized “comfort report forms”, the protocol could be used also after the refurbishment in order to evaluate the changes and the new level of comfort. Also other assessments are needed for the other environmental comfort and health forms (visual, acoustic, indoor air quality), as well as local discomfort as expressed in UNI EN ISO 15251 (2007).

The use of a multi-criteria method during the assessment of different project alternatives really helps in an objective definition of the sustainability level; this must be combined with a precise evaluation of the current state of the building. Another interesting issue is that a method like this can be easily updated with the evolution of the legislation and the related requirements.

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Bricollage Research and Agile Development in Humanitarian Architecture

Scott Shall[1]

Informal Settlements and Bricollage Research

Current efforts to measure, catalogue or otherwise document what are now known as informal settlements – a term that expresses more our lack of ability to measure than the inherent nature of the settlement itself – are limited by the mechanisms of research, a set of tools that are designed to assess conditions found within more formal sectors. As a result, architects, urban planners, policy-makers and others who are helping to frame the next generation cityscape are doing so with only a cursory understanding of the conditions faced by somewhere between 800 million and 1 billion people - a blindspot that will shortly balloon to somewhere between 1.3 billion and 2.5 billion citizens (Davis, 2007).

These paired conditions – the exponential growth in informal settlement and our almost complete inability to understand them - will only grow in importance over time. Unfortunately, to address the former is impossible unless we first address the latter and to address the latter requires that we adjust our techniques in light of the still-unknown realities of the former. This paradox forces our hand as researchers and designers of said environments, compelling us to adopt techniques of research, design and construction that permit a more gradual and systematic interrogation of current mechanisms based upon heretofore unknown conditions. Instead of entering into informal settlements as an engineer or scientist, with a preconstructed survey or premeditated mission (i.e. to tabulate numbers, design sustainable homes, or build a community center) we must enter into these situations as a bricolleur, using small acts of observation, data-collection, and construction in order to gain the knowledge necessary to craft more profound methods of working. In this way, the tools and measuring devices of the bricolleur-researcher function less like objects, designed to a fixed and singular purpose, and more like Claude-Levi-Strauss' objects of knowledge: artifacts designed provisionally, through which we might instigate the creation of new tools and objects (Strauss, 1968).

To illustrate these concepts, this paper will turn to a series of $5 architectures created in this spirit within informal settlements around the world. The measurements, insights, and methods unearthed through these small architectures will be presented, analyzed and discussed, in the hopes of, eventually, developing a more iterative research paradigm.

Keywords: Objects Of Knowledge, Agile Development, Humanitarian Architecture,

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Bricollage, Iterative Research Models

1. The Agile Manifesto

In February of 2001, 17 software developers met in Utah to discuss lightweight development methods. From this conversation, they authored the *Manifesto for Agile Software Development*, which established a rapid, adaptable and profoundly crowd-sourced method for software development. The *Manifesto* offered twelve key principles (Beck, 2001):

- Customer satisfaction by rapid delivery of useful software
- Welcome changing requirements, even late in development
- Working software is delivered frequently (weeks rather than months)
- Working software is the principal measure of progress
- Sustainable development, able to maintain a constant pace
- Close, daily co-operation between business people and developers
- Face-to-face conversation is the best form of communication (co-location)
- Projects are built around motivated individuals, who should be trusted
- Continuous attention to technical excellence and good design
- Simplicity- The art of maximizing the amount of work not done - is essential
- Self-organizing teams
- Regular adaptation to changing circumstances

Through these principles, the *Manifesto for Agile Software Development* took to task several long-standing parameters of software development, prioritizing self-organizing bodies over hierarchical orders, customer collaboration over contract negotiation and continuous development over realizing the goals of a predetermined plan.

1.1 Strategies of Agile Development

To realize these goals, proponents of agile development redesigned the project delivery process, replacing traditional methods with processes that would not only *permit*, but *promote* development, teamwork, collaboration, and process adaptability throughout the life-cycle of the project (Ambler, 2002). Several key strategies emerge from this base:

1.1.1 Continuous Integration

At its core, agile development requires the continuous integration of new or changed code into an existing code repository, with the smallest intervening window possible. This places great emphasis upon reducing or eliminating the gap between commit and build. It also places great importance on continually cultivating techniques of exchange that would allow contributors to rapidly find and address any errors that might emerge through this fluid process. Project delivery systems, as well as those dedicated to project documentation, assessment, and development, collapse into a single, iterative process without end. The build becomes automated – a process of overlapped research, design, testing and use that allows for the immediate testing of new work and the continuous integration of necessary corrections. A self-sustaining, regenerative information architecture thus emerges (Black, 2009).

1.1.2 Incremental Improvement

To realize continuous integration, proponents of agile development had to first break large tasks into smaller increments, offering the actors engaged in the continuous integration process small, self-contained nuggets of insight in real time. Wisdom thus becomes a matter of many insights piled up, not a carefully choreographed and predestined process authored by a predetermined body of experts. New iterations of work are a product of weeks, not years. The goals of project delivery thereby shifted from offering iterations with sufficient functional improvement to warrant a full market release to offering iterations with a manageable amount of bugs capable of offering incremental improvement to the previous model (Beck, 1999). As every commit is built, many small ideas naturally trump the large. As the tools and processes behind the work become more refined, the speed and accessibility of the build improves dramatically. Correspondingly, new iterations of work are now a product of weeks, but minutes.

1.1.3 Self-organizing Teams

As the processes behind continuous integration advanced and the acceptable increment of project delivery shrunk, proponents of agile development were able to radically expand the nature of the teams behind the build. Instead of assembling a predetermined group of experts or placing the task before a large team of professionals, all stakeholders can now be involved in every aspect of the project delivery process. The indeterminate nature of the term stakeholder brought about cross-functional and self-organizing teams of contributors, without any consideration for existing corporate hierarchy or the corporate roles of team members.

1.1.4 Constant Communication

However, to realize any of these strategies requires rapid communication. In the early days of agile development, this placed a priority upon quick, face-to-face communication techniques that would expose problems as they arose. The script, not written communication became the prior means of offering updates and progress reports. Daily

meetings, often referred to as stand-ups or scrum meetings due to the habit of participants standing to keep the conversation short, were ritualized. The fifteen-minute office meeting became the norm. As internet-based communication technologies advanced, these meetings fractured, allowing anyone with access to the script and the knowledge, skills and toolsets necessary to evolve it well could contribute. The wisdom of crowds could be harnessed to an extent never before thought possible (Surowiecki, 2005).

1.2 Essential Conditions for Agile Development

To realize agile development strategies requires that those framing the work ensure that three core conditions are in place:

1.2.1 Shared Language

First, those framing the work must offer the focus of the work in a language understandable to all who are expected to contribute to the work. Within the world of information technologies, this shared language finds its root in the nature of the program itself. Traditional language definitions – as offered by spoken tongues or written conventions – are of secondary importance. Thus, although it might be helpful in some instances if the contributors all spoke the same language, it is not required; the language of programming is the core mode of exchange. This casts a wide net, permitting experts from around the world to contribute their wisdom to the work. For the architect operating as a socially-responsive creative actor, this approach offers a potential address to a common hurdle to collaborative work and, with it, a challenge. If the architect can couch the creative process in terms common to a wide body of potential contributors, he/she could potentially overcome the difficulties in creating collaborative work with people who speak many different languages and hold many different conventions of information exchange, as is often the case in fringe settlements. Images thus trump words; executed work, discussion.

1.2.2 Shared Tools

Secondly, the team farming the work must ensure that the tools necessary to engage the design action are accessible to all parties who will contribute to the work. Obviously, for the information architect, this tool set is found within the various computing technologies required to understand the context for the design action, analyze the various conditions that will inform the address, and disseminate the resulting position to all potential future contributors. Provided that this requisite tool set, including the computer, peripherals and all requisite tangible and intangible infrastructures, is available to all parties, the potential for engagement exists. For the architect engaged in socially-responsive design work, this tool set is based upon the material and practice conventions found within the work's immediate context. Indigenous materials and practices are a natural cornerstone of the design response, with a particular emphasis upon those materials and practices that are common, accessible and replicable. Considerations of cost (less expensive materials are more easily purchased), workability (resources more easily worked will permit a wider body of contributors), and assumed expertise (if the talents required to use the materials are easily mastered, more people will be able to engage the work), become quite important. Although

less inclusive tools sets, including those found within more expensive physical supports (laptops, 3d printers, etc.) and more exclusive methods (environmental modelling, scripting, etc.), are valid modes of pursuing the initial design response, any insight found using said mechanisms must be quickly translated into more universal means. The laptop may be used to model iterations and the CNC router, produce studies, provided that the final disseminated result of these investigations are based upon tool sets of the place.

1.2.3 Shared Knowledge

Third, any team attempting to execute agile development strategies must make sure that all knowledge required to engage the work is universally accessible. The complexity of this mandate is found within the paired needs for speed and accuracy. If the knowledge base is not up-to-date or is not verified, the contributed wisdom of every step of the process from that point forward will be sacrificed. Google works because it is consistently updated and verified, Wikipedia fails, at times, because the system of updating and correcting is not as robust. Similarly, Linux contributors wield great wisdom because they have access to the latest updates and all the facts that went into these decisions. The speed with which these paired concerns are met will greatly impact the speed of development: instantaneous, accurate updates will pave the way for a very fast development; slow, inaccurate updates will stop it altogether. For the socially-responsive architect, these concerns for speed and accuracy are not easily met, as the tool sets used to transfer information within fringe settlements – conversation, word-of-mouth truisms and, eventually, traditions - are not designed to exchange new wisdom with great speed or provide for consistent verification. In fact, most of these mechanisms are prone to encourage behavioral patterns, such as information cascade, social comparison, and polarization, that lead to rumors, gossip, and other oft-erroneous reports (Surowiecki, 2005).

1.3 From Agile Development to Humanitarian Design

To cultivate a shared base of exchange – in terms of language, tools and knowledge – that can keep pace with the rapid development of fringe settlements, the socially-responsive architect must break down the offered insight into more manageable units of transference. Instead of elaborate arguments or complex propositions, the architect must cultivate wisdom gradually, through a series of concise addresses couched in a language easily understood and transferred using tools and means easily engaged. To operate well in fringe settlements, the architect must pursue the work through meme-tectonics.

2. Meme-Tectonics

The utility of the meme - a bit-sized morsel of information easily shared and virally propagated - is well-known to the advertising agent, TV executive and counter culture warrior (Lasn, 2000). To those dwelling within informal settlements, this idea, although generally couched using different terminology (if at all) is of vital importance. Without it, critical messages – where to hijack free electricity, how to find clean water and what materials are best suited to keep the rain off your head – can be misunderstood, mistranslated or misjudged, missteps that could greatly impact one’s odds of survival.

From this foundation, emerges meme-tectonics – bite-sized construction morsels based upon the methods of the bricolleur and the potentials found within undervalued resources (Frampton, 2001). For the activist artist and socially-responsive designer, meme-tectonics offers a method of project delivery that sidesteps the limits of top-down project dissemination, which are too slow to keep pace with the rapid growth of edge settlements and assume a hierarchy of knowledge transference, without sacrificing the knowledge base of the external expert.

For the activist artist and socially-responsive designer, meme-tectonics trades the creation of objects for the creation of objects of knowledge – material constructs that collect the wisdom of many and propagate virally (Levi-Strauss, 1968).

2.1 Three Studies

Each of the projects shown here represent the promise of meme-tectonics within distinct fringe settlements: the site of the first work, affectionately titled streetURCHIN by its original makers, is based upon economic situation, the site of the second work, fencePOCKET, is based upon a perceptual situation, and the site of the third work, projectionMAIL, is based upon a situation of custom. To address these diverse concerns, all three works collect around the promise of simple, easily transferred tectonic knowledge, as offered by the following descriptions:

2.1.1 Meme-Tectonics 01 _ streetURCHIN (total cost: $0.50)

streetURCHIN is borne of an invitation to exhibit previously realized work and the designers' strict refusal to engage in such a limited, object-centric action. Instead, those responsible for this work requested to use the exhibition as an opportunity to engage a set of architectural systems present within the context of the gallery space. Specifically, the designers requested to engage the systems that defined the distinct lifestyles of the transient peoples who inhabited the sidewalks around the gallery. The resulting work presents itself not as a solution to homelessness, but as a minor tectonic address to the issue of sleep faced by said populace: the construction of an urban tent that is safer, drier, warmer and more portable than the cardboard tenements currently deployed, using only discarded materials and simple methods of construction. The eventual product of the designer's effort uses simple, repetitive techniques to produce a completely watertight and easily transported shelter from nothing more than discarded plastic shopping bags, rubber bands, and used water bottles.

However, this incarnation only represents a small piece of the value held by the work. As is the case with any work of meme-tectonics, the impact of the address is proportional not to the final object crafted by the originators, but the extent that this object instigates others to use the approach to realize more profound versions of it. To facilitate this process, the originators of the first *streetURCHIN* sought to disseminate the findings to the widest audience possible using a small, pocket-sized manual that uses simple graphics and photos to describe our twelve-step construction process. The team then sent hundreds of these booklets to galleries, agencies and other activist organizations in cities around the US. The

manual thus became an invitation for others to enter into the conversation, build alternative versions of the work, enter into the issues faced by the homeless, and get involved in finding a more permanent solution.

2.1.2 Meme-Tectonics 02 _ fencePOCKET (total cost: $0.00)

Like *streetURCHIN, fencePOCKET* does not attempt to solve anything, for the problem-solving dynamic has little value in fringe situations, serving only to understate the complexity of the conditions engaged or overstate the potential of external interlopers to do so. Rather, *fencePOCKET* is a meme-tectonic based upon a two observations: (a) that our nation's urban areas contain miles of chainlink fencing, guarding our property lines and defining a perceptual edge between public and private lands and (b) that chainlink fencing, although very resistant to vertical forces, often falls victim to horizontal forces, resulting in bulges, creases and other deviations. When brought together, these observations offer hidden potential within fencescape deformations: a blurring of the perceptual edge offered by the fence and thickening of the assumed line between public and private lands. The meme-tectonic offered by *fencePOCKET* is designed to instigate the creation of new public space within these fencescape deviations.

To work well within this context, *fencePOCKET*'s meme-tectonic is designed to be:

* SUSTAINABLE: *fencePOCKET* is constructed entirely of reclaimed tarp, becoming a consumer of waste, not a generator of it. The resiliency of this tarp, a deficit if placed within a landfill, becomes a huge asset when used to create *fencePOCKET*, adding durability and longevity to the construction.

* LEGAL: *fencePOCKET* can be tailored to any deformation, eliminating any legal issues associated with trespassing into either public or private lands.

* EFFICIENT: *fencePOCKET* uses a simple weave construction – a process that allows even the smallest sections of reclaimed tarp to tap into the strength of existing fences.

* ELASTIC: *fencePOCKET* can be built anywhere a fencescape deviation exists: any city, any country, any place.

* USEFUL: *fencePOCKET* can accommodate a wide range of uses: *fencePOCKET_PARK* [public lands are vanishing], *fencePOCKET_GARDEN* [the average American meal travels about 1500 miles], *fencePOCKET_FREE STORE* [Americans deposit 56 tons of trash into landfills every year, around one-third of which is related to new purchases], *fencePOCKET_BENCH* [US cities are quickly removing benches to combat public sleeping], *fencePOCKET_COT* [there are currently over 650,000 people in the US without shelter]

Once again, the incarnations shown here only represents a small piece of the value held by the work. *fencePOCKET* is completely open source: created wherever a fencescape deviation exists (open-site) by anyone who would like to take possession of wasted space (open-architect/contractor), programmed by whoever has the desire to realize its utility (open-developer) and occupied by whoever desires to do so (open-user).

2.1.3 Meme-Tectonics 03 _ projectionMAIL (total cost: $2.00)

The final work, *projectionMAIL*, is borne of the tension found within the exhibition of design work in a location completely foreign to the context of the work itself. Specifically, this work stems from an invitation to exhibit work created when a forty-person team representing two countries, eight universities and six disciplines travelled to Mumbai, India to help develop new architectural strategies with an Indian non-profit that provides education and health programs for children living on the construction sites of Mumbai. During this five-week project, this team of students, artists, architects and designers would forge a collaborative effort with a people who spoke a different language, had different customs, and carried different values to address the complex and fluid set of programs, sites, and communities offered by a migratory client existing on borrowed land. The resulting effort produced not a single project, but an infrastructure through which many projects might be realized over time by a myriad of publics over a long period of time.

The invitation to exhibit this work created *Publics Stimulus Packages*: an open-ended series of exhibitions (*ACTS*) and conversations (*TALKS)* intended to use the potential of meme-tectonics to question and expand the relevance of this infrastructure to other sites, publics and spheres. ACT I of this series, *Projection Mail: Uniting Systems in the Public Sphere*, employs hundreds of *PROJECTION MAILboxes [SMALL],* a $3 projection system with a range of over 10'-0", to offer patrons a myriad of perspectives on the aforementioned work. The size and weight of these projectors, as well as the nature of the projected image, allows patrons to cultivate new overlaps between these perspectives and their own, convergences which both reflect and rearticulate the relationship between the work, those viewing it, and, invariably, those responsible for re-creating it. So that this movement might expand to include publics, spaces and time periods not offered by any single exhibition, patrons to both the physical space of the gallery and a parallel online event are invited to propose alternative venues for the work by "stealing" one or more of the boxes and taking it to (what they believe to be) a more suitable location.

Once repositioned on a new site, the *PROJECTION MAILbox [SMALL]* uses simple graphic mechanisms to clearly communicate its intent to the now-expanded body of contributors, stimulating them to [re]position the work into unknown contexts, [re]project the image onto unanticipated surfaces, [re]purpose the box (through graffiti or the substitution of images) to new ends and [re]present their movements, insights and photos to a growing body of online contributors. The trans-personal experience thereby created brings together acts of transition and alienation, fantasy and translation, compelling those engaging the work to trade the position of voyeur (gawking at another, exotic experience) for one that is more personal (building one's awareness of 'projecting' onto a foreign culture offering), interactive (interaction between the given image and the creative potential of the spectator) and expressive (specifically related to their own experience as it relates to the Indian experience). The translation of the work thus becomes both relational to the original context and self-relational, creating a critical awareness of one's own position vis-à-vis the site of the observed. In so doing, *Projection Mail*, like the work that proceeded it, offers not a project, but an infrastructure through which others might stimulate a new set of negotiations between the structures offered by our work in India and those inherent within new sites, programs, and publics.

3. Language > Object | Architecture > Design

In software engineering, two patterns of replicable solutions exist. A design pattern refers to a reusable solution to a common problem within a given context. An architectural pattern refers to a reusable solution that engages a system-wide pattern (Buschmann, 1996)). Both design patterns and architectural patterns are templates: a series of best practices that can be used in many different situations. Over time, these practices become formalized, creating a pattern. Patterns that are object-oriented – showing relationships between classes or objects – are generally more mutable. Thus, object-oriented patterns are not as applicable in functional programming, regardless of whether the scale of the address is a given context – design pattern – or a given system – architectural pattern.

These differentiations provide a great deal of insight into why some acts of the humanitarian architect have far greater resonance than others (Lasky, 2010). First, works that are object-oriented will generally have far less range and yield than those that are language-oriented. The range of object-oriented humanitarian architecture will be proportional to the range found within the objects engaged. Conversely, the range of language-oriented humanitarian architecture will be proportional to the range offered by the language that furnishes its base. This returns us to the core methods, continuous integration, incremental improvement, self-organizing teams, and constant communication, and concerns, shared languages, shared tool sets, shared knowledge, of agile development. If the architectural proposition engages these methods well, the range of the work, like that of the information architect, will extend dramatically. Secondly, works that find their base in architectural patterns will generally outperform works that find their base in design patterns. Architectural patterns describe a higher-level system of organization: the parameters and infrastructures engaged will, by definition, impact a larger frame than will design patterns. Thus, although architectural patterns can be more difficult to discern, their proper engagement must remain of core concern to the socially-responsive designer.

The exponential growth found within fringe settlements demands it.

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A Case Study Investigation into the use of Computer Generated Visualisations to Assist with Construction Delay Claims

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Abstract

It is probable that a construction project will encounter some form of delay which can have differing adverse effects on the various parties involved in the works. Those affected by the delay are entitled to claim a form of compensation but the burden of proof lies with the party making the assertion. Analysing the cause and effect of a delay event is difficult given the ever increasing complexity of construction works; thus, experts are often employed to undertake the task but face the challenge of clearly representing and communicating their findings. This paper identifies the accepted traditional methods of representing construction delays and explores how they could be assisted through technological developments in computer generated visualisations, which have gained growing acceptance within legal proceedings. An in-house case study presents two different visualisations, one in 2D and one in 4D, which were developed in an attempt to assist with the same delay claim. The benefits, limitations and areas of improvement are discussed for each and an overall recommendation on the potential use of visualisations to assist with construction delay claims is presented. The paper recognises further investigation into the use of Building Information Modelling to support delay claims which forms part of on-going research towards an engineering doctorate.

Key words: BIM, claims, delays, disputes, visualisation.

1. Introduction

Construction projects are becoming increasingly complex, yet tender values in the UK are decreasing (BCIS, 2012). The more complex a construction project, the more likely it is to encounter time delays, which may result in financial implications (CIOB, 2008). Given that 70% of UK construction projects are delivered late (HM Treasury, 1999) and that organisations cannot financially absorb the difference from what was planned, if the delay is beyond the organisations control, it is likely that a claim will be made for some form of

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compensation. If the claim is not accepted, the project may go into dispute. The number of construction disputes in the UK has risen by a third during the recent recession (Sweet & Maxwell, 2010) with both the value and length of the average UK construction dispute increasing by US$2.7million and 1.95months (EC Harris, 2012). Owing to the extensive resources required to undertake a construction claim, the divergence away from the proactive management of the organisation, as well as the migration of cash flow out of the construction industry when disputes occur, it is imperative that steps are made to improve the claim process.

This paper investigates the use of computer generated visualisations to assist with construction delay claims, an area in which to date there has been very little published research. The research reported in this paper is based on an in-house case study which presents two different visualisation approaches, one in 2D and one in 4D, which were developed to assist with the same delay claim.

2. Background

The term delay is exhaustively used in the construction industry; however, no standard form of construction contract defines the term due to the comparative nature in which it is used (Pickavance, 2010). In this paper, the term delay refers to the non-completion of works by a date set in the construction contract (Fenwick Elliott, 2012). Therefore, the process of analysing delays can be viewed as the forensic investigation into an issue which has caused the project to overrun on time (Farrow, 2001). This is distinctly different from disruption, a term generally conjoined with delay, which investigates loss of efficiency due to a lower productivity or an interference with progress (Cooke, 2009). The topic of disruption is not covered in this paper; however, both can become intertwined and result in construction claims.

Subject to the claiming party, different forms of compensation are available depending on how the delay is categorised (Trauner, 2009). On the one hand, the client can claim unliquidated or liquidated damages which protect their investment if the project is not completed by the contract completion date. On the other hand, the contractor can claim an extension of time and/or loss and expense if the project is delayed for reasons beyond their control. In order for the claimant to receive compensation, a construction delay claim must be made. This is broken down into three stages: causation, liability and quantum, all of which can prove a challenge for delay analyst (Williams, 2003).The burden of proof is placed with the claimant to prove each of these by showing on the balance of probabilities through cause and effect (Carnell, 2000). The balance of probabilities can then be shifted based on the standard of evidence, with stronger evidence required for more severe cases.

Construction programmes are the most common way to represent the cause and effect of delays and a variety of methodologies are available which use them, but some are preferred to (SCL, 2002). The chosen approach will be influenced by a variety of factors (Braimah, 2008); therefore, the choice of methodology should be the one which best represents the claim (Bubshait, 1998). It is argued that the most reliable of these methodologies is Time Impact Analysis which breaks the construction programme into a series of windows, each

with their own baseline, and re-sequences in line with as-built activities to analyse the relationships and durations of individual delay events by inserting them into each window to identify the event and the delay caused in that period (Arditi, 2006).

The findings from the analysis must be supported by a narrative, which will attempt to explain the claimants interpretation of what occurred on the project. Visual information is preferred to oral information as it improves understanding and retention (Keane, 2008); thus it allows for a more informed decision to be made. At present, the submission of a delay claim may involve numerous lever arch files with complex construction programmes and supporting evidence. Although accepted as a means to show cause and effect, the various delay analysis methodologies can be difficult to understand (Kumaraswamy, 2003). This is emphasised by Humphrey Lloyd QC in Balfour Beatty Construction v. London Borough of Lambert:

"This letter shows that the adjudicator was unable to make use (and, possibly, sense) of the material submitted on behalf of BB which included BB's "as-built" programme and analysis."

Furthermore, deciphering supporting information to allow for an informed judgement to be made can prove a challenging task, especially interpreting technical construction drawings (Dziurawiec, 1986). This is apparent in Hunte v. Bottomley where Arden L.J. states:

"Those who prepare bundles or skeleton arguments would do well to remember that a plan, map, diagram or photograph which is clear to people who are fully familiar with the case may well not be wholly clear to a judge coming to the case for the first time."

In an attempt to combat these problems, the courts are moving closer to e-disclosure and the use of screens as a method of communication. Therefore, the potential to use modern technology, particularly computer generated visualisations, to represent construction delays is possible. With continual developments in computer hardware along with the reductions in its cost, there has, and continues to be, a rise in the quality of computer generated visualisations. The definition of visualisation is open to interpretation and its meaning will vary between individuals. To some, a construction programme is a visualisation; whereas others, a simple line may suffice. In general, the term relates to a visual representation of information to enhance understanding (Card, 1999). For the purpose of this paper, 'visualisations' are Computer Generated Imagery (CGI) of tangible construction works which represent the progress of the project at a point in time.

Since the 1980s the entertainment industry has developed CGI for the internet, television, computer/video games and film (Parent, 2012). These platforms have progressed rapidly because the information is stored digitally, which allows it to be enhanced through bespoke software packages. Despite its rapid uptake in this sector, the UK construction industry has been slow to adopt electronic information as a communication method. Developments towards Computer Aided Drafting/Design (CAD) were made in 1963 (Tizzard, 1994); however, the current level and use of CAD within the industry is extremely varied, with 35% of organisations not using CAD (NBS, 2012). This could be attributed to the fact that

although the information is electronic, it is uncoordinated and must be interpreted by individuals; thus, it is little different to the traditional drawing board (Sacks, 2004).

Within the construction industry, visualisations are predominantly used in architectural design, but their benefits can be realised throughout the construction lifecycle (Bouchlaghem, 2005). Their main benefit is assisting with understanding and communication. The value of visualisations can be extended to legal proceedings and their use is expected to rise as courts are becoming increasingly technologically sophisticated (Narayanan, 2001). Visualisations have assisted the courtroom in the 1998 UK inquiry into the events of Bloody Sunday in Londonderry 1972 and the 2001 Carla Terry murder case in Connecticut. The criteria for visualisations to be accepted as supporting evidence are identified in the latter case as:

1. The equipment used is standard in the field and is shown to be in good working order
2. Qualified operators, procedures and reliable software are employed to produce the output
3. The equipment was operated correctly
4. The exhibit is identified as the output produced.

Unfortunately, delay claims have not advanced in the same manner and the technology associated with them lags behind that of other stages in the lifecycle of a construction project (Vidogah, 1998). Pickavance (2007) identifies how technology can be used to create animations of tangible construction works to support construction disruption claims. Using both static and dynamic images to visually represent the cause and effect of disruption, the research highlights the importance of a side by side comparison of as-planned v. as-built progress. If used correctly, this method may be suitable in some adjudications and arbitrations (Pickavance, 2010); however, its value as evidence will vary depending on how it is employed and the supporting documentation (Schofield, 2005).

Numerous software providers offer products which allow you to virtually construct a construction project. The rise can be attributed to the growth of Building Information Modelling (BIM), a process of working which the UK government has mandated a minimum level of use on all public sector construction projects by 2016. BIM is seen as a way of tackling the inefficiencies present in the industry (Cabinet Office, 2011) through the process of recording all of a project's information throughout its lifecycle in one, central, electronic, location. This information is linked to a 3D virtual representation of the project which is produced using object based parametric modelling software. This software advances from 'traditional' CAD based lines and instead places objects with rules and parameters which determine both geometric and non-geometric properties and features (Eastman, 2011). The relationships and constraints between objects ensure realistic connections between elements and when designed in a single source model, a change to an object in one view will automatically update all other views and linked information. Through the coordinated information, multiple dimensions become available. These include 4D (time), 5D (cost) and 6D (FM) (RIBA, 2012) where a change in any view or dimension will instantly change all dimensions, views and report the most up-to-date information on the project. The benefits of

this to assist with delay analysis are discussed by Gibbs (2012) while the process of BIM is also recognised as being able to assist with dispute systems (Greenwald, 2012).

3. Method

In order to determine how visualisations can assist with construction delay claims, primary data was collected through an in house case study. The use of a case study as a viable research methodology for construction claims is enhanced through Pickavance's (2007) research. Although the conclusions drawn from the research will be specific to a single project, the lessons learnt should be transferable. The author was unable to assist with the delay claim as it occurred before they joined the organisation and the dispute remains strictly confidential; therefore, the level of detail in the paper has been limited.

3.1. Background to the case

Claim consultants were approached in 2010 by a Sub-contractor (from here on known as the Client) requesting expert delay analysis support on a construction project in the United Kingdom. The works, valued at several million pounds, included for the design and construction of a reinforced concrete frame, internal stair cases and the provision for tower cranes including the construction of the tower crane bases.

After investigation by delay analysts, critical delays were found in areas 'A' and 'B' for periods, EOT1 and EOT2. The chosen delay analysis methodology was time impact analysis, which broke the total project duration into one month windows. This identified protective scaffolding and edge protection restrictions, which were the responsibility of others, as prominent delaying activities through stop-start relationships restricting the continuity of successive activities. Although not a complex site, the numerous on-going parallel tasks made it difficult to understand the cause and effect of these delay events. In an attempt to provide clarity on this, computer generated visualisations were explored as a method of communication.

3.2. 2D visualisation

A prototype 2D visualisation of area 'A' was created by a delay analysts using Microsoft Excel to determine whether a visualisation would offer clarity on the delay claim (Figure 1). The Excel visualisation compares as-planned v. as-built progress side by side for the North, South, East and West faces of the building. Each floor compromises of the key sequencing activities required for its completion which include: deck installed, scaffolding, edge protection, freedom to complete floor and floor compete. Individual colours were applied for each activity and represented on each level at all four faces of the building when complete. The progress of the works were automated by linking the model to a bespoke Microsoft Excel construction programme in a separate tab, which automated side by side progress over time. The visualisation could also be used to demonstrate the exact progress for a point in time.

The benefits associated with the visualisation were clear to the Client who decided to progress the concept further into 4D, which subsequently halted the developments of the 2D visualisation. As the claim consultants did not have expert skills in virtual modelling, an external organisation was employed to create a visualisation of the works. Under the Clients request, communication was not allowed between the parties.

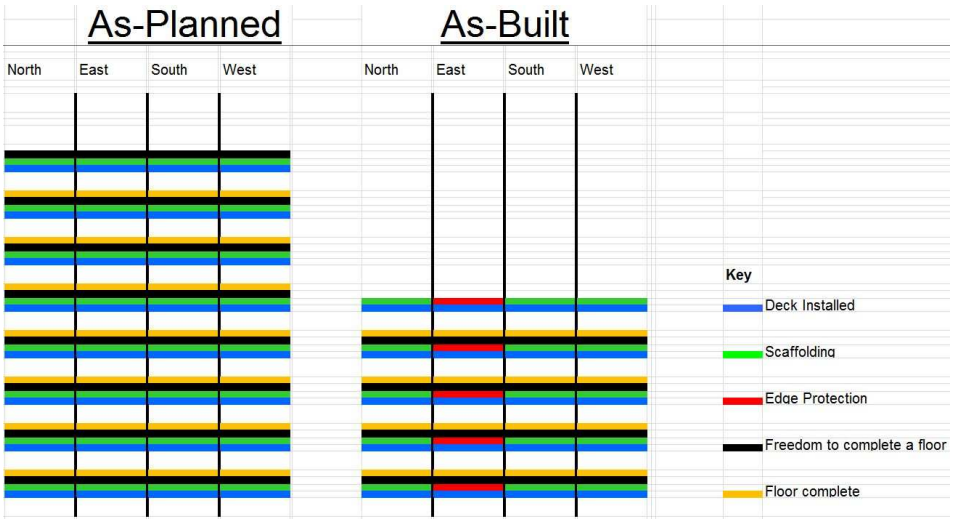

Figure1: Snap shot of a buildings progress from the 2D visualisation

3.3. 4D visualisation

A 4D visualisation of the Clients work was created by a virtual modelling organisation using Synchro. An open viewer of the software was obtained which allowed the visualisation to be viewed and analysed by the claims consultants, although no alterations could be made.

The visualisation incorporated all of the Client's work which included all of the concrete superstructure levels which were individually coloured for each level (Figure 2). The visualisation was linked to an as-built programme within the software to create a fourth dimension, time. Under the 4D visualisation, the delayed elements were highlighted in red, returning back to the original floor level colour once the delay had passed.



Figure 2: Snap shot of a building from the 4D visualisation

4. Analysis

4.1. 2D visualisation

4.1.1. Benefits

The 2D visualisation provides an easy to understand representation of the causes of delay on the project. The visualisation identifies five colour coded elements of sequencing works which make up the construction of each floor of the project. Through automated sequencing which shows as-planned v. as-built progress side by side, the visualisation demonstrates which elements are delayed for a point in time in relation to all faces of the project. Seeing all faces of the project simplified the understanding of how works progressed in an area and the impact of delay. In order to assist the understanding of the as-planned and as-built progress, the automation can be paused, or a specific date selected, to represent progress at a point in time.

4.1.2. Limitations

Despite the apparent benefits of the 2D visualisation, it was not fully developed given the Clients request for the 4D visualisation and their monetary restraints; thus, limitations exist. Some of these limitations would have been tackled if the visualisation had been continually developed; others are inherent in the software.

Had additional time and resources been available to develop the 2D visualisation, it would have included additional activities involved in constructing the project. In its current state, the 2D visualisation demonstrates the sequencing of works to complete each horizontal level, it does not take into account the erection of columns or striking of formwork. Although simple to demonstrate in Excel, the records available from the Client did not allow for its straightforward incorporation.

Whilst an extremely powerful piece of software, Microsoft Excel is not developed to assist with construction delay claims; therefore, limitations exist, with particular regard to representation. The visualisation is not eye-catching and may not retain an individual's attention, an importance expressed by Keane (2008). The visualisation is also not to scale and does not represent the site layout or space available between elements of the areas, which may give a misconception of the amount of work undertaken and incomplete. This limitation is enhanced as the visualisation only shows one building in an area. Although this may be suitable for a single tower block, if all buildings on the particular project were included on one spreadsheet, it would become difficult to understand. Consequenlty, if the site has not been visited by those passing judgement, it would not assist with understanding the project, a problem identified in Hunte v. Bottomley.

Furthermore, the visualisation is not linked to a construction programme which recognises logic and a duplication of effort is required to ensure the creation of an accurate construction programme which is transferred correctly into Microsoft Excel format.

4.1.3. Possible improvements

As the 2D visualisation was developed in a Microsoft Office software package, it is extremely interoperable. The Excel visualisation does not utilise this and the possibility exists to add annotations and link information and documents, such as the narrative, delay programme or photographs, to the visualisation to provide clarity and supportive evidence.

While the Excel model simply represents construction delays, it is limited through the software on how it is represented. Therefore, the same process could be followed using another piece of software which, if available, would make the visualisation more appealing to the eye whilst also being linked to the original delayed construction programme.

4.2. 4D visualisation

4.2.1. Benefits

The 4D visualisation provides an accurate, detailed, virtual representation of the construction works which were undertaken by the Client. This allows the governing body to clearly understand the construction site without ever having to visit. With the ability to pan around the visualisation it is possible to assess a specific building or element from any desired angle. When linked to the construction programme, it allows the viewer to virtually see the construction of the building without having to understand the construction programme in detail, a challenge encountered in Balfour Beatty Construction v. London Borough of Lambert.

4.2.2. Limitations

Despite some of the benefits realised in the 4D visualisation, it is not useful in conveying the cause and effect relationship of the delay events and subsequently was not used to support the delay claim.

The main limitation associated with the 4D visualisation is that it does not represent as-planned v. as-built progress side by side, as promoted by Pickavance (2007). Instead, both construction programmes are linked to one visual representation of the works, with colour coding depicting elements in delay. This method of representing delay does not provide a clear insight into the as-built progress of the works as the visualisation appears to progress at the as-planned rate but under different colours. Therefore, the stop-start relationship of the works is not clear and the delayed elements are not easy to understand. Given the restrictions of the software no annotations, links or photographs could be included to assist with understanding. Furthermore, despite the ability to pan around the visualisation, it was not possible to see all faces of the building at once. With the single view window of the project, it was not possible to see the effect of scaffolding restriction on sequencing works for all faces of the building at one moment in time. This was not supported through the emission of scaffolding objects within the visualisation. The visualisation only represented the finished floor and column elements, it did not break down the sequencing of delay events or include

any resources, such as scaffolding, which the software supported that would have assisted with understanding the cause and effect of delays.

4.2.3. Possible improvements

The limitations of the 4D model could have been mitigated if direct contact was allowed between the claim consultants and the virtual modelling organisation. The reason why communication was not allowed is unknown, but it is expected to be due to confidentiality reasons given the legal situation of the case. It is thought that the individuals developing the visualisation had no experience of delay analysis; therefore, if direct communication was allowed, the delay analysts would have been able to instruct the virtual modelling organisation on the effective use of the visualisation to represent their findings. This would have solved the main problem of not having as-planned v. as-built progress views side by side. This function is not included in all software packages; however, the software used in this particular case is capable. Additionally, the software could have been used to generate multiple angles, or snapshots, of the project in one view for an exact moment in time. This would allow the effect of delay to be analysed on the project at one point in time.

The 4D visualisation could be further enhanced through attaching or linking information which relate to the delay report. If this is not available in the software, a voice recorded description of the analysis which plays over the visualisation would have been of benefit.

5. Overall recommendation

Firstly, a cost benefit analysis should be undertaken to determine whether the costs associated with the development of the visualisation will add value to the representation of the delay claim. This was overlooked in this case study, which resulted in neither visualisation being used as a supporting tool. Despite this, the case study identifies the potential benefits of using visualisations and that the problems encountered can be mitigated.

In future, if visualisations are used to support construction delay claims, it is recommended that they have a side by side comparison of as-planned and as-built progress which is linked to a construction programme, as promoted by Pickavance (2007). Ideally, an accurate 3D visualisation would be developed of all the main construction works on the site, including the main resources used in its construction. Therefore, if simultaneous delays occur, multiple views of the project can be represented in different windows to see the effect of the delay on the entirety of the project. Supporting information could then be coordinated and linked to the model to add clarity. With the rise of BIM, software packages are becoming available which offer these services in a bid to support the new process of working.

Regardless of the capabilities of the software, the case study highlights the importance of strong communication between all parties in order to provide a visualisation which effectively represents the delay analysts findings. Given the justification for this research, it is unfair to expect a virtual modelling organisation to understand a complex delay claim and accurately demonstrate it in a virtual environment with no support from a delay analyst. Preferably, a

delay analyst with virtual modelling skills would be employed to create the visualisation, or visa-versa. If not, as is always the case where different professional disciplines are required to work together to produce a solution, strong communication between both parties is required to ensure the visualisation conveys the delay findings as accurately and effectively as possible.

In order to assist the research, further case studies should be undertaken in which a visualisation are used and the recommendations identified in this paper should be incorporated on a delay claim using visualisation and reported on.

6. Conclusion

One of the challenging tasks faced by delay analysts is to clearly represent their findings to support a construction delay claim. The traditional methods of representing construction delays through construction programmes can be difficult to understand, as highlighted by the case law, and assistance through technological developments in computer generated visualisations is recognised.

The potential to use visualisations to support construction delay claims is discussed through an in-house case study where two different visualisations, one in 2D and one in 4D, were developed to assist with the same delay claim. Despite neither of the visualisations being used to support the delay claim, the research highlights some important findings. These include the need for a cost benefit analysis before a decision is made on whether to use a visualisation to support a claim, the importance of a linked logically driven construction programme to the visualisation as well as a side by side comparison of as-planned v. as-built progress. Given the justification for the research, as with any project, the importance of strong communication is required in order for the project to succeed. Further research is required to put the recommendations found in this paper into practice to demonstrate how they can support a construction delay claim. The potential to exploit elements of BIM to assist with construction delay claims are also discussed to assist with construction claims and will continue to be researched as part of an engineering doctorate.

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Integrated procurement and whole life cost: a graphical representation of the relative benefits of alternative procurement methods

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Abstract Title

This paper examines the theoretical relative whole life cost (WLC) efficiencies of alternative forms of serviced infrastructure procurement such as the Private Finance Initiative. Alternatives are considered in terms to levels of contract integration in relation to a facility's design, build and operations (DBO). It uses a production function approach in which contractible output is a function of quantities of two inputs (Capital resource (CAPQ) and Operating resource (OPQ)), with marginal substitution between inputs, and their relative cost, represented graphically with use of isoquant output curves and isocost input lines respectively. Alternative procurement methods are considered in terms of whether they contain constraints on factor inputs, with a specific focus on whether the public sector client faces a constraint on CAPQ resulting from front-end cost aversion rather than pursuit of WLC. Both for realism and for analytical simplicity, it is assumed that the client specifies the same required level and standard of output (FM service quantity and quality) in all procurement options. Therefore subsequent analysis is in terms of WLC minimisation rather than Net Value Maximisation. It is demonstrated that integrated procurement allows for greater allocative efficiency between CAPQ and OPQ to be reached, minimising WLC. This is partly due to reduced waste of separate untendered in-house operations that is decreased x-inefficiency. Furthermore, integrated procurement improves upon separately competitively tendered operations by internalising the incentivised option for higher upfront CAPQ, if anticipated lower OPQ and WLC over the asset life are realised.

Keywords: Integrated contracting, capital resource, operational resource, isocost, isoquant

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1. Introduction

1.1 PFI summary

The Private Finance Initiative (PFI) is a procurement method for the provision of serviced infrastructure that supports essential public services (NAO, 2003). It involves the private sector securing the initial finance required for investment to design, build and operate a facility for the provision of public services. As part of this form of integrated contract, responsibility for on-going facility maintenance (FM) is passed to the private investor under a long-term concession arrangement. In UK PFI contracts, the public sector client normally has the right to take ownership of the facility at the expiry of the contract term. The use of PFI sees the government's role in public service provision change from being the owner and manager of the capital infrastructure, to the purchaser of services on behalf of the public. It is supposed that this type of contract provides the private sector with the incentive and opportunity to minimise the whole life cost (WLC) of the serviced infrastructure (Hart et al., 1997). Another perceived benefit is better value for money through appropriate transfer of various types of risk to the private contractors (construction, operation and technology risk amongst others). Providers of serviced infrastructure under an integrated contract have stronger incentives to control the incidence of risks relating to their provision of services (Hart, 2003). Additionally, the output-based form of specifications associated with these contracts provides incentive and opportunity for the private provider to optimise the net revenue from expenditure on capital and investment in operations, which again, at least in theory, incentivises minimisation of WLC (Rintala, 2004). The private sector manages risk in part by establishing Special Purpose Vehicles (SPVs) for each project. SPVs are independent legal entities in which key project sponsors each potentially invest. These often include construction and FM contractors, private investors including banks, as well as recently a tendency to involve the pubic client (Partnerships UK, 2009). It is the SPV that takes legal responsibility for delivery of the project through sub-contracts with construction, FM and service providers. The public sector pay the SPV for the serviced infrastructure through a unitary charge payment (UCP) paid periodically over the contract tenure, on proviso the specified services are available to contractually agreed standards. This UCP covers payment for the upfront finance and on-going operational expenditure incurred by the SPV. From this the SPV provides for ring-fenced budgets set aside from the beginning of the contract to cover life cycle maintenance of the physical asset.

In Q1 2011, there were 698-signed PFI contracts in the UK, with 632 in the operational phase (HM Treasury, 2011). Based upon analysis of these data, they range in total capital value from under £1m to over £2.65bn throughout the whole contract life (the largest contract being the Military Flight Training Scheme). The average capital value is £76.5m with an associated standard deviation of £161.5m. Normally, the majority of capital expenditure occurs in the initial construction phase, followed by a much lengthier operating phase, together comprising the contract period. Contract periods typically range from around 25 to 35 years, with the average contract length being 26.3 years with an associated standard deviation of 5.2 years. The considerable length of contracts provides potential for transfer of the range of operational risks form the public sector, as well as potential reward for the private sector in terms of recouping investments in operations.

In summary, the defining characteristics of PFI contracts are; their long duration, their scope (to integrate design, construction, operation and finance), their incentives (linking payment to measured availability and performance relation to output specifications), and their ring-fencing of funds intended for maintenance and management of the facility (NAO, 2003).

1.2 Operational PFI commentary

There has been considerable literature produced concerning PFI provision, in part encouraged by the politically sensitive nature of this type of procurement. Authors of the literature range from governments and national auditing bodies, academics (globally based given the international relevance of public procurement practises), industry bodies and trade unions (each with their own interest in the application of PFI).

In the UK the National Audit Office (NAO) have produced numerous case studies of PFI projects (NAO, 2005), as well as two main analyses of the comparative performance of the construction phases of PFI and conventionally procured projects (NAO, 2003 & 2009). Yet only recently has there been any note worthy objective comparisons of the performance of projects within the operational phase that might allow us to comment on WLC considerations (NAO, 2010). This study cites that 'the cost and performance of PFI hotel services[1] are similar to those in Non-PFI hospitals' (NAO, 2010, pg. 6) The need for further analysis is clear in light of the NAO's recent calls:

> "there is a pressing need for better quality evaluation of private finance and other forms of procurement … Government … need particularly to ensure that they can compare the benefits and costs of different procurement routes" (NAO, 2009b, page 4)

and,

> "the systems are not in place to collect comparable data from similar projects using different procurement routes … together with robust evaluation of the overall whole-life costs of alternative forms of procurement" (Ibid, page 8)

Debande (2002) noted that data had yet to be amassed, as there had not been sufficient PFI contracts in the operational phase for data to be available. In 2012 this is no longer the case so there will be increasing opportunities to develop empirical analyses of operations between PFI and non-PFI facilities, providing insight into realities of WLC issues. This paper acknowledges the need for more empirical work in this area, but proposes to undertake a theoretical assessment of the opportunities for integrated contracts to realise WLC savings.

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[1] In this context, hotel services refer to the range of FM services required for the accommodation element of the facility provision.

1.3 Aims and objectives of this paper

The aim of this paper is to examine the context for the selection of the mix of capital and operational resources that deliver the optimal mix of highest operational services against lowest WLC. It does this by applying a common form of graphical representation used in the economics of production theory to the context of alternative forms of serviced infrastructure procurement. The reason for this application to the context of alternative procurement methods is to firstly, enhance understanding of the relative benefits of alternative procurement methods, while secondly seeking to improve the debate concerning what constitutes the optimal point of allocation between investment in the capital asset and operational services for the provision of public serviced infrastructure.

1.4 Term clarification:

CAPQ vs CAPEX: A distinction is made here between capital expenditure (CAPEX) and capital resource (CAPQ) and the operational equivalents of OPEX and OPQ, so as to disentangle price from expenditure to leave physical quantity. To talk about CAPEX may require us to assume that the cost of capital resource for alternative procurement methods is the same, where as this is not necessarily true. PFI projects resort to private finance typically at rates higher than that available to publicly financed projects.

Operations: this refers to the phase of the contract following construction when the serviced infrastructure is in use and where the SPV is in receipt of UCPs.

Contractible output: This refers to the performance of the physical facility as defined by an output specification. The simplest aspects to consider in this are the levels of availability of rooms and spaces that are maintained to a contractually defined quality. This may include, for example, that a hospital ward is maintained within a certain temperature range, lit to a specified standard and achieving defined levels of cleanliness.

Infrastructure: the accepted definition of 'infrastructure' in this investigation aligns with that of Fourie (2006), where a distinction is made within infrastructure, between excludable assets based services and public goods, where there is true non-rivalry and non-excludability. Hirschman (1958) also adds to these concepts highlighting that infrastructure is characterised by its fixed capital nature. Furthermore, we breakdown the general term infrastructure into the two subsets of Social and Economic infrastructure, as laid out by Fourie (2006):

- *Social*: infrastructure which promotes the "health, education and cultural standards" of society and broadly includes schools, hospitals, courts and forms of cultural capital such as museums.

- *Economic*: those infrastructures which promote economic activity in terms of facilitating market transactions and related undertakings, and so include roads, rail lines, air and sea ports, electricity generation, transmission and distribution networks, telecommunications and water.

Whole life cost: An effective definition of WLC includes: “the systematic consideration of all relevant cost and revenues associated with the ownership of an asset” as developed by the UK Construction Research and Innovation Strategy Panel (Constructing Excellence, 2004).

2. Theoretical framework

The theoretical framework to be applied is based on the notion of incomplete contracts and private information (Hart et al. 1997; Hart, 2003). Under a PFI contract, specified standards of operational performance must be achieved for the SPV providing the service to avoid financial penalties being imposed. A specified standard of output implies a certain level of expenditure on inputs. It is proposed that this expenditure can take one of three forms, the first being upfront CAPEX, the later two being subsets of OPEX:

- Upfront CAPEX – leading to a better-built or higher specification physical asset.
- Annual maintenance – frequent planned and responsive non-capital upkeep expenditure.
- Life cycle replacement – periodic infrequent renewal of capital elements of the asset.

There is an option of substitution between the three expenditures above with, in theory, an associated optimum lowest level of total expenditure (in present value terms) able to provide the contracted standards. This optimisation can be considered as the internalisation of a positive externality (Bennett & Iossa, 2006). This externality is the potential for WLC savings when there are separate contracts for the design, build and operation, which in the UK has been the default position in recent economic history. Furthermore, it is not just the bundling of the contract that is relevant, but the ownership and stewardship of the asset. This matters especially when investment cannot be verified or measured (Hart et al., 1997). Placing asset ownership within the SPV would be expected to incentivise optimal WLC investment to ensure the asset value (in terms of meeting contractual standards and the resulting revenue stream) is maintained. On contracts and incentives Grout comments:

> “If contracts can always be written to replicate any reward scheme, then it should not matter whether we have the same entity building, owning, and providing services, or have different entities with public ownership. The difficulty with this argument is that it assumes that contracts can always be complete in the sense that every eventuality can be covered and, therefore, incentives are not a problem.”
>
> *Grout, pg. 63, 1997.*

In that study, Grout goes on to concede the reality of incomplete contracting commenting:

> “In a world of efficient capital markets, full information, and complete contracts, the ownership transfer between the public and private sectors should have no economic effect. In practise, contracts cannot be complete and capital markets may not be perfect, so there is considerable scope for economic impact to

arise as a result of the specific ownership and contractual structure."

Grout, pg. 56, ibid.

On the completeness of contracts, Hart (2003) asserts that no contract can account for every possible eventuality. Furthermore, he suggests the lack of vertical integration between the client and provider incentivises innovation during operations, as savings can be realised for the providers' benefit in terms of increased profit for the SPV. When innovations are pre-envisioned during the tendering, some of the benefits will be passed on to the client in the context of a competitive tendering environment. When innovations are not envisioned, the provider is more likely to reap more of the reward of cost savings. Furthermore, Leiringer (2006) suggests innovation is more likely to occur if it has scope for application elsewhere, by reducing risk exposure to an uncertain single 'investment in operation'. Hart (1997) concedes that the freedom and incentive to innovate comes at a cost in terms of opportunity to shade on quality, as the provider's investments are non-verifiable.

In providing the SPV with a certain enough context in which to realise minimised WLC throughout an assumed 25 plus year contract, there is, however, a trade off in the flexibility of scope and standard in the operational services provided (HM Treasury, 2008; NAO, 2008). Some question the ability of PFI to deliver efficiency gains in sectors where the quality of the infrastructure cannot so directly reduce operational cost (including cost of provision of final services), such as in forms of social infrastructure, as opposed to say transport and water (Iossa & Martimort, 2008).

Given the output-based nature of the PFI contract, this study proposes:

A) SPVs will trade-off capital resource on design quality for contractible build quality, resulting in higher levels of the latter (than in Non-PFI facilities) per unit of CAPQ. This will tend to reduce OPQ of both forms, annual maintenance and life cycle replacement.

B) The relatively high discount rate SPVs will use in investment decisions, taken together with their ability to commit to levels of maintenance and replacement expenditure, will lead them to spend more on OPQ relative to CAPQ.

C) Banks will want as much as possible of the total expenditure to be CAPEX, so that when the riskiest period of the project is complete, i.e. construction, the cost risk can be minimised (and so costly monitoring activity reduced).

3. Research method

The research method of this paper is based on standard economic production theory. Specifically, the form of graphical representation of the available factor inputs facing a producer with a given budget (isocost), as well as the potential output of various combinations of those factor inputs (isoquant):

- Isocost: a line representing a varying maximum combination of units of factor inputs available with a given budget

- Isoquant: a curve representing equal levels of outputs within a 2 dimensional space defined by quantities of alternative factor inputs

In this paper isoquants represent a consistent level of contractible output of serviced infrastructure facilities, which is assumed to be the same between alternative forms of procurement to allow focus on consideration of WLC. The graph below illustrates these graphical forms of factor input cost (isocost) and performance output (isoquant). The efficient point is found where the isoquant is tangential to the isocost (shown at point A below). At this point WLC is minimised subject to a fixed level of contractible output. This point also tells us the optimal mix of factor inputs required at this efficient point of production.

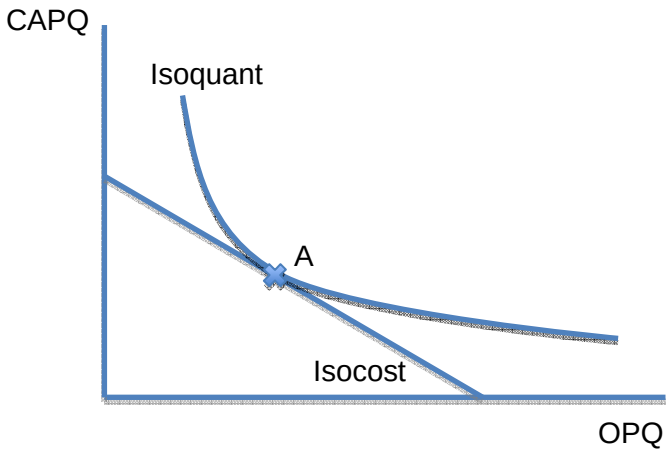

Figure 1. Isocost and isoquant diagram within a 2 dimensional space representing differing amount of the determinants of WLC, namely CAPQ and OPQ

4. Findings and discussion

4.1 Findings

4.1.1 CAPQ constraint

The first consideration of comparing where integrated and non-integrated forms of procurement are within our graph considers the notion that procurement method may impact on the ultimate freedom in choice between quantities of factor inputs. This is not necessarily due to a lower budget (lower isocost line would represent a reduction in WLC at given output). It could be a potential lack of knowledge about the relative productivities of the factor inputs in terms of whole life provision, or simply an aversion to CAPQ resulting from the inherent bias of the NPV method against upfront expenditure. Conventional procurement in the public sector has a reputation for failing to acknowledge the role of capital expenditure in WLC, so is thought to underspend on CAPQ generally. If this were the case, we would have a situation as below (Fig 2, point A), where there would be a conventional design and build construction contract with operational services provided in-house or separately procured via outsourcing. This scenario would restrict the ability to optimise the allocation of CAPQ and OPQ, resulting in a higher WLC represented by the dashed Isocost 1.

Fig. 2 below demonstrates the relevance of integrated contracts in helping to minimise WLC. Assuming there is some level of waste in the provision of in-house services resulting from a lack of competitive forces acting to improve provision, the move from point A to B represents the potential reduction of x-inefficiency through the introduction of competition for outsourced service contracts. However, any outsourced service supplier will be unable to make significant changes to the capital asset, so is restrained as to how much they can 'invest in operations'. Further, contract length will likely not be sufficient to allow them to recoup any significant investment in operations. The introduction of integrated contracts allows the provider to consider minimisation of WLC from the project outset as a constrained optimisation. This is defined by the relative cost and productivity of CAPQ and OPQ, allowing the move from a semi-optimised position 'B' to the optimal point C.

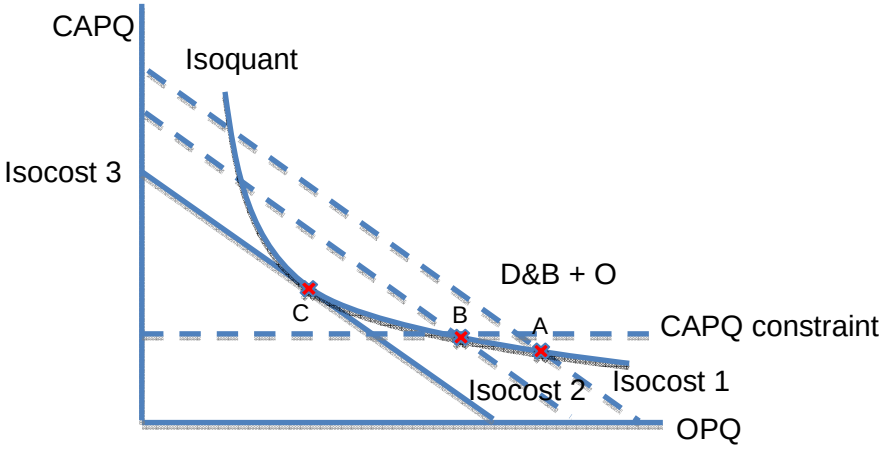

Figure 2: WLC minimisation with integrated procurement vs CAPQ constrained conventional procurement

4.1.2 Cost of CAPQ

One of the overarching criticisms of PFI in the UK is the generalised fact that as it must make recourse to private finance (as opposed to cheaper public debt) it will inevitably have a higher cost of capital. This capital in PFI projects is a blend of debt finance and equity investment typically in a 90:10 ratio. In the context of our analysis, we can illustrate this by a reduction in the ability to afford higher levels of CAPQ against a fixed WLC budget, shown below if Fig. 3 by the shift from Isocost 1 to Isocost 2. This finding suggests the increase in the relative price of CAPQ to OPQ will force a lower level of contractible output, illustrated via a move from point A to point B. Privately financed integrated contracts may be unable to meet the same level of contractible output as conventional procurement with a given WLC. This deficit may be compensated for by benefits of innovations in operations reducing WLC.

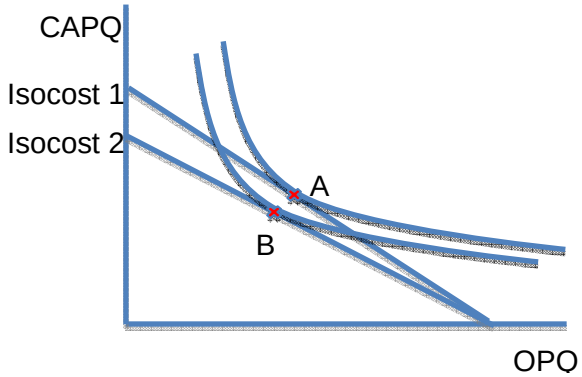

Figure 3: Illustration of the impact of higher cost of capital increasing relative cost of CAPQ to OPQ resulting in potentially lower levels of performance

4.1.3 Marginal productivities of factor inputs

The presence of financial incentives for maintaining or improving performance in PFI contracts stimulates increased pressure to seek efficiency gains during operations. The combination of integration and the long-term nature of the contract provide opportunities for these. Further, it could be argued there is greater potential for innovation during operations than there is for innovation in design and construction. In the context of our analysis we can represent this change in the productivity of OPQ as below in Fig. 4 with the shift from point A to B. We see an increase in productivity of OPQ meaning the same level of output can be achieved with lower amounts of OPQ input. This allows a reduction in the expenditure on quantity of factor inputs, represented by the new lower Isocost 2, with no associated decrease in output (both isoquants represent the same level of contractible output as shown by their convergence at low amounts of CAPQ). In the context of UK PFI, a reduction in OPQ may reduce the real WLC for the facility, but not necessarily the cost to the public sector as the UCP may remain the same. It is the SPV that would benefit from such an increase in the productivity of factor inputs, via anticipated reduced expenditure on factor inputs and hence higher residual profits.

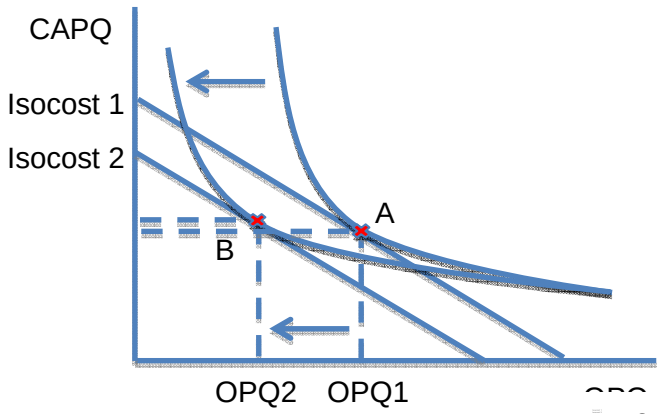

Figure 4: Illustration of an increase in the productivity of OPQ in terms of a static level of serviced infrastructure output

4.2 Discussion

The relatively high discount rate SPVs will use in investment decisions resulting from the margins paid on private commercial debt and dividend seeking, taken together with their ability to commit to annual maintenance and life cycle expenditure, will lead them to spend more on OPEX relative to CAPEX than a socially benevolent far-seeing planner would. However, the more relevant comparison is with the public sector ‘as it actually is’, where capital and operating budgets are often set separately and are the responsibility of different managers, and where construction expenditure decisions have therefore tended to disregard (and not merely discount) impacts on operating cost and resulting WLC.

Even if opportunities do exist for SPVs to reduce WLC through investment in operations and innovation, some comment that financiers of PFI serviced infrastructure, and specifically the providers of bank debt are sufficiently risk averse that any novel design solutions or high cost CAPQ investment in operations will either be excluded, on their demand due to their risk aversion to unproven technologies, or excessively priced (Rintala, 2004). The overall affect of this is likely detrimental for WLC if innovations cause the WACC to increase significantly through higher priced debt. A further barrier to reduction in WLC is the fact the SPV often re-fragments the integrated scope of the PFI contract into separate sub-contracts for construction and operations (Rintala, 2004). The result being incentives for realising capital investment in saving operational costs are reduced by suboptimal co-ordination between those that may benefit from reduced WLC, and those that will not, such as fixed price construction contractors. However, as a counter to this Rintala (2004) supposes:

> 'The client's use of PFI procurement and, thus, task integration improves the ProjectCo's opportunity to minimise *C*WLC*P*. This is because the fragmented and sequential traditional procurement creates contractual and organisational barriers between the private sector actors, which come under a single DBFO contract in PFI procurement. In addition, some of the private sector actors that are involved from the inception of PFI project development are only introduced to traditional service provision at a stage when the functionality and the quality of the building has already been determined.'

The economic efficiency of accommodation service PFI projects, Rintala, 2004, pg 44.

5. Conclusions and further research

5.1 Conclusions

Representation of the interplay between capital and operational resources can be represented through use of standard diagrams used in Economic theory of production. As a means of communicating the concept of potential for 'investment in operations' this could prove to be a powerful teaching tool, and further, a potentially valuable framework for the exploration of the relative benefits of alternative procurement routes for means of achieving minimised WLC.

While it was demonstrated graphically that integrated procurement may allow for WLC reduction (Fig. 2), it must be conceded that this could be restricted by the higher cost of capital resource maintaining the same level of output (Fig. 3). Further, based on this analysis, there seems no particular reason why non-integrated forms of procurement cannot seek to minimise WLC, if there were better knowledge about the relative pay-offs of CAPQ and OPQ and co-ordination in the budgeting for whole life provision.

5.2 Further research

This method of analysis will be applied more extensively to more scenarios within the context of alternative procurement methods, specifically with respect to potential changes in

the productivity of factor inputs. It is hoped in time to use this method of analysis to isolate the competing effects of differing factor costs and productivities, to develop a better understanding of when integrated procurement is more appropriate. Further, it is hoped this method can be developed to provide a more easily interpretable model for understanding the relative benefits of alternative procurement methods varying the level of integration between CAPQ and OPQ. There is scope to relax the assumption of an equal level of contractible output, as reflected in empirical studies produced recently (Ive et al., 2010) that show there is evidence to suggest some PFI projects may perform better than more conventionally procured facilities.

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Utilization of BIM-based Automated Safety Checking in Construction Planning

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Abstract

The applications of Building Information Modeling (BIM) in building design, construction production planning, and 4D simulation are growing rapidly. BIM-based modeling and simulation has brought many benefits to safety and logistic applications. However, tedious manual work is still required to model and schedule protective equipment in current BIM software. Limited automation in modeling and planning safety processes has been exploited so far. The objective of this paper is to investigate how safety issues that are unknowingly built into the construction schedule can be automatically identified early in the planning phase of a project. The developed automated safety rule-checking prototype for BIM was tested on a residential building project in Finland. The results of the case study demonstrate the feasibility of integrating safety into BIM as an effective and practical method for detecting and eliminating fall-related hazards. Presented are also considerations which explore what impact the developed approach has on safety issues and traditional safety management practices.

Keywords: building information modeling, construction safety, design for safety, rule checking, safety-in-design, safety planning and simulation.

1. Introduction

As many research and statistics indicate, occupational safety in building construction remains a worldwide problem, of which falling from heights is a major safety risk at a construction site. In several other disciplines, safety planning has a key aspect position in the field of production planning, however, in building construction industry safety planning

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has been carried out separately with other production planning and control. For example, a concrete falling protection plan is not created in most of the existing projects (Sulankivi et al. 2010).

The growing implementation of Building Information Modeling (BIM) in the Architecture/Engineering/Construction (AEC) and Facilities Management industry is changing the way safety can be approached (Zhang et al. 2013). One starting point is to emphasize safety aspects early on in building design and engineering phase (Zhou et al. 2012). However, the application of BIM is currently increasing rapidly in construction operations management and also in safety management. BIM-based methods are being applied in planning and in implementing these plans in site management and supervision. Main approaches for improving site safety with digital models are: 1) to virtually and proactively plan the sequences of tasks together with the needed safety arrangements and utilities, 2) to ensure that all constructions can be built without any safety threat and necessary joints exists for fixing the safety utilities, 3) to document planned detailed safety solutions in a self-explaining way, and to conveyed these information throughout all key players until the last worker in chain, and 4) to have up to date status information in the main contractor's site model for managing work tasks and to avoid interference of work activities when changes occur.

Full exploitation of the opportunities for improving safety with help of BIM technology requires still further developing of the programs, tools and working methods. Furthermore, there is a need to get more practical experience of safety planning using BIM and more competence in construction projects to use BIM-based methods and programs (Kiviniemi et al. 2011).

Based on previous research, targets of developing the automatic safety hazards identification and planning tool might include: to effectively assist labor-intensive safety related modeling and planning tasks, to get the safety checking and planning comprehensive enough, and to get visualizations as good as needed for real use on sites or for other purposes.

This research study aims to evaluate possibilities, benefits and development needs of automated safety checking and planning, as well as usability and maturity of a developed BIM-based prototype tool to support fall prevention planning in real building construction projects.

2. Background

BIM can be utilized to promote safety management, and combine safety with other construction planning processes. Downey from Turner Construction describes (Downey 2012) how the contractor's continued commitment to safety is enhanced through the use of advanced technologies for model checking. First they conducted a study of incidents across the country and determined that falls from height, and incidents related to material handling could be addressed through the integration of innovative practices and technologies, particularly the application of BIM. After that they worked to develop a rigorous modeling

standard and review process focusing on the key areas of falls from height and material handling tasks. They established a standard, model-checking procedure to ensure compliance with rigorous standards of safety. Turner's BIM specialists developed a custom, Ruleset package, a 50 point check, which users can apply to any model. For example, in a superstructure check, running a model through the rule Checking process in Solibri will verify that the model contains plans for protection at all slab edges and slab openings, and that edge protection is at a regulation height, as well as check for fire extinguisher locations in the model using the rule-checking process will not only verify standard spacing and height requirements, but also that extinguishers are present at all required places.

The strength of using Solibri Model Checker as a BIM-based tool in the previous case is its capability to use Industry Foundation Classes (IFC) data exchange format, which makes the checking independent from BIM-based software used for modeling. However, while automation is used to carry out the routine checking work, someone still needs to model all safety related temporary equipment and structures, which are not supported/are lacking from existing object libraries in BIM-based modeling software.

VTT Technical Research Center of Finland has developed detailed falling protection modeling and 4D visualization including both the parts to be permanently installed to the building and the temporary structures and equipment needed during construction work. 4D production planning is seen as a breakthrough in construction production management. Connecting safety management tasks into the 4D-model opens up entirely new chances to review and evaluate safety as part of construction operations, to increase cooperation in safety planning, and to enhance safety communication. 4D planning can create a safety planning practice that is undertaken earlier than traditionally in construction projects, and furthermore it can capture a more detailed planning level. In early stages, essential safety arrangements to be modeled and included in 4D-modeling are related to protection against falls, such as guardrails, protective covers and nets, and safety harness anchor points (Kiviniemi et al. 2011).

In VTT research the structural model of a building has been found to be suitable base/platform for falling prevention planning, and safety modeling is suggested to be done with same level as detailed design and engineering of the permanently installed building parts. Basic hypothesis from their research was that better planning will lead to better managed site operation which improves safety. However, 4D scheduling and visualization of these parts was found to be complicated with current modeling tools. In a short term new human and technical resources are needed in the BIM-based planning activities which mean also costs and those will be compared with the benefits. Clear benefits of BIM-based procedures must be identified and emphasized, or there must be demands from the client, before construction companies will in wide scale do investments to increase the use of BIM for safety purposes (Kiviniemi et al. 2011). A significant shortcoming of 4D approach identified by Zhou et al. (2012) is the dependence on computerized construction schedules. Construction operations are dynamic and subject to frequent changes that do not comply with originally scheduled work. Hence, digital schedules are rarely updated sufficiently and frequently to accurately reflect all operations underway at any given point in time.

Another subject is development of the planning procedures because more co-operations are needed between both the main contractor and the designers and the main contractor and the subcontractors to make better value adding plans (Kiviniemi et al. 2011). Zhou et al. propose an approach, where the target is to obtain the most reliable plan possible in the multidisciplinary construction field using collaborative 4D construction planning. They suggest new kinds of interventions, such as the development of tools and processes for multi-party collaboration on safety around digital models. New directions of research on construction safety and digital design could, for example, focus on technologies that enable constructors to share their knowledge with designers; using the visualization potential of new technologies to bring knowledge of the construction site into design.

Georgia Tech (Zhang et al. 2013) pointed out that the industry is in need of improving the inefficiencies of the existing paper-based and manual safety processes in place, and has identified a need for an automated rule-based safety checking and planning system. The researchers have approached the problem by developing BIM-based safety planning procedures by applying automated safety rule checking to Building Information Models. Beside automated safety checking, there are capabilities to also model automatically the suggested fall protection, which is labor intensive task with current BIM-based tools. Possibilities and current limitations of the software are not known very well yet, since this far safety prototype tool has been in us at the university only, and there isn't experience and feedback related to utilizing it in real building projects.

3. Research Method

3.1 BIM-enabled safety rule-checking

Existing safety rules, guidelines, and best practices can be used in conjunction with existing three-dimensional (3D) design and schedule information to formulate an automated safety rule checking system. The intention is to automatically identify these dynamic conditions, as the building is constructed, identify their location in a virtual 3D space, and interactively or automatically provide solutions and visualization of protective systems to mitigate identified hazards.

Such platform developed by Zhang et al. (2013) can function as a tool for providing easily accessible and understandable visualization of up-to-date progress on construction and safety over time, and in particular, to detect dangerous hazard locations on the site. The indication of safety measures will help safety managers planning upfront for safety during the construction planning phase, as well as during construction. The rule checking process consists of the following procedures:

- Rule interpretation: The interpretation of safety rules from safety regulation or best practices (e.g., OSHA) is a logic-based mapping from human language to machine readable form. The name, type, and other properties in the rule can be analyzed and extracted from the written rule.

- Building model preparation: A building model must be well constructed to include needed objects, attributes and relations used to carry out the rule checking. In addition, since the need of fall prevention equipment depends on the status of the construction work, a 4D model including the installation schedule/order of building assemblies is required.

- Rule execution: The rule execution phase brings together the translated rule sets with prepared building model. The rule may apply to thousands of condition cases, requiring combinatorial tracking. The rule execution has two steps: (a) automatically check the model to identify unsafe conditions, and (b) identify and apply candidate resolution actions to correct the unsafe condition. This last step can be variously controlled, manual intervention for each condition, to completely automatically resolve through the application of rules to determine the best correction.

- Rule checking reporting: The checking results can be reported in multiple forms: (a) visualization of applied safety protective equipment in the model, and (b) PDF-generated reports of unsafe conditions and the corrective actions taken. In addition, quantity-take-off information for resource leveling of safety equipment and importing the generated information into project schedules is also possible.

- Safety correction: The primary corrective actions that will take place on job sites are to schedule and track logistical movements of (safety) material based on rule check reports. An implementation in the field, for example, could be reports on a BIM platform that assign work tasks to install/remove safety equipment on a building floor.

3.2 Applied methodology in case study

Once the building information model has been prepared and the connections between the model objects and the schedule have been established, rules can be applied for detecting safety hazards. Figure 1 illustrates how the algorithm works for detecting required prevention methods according to OSHA. For each task, it examines if there are slab objects linked to that task and then detect all the related slab objects. Secondly, the algorithm will check the existing slabs/the slabs will be erected before this task to see whether merge of different slab sections is needed. Finally, according to different conditions, guardrails will be installed to unprotected edges and the removal of guardrails will also be considered and inserted into schedule if two slab sections merge and guardrails in between are no longer needed.

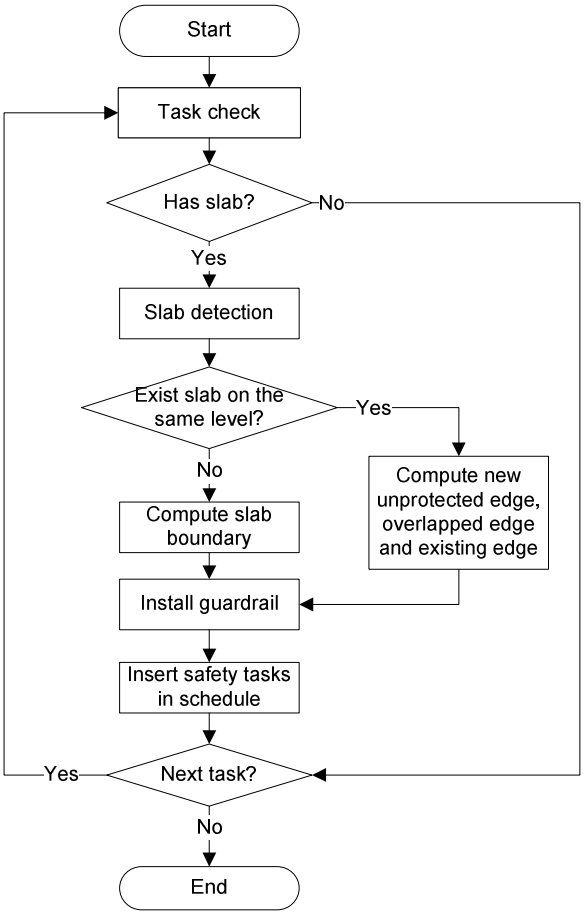

Figure 1. The rule checking algorithm for detecting required prevention methods

4. Case study: BIM-based automated safety checking and fall prevention plan

4.1 Case study project and model information

The developed automated rule-checking tool was applied on a multi-story precast apartment building model (Figure 2). All the precast concrete pieces are fabricated and transported to the construction site and will be erected with predefined order starting from section C. Section B is erected after section C has been completed, and section A is erected after completing section B. Additionally, the façade insulation and brick walls are built on site after the erection of precast concrete related to the frame. Since the focus is in falling prevention, the frame erection is in the focus of this work. The project's structural model used for the Case study has been modeled by Finnmap Consulting Oy using Tekla Structures 17.0 modeling software. 4D schedule needed for the automated rule-checking was added to the structural model based on information obtained from the contractor (Skanska Finland) in traditional format of schedule and additional information concerning the installation order received from the site engineer.

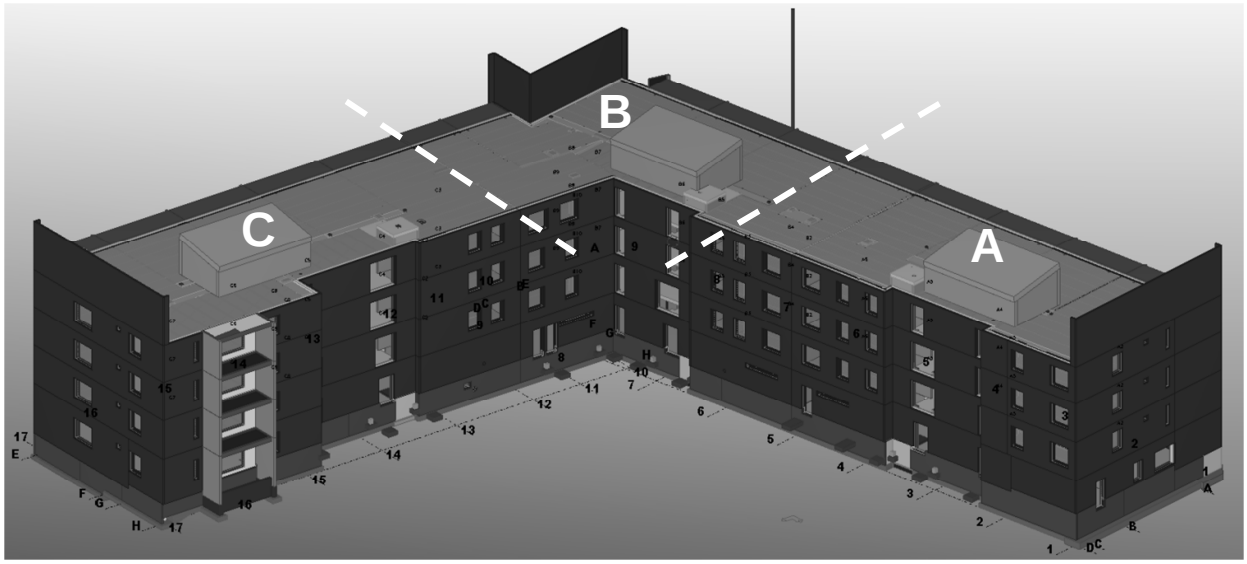

Figure 2. Overview of the multi-story precast apartment building model and its divided sections

Figure 3 shows a closer view of the slab pieces. The connections of the slab pieces are reinforced and casted after the erection of slabs, while before the erection of the following floor wall panel erection is started. Walls and lift shaft together with the slabs work as a structural system which transfers the loads to the footings which are based mainly on bedrock. The model has been divided into Section C, Section B and Section A according to the erection sequence.

The slab sections are erected by story. It takes about 7 days to erect one story of a section and about 5-6 weeks to erect one section. The guardrail solutions need to be updated according to the growth of the slab sections, for example, when two slab sections merge on the same level, the guardrail in between need to be removed.

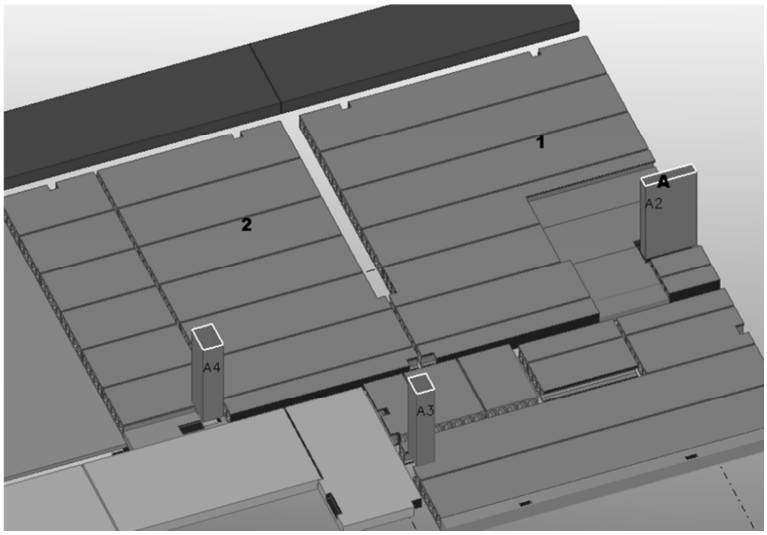

Figure 3. Closer view of precast slab panels

4.2 Utilization of automated safety checking and fall prevention planning in the case study

The rule checking algorithm is executed on the case study model automatically and install the guardrails in the model and also created subtask of its installation and removal into the schedule. Figure 4 shows the updated schedule with safety solution and Figure 5 shows four different phases of the model simulation. Since the slab on the first floor grows from section c to section b and they merge together, the guardrails exist in between has been removed in figure 5-b and 5-c.

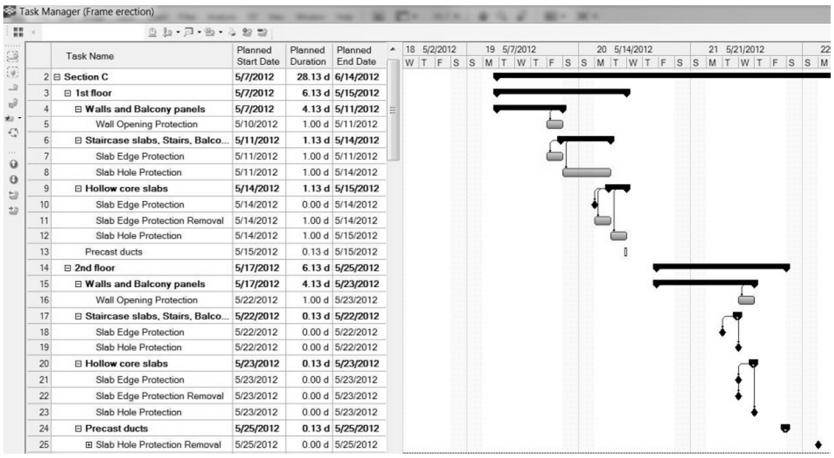

Figure 4. Updated schedule with the installation and removal of prevention methods

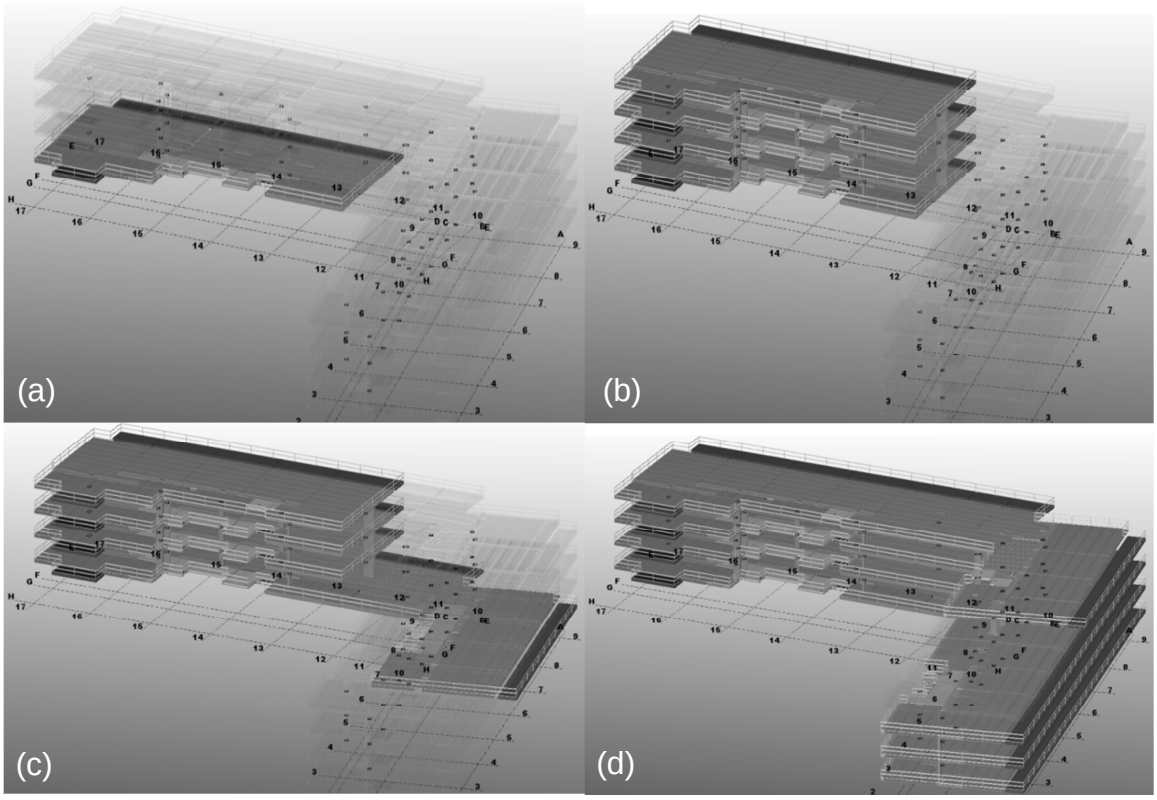

Figure 5. 4D simulation of the model slab, column and guardrail system

4.3 Discussion

The tool detected unprotected slab edge and installed required guardrail system both automatically and successfully. Quantity-take-off of the guardrails can be easily calculated using software's built-in function. In addition, the automated installed guardrail can be modified by user later flexibly.

The limitations are also identified from the case study. The case study focused purely on slab without considering wall installation and other more complicated situation which is also quite important for determining required fall protection methods and also their removal. Additionally, more case projects are needed to investigate applicability and performance of the automated safety checking and planning tool. Secondly, the presented guardrail model is rather simple than the real one used in field. More sophisticated 3D model/representation of safety equipment can provide better understanding of both its geometry and shape. In test trial, a detailed model for so-called hook post was successfully integrated to the tool, and as a result, user is able to select a simplified model representation or a detailed representation (Custom components) for safety railing modeling, but more options/different kind of post types are needed for real construction projects. In addition, with more detailed and developed guardrail model, related safety parts/components such as welded fittings could be added automatically into steel beams or concrete panels for guardrail installations. The corresponding connections can be pre-considered in the steel beam or concrete panel fabrication, hence reduce the work at height.

The potential future development based on test trial experience has been identified include the following:

1) More comprehensive BIM-based fall prevention planning solution need to be further developed, for example, safety nets related to prevention of either small construction equipment or humans.

2) Since software independent data exchange format is promising to benefit the interoperability among different project stakeholders, IFC-based solution needs to be explored for safety planning purpose. Ability to use an IFC model for automated safety checking and planning would enable more general checking capability of models created in modeling software for various modeling or viewing purpose, for instance, safety checking of combined BIM of both the structural and MEP models.

3) Today it's not common to make detailed BIM-based 4D-construction planning, where the installation order of all precast concrete parts in one story would had been defined. Instead, one task in a schedule may cover installation of all precast wall panels in one story, and as a result, there isn't data to plan and visualize need of falling prevention either in that detailed level in each relevant phases of the installation work. More detailed/careful construction and safety planning might take place if construction companies will get interested in taking full advantage of virtual construction (4D BIM-based construction order and schedule planning).

5. Conclusion

The developed algorithm has been successfully implemented in the conducted case study for slab boundary checking and guardrail installation along the erection of slab panels. The results show the usefulness of the proposed approach in detecting and visualizing the potential fall hazards in particular during the safety planning stage. It is recommended that temporary structures and safety protective methods are included already during project planning to enhance a project's safety understanding and communication. Some of the processes that are part of the developed framework can also be automated based on the geometry, schedule and relationship information provided in BIM. Since the construction schedule is linked to the model objects in BIM only a few weeks before the construction starts, it is essential to check the model for changes and detect any of the potential safety hazards. The developed system assists human decision makers in this review process by eliminating both the hazards in the design/planning stage and making sure that safety equipment is procure and ready for installation at the right place and time when needed.

Current concerns about the application of the developed system include: 1) Since the construction drawings and model-based designs are subject to change in a dynamic construction environment, it is necessary to frequently check the model to ensure all safety equipment is up to date; 2) Not all models provide all of the necessary information for safety planning and checking purposes, for example, the relationship/connection between wall and slab sections may not be well established; this may prevent identifying the removal of the guardrail as construction proceeds. Such safety related design standards or extended BIM requirement need to be studied and formalized; 3) Additional cases studies and in particular using more complex BIMs are needed to test the developed system; and 4) To take full advantage of BIM-based 4D-planning, a future system might need to be easy enough to use for practitioners in the field.

Acknowledgement

The results presented in this paper are based on close co-operation of Georgia Tech, VTT Technical Research Center of Finland, Skanska Finland and Tekla. The research was funded by a Finnish research project called BIMCON (Building Information Model Based Product Data Management in Industrialized Construction Supply Chain), which is part of the Finnish research-programme called PRE organized by RYM Ltd and a consortium of Finnish research bodies, universities and companies, and a remarkable part of which is financed by Tekes (the Finnish Funding Agency for Technology and Innovation). The BIMCOM project is coordinated by Skanska Finland, and the other project parties are VTT Technical Research Center of Finland, Parma Oy, Weber Oy Ab, Rautaruukki Oyj, Tekla Oyj and Aalto University.

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Consideration of ecosystem services in urban resilience in South African cities

Emmarie Otto[1]; Chrisna du Plessis[2]

Abstract

In 2011 South Africa published the 3rd State of Cities Report (SoCR) for its nine largest municipalities. This report, titled: ''Towards Resilient Cities, a Reflection on the first decade of a democratic and transformed local government, 2001 – 2011'', sets out to view the various economic, environmental, social and governance issues of the cities from a resilience perspective. The purpose of this paper is to critically examine the use of resilience thinking as an analytical framework for State of Cities Reporting, by using the Resilience Assessment Framework (developed by the international Resilience Alliance for assessing resilience in social-ecological systems) as a measure against which to interrogate the 2011 State of Cities Report (SoCR). For reasons of economy, the focus was on how the SoCR considered resilience in terms of ecosystem services provided to cities, and specifically the ecosystem service of fresh water. The objective of this paper is to critically examine how the resilience of urban ecosystem services was considered in the South African SoCR. It was found that while the 2011 SoCR opened the door to using a resilience approach in discussing the sustainability of cities, it does not really allow the user to gain an understanding of the resilience of the ecosystem services in South Africa's main cities and the reporting methodologies needs to be adapted in future reports. The paper concludes with recommendations for future reports.

Keywords: Urban resilience, urban ecosystem services, State of Cities, South Africa

1. Introduction

According to the UN-HABITAT (2010) in 2009, Africa's total population for the first time exceeded one billion, of which 395 million (or almost 40 per cent) lived in urban areas. Africa should prepare for a total population increase of about 60 per cent between 2010 and 2050, with the urban population tripling to 1.23 billion during this period. ''With a projected 61.7 per cent of its population living in urban areas, Southern Africa remains the most urbanised sub region on the continent'' (UN-HABITAT, 2010, p14). Furthermore, 62% of South Africa's population currently live in urban areas, mostly concentrated in the large metropolitan areas of Cape Town, the Gauteng Urban Region and eThekwini (Population Reference Bureau,

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2011). These statistics paint a picture of great challenges to a global social-ecological system which is already under huge strain.

The State of Cities Report (SoCR) is acknowledged as a global tool to understand these challenges at an urban level and monitor progress towards set development goals, informing policies which allows for improved and more innovative public management and governance (Cities Alliance 2013). Since 2001 several State of the World's Cities Reports have been published by UN HABITAT and most members of the global Cities Alliance have published regular country reports of their own. In 2011 South Africa published the 3rd State of Cities Report (SoCR) for its nine largest municipalities. This report, titled: ''Towards Resilient Cities, a Reflection on the first decade of a democratic and transformed local government, 2001 – 2011'', sets out to view the various economic, environmental, social and governance issues of the cities from a resilience perspective. This is the first time that resilience has been introduced as an analytical framework for State of Cites Reporting. Previous reports have used concepts of productivity, inclusivity, sustainability and governance as an analytical framework.

The purpose of this paper is to critically examine the use of resilience thinking as an analytical framework for State of Cities Reporting, by using the Resilience Assessment Framework developed by the international Resilience Alliance as a measure against which to interrogate the 2011 State of Cities Report (SoCR). For reasons of economy, we will focus on how the SoCR considered resilience in terms of ecosystem services provided to cities, and specifically the ecosystem service of fresh water.

The first half of the paper introduces the theoretical frameworks used to frame the study, namely resilience theory (especially in the context of social-ecological systems) and the Resilience Assessment Framework developed by the Resilience Alliance, as well as the notion of ecosystem services. In the second half of the paper the State of Cities Report and its approach to resilience and ecosystem services is introduced. The paper will then proceed with assessing how three steps of the Resilience Assessment Framework can be used to understand how the SoCR considered resilience in terms of ecosystems services, before concluding with recommendations for future reports.

2. The Resilience Assessment Framework

2.1 What is resilience?

There are a number of definitions and interpretations of resilience (Holling and Gunderson, 2002; Walker and Salt, 2006; Pendall et al. 2010). The Resilience Alliance (2010, p5) describes the resilience of social-ecological systems as: ''Resilience is fundamentally a system property. It refers to the magnitude of change or disturbance that a system can experience without shifting into an alternate state that has different structural and functional properties and supplies different bundles of the ecosystem services that benefit people''. However, it should be noted that the definition of resilience in an urban context is still under contestation, with the definition by the Resilience Alliance (see above) being criticised as

equilibrist and not suitable for cities which are characterised by constant evolutionary change and multiple desirable states (Simmie and Martin, 2010).

The city can be described as a special category of social-ecological system, reflecting an ecosystem which consists of a community of plants and animals and the physical environment of that community (Rowe, 1961). In the city the physical environment would include the built environment and the community of animals would include humans and the individual and collective normative and functional institutions they contribute (Du Plessis 2012). The resilience of a social-ecological system is determined by the presence of certain values and characteristics within both the tangible and intangible components of the city. These include adaptive capacity, (determined by factors such as diversity, modularity, degree of connectedness and tightness of feedback loops); the potential available in the system, whether social capital or system reserves and variability in critical ecosystems services; and an acknowledgement of slow variables (Holling and Gunderson 2002; Walker and Salt 2006, pp145-148).

2.2 The Resilience Alliance Framework for assessment

The Resilience Alliance (2010) proposes an iterative and reflexive process for assessing resilience in social-ecological systems that follows five main stages (described in Figure 1).

The first step is to develop a description of the system including the key components of the system and, in order to focus and direct the assessment, the main issues (or disturbances) that should be considered. (Resilience Alliance 2010, p13) These are identified by asking resilience of what to what, and by investigating the dynamics in the system. This requires that the history of the system be considered to identify changes across multiple scales of time and space and the social and ecological dimensions that interact with the focal system. (Resilience Alliance, 2010, p18). This is follow by **step two** where the Resilience Alliance (2010) further proposes that different thresholds and system states can be identified that create a panarchy of adaptive change cycles that leads to the **third step**. In this step, the interaction between the different systems are assessed through investigating the influence of and the interaction between the larger-scale systems in which the social-ecological systems are entrenched as well as with the smaller scale systems which it consists of (Resilience Alliance 2010, p29). By identifying the present phases of the connected systems, potential vulnerabilities and opportunities in the focal system is revealed (Resilience Alliance 2010, p29). This step therefore assesses how the system variables might be expected to interact. This is valuable information and important for management decisions (Resilience Alliance 2010, p32) This

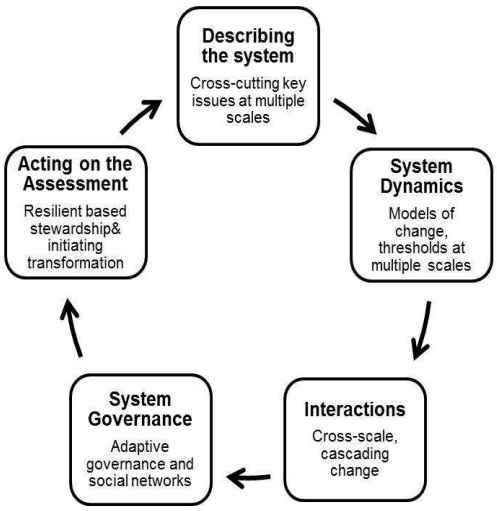

Figure 1: Framework for Assessment (Resilience Alliance, 2010, p5)

leads to the **fourth step**, which deals with evaluation of the governance in terms of its adaptive governance capacity and the strength of the social networks that exists (Resilience Alliance 2010, p41); and then the final step, **step five**, in the Resilience Assessment Framework, is to evaluate how to best act on the assessment through synthesising the assessment findings, identifying the thresholds interactions, the development of stewardship strategies, timing the transformation and finally implementing the resilience assessment. (Resilience Alliance 2010, pp43-50)

According to the Resilience Alliance (2010), the resilience of the urban system is compromised when it's supporting ecosystems services are threatened and degraded as a result of ineffective and inflexible institutions, loss of biodiversity, pollution and a focus on production and increased efficiencies, which in turn leads to a loss of functional and response diversity and redundancy. Ecosystem services are more often than not recognised only after they have been lost. Planning for resilience would include ecosystem services in development strategies and proposals in contrast to purely market driven economies where ecosystem services are ignored. (Walker and Salt, 2006; Resilience Alliance, 2002)

Ecosystem services can be summarised into four groups, as described in UNEP's Millennium Ecosystem Assessment (MEA 2005, p7):

- Provisioning of services: food, water, timber, and fiber, natural medicines, pharmaceuticals, genetic resources and biochemicals;
- Regulating services: climate regulation, air quality regulation, water regulation, erosion regulation, water purification and waste treatment, disease regulation and pest regulation, pollination, natural hazard regulation;
- Cultural services: spiritual and religious values, aesthetic values, ecotourism and recreation; and
- Supporting services: soil formation, photosynthesis, and nutrient cycling.

3. Resilience and ecosystem services in the SoCR

3.1 Resilience as defined in the South African SOCR

Opposed to the approach to urban resilience which implies ''..coping with or ameliorating the effects of the problem and restoring the position that existed beforehand. (SACN 2011, p12), the SoCR supports an approach to resilience which implies "transforming local conditions for the better, based on experimentation, creativity and innovation, therefore using a more dynamic approach of resilience" (SACN 2011, p12). The SoCR defines the concept of resilience as, *"*the capacity of a place to anticipate, respond and adapt successfully to challenging conditions, such as global recession, environmental threats or pressures of population growth*.''* (ibid). The resilience theme in the SoCR recognises that ''change is necessary to avoid being locked into inefficient urban structures, outmoded environmental technologies, obsolete industries, conflicting social patterns and inflexible institutions" (SACN 2011, p12). The SoCR also establishes the link with ecosystems in the context of

resilience and describes the cities' dependence on healthy supporting ecosystems to cope with global crisis such as food crises and riots and natural disasters (SACN 2011, p88). The SoCR also emphasises that the current patterns in which cities conduct their business, have the potential to destroy the very ecosystems on which cities' livelihood depend, unless significant change are made in the way settlements are managed.(SACN 2011, p88). In considering resilience the SoCR looked at four aspects of the city: the economy and the financial state of the city, city governance, social resilience as supported by the built environment, and cities as life supporting systems (including ecosystem services). The SoCR discusses a number of critical concerns which can be considered as press disturbances on the city system. These include economic transformation, social division, natural resource depletion and climate change, and the spatial and institutional structures of South African cities.

3.2 What ecosystem services were included in the SoCR?

The SoCR deals with the natural resources in the city under the topic: 'Cities as Life Supporting Systems''. This is done in three sections, the first deals with 'Improving Resource Productivity'' which include issues of water, electricity and transport fuel, although the latter two is not regarded as ecosystem services as such. The second section addresses ''Enhancing Local Capacity'', which deals with the issues of food supply, sustainable energy and ecosystem goods and services. The ecosystem goods and services covers the valuing of ecosystem services in general, it also refers to biodiversity initiatives in the city, conservation and wetland rehabilitation and forestation. The third and final section, describes 'Closing the Waste Loops'' and include issues on solid waste recycling, waste to energy and water re-use, these are not addressing ecosystem services as such, but rather how city infrastructure is replacing regulating ecosystem services such as water purification and waste management.

It can therefore be concluded that the ecosystem services addressed in the SoCR, include food and freshwater as *provisioning services* for the city; forestation(climate/air quality regulation) and wetlands(water regulation/purification) under *regulating services*; and biodiversity as part of *supporting services*. To discover how resilience was approached in the way the SoCR's considered ecosystem services, this paper will focus on the ecosystem service provided by freshwater.

3.3 What characteristics of resilience did the SoCR consider?

Although the SoCR did not explicitly address the characteristics of resilience, in the discussion on ecosystem services the following characteristics of resilient systems were revealed. Diversity was addressed in terms of biodiversity. Social capital, modularity and tightness of feedback were briefly revealed in illustrating biodiversity initiatives in communities. Emerging policies in support of urban food production initiatives entering the system hints at openness. System reserves were discussed in terms of the expected shortage of freshwater reserves by 2025; ecosystem services were discussed but not ecological variability; and innovation was indirectly addressed as a solution to extend the

freshwater resources by reclaiming waste water through a waste water recycling facility to provide water for industrial use, therefore saving potable water supply

4. Using the Resilience Assessment Framework to describe the State of Cities from an ecosystem services perspective

Although the SoCR aims to use a resilience lens to engage with the state of cities it did not explicitly include a framework for resilience assessment. In this section the process suggested in the Resilience Alliance Workbook (2010) is used to test the usefulness of the current SoCR in assessing resilience with the intention to develop suggestions for how this aspect of the report can be improved. This will be done in three steps, firstly by looking if a focal system/s was identified, followed by considering if system dynamics was considered and thirdly assessing if, and how the cross scale interactions were taken into account.

4.1 STEP 1: Describing the focal system - setting soft boundaries

As suggested by the Resilience Alliance (2010), the first step includes the setting of the system boundaries and defining the focal system. This is done by identifying the main issues; determining the key components off the systems (and asking resilience of what?); identifying the key disturbances, disruptions and uncertainties in the systems (and asking resilient to what?); and lastly, understanding the multiple space and time scale of the system.

There are two issues which emerged in terms of freshwater in the SoCR. They are the adequate supply of freshwater and the quality of freshwater. Based on the SACN (2011, p91), South Africa is a semi-arid country with a shortage of water supply for beneficial water and sanitation services. ‘’Few cities are currently self-sufficient in terms of their water supply...’’(SACN 2011, p91), with a projection that by 2025 the supply of water in 58% of South Africa’s water management areas will be outweighed by demand (SACN 2011, p92). The SoCR also briefly highlighted issues on water quality, as the quality of ecosystems and water bodies are affected by the polluted water coming from ineffective waste water treatment works and acid mine drainage. The following drivers of the focal system in terms of fresh water were identified: badly maintained water supply systems and unsustainable consumer consumption patterns and ineffective functioning of water purification plants.

Resilience assessment requires also that a time frame of relevance to the issues be determined. Although the SoCR speaks of the progress of the last 10 years, the data generally only covers a five year historical period, while future projections of fresh water availability is limited to 13 years.

The SoCR did not explicitly highlight what aspects of this ecosystem service the city needs to be resilient. However, these aspects can be inferred as healthy freshwater systems (ecological components) and supply of clean freshwater systems (social components). These two interdependent systems (the natural freshwater systems and the technical infrastructure to supply and purify water) can be seen as focal systems of the SoCR.

The following disturbances affecting freshwater supply could be identified from the SoCR: unpredictable weather patterns (droughts and floods), unsustainable per person water consumption, wastage of water due to poorly maintained water supply systems and the uncertainty of city level data on resource stocks and flows which cities require in order to be accountable for their resource.

The SoCR has not addressed any historical disturbances or their effects on the focal systems. Except for the demand of freshwater, which poses a potential future uncertainty in terms of the shortage of water supply, there is also no interpretation of the current disturbances presenting a concern. Neither ‘“pulse” disturbances that occur as singular events’’, or ‘“press” disturbances that occur continually’’ and over a longer period of time, were considered in the discussions of the two focal systems. (Resilience Alliance 2010, p16) The SoCR does list management strategies relating to minimising the effect of disturbances of freshwater. These include Water Conservation and Demand Side Management (WC/WDM) strategies and projects to ensure improved water resource management. The SoCR also suggests of the improvement of government resource management through innovative strategies that encourage more efficient use of resources and minimise waste and input cost (SACN 2011, p91). A further uncertainty highlighted is the undervaluing or in cases ignoring the economic value of the benefits and potential contributions to disaster mitigation and management provided by features of the freshwater ecosystem such as wetlands (SACN, 2011, p107).

As suggested by the concept of the panarchy, the focal system is part of a hierarchy of nested systems that function at multiple space and time scales (Resilience Alliance 2010, p18). Although some issues originating in larger or smaller scale systems that pressurise the focal systems can be identified in the SoCR, there has been no attempt to structure these in a more comprehensive understanding of the interactions between these two focal systems or their larger or smaller scale manifestations as these relate to the city. Neither of these focal systems was considered against a historical timeline that included social and ecological dimensions of these systems at larger and smaller scales.

4.2 STEP 2: System dynamics

As suggested in the Resilience Alliance Workbook (2010), the next step is to investigate the dynamics in the system. This requires that the history of the system be considered to identify changes across multiple scales of time and space and the social and ecological dimensions that interact with the focal system. From this, different thresholds and system states can be identified that create a panarchy of adaptive change cycles that leads to the third step.

Although this is not highlighted by the SoCR, it can be assumed that the freshwater system in the SoCR can be described as moving from a rapid growth phase into a conservation phase. The SoCR did not explicitly draw on the context of the adaptive cycle or identified the phases of the adaptive cycle through which the system has moved over time. As there was no historical timeline done in the SoCR, it is difficult to infer the key variables that would allow the tracking of changes over the history of the system. Locating the key variables over

time can provide knowledge regarding the timing and nature of the changes in the system (Resilience Alliance, 2010, p24). The SoCR did not describe its ecosystem services in terms of the alternate states or historical state(s) of the systems, as seen in the phases of the adaptive cycle. It furthermore did not describe the transition phases between alternate states of the system and the key variables that determine a transition between alternate states (Resilience Alliance, 2010, p24). Except for the freshwater system where a future prediction of a clear tipping point and transition is predicted by 2025, the SoCR did not identify any possible thresholds or tipping points.

4.3 STEP 3: Cross scale interactions

As suggested by the Resilience Alliance (2010, p29), the third and final step addressed in this paper will assess the cross scale interaction found in the panarchy of the system, as well as the interacting thresholds and cascading of change. This will lead to a discussion of the general and specific resilience of the system.

The SoCR does not address the desirable and undesirable influences from larger-scale systems or describe any system vulnerabilities at the focal scale identified by considering cross-scale interactions. It also did not "characterize the balance (or tradeoffs) between flexibility and efficiency in the focal system", as suggested by the Resilience Alliance (2010, p31).The SoCR also did not list "the main thresholds associated with key slow variables", nor did it indicate any effects arising through the interactions which includes factors that influence the crossing of one threshold to another either by increasing or decreasing the effect (Resilience Alliance, 2010, p34).

The Resilience Alliance (2010, p35) considers the elements of general resilience to include diversity, openness, tightness of feedback, system reserves and modularity. When these concepts are applied to the discussion of the freshwater ecosystem services by the SoCR it can be seen that the following elements of general resilience were considered in the SoCR in terms of fresh water supply and quality. The element of system reserves was highlighted in terms of the freshwater supply, which is depreciating as demand growths. The element of diversity was also indirectly addressed in discussing the expansion of the city's water resources through reclaiming waste water, which requires innovation and openness in the system.

5. Findings

The SoCR supported a transformative resilience approach. This places emphasis on change and renewal, and considers the building of adaptive capacity and potential in the system, enabling the system to adapt to the challenging conditions of global pressures, environmental threats and the dynamics of population growth, which cities need to deal with (SACN 2011, p12).

The discussion of the freshwater system does not reveal sufficient information to obtain a view on the resilience and the actual vulnerability of the current system. This is due to the

fact that it fails to acknowledge the slow variables associated with critical thresholds. The SoCR does not reveal a historical profile of the focal systems (freshwater systems in this case), depicting what where the ‘’driving forces that contributed to or triggered major change’’ (Resilience Alliance, 2010, p21). By extracting the information of the various driving forces through time and understanding the patterns of past disturbances which shaped the current system, this knowledge increases the capacity of managing these effects better in the future, therefore increasing the resilience of the system (Resilience Alliance, 2010, p18).

Fresh water systems also need to be considered in a wider context to include their interdependence with the other systems to which they are connected. The issue of freshwater stretches far beyond the supply of water to the city, it also needs to be considered as part of a bigger ecosystem which spans regional, national and even international boundaries. As Folke et al suggest (2002, p10) ‘’freshwater is required to sustain the capacity of, for example, forests, wetlands, agricultural land, and savannahs to uphold the flow of ecosystem goods and services to humans.’’ Future reports need to recognise that the resilience of the ecosystem service provided by freshwater cannot just be determined by considering the quantity of water. It is also necessary to acknowledge the human related challenges such as industrial pollution, untreated effluent, use of fertilisers, unmanaged water-thirsty alien vegetation and development in floodplains, which decreases the functioning of the freshwater systems and increases its vulnerability.

It would be valuable for future reports to include a more detailed investigation into the resilience aspects of a system, to pinpoint the real problems which could then be addressed to enhance resilience. Future reports should:

1. Clearly identify focal systems and the focal scale that serves as point of departure. This will allow the construction of a panarchy model for each focal system that will illustrate the systemic interactions between higher/larger scales of the system (e.g. national or regional water systems), the focal scale of the system (e.g. a watershed) and the lower/smaller scales of the system (e.g. wetlands) that are usually the subject of illustrative case studies.

2. Develop a systems perspective that can improve understanding regarding the interactions between different systems and the changes/disturbances that result from these interactions (e.g. the industrial system and its resultant demands for freshwater and pollution of water sources). To do this it is necessary to identify the key variables that describe the system, the potential thresholds in these variables that separate one system regime/ state from another and the pressures on these variables as a result of disturbances introduced by other systems.

3. Describe the changes in the focal systems along timeframes that can adequately capture change at larger system scales. This will necessitate the development of historical timelines that span at least 50 to 100 years in the case of ecosystem services.

4. Use the above information to establish the adaptive cycle phases exhibited by the focal system and its current position in this cycle. By monitoring this in successive State of City Reports, city managers will be able to identify possible threats and opportunities in the system that are opened up by the specific phase of the adaptive cycle the system is experiencing.

5. Gather and organise data on changes in the system that will allow the identification of attributes of resilience such as diversity, adaptive capacity and connectedness, exhibited by the system being studied.

6. Conclusions

The objective of this paper was to critically examine the use of resilience thinking as an analytical framework for State of Cities Reporting, as expressed in the 2011 South African State of Cities Report, with specific reference to the resilience of urban ecosystem services. This was done using a comparison with the Assessment Framework suggested in the Resilience Alliance Assessment Workbook. It was found that the resilience of ecosystem services was not adequately addressed in the SoCR. This can be remedied in future reports by incorporating wider and more integrated historical information of the various systems and the changes in the systems over time, including information on the drivers of those changes. There is also no discussion around critical aspects of resilience such as cross-scale interactions, thresholds and methods for monitoring these thresholds. Future reports could address fewer ecosystem services but those that are addressed should be assessed in more detail to determine their adaptive capacity and to reveal the thresholds of change, in order to enable the management of these systems. Overall, while the 2011 SoCR opened the door to using a resilience approach in discussing the sustainability of cities, it does not really allow the user to gain an understanding of the resilience of the ecosystem services in South Africa's main cities.

7. Acknowledgements

The authors are grateful to the National Research Foundation who supported the production of this essay through NRF Grant no 78649.

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Exploring Critical Success Factors for Enterprise Risk Management in Chinese Construction Firms

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Abstract

Enterprise risk management (ERM) has been widely used in various industries and construction firms have been recognized as the prime candidates for ERM implementation. This study aims to identify Critical Success Factors (CSFs) for ERM in Chinese construction firms. To achieve this objective, a total of 16 CSFs were identified through a comprehensive literature review and a questionnaire survey with 89 responses was conducted to collect the perceived importance of these CSFs. The survey results implied that all the 16 CSFs were significantly important. The top six important CSFs were "commitment of the board and senior management", "risk identification, analysis and response", "objective setting", "ERM ownership", "integration of ERM into business processes" and "sufficient resources". In addition, although there were significant differences in the importance of a couple of CSFs between different groups, all the respondents agreed on the CSF ranking, regardless of their institution type and work experience. The CSFs identified in this study would help construction firms to prepare their customized list of CSFs and to better understand the key areas of ERM implementation, significantly contributing to the global body of knowledge relating to ERM.

Keywords: Success factors; Enterprise risk management; Construction firms

1. Introduction

In construction firms, risk management should cover not just project risks, but also the risks faced by being an enterprise (Schaufelberger, 2009). Hence, construction firms should adopt a holistic approach to collectively consider the risks that projects face and to link these events to the corporate strategy (Adibi, 2007). As a holistic approach, enterprise risk management (ERM) has been promoted in various industries. The Committee of Sponsoring Organizations of the Treadway Commission (COSO, 2004, pp2) defines ERM as "a process, effected by an entity's board of directors, management and other personnel, applied in strategy setting and across the enterprise, designed to identify potential events that may affect the entity, and manage risk to be within its risk appetite, to provide reasonable assurance regarding the achievement of entity objectives." In the construction industry, ERM

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was forecasted to grow (Deloitte, 2010) and construction firms were recognized as prime candidates for ERM adoption (Druml, 2009).

Successful ERM programs could bring about benefits, such as improved financial stability, improved decision-making, increased management accountability, competitive advantages, better resource allocation, and improved control on projects (Gates, 2006, Liu et al., 2011, Zhao et al., 2012). These benefits were believed to far outweigh the costs of ERM initiation (Hallowell et al., 2012). To ensure the ERM success and the achievement of the benefits, Critical Success Factors (CSFs) for ERM should be identified. The term CSF defines the key activities in which favourable results are absolutely necessary for a particular manager to reach his or her goals (Rockart, 1982).

The objectives of this study are: (1) to investigate the CSFs for ERM in Chinese construction firms; and (2) to identify the differences in the relative importance and ranking of the CSF between different respondent groups. The identification of CSFs enables the management to understand the essential areas for ERM success and to take necessary steps to strengthen these critical areas represented by the top CSFs. In addition, the CSFs identified from the literature review in this study would help construction firms to prepare their customized list of CSFs for ERM and to gain an in-depth understanding of the key areas for ERM success.

2. Literature Review

As there have been few studies on ERM implementation in construction firms, this study reviews the literatures related to ERM in other industries to identify the CSFs for ERM. Some literatures presented successful ERM case studies while others explored the critical factors facilitating successful ERM implementation. In addition, some organizations, such as the COSO and the Casualty Actuarial Society (CAS), have developed ERM frameworks to facilitate ERM implementation in various industries. Thus, a total of 16 CSFs were identified through the comprehensive literature review and are described in the following paragraphs.

CSF01 Commitment of the board and senior management: Commitment of the board and senior management is recognized as a critical success factor (Sharman, 2002, Ward, 2006) because such commitment is also an internal force that drives ERM implementation within a company. Visible commitment makes employees perceive ERM as a priority for the leadership and is essential for organizational buy-in, aligning risk strategy with organizational objectives and incorporating a risk-based approach at the planning and strategy stages (Sharman, 2002). More importantly, the commitment should not be interrupted by changes in the ERM champion because ERM practice is an on-going process (Bowling and Rieger, 2005, Simkins, 2008)

CSF02 ERM ownership: A company should have an ERM owner to centralize risk management and take charge of risk oversight (Banham, 2004). A chief risk officer (CRO) position can be created to take responsibility for ERM, and thus signals the firm's emphasis on risk management to its employees and investors (Cendrowski and Mair, 2009). Alternatively, the ERM owner can be a dedicated senior executive, a stand-alone department, or a board-level risk committee (Zhao et al., 2012).

CSF03 Risk appetite and tolerance: Risk appetite is the “amount and type of risk that an organization is willing to pursue and retain”, while risk tolerance is an “organization's or stakeholder's readiness to bear the risk after risk response in order to achieve its objectives” (ISO, 2009, pp9). Risk appetite, which is established by management with oversight of the board of directors, relates primarily to the business model and is a guidepost in strategy setting, while risk tolerance relates primarily to the organization’s objectives and is tactical (COSO, 2004, Protiviti, 2006). Operating within risk tolerance provides management with greater assurance that the company is within the risk appetite, which, in turn, produces a higher degree of comfort that the company will achieve its objectives (COSO, 2004).

CSF04 Risk-aware culture: Nothing is more crucial to the ERM success in an organization than a supportive culture (Brooks, 2010, Cendrowski and Mair, 2009), which is called a risk-aware culture (Brooks, 2010, Protiviti, 2006), risk management culture (Santori et al., 2007), or risk culture (Collier, 2009, Zou et al., 2010) in the existing literature relating to ERM. Previous studies indicated that risk-aware culture was a success factor for ERM implementation (Ward, 2006). A risk-aware culture requires the buy-in of organizational individuals at all levels (Hopkin, 2010) and embedment into the corporate culture (AON, 2010). In addition, risk awareness should be integrated into the decision-making process (AON, 2010, Santori et al., 2007), especially into the strategic decision-making process.

CSF05 Sufficient resources: Resources, such as funds, qualified staff, time, knowledge and expertise, are necessary for ERM implementation in construction firms. Resources should also be consistently allocated for improving the risk management process, tools, techniques, and personnel skills (Zou et al., 2010). Thus, ERM implementation can be maintained at a high level. In addition, resources should be allocated and distributed for risk response based on the results of risk analysis (Aabo et al., 2005, RIMS, 2008).

CSF06 Risk identification, analysis and response: Management needs to identify all categories of potential risks from internal and external sources that the enterprise faces. Risk analysis techniques help management prioritize the risks identified and identify the key ones. Thus, a corporate risk profile, which is “a periodic documentation of key risks to an organization to achieving its stated objectives over a specific future time” (Fraser, 2010, pp171), can be formed. It can be a list of top risks or a risk map, which has been used in successful ERM cases (Aabo et al., 2005). The appropriate risk response measures are then identified, considering their significance in terms of likelihood and impact.

CSF07 Iterative and dynamic ERM steps: An ERM process encompasses monitoring and review, risk identification, risk analysis, risk evaluation and risk response. The iterative and repetitive steps comprise a continuous improvement cycle. Such an ERM process also involves monitoring, identifying and assessing new risks that may emerge following changes in the environment (AON, Dafikpaku, 2011, Garvey, 2008, Santori et al., 2007), thus enabling an enterprise to deal with risks in a proactive way and to update its risk profile.

CSF08 Leveraging risks as opportunities: Sharman (2002) argued that emphasizing upside opportunities as well as downside threats was a success factor for ERM. In addition to focusing on dealing with downside risks (threats), ERM also involves leveraging and

exploiting the upside risks (opportunities) for competitive advantages (Banham, 2004, COSO, 2004, Dafikpaku, 2011, Pagach and Warr, 2010). Opportunities exist where a risk is more dangerous to competitors, or where an enterprise has a greater ability to manage the risk than its competitors (Berry and Phillips, 1998). The more an enterprise understands its risk landscape, the more it can leverage opportunities (AON, 2010).

CSF09 Risk communication: To be successful, ERM should have proper communication flow between the management staff and the risk management function (Kleffner et al., 2003). Relevant and reliable risk information obtained from various sources should be communicated transparently across multiple projects and departments of a construction firm. Such transparent risk communication encourages individual comments and expert views during the development of risk management strategies and cross-functional understanding of risks (AON, 2010). In addition, a mechanism should be set up to ensure that critical risk information is reported to the board and senior management (Dafikpaku, 2011) and that line managers, project managers and staff are promptly notified of critical information and decisions (Barton et al., 2002).

CSF10 A common risk language: A common risk language, which explains the terminologies and methodologies and contributes to a common understanding of their meanings and context throughout the enterprise, is viewed as a key quality of an effective ERM program (Duckert, 2011) and an imperative for successful ERM deployment (IMA, 2006). This is because such a risk language underpins risk culture, facilitates risk communication, cut through the layers and breaks down the silos (Espersen, 2007).

CSF11 A risk management information system (RMIS): Information and communication technology (ICT) plays a key role in enabling the flow of information across an enterprise (Dafikpaku, 2011). A RMIS serves as a platform for risk communication and reporting, records risk management activities, or even undertakes risk identification and analysis and provides response plans. Staff should be clear about the application of the RMIS, thus ensuring that the functions are fully used.

CSF12 Training programs: To succeed in implementing ERM, it is critical that staff at all levels throughout an enterprise accept ERM adoption (Kleffner et al., 2003, Nocco and Stulz, 2006). Thus, training programs are critical to ERM success (IMA, 2006, KPMG, 2010). Training programs can be used to reduce misunderstanding and anxiety about ERM, and help staff clearly understand the ERM philosophy and policy, the ERM process, and the value of ERM. Through such programs, employees recognize that ERM is not a quick process but a multi-year journey (Bowling and Rieger, 2005).

CSF13 Formalized key risk indicators (KRIs): A KRI is “a measure to indicate the potential, presence, level, or trend of a risk” (Hwang, 2010: p.126). KRIs should be identified for all the risks that a firm faces and should be periodically analysed by risk owners (RIMS, 2008). In addition, KRIs help monitor risks and involve predetermined thresholds for each KRI that will trigger actions by management to adjust its strategies proactively to manage the risks accordingly (Beasley et al., 2010). Thus, well-defined KRIs were critical to successful ERM programs (Duckert, 2011).

CSF14 Integration of ERM into business processes: To be successful, ERM should be fully integrated into the management and business processes of an enterprise (COSO, 2004). These processes include decision-making and strategic planning. In all decision-making processes, the risks identified should be consistently considered, and emerging risks should also be anticipated. In addition, full integration of ERM is not easy and time-consuming. In large companies, full integration would take from three to five years once ERM is initiated because of delays in moving level by level and the need for change management to overcome inertia (Shortreed, 2010).

CSF15 Objective setting: ISO 31000:2009 defined risk as “effect of uncertainty on objectives” (pp1). Thus, risk is linked with objective setting. Objective setting is one of the eight components of the COSO ERM framework, and is seen as a precondition to risk identification, risk assessment and risk response (COSO, 2004). Hence, corporate objectives should be clearly identified. All objectives should have performance measures and all performance measures should be linked with objectives.

CSF16 Monitoring, review and improvement of ERM framework: On-going monitoring and review of the ERM framework are necessary to ensure that ERM is effective and continuously supports organizational performance (Ward, 2006). According to ISO 31000:2009, management should periodically measure progress against the risk management plan, and review whether the risk management framework, policy and plan are still appropriate. Considering the results of monitoring and reviews, decisions should be made on how the ERM framework, policy and plan can be improved.

3. Methodology and Data Presentation

Table 1: Profile of respondents

Characteristics	Categorization	Industry (N=64)		Academia (N=25)		Overall (N=89)	
		N	%	N	%	N	%
Work experience	5-10 years	40	62.5%	3	12.0%	43	48.3%
	11-15 years	8	12.5%	6	24.0%	14	15.7%
	16-20 years	7	10.9%	9	36.0%	16	18.0%
	21-25 years	4	6.3%	4	16.0%	8	9.0%
	Over 25 years	5	7.8%	3	12.0%	8	9.0%
Title	Professor	—	—	11	44.0%	11	12.4%
	Associate Professor	—	—	14	56.0%	14	15.7%
	Senior management	14	21.9%	—	—	14	15.7%
	Department management	12	18.8%	—	—	12	13.5%
	Project management	38	59.4%	—	—	38	42.7%
Location	China	37	57.8%	25	100%	62	69.7%
	Asia (without China)	12	18.8%	—	—	12	13.5%
	Africa	11	17.2%	—	—	11	12.4%
	Europe	2	3.1%	—	—	2	2.2%
	Latin America	2	3.1%	—	—	2	2.2%

A questionnaire survey was conducted to collect the importance of the CSFs for ERM from Chinese construction firms. In this study, the target sample consisted of the senior and middle management in Chinese construction firms and the academics with in-depth knowledge of risk management in these firms through research. Based on the comments from the pilot study, revisions were made to improve the readability and accuracy of the

description of the CSFs. In the finalized questionnaire, the respondents were asked to provide their general information and to rate the importance of the 16 CSFs according to a five-point scale (1=very low, 2=low, 3=medium, 4=high, 5=very high).

A total of 390 questionnaires were sent, and 89 completed questionnaires were obtained from 25 academics and 64 practitioners, representing a response rate of 22.8%. The respondent profile is indicated in Table 1. 51.7% of the respondents had over 10 years of experience, ensuring the response quality. In addition, responses were collected from the domestic and overseas subsidiaries Chinese construction firms, thus representing the views of Chinese construction firms in the global construction market.

4. Data Analysis and Discussions

4.1 Overall Importance of the CSFs

The Cronbach's alpha coefficient of 0.920 suggested that the data of the importance of the CSFs had high reliability. Table 2 reports that the importance mean scores of the CSFs range from 3.40 to 4.55. The one-sample t-test was performed to test whether each CSF was significantly important. The p-values of all the CSFs were 0.000, suggesting that all the CSFs had significant importance. A total of six CSFs obtained overall importance mean scores over 4.00.

Table 2: Overall ranking of the CSFs for ERM

Code	CSFs for ERM	Mean	Rank	p-value
CSF01	Commitment of the board and senior management	4.55	1	0.000*
CSF02	ERM ownership	4.16	4	0.000*
CSF03	Risk appetite and tolerance	3.51	15	0.000*
CSF04	Risk-aware culture	3.82	12	0.000*
CSF05	Sufficient resources	4.01	6	0.000*
CSF06	Risk identification, analysis and response	4.28	2	0.000*
CSF07	Iterative and dynamic ERM steps	3.97	8	0.000*
CSF08	Leveraging risks as opportunities	3.61	14	0.000*
CSF09	Risk communication	3.90	10	0.000*
CSF10	A common risk language	3.40	16	0.000*
CSF11	A risk management information system	3.76	13	0.000*
CSF12	Training programs	3.92	9	0.000*
CSF13	Formalized key risk indicators	3.89	11	0.000*
CSF14	Integration of ERM into business processes	4.08	5	0.000*
CSF15	Objective setting	4.26	3	0.000*
CSF16	Monitoring, review and improvement of ERM framework	3.97	8	0.000*

*The one-sample t-test result was significant at the 0.05 level (two-tailed).

"Commitment of the board and senior management" was ranked first, suggesting that the support from the top management was the most important. In Chinese construction firms, the attitude of the top management towards ERM determines whether ERM implementation is successful or not. This is because the management hierarchy is clear in these firms and the subordinates follow their superiors in most cases. In addition, the result echoed the findings of Gates (2006) and Kleffner et al. (2003) that the commitment of the board and senior management was an internal driver for ERM implementation.

“Risk identification, analysis and response” obtained the second position, implying that Chinese construction firms attached great importance to the actual execution of ERM because this CSF describes the critical steps of a generic risk management process. In addition, the high mean score of this CSF confirmed the validity of the COSO ERM framework (COSO, 2004) because this CSF can reflect three components of this framework, i.e. event identification, risk assessment, risk response.

The third ranked CSF was “objective setting”, indicating that clearly identified objectives at various levels were highly important to ERM success in Chinese construction firms. Objective setting also involves clearly identifying strategic objectives (Bowling and Rieger, 2005) because ERM should be applied in strategy setting (COSO, 2004). The result also confirmed the validity of the COSO ERM framework because objective setting is one of the eight components of this framework.

“ERM ownership” was the fourth important CSF. This result suggested that successful ERM programs in Chinese construction firms needed an owner to centralize risk management and to take charge of risk oversight, which was consistent with the ERM practices in other industries (Banham, 2004). According to a case study relating to a Singapore subsidiary of a leading Chinese construction firm (Zhao et al., 2012), the ERM responsibility was included in the function of the Managing Director while the board of director itself served as a risk committee.

The fifth ranked CSF was “integration of ERM into business processes”. This result echoed the ERM Guidance for Central Enterprise issued by the State-owned Assets Supervision and Administration Commission of China’s central government (SASAC, 2006), which stipulates that ERM should be fully integrated into the management and business processes of an enterprise. Central enterprises are the state-owned enterprises administered by the SASAC with the authority vested by China’s central government. Most leading Chinese construction firms are central enterprises that need to comply with the guidance and this CSF has been recognized as a key performance indicator of ERM implementation by the SASAC.

Another highly ranked CSF was “sufficient resources”, implying resources (e.g., funds, qualified staff, time, knowledge and expertise) were inevitable and necessary for ERM implementation in Chinese construction firms. Thus, resources should be consistently allocated to ERM programs to assure their success. By contrast, previous studies identified insufficient inputs of time, fund and staff, and lack of internal knowledge and expertise as hindrances to ERM implementation (Gates, 2006, Rao, 2007).

4.2 Importance of the CSFs by Respondent Characteristics

This study also investigates the differences in CSF importance between different groups of respondents to check whether there was consensus on the top CSFs. Meanwhile, possible reasons were provided to highlight the different viewpoints on the CSFs with statistical differences in their importance. Table 3 reports the importance mean scores and ranks of the CSFs by institution types and work experience.

According to the institution type, the respondents were grouped into practitioners and academics. The independent-sample t-test results showed significant differences in the importance mean scores of three CSFs between the two groups (see Table 3). Although the practitioners and academics assigned significantly different scores to “commitment of the board and senior management” and “risk identification, analysis and response”, the mean scores were high and both CSFs were among the top three CSFs of each group. However, “integration of ERM into business processes” obtained great differences in both mean scores and ranks between the two groups. The practitioners ranked it ninth while the academics ranked it third. Because the full integration of ERM is not easy and time-consuming (Shortreed, 2010), practitioners did not think it very important when they initiated ERM. From the pragmatic perspective, at the early stage of ERM implementation, management needs short-term wins to convince employees that ERM can create value and benefits for the company. Obtaining continuous support from the top management and employees, ERM can be implemented across the company and integrated into the business processes. By contrast, the academics would emphasize the full integration of ERM as this has been emphasized in existing ERM frameworks or guidance (e.g. COSO, 2004, SASAC, 2006).

Table 3: Ranking of the CSFs for ERM by institution type and work experience

CSF code	Institution type					Work experience							
	Industry (N=64)		Academia (N=25)		p-value	5-10 yrs. (N=43)		11-20 yrs. (N=30)		> 21 yrs. (N=16)		ANOVA	
	Mean	Rank	Mean	Rank		Mean	Rank	Mean	Rank	Mean	Rank	p-value	Post-hoc
CSF01	4.47	1	4.76	1	0.028*	4.42	1	4.77	1	4.50	1	0.111	NSD.[a]
CSF02	4.13	4	4.24	5	0.570	4.16	3	4.20	7	4.06	5	0.874	NSD.
CSF03	3.56	15	3.36	15	0.318	3.51	15	3.53	14	3.44	16	0.936	NSD.
CSF04	3.78	13	3.92	10	0.543	3.79	12	4.03	10	3.50	15	0.193	NSD.
CSF05	3.95	6	4.16	6	0.317	3.95	5	4.23	5	3.75	12	0.169	NSD.
CSF06	4.17	3	4.56	2	0.025*	4.07	4	4.60	2	4.25	3	0.009**	G1<G2 [b]
CSF07	3.95	6	4.00	8	0.816	3.86	9	4.20	7	3.81	11	0.175	NSD.
CSF08	3.63	14	3.56	14	0.779	3.63	14	3.53	14	3.69	13	0.863	NSD.
CSF09	3.92	9	3.84	12	0.700	3.93	6	3.87	12	3.88	10	0.951	NSD.
CSF10	3.48	16	3.20	16	0.212	3.40	16	3.37	16	3.50	15	0.903	NSD.
CSF11	3.83	12	3.60	13	0.342	3.81	11	3.53	14	4.06	5	0.219	NSD.
CSF12	3.95	6	3.84	12	0.623	3.88	8	3.97	11	3.94	8	0.936	NSD.
CSF13	3.88	11	3.92	10	0.833	3.77	13	4.03	10	3.94	8	0.452	NSD.
CSF14	3.92	9	4.48	3	0.015*	3.81	11	4.33	4	4.31	2	0.046**	G1<G2 [b]
CSF15	4.20	2	4.40	4	0.319	4.19	2	4.47	3	4.06	5	0.216	NSD.
CSF16	3.92	9	4.08	7	0.438	3.88	8	4.10	8	3.94	8	0.570	NSD.

* The independent-sample t-test result is significant at the 0.05 level (two-tailed); ** The one-way ANOVA result was significant at the 0.05 level (two-tailed); [a] NSD.= No significant difference; [b] G1=5-10 yrs; G2=11-20 yrs.

In addition, according to the work experience, the respondents were divided into three groups, i.e. respondents with 5-10 years (G1), 11-20 years (G2) and over 21 years (G3) of experience, respectively. The one-way analysis of variance (ANOVA) results suggested that the three groups had differences in the importance mean scores of two CSFs: “risk identification, analysis and response” and “integration of ERM into business processes”. The least significant difference (LSD) test was adopted as the post-hoc test because it has more power than other methods (e.g. Tukey test) (Williams and Abdi, 2010). The LSD test results indicated that the G2 respondents attached more importance to these two CSFs than the G1 ones, and that there were no significant differences between G1 and G3 and between G2

and G3. In terms of “risk identification, analysis and response”, although the G1 respondents rated it significantly less than the G2 ones, all the three groups considered that “risk identification, analysis and response” was very important (mean>4.00) and ranked it among the top five CSFs. However, as for “integration of ERM into business processes”, the G1 respondents ranked it very low, suggesting that this CSF did not attract adequate attention from the ones with less experience. This is possibly because this CSF involves a long-term view on ERM implementation and the staff with less experience did not have such a long-term view. More experienced ones would hold a long-term view on ERM and understand that integration of ERM into business processes can bring about more benefits.

In case of the CSF ranking, all the groups ranked “commitment of the board and senior management” first, thus confirming its top position in the overall ranking. The Spearman rank correlation was performed and the result indicated strong correlation between the practitioners and academics (see Table 4). Thus, the two groups agreed on the CSF ranking. In addition, there were significant correlations among the G1, G2 and G3 respondents, suggesting the agreement on the CSF ranking among these three groups.

Table 4: The Spearman rank correlation

Characteristics		Institution type		Work experience		
		Industry	Academia	5-10 yrs.	11-20 yrs.	> 20 yrs.
Institution type	Industry	1.000	0.849*	——		
	Academia	0.849*	1.000			
Work experience	5-10 yrs.	——		1.000	0.784*	0.672*
	11-20 yrs.			0.784*	1.000	0.689*
	> 20 yrs.			0.672*	0.689*	1.000

* Correlation is significant at the 0.01 level (2-tailed).

5. Conclusions and Recommendations

The study identifies the important CSFs for ERM in Chinese construction firms. A total of 16 CSFs were identified through a comprehensive literature review and a questionnaire survey was conducted to collect the data relating to the relative importance of these CSFs. The analysis results implied that all the 16 CSFs were significant important to ERM success. The top six important CSFs were “commitment of the board and senior management”, “risk identification, analysis and response”, “objective setting”, “ERM ownership”, “integration of ERM into business processes”, and “sufficient resources”. In addition, although there were significant differences in the perceived importance of a couple of CSFs between different groups, all the respondents agreed with the CSF ranking, regardless of their institution type and work experience. Thus, it can be concluded that there was consensus on the top CSFs.

Although the objectives of this study were achieved, there are limitations to the conclusions that may be drawn from the results. First, the CSFs identified in this study were not exhaustive. In addition, as the data were collected from the professionals with experience and knowledge relating to ERM in Chinese construction firms, one should be cautious when the results are interpreted and generalized. Nonetheless, construction firms from other countries can also use the CSFs identified in this study to prepare their customized list of CSFs for ERM. Also, the findings of this study provide valuable information for future studies

related to ERM in the global construction industry. Thus, it is believed that this study contributes to the body of knowledge relating to ERM in the broader global community.

Future studies can develop a set of ERM performance indicators related to the key areas of ERM for performance assessment. In addition, the critical hindrances to ERM implementation in construction firms can be identified, and thus management can take measures to deal with them to guarantee ERM success.

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Durability Evaluation of External Thermal Insulation Composite Systems: Frequency Assessment of Thermal Shocks

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Abstract

The External Insulation Composite Systems (ETICS) are nowadays widely used to improve the energy efficiency of the building envelope. To assess the durability of ETICS we first performed a Failure Modes Analysis, studying effects and actions of the stressing agents, and we isolated the most relevant critical climate conditions that cycled many times lead to failure. Then, by means of Heat and Moisture Transport (HMT) numerical simulations, we evaluated the frequency of those events that are more critical for the durability of ETICS (such as thermal shocks or cyclic seasonal variations in surface temperatures) and the performance decay over time in several climatic contexts, especially Southern Europe.

The main results achieved with HMT simulations on a specific ETICS component, with different insulation types, showed that there is no relevant difference in intensity and frequency of thermal shocks, in terms of sudden surface variations, between expanded polystyrene (EPS) and mineral wool insulation (MW) systems. In fact, just a few more events occur for EPS than for MW systems. We also compared the performance of ETICS in Northern with Southern European climates, and we note that, also in summer, contrary to expectations, there is a large amount of events of thermal shocks in Northern Europe, up to 50% higher than Mediterranean cities, albeit with different intensity. Thanks to this analysis is possible to point out that also for Northern Europe is important to take into account summer conditions in procedures for accelerated ageing in the laboratory. This can represent an example of how the differences in terms of stressing agents and system reactions could affect the reference conditions which should be set for the ageing tests.

Keywords: Durability, ETICS, HMT simulations, EPS, Mineral Wool, Thermal Shocks

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1. Introduction

The Durability Research Group of Politecnico di Milano, within the framework of CIB W080 “Service Life Methodologies”, has developed an experimental programme for the evaluation of the durability of ETICS (External Thermal Insulation Composite Systems), which is a technological component widely used to improve the energy efficiency of the building envelope.

To evaluate the durability of building components it is important to study the failure modes that can occur over time. In the case of external insulation systems, failures occur mainly on the finishing layers, at interfaces between coating and insulation, or between insulation and substrate. The failures depend on the type and properties of coating and insulation. Some failures are particularly interesting considering ETICS: cracking, detachments, bulging and wrinkling, and biological growth. They are due to weathering, or design and laying errors, which often combine and enhance their influence. The classification of failures can be made considering their seriousness, their extension over the surface, or their probability.

We analyzed the agents, their actions, and effects resulting in the main failure modes, as shown in (Daniotti et al., 2012), with experimental studies we performed on that kind of systems (Daniotti et al., 2005), survey on existing buildings (Re Cecconi et al., 2008), literature review, and assessing failure cases provided by a manufacturer of mineral wool. The discussed failure modes are mainly related to ETICS with expanded polystyrene (EPS) - currently the most used - and mineral wool (MW) insulation. The reinforced base coat is usually cement-based with polymeric resins added, while the finishing coat may be an acrylic or mineral thick coating (only if the base coat has excellent planarity it may be a paint). In this analysis, we focused on degradation related to the natural ageing processes, thus excluding conception and construction errors (i.e. building pathologies). The main agents we considered are thermal shocks (actually a combination of agents), moisture, freeze-thaw, algae, mould, and other biotypes.

Thanks to the previous analysis, we saw that cyclic thermal shocks and water absorption are, in Southern Europe climates, often the most relevant mechanisms that cause degradation, loss in performances, and failures of ETICS. Whether the relevance of their effects on ETICS is known (ETAG 004, 2000), less studied, instead, are both the intensity of the shocks, which shall be reproduced in the laboratory, and their frequency in different climate areas. In fact, intensity and frequency are fundamental knowledge to study the durability of objects exposed to cyclic stress (Daniotti et al., 2008).

2. Hygrothermal Modelling

To evaluate the intensity and frequency of the most critical events, we performed heat and moisture transport simulations (HMT) with the software WUFI 5.1, a finite differences model, based on the numerical solution of the heat balance and the moisture balance equations (Kunzel, 1995). The main features of the WUFI model are the ability to simulate the thermal conductivity as a function of temperature and water content, the moisture transport in liquid phase by capillarity, beyond water vapour diffusion (with moisture transport coefficients as a

function of water content itself), and latent heat exchanges, as well as heat and moisture sources/sinks. We used WUFI to compute the surface temperatures and assess their variations, in terms of thermal shocks, of an ETICS with a mineral wool compared to an EPS system in different climatic conditions. The insulation materials were modelled with the same thermal conductivity (λ = 0.04 W m^{-1} K^{-1}), so as to compare the results in terms of thermal shocks (materials properties are presented in Table 1). The simulations were performed in one-dimension, considering, thus, the main section.

Table 1: Properties of the layers of substrate and ETICS with MW or EPS

n°	Layer	t (m)	ρ (kg m^{-3})	$\lambda_{dry,10°C}$ ($Wm^{-1}K^{-1}$)	μ (-)	Porosity (-)
1	Silossanic finishing coat	0.0015	1340	0.70	150	0.40
2	Reinf. mineral base coat	0.004	1200	0.87	25	0.30
3 a/b*	Mineral wool	0.10	146	0.04	1.2	0.95
	EPS	0.10	30	0.04	50	0.95
4	Adhesive	0.005	1200	0.87	25	0.30
5	Cement lime plaster	0.015	1900	0.80	19	0.24
6	Aerated clay brick	0.200	650	0.13	15	0.74
7	Cement lime rendering	0.015	1900	0.80	19	0.24
* For layer two options were considered: a) MW, b) EPS.						

2.1 Reference conditions and input data

For the surface properties the solar absorbance α was set as a variable, ranging from 0.01 to 0.99 (extreme non-realistic cases useful just to show the influence of the incident solar radiation), with steps of 0.10 from 0.20 to 0.80; while the emissivity ε was kept constant and equal to 0.90. We considered the ETICS oriented in the four cardinal directions (herein we present the results just for the South exposure) and applied on a low rise building (height up to 10 m). The calculation period of simulations was set as three years. For the interior climate, we considered the conditions prescribed by the European standard EN 15026, with normal moisture load.

Weather data of some European cities selected as representative were selected from databases (Meteonorm) and include temperature, relative humidity, solar radiation, precipitation and wind speed. The following examples are related to two Italian cities (Milano and Palermo) representative for Southern Europe at two different latitudes, with respectively semi-continental and Mediterranean climate, and two cities in Middle and Northern Europe (Nantes and Espoo), with Atlantic and Baltic climate. The aim of this choice is to highlight the possible differences in terms of frequency and intensity of stressing conditions. A prospect of the weather data is shown in Figure 1, while Figure 2 shows the comparison in percentiles between the analyzed cities about the external air temperature (°C) and the solar radiation G_t (W m^{-2}) on a South facing surface, also distinguished into direct G_b and diffuse G_d component. In terms of solar radiation Milano and Nantes are very similar; Espoo, instead,

has a G_t less than 100 W m^{-2} and Palermo less than 300 W m^{-2} for the 75% of hours. At the 95-th percentile the value of G_t is less than 500 W m^{-2} for all the considered contexts.

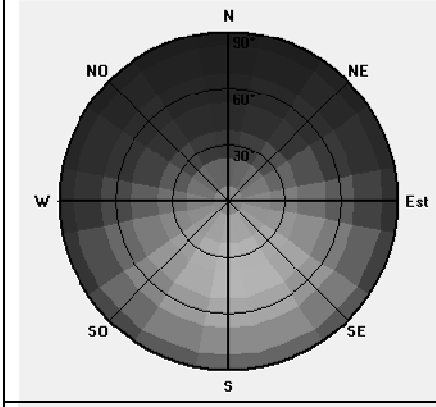
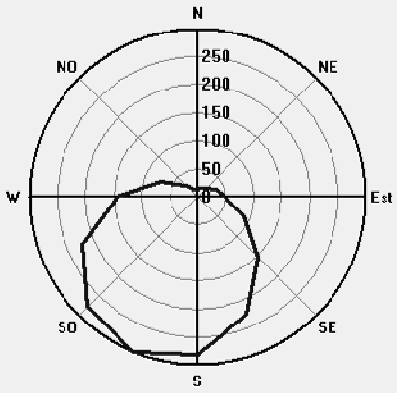
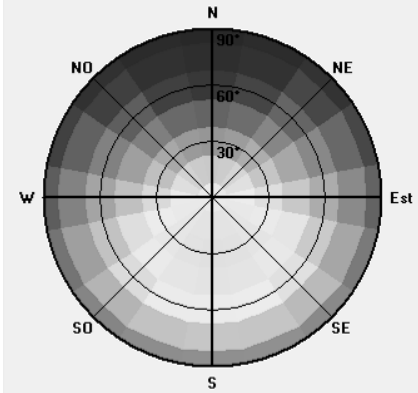
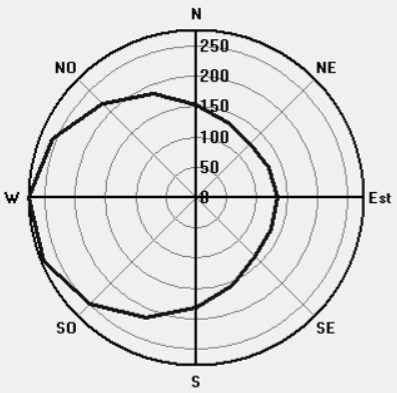
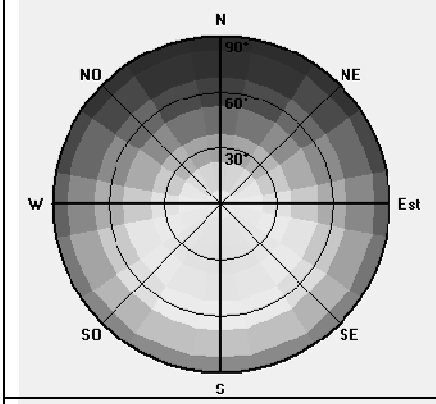
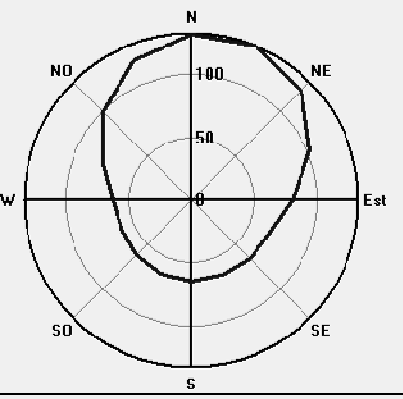
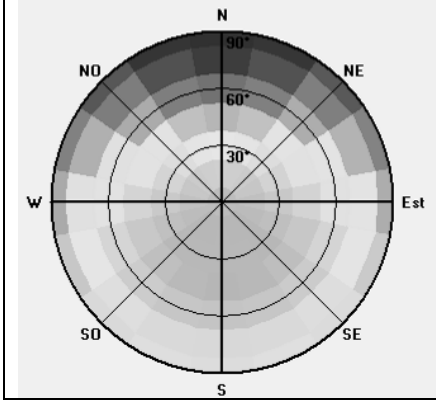
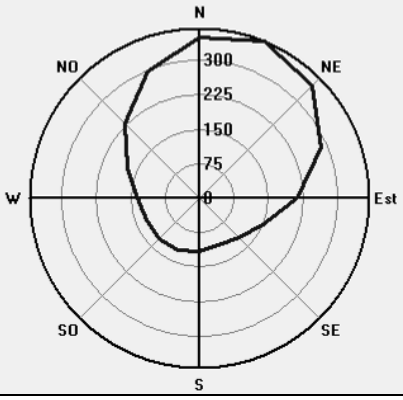
Total Solar Radiation (Kwh m^{-2} y^{-1})	Rain (mm y^{-1})	Cities	
		Espoo	
		T mean (°C)	5.5
		T max (°C)	28.4
		T min (°C)	-25.2
		RH mean (%)	79
		RH min (%)	22
		Rain (mm/y)	639
		Nantes	
		T mean (°C)	11.7
		T max (°C)	32.8
		T min (°C)	-5.4
		RH mean (%)	81
		RH min (%)	34
		Rain (mm/y)	786
		Milano	
		T mean (°C)	11.7
		T max (°C)	31.7
		T min (°C)	-6.9
		RH mean (%)	79
		RH min (%)	30
		Rain (mm/y)	950
		Palermo	
		T mean (°C)	18.0
		T max (°C)	34.9
		T min (°C)	4.0
		RH mean (%)	77
		RH min (%)	43
		Rain (mm/y)	599

Figure 1: Main climatic data for Espoo, Nantes, Milano and Palermo.

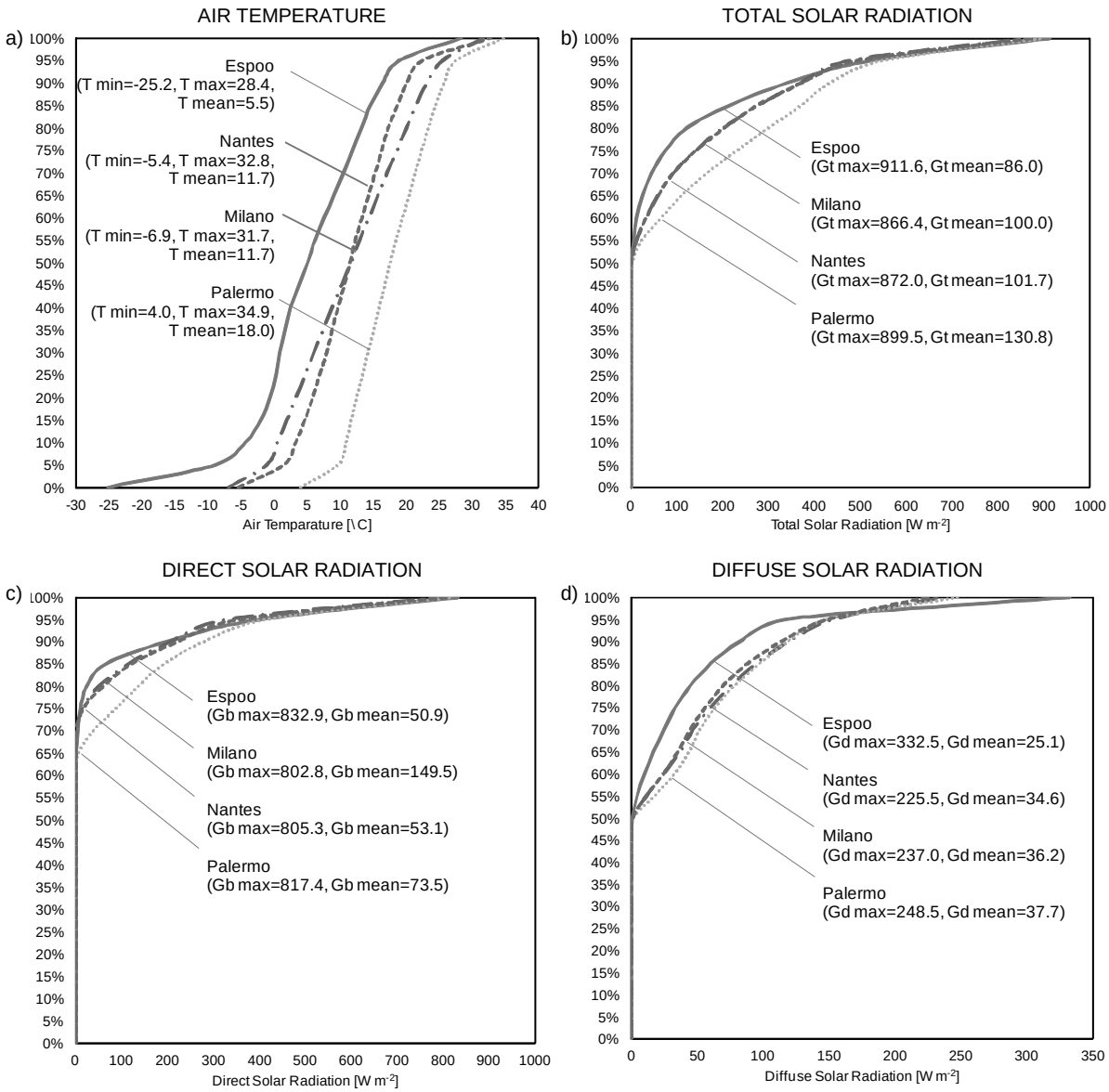


Figure 2: Air Temperature and Solar radiation for a South facing wall

2.2 Thermal shocks analysis

The analyses are based on hourly values of surface temperatures and are divided into different steps: partitioning in surface temperature classes, computation of surface temperature variations, with or without rain, just in summer conditions, and at the end considering the case with surface temperatures higher than or equal to 40°C. For this analysis (described more in detail in Daniotti et al., 2012) we considered as an example a South oriented wall in different weathering conditions.

2.2.1 Surface temperatures

The Figure 3 shows the surface temperatures divided into intervals of 5°C (ranging from -5°C to +70°C), and the hours per year in which can occur for each interval for the different cities. With this analysis we estimate the risk of failure due to stress-strain cycles produced by expansions and contractions.

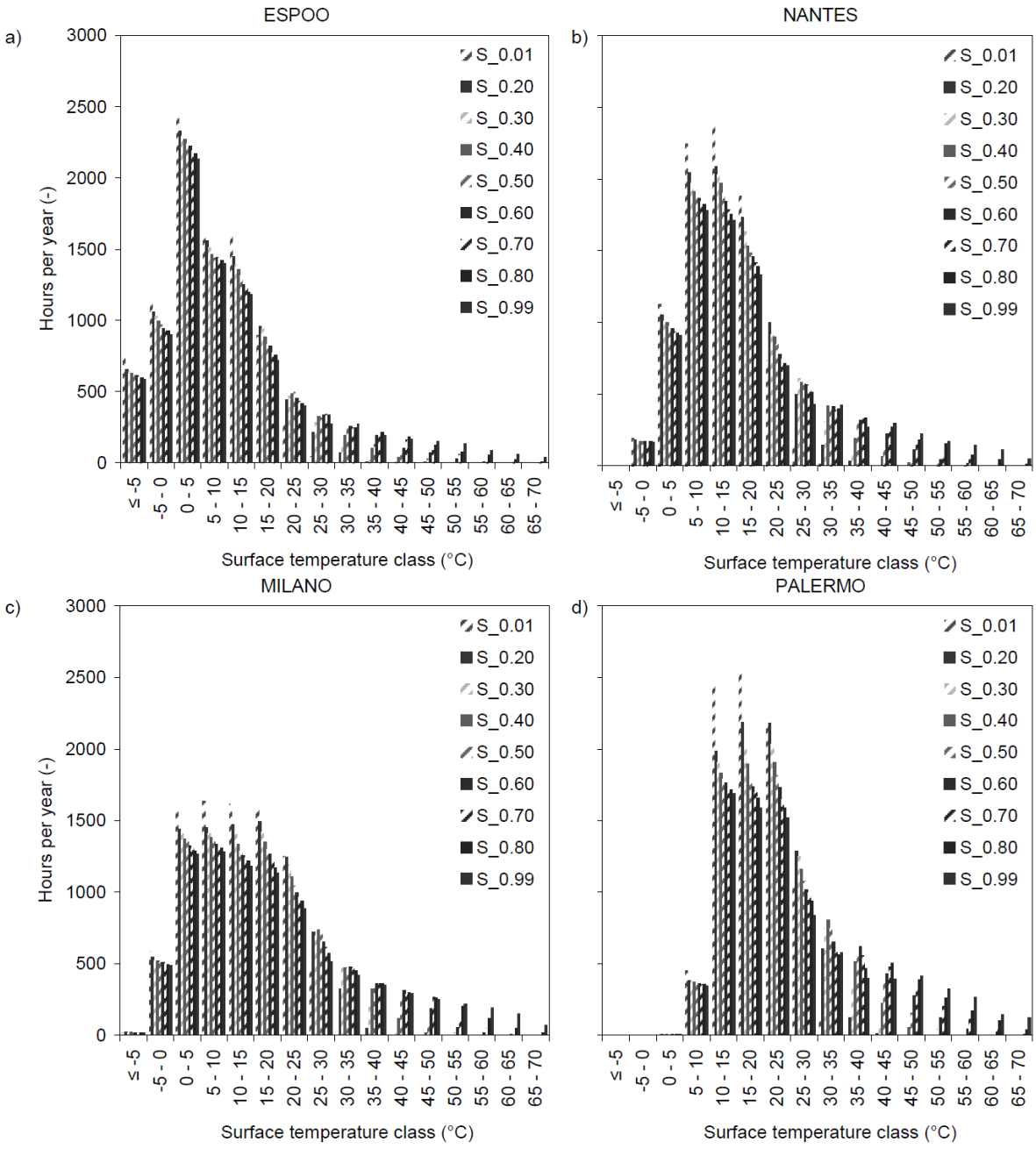


Figure 3: Surface temperature classes for different cities (EPS System)

In case of Espoo, in Finland, there is a high peak in the range 0 – 5 (°C), but the distribution type is similar to those for Nantes and Palermo, while for Milano we see a flatter distribution, with about 1000-1500 hours per year for several ranges from 0 to 25 (°C).

2.2.2 Surface temperature variations with driving rain

A thermal shock may be produced by several combinations of agents, such as: night-time surface cooling for exchange with a clear sky atmosphere and sunrise; rapid change in cloudiness; surface cooling by the action of a cool wind and subsequent heating when the surface is sunlit and heated; and the cycle of heating, cooling because of a summer storm, and subsequent heating when the storm is over.

Even though many thermal shocks occur during one year, the most critical events are those associated with rain, because water changes all properties of porous media: tensile and compression strength decrease, solar absorbance increases, thermal conductivity increases.

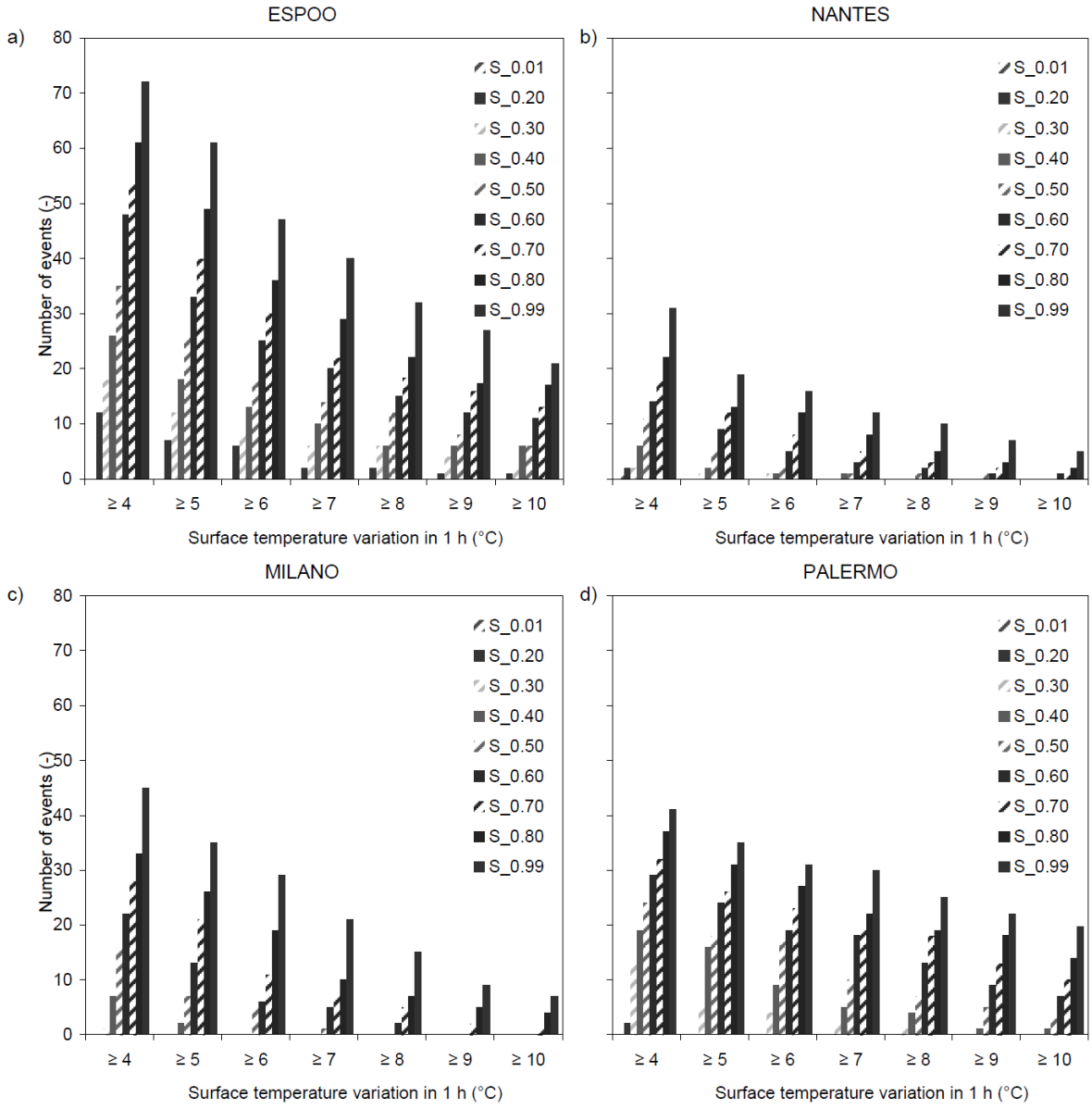


Figure 4: Surface temperature variations with rain for South facing of ETICS with EPS

As a consequence, when the reinforced base coat and top coat get wet, the surface temperature falls, and the rendering is subject to a rapid contraction right when its tensile strength is decreased because of the increased moisture content.

We counted how many times there was a sudden temperature variation and filtered the results counting only the events corresponding to a rapid change in surface temperature coupled with driving rain, considering the total number of events for the entire simulation period and computing a yearly average. In this case, the results of our analysis show (Figure 4) a higher number of events for Espoo, up to 60 with a temperature variation greater than or equal to 4 °C with solar absorbance equal to 0.8, which is the double compared to Nantes and even higher than for the cities of Southern Europe. Also considering just the spring and summer conditions, from April to September (Figure 5), the events of thermal shocks are more frequent for Espoo than for the other cities.

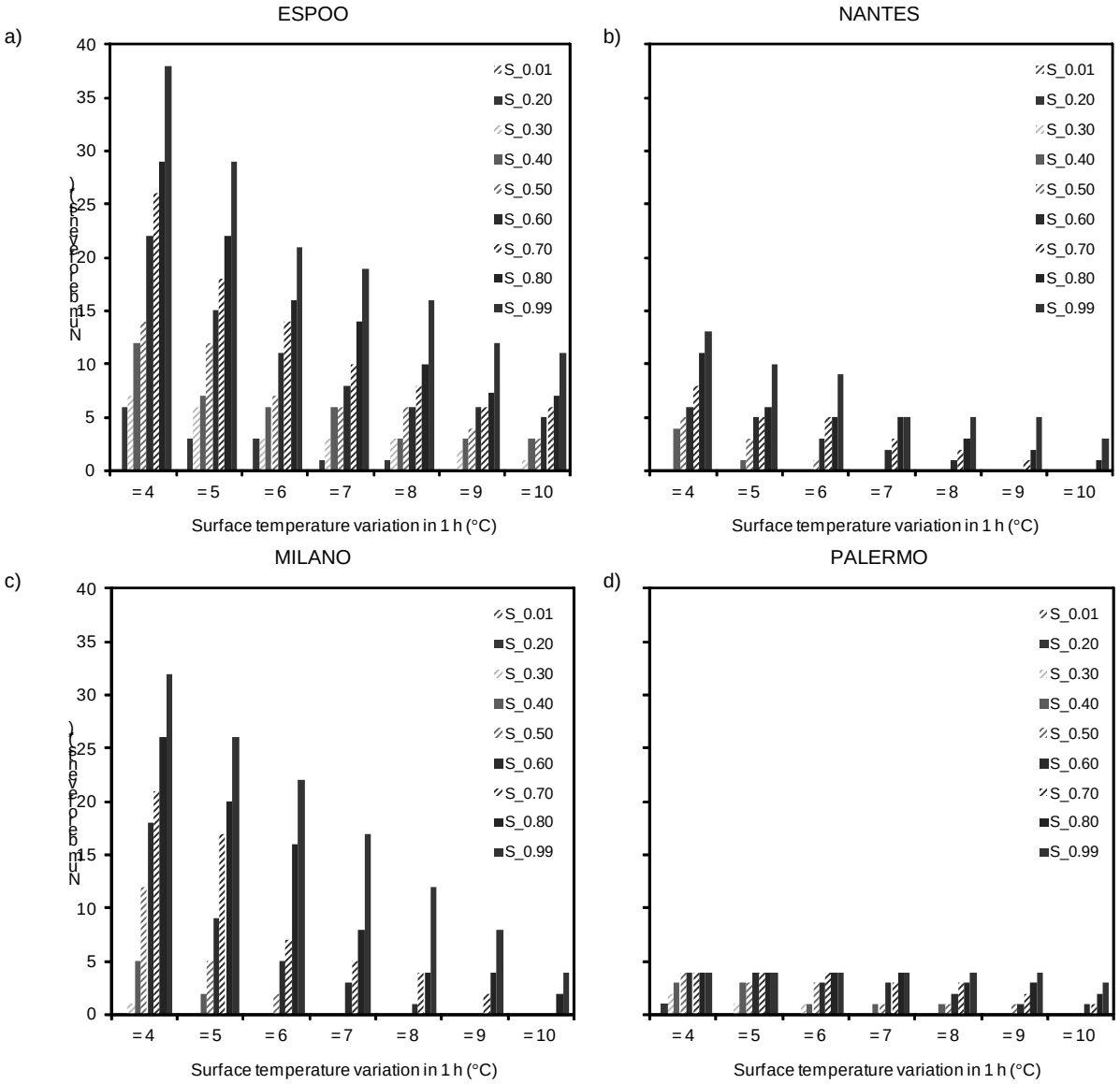


Figure 5: Surface temperature variations with rain in summer conditions.

2.2.3 Surface temperature variations with temperature ≥ 40°C

We considered just the events during which a sudden temperature change occurs combined with driving rain and the surface temperature of the initial or the final condition (the thermal shock may happen both with a sudden heating or a sudden cooling) is above 40°C. As shown in Figure 6, also the more extreme cases, in summer conditions, occur more frequently for Espoo respect to a Mediterranean city with an increase of number of events of about 50%.

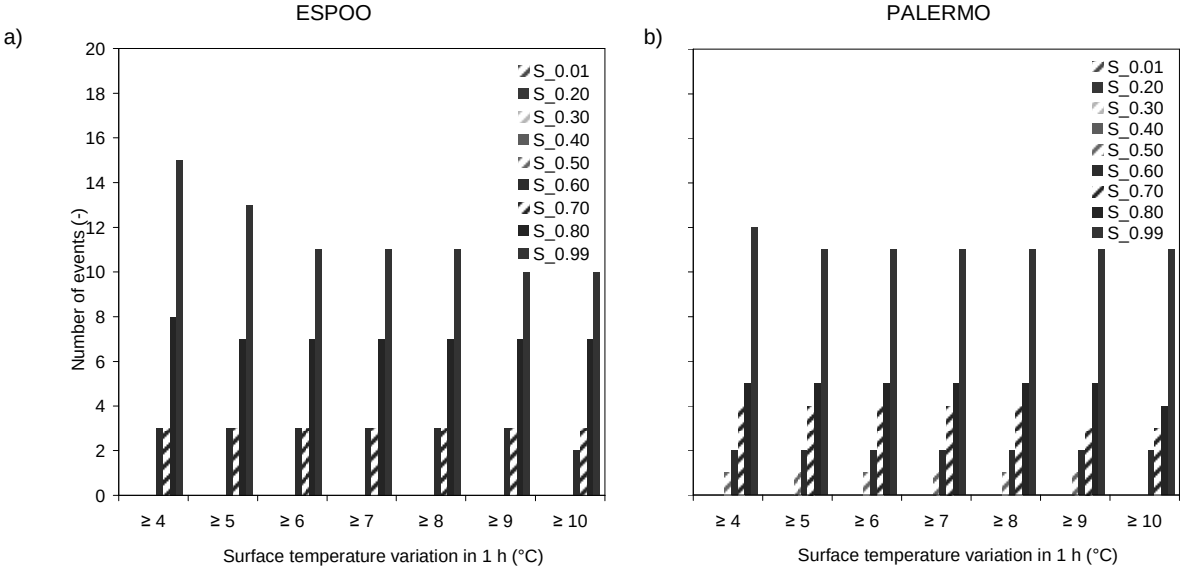


Figure 6: Surface temperature variations with high temperatures (≥40°C).

3. Results and discussions

3.1 Comparative analysis of Thermal shock for MW and EPS systems

The simulations carried out for the two systems, composed by the same rendering but with a different insulation panel, mineral wool or EPS, showed that there is no relevant difference in terms of intensity and frequency of thermal shocks, in other words for different surface temperatures.

Just for some values of solar absorbance (from 0.50 to 0.99) but for every weathering condition, it is possible to see a very light increase of number of events (about 10% more) of ETICS with EPS compared to ETICS with MW as shown in Table 2 for Milano, in which the grey cells represent the different values, from one to a maximum of three events.

Although there are small differences analyzing the surface temperatures, a different response in terms of thermo-mechanical behaviour should be expected due to the compression and tensile strain because of differential thermal expansion coefficient of materials.

Table 2: Surface temperature variations, comparison between ETICS with EPS or MW.

Milano_ΔT & Rain (ETICS - **EPS**)									
αs (-) / ΔT(°C)	S_0.01	S_0.20	S_0.30	S_0.40	S_0.50	S_0.60	S_0.70	S_0.80	S_0.99
≥ 4	0	0	1	7	16	22	28	33	45
≥ 5	0	0	0	2	7	13	21	26	35
≥ 6	0	0	0	0	5	6	11	19	29
≥ 7	0	0	0	0	1	5	7	10	21
≥ 8	0	0	0	0	0	2	5	7	15
≥ 9	0	0	0	0	0	0	2	5	9
≥ 10	0	0	0	0	0	0	1	4	7
Milano_ΔT & Rain (ETICS - **MW**)									
αs (-) / ΔT(°C)	S_0.01	S_0.20	S_0.30	S_0.40	S_0.50	S_0.60	S_0.70	S_0.80	S_0.99
≥ 4	0	0	1	7	14	22	27	32	44
≥ 5	0	0	0	2	6	11	21	25	32
≥ 6	0	0	0	0	2	6	8	18	28
≥ 7	0	0	0	0	0	4	6	9	20
≥ 8	0	0	0	0	0	1	5	5	14
≥ 9	0	0	0	0	0	0	2	5	9
≥ 10	0	0	0	0	0	0	0	2	5

A further analysis in water content (kg m^{-3}) is necessary, because we expected a different amount in the coating layers due to different capillary water absorption coefficient $A_{w,24}$ (Kg $m^{-2}s^{-0,5}$), even if it is very low, and the different water vapour diffusion resistance factor μ (-) of the insulation boards.

3.2 Comparative analysis in the Europe Climate

Contrary to results one might expect, there is a higher number of events of thermal shock in summer condition in the cities of Northern Europe than in the cities of Southern Europe, maybe due to the different direct solar radiation on the wall, Southern exposure in our case. In fact, as shown above, for Espoo there is an increase of the number of events up to 50% respect to the cities of Southern Europe. The differences could be generated also by the different amount of driving rain on the surface which changes the surface temperature.

In order to understand the reason, besides the water content analysis, further thermal shock studies are necessary just in winter conditions. Moreover, frequency and intensity of freeze-thaw cycles should be assessed. In addition, in order to point out the critical intensity for the thermal shocks the effect of temperature variation on the stress-strain curves should be evaluated.

4. Conclusion

We analysed the surface temperatures of ETICS, with mineral wool and EPS insulation having the same rendering and considering different values of solar absorbance. The assessment has been computed with Heat and Moisture Transfer (HMT) simulations for different climatic contexts, in order to highlight the differences in behaviour, making a comparison between Northern and Southern Europe.

The results, in terms of frequency and intensity of thermal shocks, have shown that there is no relevant difference between the two insulation systems, with mineral wool or EPS, for each weathering condition. The difference is just a light increase of events for EPS, respect to MW, in case of high solar absorbance. Of course, we have to expect a different response in terms of thermo-mechanical behaviour that we are going to analyze by Finite Element Methods. The critical reference ranges of values for thermal shocks should be defined knowing the effect of temperature on the stress – strain curves.

A higher number of thermal shocks, also in summer condition, occur in a city of Northern Europe, with a double amount respect to the Mediterranean cities, maybe due to the different direct solar radiation on the wall, but a deeply analysis should be carried out, with also a detailed survey about the climatic data. In fact, we know that there is a systematic error in the solar radiation modelling (diffuse and direct components) which determines an overestimation of the values. We are working on a new model based on actual data. Until now we have processed data for one year and we are going on with this analysis.

A further analysis of thermal shocks is also necessary just in winter condition, and the future work will be also analyzing the water content in each layer and the frequency and intensity of freeze-thaw cycles.

The first achieved result is that the analysis of frequency and intensity of critical events are fundamental for setting the right laboratory test parameters for the durability evaluation of ETICS in different stressing conditions. In fact we have seen, for example, that also for the Northern Europe is important to take into account the summer condition for the accelerated ageing test.

The analyses carried out for some climatic contexts should be repeated for more cases in order to achieve a complete scenario for Southern and Northern Europe, to have benchmarks, needed to evaluate the system behaviour and the best proprieties of materials to ensure the limit performance in different contexts.

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Congruence and scope for incorporating ACTIVE principles into project management competency frameworks

J. W. Hodgson[1], M. M. Tuuli[2] and N. J. Brookes[3]

Abstract Title

Project Management competency has been recognised as a critical source of competitive advantage and key to successful project delivery. For this reason it is important that the competency frameworks used to achieve competence in project organizations are effective and fit for purpose. The European Construction Institute (ECI) developed eight principles through the ACTIVE (Achieving Competitiveness Through Innovation and Value Enhancement) initiative in an attempt to add value to the delivery of projects. This research explored the congruence and scope for incorporating the ACTIVE principles into current competency frameworks in use by project organizations. An interpretive and qualitative research approach was adopted, using semi-structured interviews with eight Project Managers and Learning and Development Managers in project organizations. The use of competency frameworks is not as widespread as first thought. Current competency frameworks in use in project organizations are based on a fairly comprehensive body of knowledge and largely congruent with the ACTIVE principles centered around concept definition, team management, supply chain relationship management, communication, risk management, innovation, project execution and performance measurement. However, ACTIVE principles' underpinning ethos of creating a collaborative working environment in projects is a missing piece worthy of incorporation into competency frameworks currently in use in project organizations.

Keywords: Competency, Frameworks, Competence, ACTIVE, PMBoK, European Construction Institute (ECI)

1. Introduction

The successful delivery of any project relies on the competency of its project management team. Within the dynamic industry of construction, with ever changing project needs and roles, it is important that the competency of the Project Managers accurately reflect the qualities required for successful delivery of projects. This should be considered by any organisation in an effort to ensure their competitiveness within the industry. For this reason, project management competency has been recognised as a critical skill set for ensuring

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project success, and hence something that should be a priority for companies. Munns and Bjeirmi (1996) suggest that the factors of success in project management include commitment to complete the project, appointment of a skilled project manager, adequate definition of the project, correct planning of the activities in the project, adequate information flow, accommodation of frequent changes, rewarding the employees, and being open to innovations. Based on these factors, project organisations have often attempted to develop the competences of their key project management staff using templates referred to as competency frameworks. There are however several competency frameworks in use that it is not clear how organisations arrive at their choices, how they are used and how they are implemented. The European Construction Institute (ECI) developed eight principles through the ACTIVE (Achieving Competitiveness Through Innovation and Value Enhancement) initiative in an attempt to add value to the delivery of projects. This research set out to explore the congruence and scope for incorporating the ACTIVE principles into current competency frameworks in use by project organizations. In the sections that follow, comptency frameworks and the ACTIVE principles are explained. The results and discussion of the findings from interviews with Project Managers and Learning & Develoment Managers in project organisations are then presented. Current competency frameworks in use in project organizations are based on a fairly comprehensive body of knowledge and largely congruent with the ACTIVE principles centered around concept definition, team management, supply chain relationship management, communication, risk management, innovation, project execution and performance measurement. The ethos that underpin the creation of a collaborative working environment in projects however appears to be a missing piece in the ACTIVE principles. Project organisations may therefore consider incorporating these into competency frameworks currently in use.

2. PMBoK and Competency Frameworks

2.1 Competency versus competence

The PMI Project Management Competency Framework Standard (PMI, 2002) makes the distinction between competence and competency, stating that ‘a competency is a cluster of related knowledge, attributes, skills, and other personal characteristics’ and it is these which ‘can be broken down into dimensions of competence’. Applying the concept of competence, in a context specific to managers, Boyatzis (1982), defined competency as “an underlying characteristic of a person. . . including motives, traits, skills, aspects of one's self-image or social role, or a body of knowledge which he or she uses”. Mirabile (1997) also describes competency as “a knowledge, skill, ability, or characteristic associated with high performance on a job, such as problem solving, analytical thinking, or leadership”. This view is consistent with the definition provided by Engineers Australia (2003) to whom competency implies the capability to work to a standard expected which may be ‘high performance’.

In this study, competency will be used in a person-related sense; however this will still directly affect the company 'since organisational-level competencies are embedded in employee-level competencies' (Cardy and Selvarajan, 2006 p.236). Competency will be defined as a cluster of knowledge, attributes, skills, and other personal characteristics (c.f. Boyatzis 1982, Mirabile 1997, Engineers Australia, 2003). Competence will be used in the

job-related sense (area of competence), defined as the individual dimensional elements that make up an individual's job related 'competency'. For the construction industry, the essence in focusing on improving competency of project managers derives also from the impact of projects on the company's business (Edum-Fotwe and McCaffer, 2000 p.112). A project may involve such a large amount of capital that failure may bring the organisation down.

2.2 Competency frameworks

The Project Management profession emerged as a new discipline in the 1960's. Project Management societies created forums in the early 1970's for interested parties to share information, however not enough attention was focused on the standard of the output of this new discipline. In the mid 1980s, the US headquartered Project Management Institute (PMI), and later APM, the UK Association for Project Management (APM), embarked on certification programs to test whether people met their standards of project management professionalism (Morris et al., 2006, p.462). The PMI established its first 'Body of Knowledge' (BoK) in 1976, which became the basis of its certification program in the mid 1980's; with further updates occurring during the 1980's and 1990's and 2000's.

Concern for project management competence has led to the development of standards for project management knowledge and practice that are used for assessment, development and certification (Crawford, 2005). Professional competency in project management is attained by the combination of knowledge acquired during training, and skills developed through experience and the application of the acquired knowledge (Edum-Fotwe and McCaffer, 2000 p.112). This combination of knowledge and relevant skills needs to be assessed against a benchmark. This is done through the use of a competency framework, which is built upon the necessary competence elements specific to the role of a project manager contained in Bodies of Knowledge.

There are a number of existing competency frameworks based on individual BoKs, each containing a slightly different set of competences, deemed by that institution, as the set required for the project management discipline. The three main frameworks are the Association for Project Management competence framework (Association of Project Management, 2008), the Project Management Institute - Project Manager Competency Development Framework (Project Management Institute, 2002) and the International Project Management Association (IPMA) competence baseline Version 3.0. (Caupin, 2006). Another big framework, however less common in the UK, is the Australian Engineering Competency Standards (Engineers Australia, 2003). In 1998 IPMA, produced an amalgam of these national BoKs: The IPMA Competence Baseline – together with proposals for harmonising the various national project management qualifications (Morris et al., 2006, p.462). The latest edition of this document is the IPMA Competency Baseline Version 3.0 (Caupin, 2006), which is based on some of the updates and contributions made by IPMA member associations.

The role of a construction project manager involves a diverse number of competencies comprising many individual elements. To account for this, Lampel (2001) refers to four types of core competencies (entrepreneurial, technical, evaluative and relational), however Caupin

(2006), within the Version 3.0, refers to three types of core competencies (contextual, technical and behavioural). This change in breakdown may have come about as a result of changes that have been identified through analysis of the industry; with the new set from Caupin (2006), more accurately reflecting the important factors required by the role of project manager. For this reason, this study will focus on the three areas of competencies as explained within the most recent Version 3.0 (Caupin, 2006) which contains a grand total of 46 fundamental competencies.

3. ACTIVE Principles

ACTIVE is the acronym for an initiative launched by the ECI (European Construction Institute) in 1996, in an effort to improve competitiveness of capital projects within the onshore process, energy and utility industries within the UK. ACTIVE stands for 'Achieving Competitiveness Through Innovation and Value Enhancement'. Its aim is to change adversarial behaviours and apply better practices in the delivery of capital projects. The initiative is underpinned by a set of eight principles which provide the foundation for building an industry culture characterised by co-operation, trust and commercial efficiency (ECI, 1998). These eight principles are as follows (ECI, 1998):

Effective Project Concept and Definition

Effective Project Team Management

Effective Supply Chain Relationships

Effective Information Management and Communication

Effective Project Risk Management

Effective Innovation and Continuous Improvement

Effective Project Execution

Effective Performance Measurement

The principles above underpin processes within the discipline of project management; however it is the competences that underpin these principles which are where the focus of this study lies. An overview of the eight ACTIVE principles suggests there are many elements which already appear within the APM Body of Knowledge and some which appear very loosely, if at all. The ACTIVE principles are a combination of the fundamental competences such as communication, risk management and procurement, however it should be noted, that the majority of these are grouped as 'technical' competences within the IPMA framework. They are associated with the elements of competency required to get the job done, rather than the personal competencies that enable the project manager to do the job as described by Boyatzis (1982).

The main criticism of the ACTIVE principles lies in their focus on increasing organisational competitiveness. However, the principles are underpinned partly by the elements which form personal competences. As Cardy and Selvarajan (2006) opine, organisational competences

are embedded within personal competences. The behavioural competence elements of ACTIVE principles therefore fulfil the personal competences need.

4. ACTIVE Principles and Competency Framework

ACTIVE, in essence, comprises a number of principles which if followed by an organisation, ensures competitiveness (ECI, 1998). In their current form however, they are not directly transferable into a competency frameworks. To do so, each of the principles will need to be broken down into their individual technical, behavioural and contextual competence elements. At that level of detail, the elements will represent the skills, attitudes and knowledge required to undertake the processes that reflect the ACTIVE principles. The literature however identifies potential barriers for implementation of some of the ACTIVE principles. According to Arditi et al. (1997) for example, innovations are rather incremental than radical in the construction industry. Therefore, it seems unlikely that there will be a widespread uptake of this competence.

5. Research Method

The main research strategy adopted is a qualitative approach using semi-structured interviews. Semi-structured interviews enable researchers 'to get large amounts of data quickly' (Marshall and Rossman, 1999, p.108). It is also the appropriate method as the research is aimed at developing a detailed understanding of individual's views, attitudes and behaviour (Moore, 1999, p.121). The target population for the study was Project Managers and 'Learning and Development managers' as these are the people who are directly responsible to recruitment, training/development and assessment of competence.

The qualitative data obtained from the interviews were supplemented with quantitative data in the form of ratings, an attempt to complement the two data sources (Neuman, 2006). Eight respondents were interviewed and comprised mainly senior project managers and learning and development managers. The respondents worked mainly in oil & gas, energy, pharmaceutical and construction sectors. During the interviews, the respondents also rated the individual technical, behavioural and contextual competences based on their importance to the role of the PM. Prior to the interviews therefore, the authors converted the ACTIVE principles into the competences they are aimed at instilling in project managers. This resulted in 25 competences comprising 8 technical, 7 behavioural and 8 contextual competences, which were then rated by the respondents during the interviews (see Table 1).

A thematic method of analysis was adopted to reveal themes from the interview transcripts. The themes were related back to the literature and the ACTIVE principles to explore areas of commonality and opportunities for incorporating the ACTIVE principles into competency frameworks.

6. Results and Discussion

Through a comparison of the three main existing frameworks (i.e. APM, PMI and IPMA) it was clear that together, they have a comprehensive coverage of competences. The

frameworks however differed in their emphasis. To facilitate the comparison with the competency frameworks, all the eight ACTIVE principles were broken down into their corresponding competence elements, identifying whether they are technical (T), behavioural (B) or contextual (C). The majority of principles contained each type of competence however the majority were technical competences. This, unsurprisingly was consistent with the three main frameworks reviewed earlier. The key emergent themes from the interviews are explained and discussed below. Through a comparison of the three main existing frameworks (i.e. APM, PMI and IPMA) it was clear that together, they have a comprehensive coverage of competences. The frameworks however differed in their emphasis. To facilitate the comparison with the competency frameworks, all the eight ACTIVE principles were broken down into their corresponding competence elements, identifying whether they are technical (T), behavioural (B) or contextual (C). The majority of principles contained each type of competence however the majority were technical competences. This, unsurprisingly was consistent with the three main frameworks reviewed earlier. The key emergent themes from the interviews are explained and discussed below.

6.1 Reliance on generic CF

There is heavy reliance by organisations on the baseline frameworks produced by the APM (Association of Project Managers) and PMI (Project Management Institute) for example. As one Senior Project Manager notes "*all competencies are covered in IPMA or PMI*" (Senior PM, ORG5). This is supported by the views of a Learning and Development Manager who pointed out that their framework is "*based on the PMI and APM competencies as these are most suited to [their organisation] and are known and accepted globally*". (L+D manager, ORG1). This suggests that they trust the scope of competences covered by these globally recognised frameworks and would therefore not require anything extra to fulfil the project management needs of their organisation. This indication of widespread use of generic competency frameworks is backed up by Morris et al. (2006) who state that as at 2006, 'there are now over 55,000 PMP's in PMI and about 10,000 certificated members of the APM'.

6.2 Organisation specificity

It became apparent that if a competency framework is to be effective it must fit the requirements of the organisation. The main advantage of a company specific framework would appear to be the benefits gained through compatibility with company processes and policies, culminating in continuous improvement. As one respondent points out "*if it was a generic framework it would be a waste of time*" (L + D Manager, ORG8). Compatibility with existing systems allows the organisation to work more collaboratively as a whole, with a common language facilitating increased efficiency. This view is echoed by a senior project manager, "*There is an advantage of having a common language spoken to ensure everyone coming from different organisations or backgrounds to the organisation use the same terminology. It can give a commonality of how things are carried out and gives a basis of what project management should be*" (Senior PM, ORG5). Here a common language has been shown to benefit the human resource department, with organisations keen to saturate

their new employees with their own company specific terminology as it is seen to allow better integration into the day-to-day work of the company.

6.3 Barriers to CF

The time related aspect of implementing competency frameworks was a concern for some organisations. Partly to blame is the vast number of competence elements that make up the frameworks. There need to be such a significant amount of competence elements to allow flexibility for each stage in the project life cycle. As one L + D Manager put it, "*the paper based framework is unwieldy for a business as it takes so much time to reach level 5 of 40 or 50 competencies*" (L+D manager, ORG1). The concept behind having such a large amount of competences may work in theory and be justified in business terms but it just does not seem practical. One respondent sums up this view, "*finding the time to take the training is often difficult*" (Project Academy Co-ordinator, ORG2).

6.4 Working Environment

The need for a collaborative working environment was emphasised. Incidentally, the ACTIVE principles aims to successful incorporate a culture of collaboration. As the ECI (1998) point out "through correct use of the principles the aim is to encourage a culture of collaboration and making people value orientated both towards themselves and the customer". This is already been considered by some organisations. As one respondent notes "*people, who can work collaboratively, have good interpersonal skills and can communicate well, are an advantage*" (Project Academy Co-ordinator, ORG2). However, this is a vision for collaboration to come directly as a result of the understanding already within the individuals not through the systematic method of implementing it through a framework. Another Senior PM (ORG6) pointed out that they were highly dependent on contractor relationships and would therefore directly benefit from increased supply chain relationships that can be fostered through use of the ACTIVE principles.

6.5 Awareness of ACTIVE

From analysis, the awareness of ACTIVE among the organisations is mixed. Some organisations have heard of ACTIVE but choose not to use them while some are aware of them and are using them under a different name. There are however others who have never heard of ACTIVE at all. Overall, this would indicate a low level of awareness.

One L+D Manager who had never heard of ACTIVE, was able to take a quick glance and was of the opinion that "*there is nothing in the ACTIVE principles that is surprising*" (L + D Manager, ORG8). This is interesting because at a quick glance you simply wouldn't be able to fully appreciate all that the ACTIVE principles can offer to organisations. Only when the competence breakdown is seen, can it be understood what is really beneath the surface of the initiative.

Of the three organisations that were aware of ACTIVE, two of these said they actively used them. The third however dismissed any intended inclusion of the principles saying "*if you*

manage a project effectively then you are carrying out the ACTIVE principles" (Senior PM, ORG5). This could be true but could be said of PRINCE2 also, for example. If you are managing a project effectively, you could say you were using the processes contained within PRINCE2. However, perhaps the point being made is that ACTIVE makes up the core set of competences behind any project. This same company views ACTIVE as part of their lean initiatives, linking it to the value enhancement side of project management. As they argue, "*lean principles seem to overlap the ACTIVE principles with regards to effectively running a project. While our organisation is in favour of making sure the project is carried out effectively, ACTIVE is probably not a well known term in the organisation*." (Senior PM, ORG5).

Table 1: Importance of Competences to PM role

Competence	Average Rating	Category
Decision Making	9.7	Contextual
Leadership Skills	9.4	Behavioural
Communication Skills	9.2	Behavioural
Problem Solving	9.0	Behavioural
Organisational Skills	8.9	Contextual
Risk Management	8.9	Technical
Teamwork	8.8	Behavioural
Stakeholder Management	8.8	Contextual
Ethics and Values	8.7	Behavioural
Change Control	8.6	Contextual
Developing Teams	8.5	Behavioural
Negotiation Skills	8.5	Behavioural
Resource Management	8.4	Technical
Commercial Management	8.3	Technical
Project Implementation Control	8.2	Technical
Planning	8.1	Contextual
Programme Management	8.0	Contextual
Contract Management	7.8	Contextual
Awareness of the Business Needs	7.8	Contextual
Implementation of Standards, Systems and Procedures	7.7	Contextual
Information Management	7.5	Contextual
Financial Management	7.5	Technical
Quality Control	7.3	Technical
Procurement Control	7.1	Technical
Technical Ability	6.5	Technical

Of the remaining two companies aware of ACTIVE, one uses them as part of their PM development, however they are quick to point out "*they are not called ACTIVE principles in the framework but are built in*" (L + D Manager, ORG1). The other organisation on the other hand however, uses ACTIVE to develop their PM procedures but do not use them for training and development purposes.

6.6 Importance of Competences

Table 1 shows the ratings of the importance of the competences to the role of the Project Manager. The results show that the behavioural competences are highly rated, being rated all above the average. Interestingly, over half of the technical and contextual competences have been rated below average. Although the technical competences feature quite heavily in the 3 main competency frameworks, the results here appear to suggest that the technical competences are relatively less important. As one respondent notes when it comes to recruitment, technical competences are not as important, "*we tend to make a judgement more on the behavioural and contextual competencies*" (Senior PM, ORG5). The fact that the technical competences can be well taught means that all of the focus lies with those which are harder to teach and are normally embedded within the PM from day one, these being the behavioural and contextual elements. Another Senior PM is even more direct, *"The more technical related competencies are possibly less important"* (Senior PM, ORG6). However, a Senior PM puts this a bit in perspective, explaining that the importance of the technical competences may depend on the project phase, "*Once you're in the build phase i'm not sure whether it matters if they have technical competencies it really depends on the phase*." (Senior PM, ORG4).

7. Conclusion

A number of key findings are worth highlighting. First, the results suggest that generic frameworks are no good, for the reason that every organisation is different. Therefore there is a need to have organisation specific competency frameworks. Part of the process of contextualising the competency frameworks is to recognise the importance of certain project phases or discipline or project size. Competency frameworks also appear to be missing necessary competences for fostering collaborative working environment. A behavioural focus is therefore paramount.

Second, of the three types of competences, the behavioural ones are more important to the role of the project manager while the technical competences appear to be the least important. This is somewhat surprising, given that competent engineers who show proficiency in their mainly technical specialism tend to be those promoted to project manager status.

Third, the findings appear to suggest that the ACTIVE principles do not add anything new which generic competency frameworks do not already provide except for innovation and continuous improvement. Yet, there is no evidence that organisations employ any systematic approach to determining what is missing within the frameworks they currently use. As far as the ACTIVE principles are concerned, the argument for their inclusion in existing

competency frameworks is not that strong as evident from this study. The majority of the ACTIVE competences comprise those of a technical nature. These have been shown in the analysis to be less important than those of a behavioural or contextual nature it would seem.

Taken together, the current competency frameworks in use in project organizations are based on a fairly comprehensive body of knowledge and largely congruent with the ACTIVE principles. However, ACTIVE principles' underpinning ethos of creating a collaborative working environment in projects is a missing piece worthy of incorporation into competency frameworks currently in use in project organizations. This therefore has implications for the competency development of project managers in terms of what should be emphasised and in terms of the scope of training programmes.

This study however has several limitations. The main limitation is with regards access to the interviewees. Due to their important roles within their organisations it was hard for them to be interviewed for longer periods of time which may have affected the breadth of the issues explored. Also, as with any qualitative study, the findings of this study cannot be generalised across all project organisations.

The study highlights potential avenues that future research can pursue. Project organisations can benefit from a systematic way of determining which competences are actually missing from a competency framework in use. It appears at present that the only way they are discovered is by chance whereby they realise they are missed when they are needed. Further research into the actual benefits of using the ACTIVE principles is required. A case study of an organisation which is planning to or is implementing the ACTIVE principles would provide valuable evidence in this regard.

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April 2009 Earthquake in Central Italy: initial considerations about reconstruction costs e procedure

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Legislation regulating earthquake reconstruction work in Italy

Italy is a country frequently struck by earthquakes of medium intensity. In April 2009, an earthquake swarm that had been carrying on for several months reached its climax with an earthquake measuring 5.9 on the Richter scale. A heavily built-up area of Central Italy was hit with damage to a large number of buildings and very many people affected. In particular, the city of L'Aquila, situated close to the epicentre, is the regional capital with an important old town centre and plenty of industry. The earthquake caused 308 deaths, 1600 injured and damage to more than 40,000 buildings. In May 2012, a new seismic event, comprising 3 tremors of magnitude greater than 5, struck the Emilia-Romagna Region in the north of Italy, causing 17 deaths, hundreds of injured and more than 17,000 homeless. Reconstruction following the 2009 earthquake and regulated by Act No. 77/2009 was handled in a much different way to previous earthquakes. Actions to reconstruct business premises, residential housing, public and monumental buildings were soon implemented with around 22,000 damage repair projects financed in the three years since the earthquake, of which 10,000 have already been completed and 12,000 are in progress. The paper provides some figures regarding the amounts actually spent, with particular reference to the grants received to repair ordinary buildings. A critical analysis has also been made of the statutory solutions adopted in order to finance damage repair operations, highlighting their strengths and weaknesses and the possible scope for improvement.

Keywords: earthquake, seismic vulnerability, buildings, damage, reconstruction costs

1. Introduction

Following a seismic event with very serious consequences, such as that which occurred in Central Italy on 6th April 2009, in a scenario where only a very small number of properties are insured, the starting point for handling the reconstruction is the drafting of specific legislation regulating the damage repair work. The seismic event in question, culminating with an earthquake of magnitude Mw 6.3, struck a heavily built-up area, causing 308 deaths and more than 1600 injured, whilst making more than 35,000 buildings uninhabitable (data from survey using AeDES forms last updated February 2011). In addition to housing, the

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categories of buildings damaged include business premises, public and monumental buildings. Act 77-2009 specifies the manner in which compensation is paid for earthquake damage, this being based on financing the detail drawings for the repair work. The procedure is completely different to those adopted following previous earthquakes in Italy where funding would be granted according to certain parameters such as the building's surface area, degree of damage and vulnerability; such legislation may be considered prescriptive and called for several steps: 1) determination of the extent of damage to each property and consequent allocation of a specific class; 2) calculation of the maximum permitted grant according to the building's allocated damage class, certain seismic vulnerability parameters and a few other characteristics such as the presence of primary residences or businesses, etc.; 3) preparation of the detail drawings for the repair work and execution. On the other hand, the legislation implemented following the 2009 earthquake may be considered performance-based since it does not allocate the building a preassigned classification based on the maximum permissible grant and does not require the execution of specific types of work, but simply specifies the level of seismic safety to be achieved, this being decided by the result of the building safety assessment following a brief survey immediately after the earthquake. Act 77/2009 also calls for immediate preparation of detail drawings for the repair work that will be used to check that the estimate is fair and the work proposed is necessary. The implementation of this legislation has allowed repairs to properties with light damage (safety rating "B" or "C") to begin very quickly, but various shortcomings have been noted when dealing with more seriously damaged buildings (safety rating "E"). For the reasons just explained, in order to deal with the reconstruction of the buildings damaged by the earthquake that struck Northern Italy in May 2012 (Mw 6.0, 17 deaths, around 17,000 homeless), the legislator has introduced some notable changes to the regulatory framework specified by Act 77/2009, preferring an approach in many respects similar to that of previous legislation.

2. The reconstruction costs of the 2009 earthquake

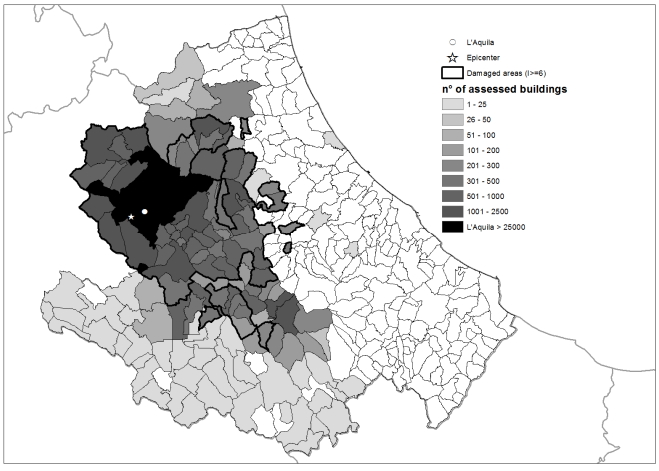
For the first time in Italy, government grants to repair damage were awarded on the basis of the results of the safety assessment carried out straight after the earthquake and the detail drawings for the repair work. On the contrary, after previous earthquakes, grants were calculated according to parameter-based costs and preliminary damage and vulnerability assessments carried out by designers following safety assessments. Details follow of the various steps specified by the above-mentioned Act 77/2009 in order to qualify for a grant to repair damaged property.

2.1 Surveying damage and safety in the post-earthquake emergency

Surveying damage and assessing safety are priority tasks in the post-earthquake emergency. Such activities allow identification of the structures and areas that could represent a risk to the population and those that may continue to be used, thus reducing inconvenience to citizens and possible further damage. In 1997, a joint working group of the National Earthquake Protection Group and National Earthquake Service comprising distinguished members of the Italian civil service and scientific community designed a form for surveying the damage, authorising emergency repairs and assessing the safety of

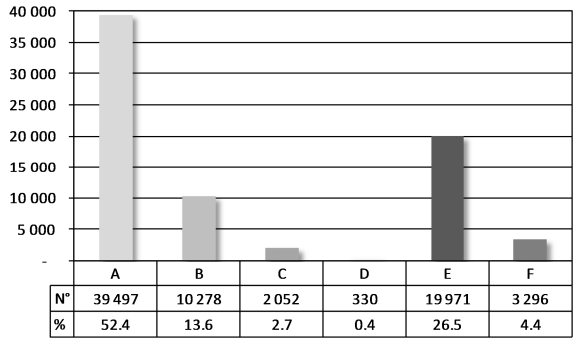
ordinary buildings after the earthquake. This form had already been tested in areas of the Marche Region struck by an earthquake on 26th September 1997. Known as the "AeDES form", it was subsequently included in the Joint Operations Centre (COM) Technical Management Manual approved in November 1998 by the National Commission for the Forecast and Prevention of Major Risks and following improvements it was also used after later earthquakes in various parts of Italy. The form is split into 9 sections; the first 3 provide unambiguous identification of the building in question and include a description and details of construction type, the others contain a description of the damage and any emergency work already carried out or needed to prevent further damage and in conclusion allocate a safety rating. The form enables completion of a quick survey and initial cataloguing of building stock since it contains details of building type and dimensions. The manual in question defines the concept of safety (and therefore usability) as follows: "*The safety assessment in a post-earthquake emergency is an expeditious, provisional assessment - meaning that it is based on an expert opinion and completed quickly by means of visual inspection and collection of readily-accessible information - that aims to establish whether, in the presence of a seismic event, the buildings that have previously been struck by the earthquake can continue to be used, providing a reasonable level of protection of human life.*".

There are 6 usability ratings, of which the most important, also used for allocating grants, are safety rating "A" (building usable, no significant damage, low risk, the entire building may be used without putting the life of its occupants at risk), classes "B" (building temporarily uninhabitable, localised damage, medium risk, simply requires certain emergency repairs in order to enable use of the entire building without risk for its occupants) and "C" (building partly uninhabitable, localised damage, medium risk, the condition of certain areas of the building is such as to place the occupants at very high risk) and class "E" (building uninhabitable, serious damage, high risk, no part of the building may be used even after completion of emergency repairs).



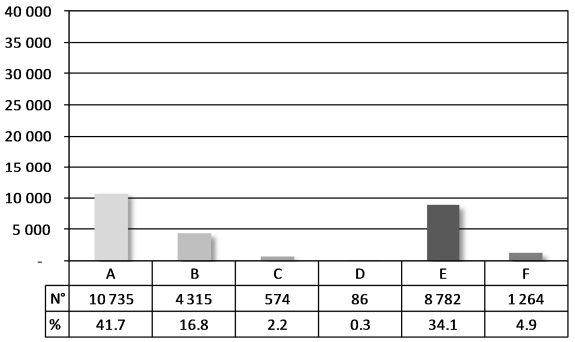
CATEGORIES ACCORDING TO USABILITY FORM (AEDES FORM)	
A	Usable building
B	Usable building following emergency work
C	Partially usable building
D	Building to be reassessed
E	Unusable building
F	Building unusable due only to external risk

Figure 1: No. of AeDES forms completed per municipality and brief description of usability ratings



	A	B	C	D	E	F
N°	39 497	10 278	2 052	330	19 971	3 296
%	52.4	13.6	2.7	0.4	26.5	4.4

Figure 2: results of the post-earthquake damage and safety assessment: all municipalities



	A	B	C	D	E	F
N°	10 735	4 315	574	86	8 782	1 264
%	41.7	16.8	2.2	0.3	34.1	4.9

Figure 3: results of the post-earthquake damage and safety assessment: city of L'Aquila

2.2 Allocation of repair grants

As happened following previous earthquakes in Italy, Act 77/2009 provides for grants to cover the cost of repairs and seismic retrofitting of buildings damaged by the 2009 earthquake. Unlike previous earthquakes, the Act in question does not set limits to the amount of the grant, there being a specific reference to the possibility of "*covering the entire cost of repairs, reconstruction or purchasing of similar accommodation* "; furthermore, with prevention in mind, the Act also provides for the allocation of additional funds for damaged buildings for the "maximum reduction of seismic risk".

Act 77/2009 also calls for the appointment of a Government Commissioner and the enactment of Prime Ministerial Ordinances in order to implement its provisions. Following the Prime Ministerial Ordinances, various decrees and circulars were enacted by the above-mentioned Government Commissioner. The use of a further two levels of legislation in addition to the original Act (Prime Ministerial Ordinances and Government Commissioner Decrees) has led to delays and created a great deal of confusion, thus creating an unnecessarily complicated and chaotic regulatory framework. Act 74/2012 regulating post-earthquake reconstruction in Emilia Romagna does away with the intermediate step of the Prime Ministerial Ordinances, thus restoring the regulatory approach adopted prior to the 2009 earthquake.

Taking their lead from the provisions of said Act, the subsequent implementing measures have split the grant into two categories: one for damage repairs, covering as much as the full cost, and the other for seismic risk reduction with a maximum lump-sum payment calculated according to the outcome of the building's safety assessment.

Another important difference compared to the legislation adopted following previous seismic events concerns the necessity to prepare detail drawings for the repair work as a first step, including a written estimate from the building contractor, before the grant application can be considered.

The grant application, complete with detail drawings for the repair work and bill of quantities, is approved by the local council (Commune) assisted by a support unit that carries out checks according to preset criteria. After the preliminary checks are complete, the Commune approves the grant for repair work. Payment is made from funds previously allocated in accordance with progress reports. While the work is in progress or following completion, the Commune performs random checks in order to verify the correct execution of the work.

In the case of previous earthquakes, the safety assessment was followed by an intermediate stage that allowed the building to be classified in a certain grant category according to the amount of damage suffered and verification of a number of preset vulnerability parameters. The grant was therefore first calculated according to certain parameters on the basis of the category allocated to the property and then paid off gradually as the work progressed. So in the past, there was no need for approval of the entire set of detail drawings for the repair work, its compliance with certain parameters specified by the emergency legislation was deemed sufficient. In most cases, a minimal amount of seismic retrofitting of the property was requested, but the overall project was subject to less specific checks.

Unlike in the case of previous earthquakes, the legislator's choices with regard to the post-earthquake reconstruction of 2009 have allowed immediate financing and execution of the work, eliminating the intermediate step of building classification that had been necessary in the past. It has also allowed more careful control to be exercised over projects and the grants given, since checks are carried out, in particular on the detail drawings, in order to confirm the fairness of the proposed costs and scope of work. Other than in an initial settling-in period lasting just a few weeks, the mechanism has worked rather well as regards the funding of repair work for lightly-damaged buildings (with usability rating B or C). The table below shows the number of grant applications received, the number approved and the amount allocated in million euro.

Table 4: number of processed requests

Usability categories	Number of requests	Funding requests	Amount financed (M€)
A	7 615	7 615	70.23
B	8451	8 185	463.03
C	1106	1 064	84.87
E	9901	4 867	1 569.88
TOTAL	**27 073**	**21 731**	**2 188.02**

The following figure illustrates the average total unit cost of repairs to buildings with a B or C usability rating as a function of gross floor area.

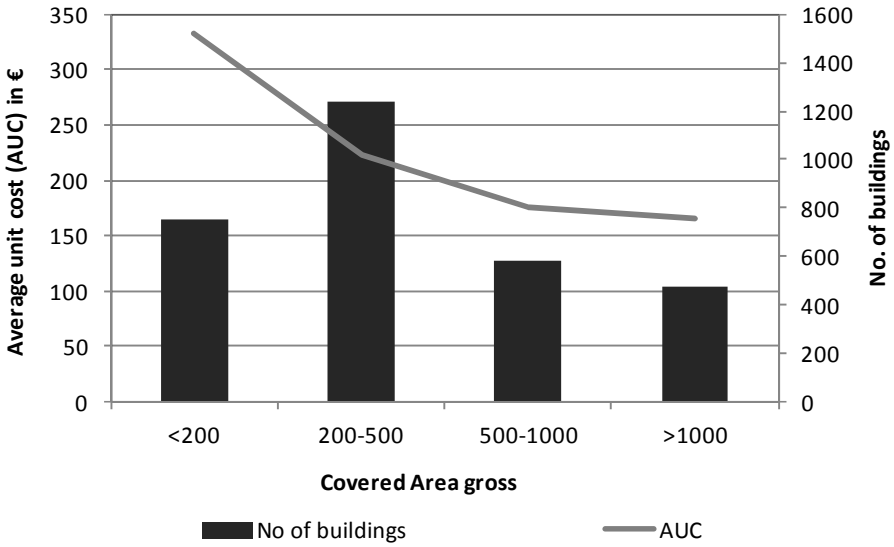


Figure 5: Average total unit cost of repairs to buildings with a B or C usability rating

By contrast, the complexity of repair projects and the consequent complexity of carrying out checks has caused long delays in granting funds to finance projects for more seriously damaged buildings (with "E" usability rating), thus leading to a backlog of several months in dealing with applications.

The initial absence of an upper limit to the size of a grant at first led to very overpriced estimates of the cost of repairs to buildings with the most damage. In many cases, the engineers consulted recommended elaborate, but extremely costly, solutions that were often not economically viable when considering the property's market value. In order to guarantee more efficient management of the funds available, the legislator introduced what has been coined "feasibility limit": the size of the grant given for repairs and seismic retrofitting of an existing building has been capped at the equivalent cost of constructing a brand new building of the same size. The actual implementation of this legislative amendment took several months, from May 2010, date of issue of Prime Ministerial Ordinance 3881 ratifying the principle of the feasibility limit, to December of the same year, date of publication of Government Commissioner's Decree No. 27 providing the implementation criteria.

The legislation in question set a time limit for processing grant applications and releasing funds with which the Municipalities' inspectorates rarely managed to comply. The average time needed to process applications for lightly-damaged buildings (B or C safety rating) was 140 days, instead of the 90 specified by the Act (the Act specified that a Municipality should process applications within 60 days, along with a further 30 days to allow the engineer in charge of the project to hand over additional paperwork). In the case of applications regarding more seriously damaged buildings, legislative requirements were completely ignored, since the average time necessary for the release of funding was 340 days. The figures below show the average time needed for the release of funding according to the quarter in which the application was submitted.

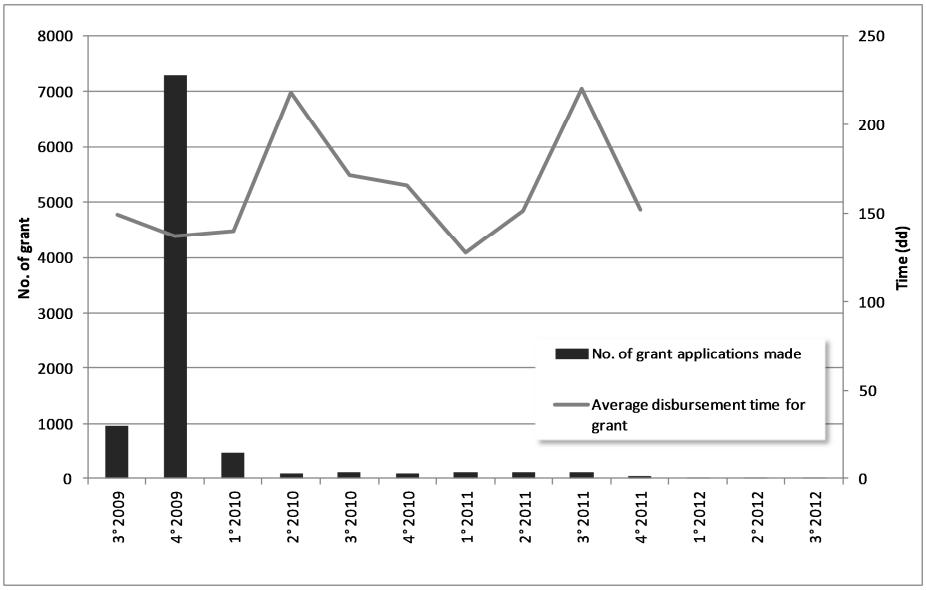


Figure 6: average time needed to release funding for lightly-damaged buildings

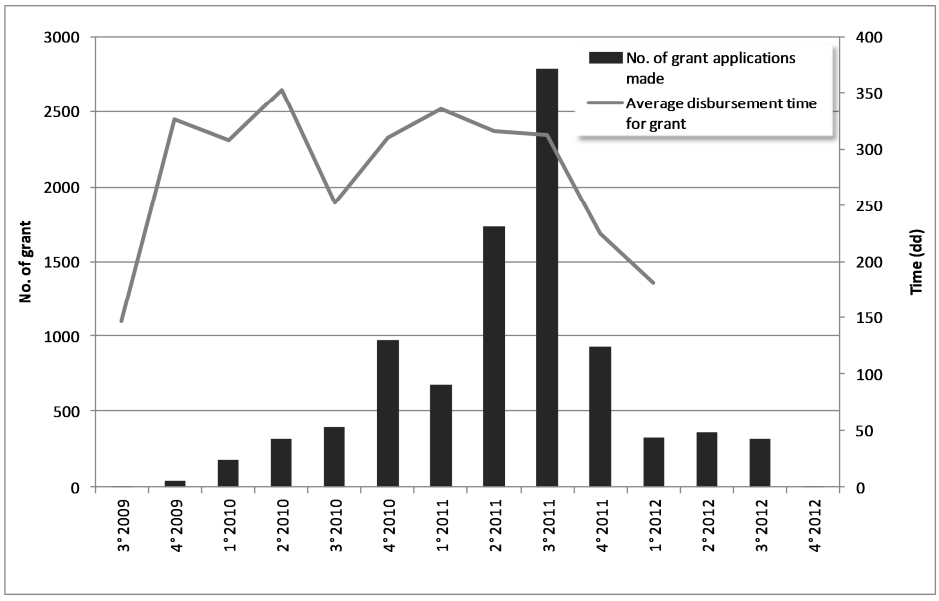


Figure 7: average time needed to release funding for seriously-damaged buildings

2.3 Delays in releasing funds for E-rated buildings

As previously stated, the checking and approval process of repair projects for buildings with an "E" rating took far longer than expected. Indeed, for seriously-damaged buildings, the Act specified that a Commune should process applications within 90 days, comprising 60 days for the Commune to examine the detail drawings and 30 days to allow the engineer in charge of the project to hand over additional paperwork.

The period in question above includes both the time needed to examine the project for which funding is sought and the time necessary for additional permits to be issued. To this end, the emergency legislation provides for streamlining of procedures regarding repairs to lightly-damaged buildings, equating them to routine maintenance operations. This equation has greatly simplified matters since Italian legislation covering this type of work merely requests that the Municipality receive written notice of commencement without imposing additional formalities. In the specific case of repairing earthquake damage, such notice was replaced by the grant application.

Conversely, as regards more seriously-damaged buildings, the emergency legislation makes no provision for fast tracking, therefore, the grant application must be submitted along with all plans and drawings specified by the current “Consolidated Building Act”, Presidential Decree No. 380/2001.

Where the work entails demolition and reconstruction, the above-mentioned deadlines are extended to allow drafting and approval of the design for the new building, the Act granting an additional 140 days plus 30 days for handing over any additional paperwork.

The detailed analysis of the design enclosed with the grant application included both an assessment of the fairness of the estimate, involving checking the costs specified in the design, and checking the appropriateness of the type of workmanship employed and the work requested.

For every type of structure (reinforced concrete, masonry, industrial buildings), the designs for lightly-damaged buildings call for similar repairs. On the other hand, the designs for more seriously-damaged buildings are far more complex due to both the greater extent of damage and the complex nature of the requested seismic retrofitting. In this respect, it should be noted that Italian technical standards for construction provide for three levels of repair to existing buildings: local repair or reinforcement, restricted to certain structural members; seismic retrofitting that requires a set of operations to change the overall behaviour of the structure and thus increase its safety rating without actually reaching the safety level requested for brand new buildings; earthquake-resistant upgrade that requires a set of operations capable of providing an equivalent safety level to that requested for brand new buildings. The first type of work (local repair or reinforcement) involves surveying the individual structural members requiring repair without the need to quantify the overall improvement in the building’s behaviour; this type of repair regards work that has little or no impact on the distribution of mass and stiffness and therefore little effect on the global behaviour of the building. Examples of such work include reinforcing reinforced-concrete structural members with carbon fibre (typically areas around joints, more rarely entire structural members), improving connections between floors or roofing and the walls of masonry buildings using metal ties and attaching non-structural elements to structures. For buildings with a B or C usability rating, bearing in mind the limited damage caused by the earthquake, the only grant available was for local reinforcement work aimed at strengthening local weaknesses in structural members and mitigating specific local structural and non-structural vulnerability.

The repetitive nature of the proposed work certainly facilitated the process of checking projects for B and C-rated buildings, unlike those for E-rated buildings for which the planned repair work was certainly far more complex and specifically adapted to suit the peculiar characteristics of each individual building. Furthermore, it should be remembered that structural repairs to any building seriously damaged by an earthquake generally require installing brand new or upgrading electrical systems, heating and plumbing in order to comply with current safety and energy-saving regulations. This lengthens the time required to complete design work and that needed to perform the necessary checks.

As regards the effectiveness of the checks carried out, an analysis of the grants approved for seriously-damaged buildings shows that of the amount requested totalling EUR 1,309,801.53, grants were given worth EUR 1,223,500,316.17, amounting to 93.4% of the total amount requested (figures updated to October 2012). The amount not approved for funding therefore totals EUR 86,301,133.76. For comparison purposes, it should be noted that in 2011 the amount paid by the Italian government to the owners of uninhabitable properties in order to provide temporary living accommodation totalled around 40 million euro.

3. Legislation implemented to manage the effects of the Emilia Romagna earthquake

3.1 Legislative changes

In the previous chapter we looked at the merits and limitations of the legislation adopted following the earthquake that struck the Abruzzo region in Central Italy in April 2009. About three years later, in May and June 2012, an earthquake swarm that reached its climax with three events of magnitude ranging from 5.0 to 5.9 Mw struck a large area of Northern Italy, mostly within the boundaries of the Emilia Romagna region. Unlike the 2009 earthquake, the area affected has a low population density, but a high concentration of businesses. The earthquake caused 17 deaths and made around thirty thousand buildings uninhabitable.

In many ways, the legislation implemented for reconstruction following this event is similar to that adopted following the 2009 earthquake in Central Italy, although with various changes aimed at generally speeding up grant approval procedures. More specifically, the following should be noted.

Despite three regions being involved in the 2012 earthquake, Emilia Romagna, Lombardy and Veneto (although the last two to a much lesser extent), unlike the 2009 earthquake, the twin legislative step (Prime Ministerial Ordinances/Government Commissioner Decrees) was eliminated since, as stated above, it had proved very difficult to put into practice. For the 2012 earthquake, following Act 74/2012, the only additional enactments are those by Government Commissioners (one Commissioner per Region who is the Chairman of that Regional Authority). The most important ordinances are issued simultaneously by the three commissioners in joint agreement. Following the 2009 earthquake, in order to regulate certain key aspects of the private reconstruction work, over a period of approx. 2 years, 10 Prime Ministerial Ordinances (Nos. 3778, 3779, 3790, 3803, 3805, 3820, 3832, 3881, 3897,

3945) and 11 Government Commissioner Decrees Nos. 3, 27, 40, 41, 43, 44, 45, 57, 59) were issued in addition to various Prime Ministerial Ordinances, Decrees and Circulars concerning secondary aspects. 6 months after the earthquake in Emilia Romagna, just three Ordinances have been issued (29, 51, 57), so far amended three times by additional corrective Ordinances.

The building safety rating is issued immediately after the main seismic event (surveys usually commence a few days afterwards) with a relatively short amount of time set aside for each property visited and it should be noted that inspections take place under difficult conditions due to the prevailing state of emergency. Further misunderstandings may arise if the maps utilised are not up to date or drafted accurately. This means there may be errors in assigning the safety rating that generally lead to a second survey being necessary. In the event of problems, the repeat survey or, in any event, the safety rating of damaged buildings that in 2009 called into play some extremely muddled procedures, has been simplified with a complete rewrite of the procedures for correcting multiple or incorrect ratings.

As part of the funding available, the 2009 legislation set aside specific funds for carrying out improvements to the damaged building. In particular, there were grants for the partial or total cost of work for improving the building's resistance to seismic actions, energy saving, making systems compliant with current safety legislation and the removal of architectural barriers. The introduction of specific limits for each of the types of work listed above was notably restricted, thus making it simpler to prepare the bill of quantities and conduct checks. This has also allowed designers to deal more easily with the specific conditions typical of every damaged building.

In the case of buildings like blocks of flats with more than one owner, the 2009 legislation called for the submission of a grant application by every owner affected and a further application by the property manager for communal areas. Therefore, for a block of flats with "n" different owners, the number of grant applications could be as many as n+1, thus placing those processing the applications under considerable pressure. On the other hand, the legislation implemented in 2012 simply calls for a single grant application to be submitted by the property manager. Multiple grant applications from every owner are no longer necessary and the division of the funds received between the various owners is merely recorded in the block's accounts. This simple amendment enables a notable reduction in the number of grant applications submitted for each building (on average 75%), making it much easier to process the applications received.

3.2 Demolition and new construction

In addition to several old town centres, including buildings of notable value, the 2009 earthquake also struck densely-populated suburbs, including reinforced-concrete buildings mostly constructed immediately after the Second World War. By introducing the feasibility limit with the enactment of Prime Ministerial Ordinance 3881, the legislator has shown that it can be more economically viable to demolish and rebuild damaged buildings rather than repair them. Such possibility was provided for by Prime Ministerial Ordinance 3881 enacted in 2010, about one year after the seismic event; however, the practical effects of said Prime

Ministerial Ordinance were postponed for several months until certain necessary implementing provisions were published. The 2009 reconstruction Act was the first to make express provision for owners to be offered the possibility of demolishing and building a new property should they see fit, even without exceeding the feasibility limit. The possibility of demolishing and reconstructing damaged buildings rather than repairing them, with the owner adding his own contribution to the Government grant, has not proved very popular. This is due to both the legislative delay and the information given to the public that was probably not very clear.

The legislation implemented following the 2012 earthquake is not yet complete at the time of writing this paper and currently fails to mirror the provisions of the previous 2009 Act.

4. Conclusions

Following the 2009 earthquake that struck Central Italy, legislation covering the reconstruction of private buildings was completely rewritten. In little more than three years, funding has been provided for around 22,000 sites, compared to around 27,000 grant applications. In the above-mentioned legislation, we can find plenty of pluses, but also several shortcomings, the latter being partly mitigated by the subsequent Act regarding the earthquake that struck Northern Italy in 2012 that has yet to be fully implemented. The difficulties that have emerged in dealing with the effects of the 2009 and 2012 earthquakes and the different ways in which they have been handled highlight all the limitations of the current Italian regulatory framework for managing post-emergency situations. In particular, there is no specific regulatory framework to provide guidance with regard to reconstruction and the return to normality following a disaster. This study provides a basis for drafting a new comprehensive law for post-earthquake measures. The aim is to establish a set of certain rules which can be applied to all large-scale seismic events. Regulatory certainty may promote greater use of insurance policies and operations to reinforce structures during scheduled maintenance work on the buildings.

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Using Public-Private Partnership towards public services improvement

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Abstract

Public-Private Partnership (PPP) has been popular among public sector due to its objectives in transferring risk, reducing cost, solving budgeting constraints problems, providing higher quality and saving time. However, global financial crisis in 2008 affected development of PPP. Realizing private sector's tendency to being involved in PPP projects, and its advantages and disadvantages from their point of view seems essential. This study aims to find out that whether private sector is interested in partnership with public sector in general and if so, in which type of infrastructure and public service facilities. A questionnaire survey was conducted among a number of high grade Iranian contractors and data was analyzed to ascertain their level of awareness and experiences about PPP and the project type they are interested for investment. The survey results showed that it is not practical for some projects to utilize PPP since local private sector is not interested to be involved with them. Furthermore, considering the projects with more potential to be noteworthy for private sector, the factors were introduced which must be taken into account for development of PPP in order to improve public service.

Keywords: Public-Private Partnership, Project Delivery, Public Service, Private Sector.

1. Introduction

During the last few decades, as method of construction projects became more complicated and required more financial resources, traditional models of contracts were not able to satisfy projects' needs and as a result, new methods of construction contracts were considered. Public-Private Partnership (PPP) is one of the most popular types of contracts which are widely used in different countries. PPP is an effective approach to enhance project productivity by bringing in management efficiency and creative skills from business practice, and reducing governmental involvement by using private sectors in the provision of public services. PPP is resulted from development of the procurement strategy of BOT (Build, Operate and Transfer) and it is particularly suitable for large scale infrastructure projects (Shen, Platten and Deng, 2006). The function of PPPs is to lower the risks of projects during the life cycle, including cost overruns and delays, while still achieving the best value (Zhang,

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2005). Meanwhile, PPP also provides the opportunity for innovation and establishment of partnerships (Bloomfield, 2006). Sagalyn (2007) contended that existing Public–Private (PP) projects have three generations. In the first generation, mistakes easily emerged due to lack of experience by public and private partners and their consultants. In the second generation, large development companies developed specialized Public-Private urban development projects, often by employing planners who managed Public-Private projects for public entities or led PP corporations. As a result of social development, the third generation has emerged, which are PP projects initiated by developers seeking private-sector involvement. The number of PP projects is expanding in the third generation and it is anticipated that they will be used more widely in public service, city reconstruction, and so forth. PPP employs private sector experts and skills to provide public goods and services. It is considered to be a suitable option for complex capital projects with significant ongoing maintenance requirements. To these partnerships, private companies can offer innovative design, project management skills and risk management expertise. PPP contracts commonly require the private agent to take full responsibility for the performance of the asset over a long term, at least for a significant part of its useful life, so that efficiencies arising from long-term investment and asset management could be realized (Nisar,2012). PPPs are arrangements which require the co-operation between public and private parties, which have a common goal in the long term, and share equally the risks and responsibilities for providing public services (Ham and Koppenjan, 2001). These contractual relationships can adopt a diversity of figures, namely concession contracts, lease-develop-operate, built-operate-transfer, built-operate-own and franchise, among others (Navarro-Espigares and Martín- Segura, 2011). A PPP is collaboration between the public and private sectors for the purpose of delivering a project or a service traditionally provided by the public sector. Recent years have seen an increasing market for PPPs for the development and operation of infrastructure projects (Ke, Liu and Wang, 2008).

Iran is a developing country which is located in the Middle East and like other countries in this region, contains enormous amount of natural resources like oil and gas. Additionally, in today's competitive market, improving the current economic and strategic conditions of Iran require ongoing process of construction and development. Currently, Prevail trend for constructing projects in Iran is based on direct investment and supervision of government without enough attention to the potential and capability of private sector. The aim of this study is to find out to what extent PPP is applicable and practical for construction projects in Iran and to discover the opinion and view of construction parties in this regard. Financial evaluation methods are only considering the benefits of the public sector or the government in Iran and only a few PPP projects have been successfully completed. However, with the fast pace of new construction in infrastructures, a delicate balance has to exist among the private sector capacity, government regulatory function, and public satisfaction. This study wants to assess the possibility of using PPP method for the delivery of projects and taking into account the viewpoints of stakeholders.

So far, several studies have been carried out to identify the function and application of new construction contracts and in particular PPP in different countries. For example, Yuan et al. (2010) stated that for more efficient and effective PPP projects, the performance management is increasingly important and the influence of stakeholders must fully be

considered and based on the perspectives of different stakeholders, they proposed several performance objective attributes. Cheung and Chan (2011) presented an evaluation model which is useful for assessing the suitability of PPP projects by studying their attractive and negative factors and they ranked the importance of 15 attractive and 13 negative factors for adopting PPP. Zhang (2005) identified, analyzed, and categorized various critical success factors for PPPs in general based on a public private principle and classified them into five main aspects: (1) economic viability, (2) appropriate risk allocation, (3) sound financial package, (4) reliable concessionaire consortium, and (5) favorable investment environment. According to the findings of Chan et al. (2010) thirteen potential obstacles toward PPP projects identified and the top three obstacles were found to be lengthy delays in negotiation, lack of experience and appropriate skills, and lengthy delays because of political debate. Grimsey and Lewis (2005) by focusing on the intricacies of the accounting issues raised by PPP have investigated and determined the value for money for PPP in construction projects. On the other hand, the study of Abdul-Aziz and Jahn Kassim (2011) examined the objectives of housing PPP, the success and failure factors and found that the public agencies desired to fulfill an array of objectives when adopting PPP, the most important being to enhance organizational reputation. The success factor which had the most impact was action against errant developers. The most influential failure factor was absence of robust and clear agreement.

As another example related to the PPP, Shen, Platten and Deng (2006) evaluated the major risks in implementing public sector works, and the ways that the application of PPP can help to manage risks in project delivery. Their results presented valuable lessons for both the practitioners and researchers in application of PPPs to manage risks in delivering of public sector projects in other countries and regions. Moreover, the research of Abednego and Ogunlana (2006) discovered the perception of proper risk allocation of construction stakeholders and utilized the findings as the foundation to develop the concept of good project governance and they achieved that proper risk allocation in projects are developed under PPP procurement system which would enhance the project performance. In order to provide insights for directing PPP research and improving the existing practices of PPP projects, Tang, Shen and Cheng (2009) reviewed PPP studies published in the six top journals in the construction field and they suggested that risks, financing, contractual agreements, development of PPP models, concession periods, and strategies in choosing the right type of PPP are preferable for future studies. Nisar (2012) examined three community PPP projects and identified critical success factors of the project outcomes and due to that two conclusions particularly stand out: first, the project must be aligned with both the public and private parties business and service plans; and second, appropriate management structures and procedures must be established for obtaining this alignment. Cruz and Marques (2012) have addressed the concept of contract flexibility as well as the several possibilities for its incorporation into PPP development. Based on existing classifications, the authors proposed a double entry matrix as a new model for contract flexibility. Another research related to PPP which was prepared by Ke, Liu and Wang (2008), developed equitable financial evaluation method which is based on characteristics of PPP projects using six separate indicators and Monte Carlo simulations. The result of this study shows that the method combines the viewpoints of all the relevant stakeholders to achieve an equitable financial evaluation of PPP projects.

In spite of all above mentioned studies, it seems that there is a lack of systematic investigation on all aspects of using PPP in Iran and in fact few studies have addressed the importance of using different project contracts such as PPP in Iranian construction industry. For example, Kheiri, Honarkar and Mousavi (2012) categorized several models between public and private sector by focusing on previous experiences of other countries and proposed them for Iran. However, due to the nature and characteristic of national projects which are complex and prone to error, different types of PPPs need to be practiced in Iran's infrastructure and based on diverse results and a variety of problems that might arise, improve and provide a cutting edge model which suits construction projects in Iran. Shahdani, Ghiasi and Bighdeli (2012) investigated several types of PPP models by using the capacities of private sector to supply public services and infrastructures in transportation sector as a fundamental sector of economic development in Iran. For this purpose they reviewed a theoretical literature of PPPs and then they investigated the barriers to the development of such partnerships in transportation sector of Iran economic, infrastructure, legal and social areas. Therefore, the aim of this study is to investigate the possibility of using PPP in Iranian construction industry and based on a survey which was prepared according to a detailed questionnaire, determine that to what extent construction parties including public and private sectors are ready to collaborate more efficiently; in which, both bring their complementary skills to national projects, with different levels of involvement and responsibility.

2. Methodology

According to the review of literature, a questionnaire survey was conducted to evaluate tendency of construction industry's parties to partnership in public projects. In order to design the questionnaire, a draft was prepared and was distributed among five graduate students in Civil Engineering department as a pilot sample. Regarding to the standard deviation of answers and participants recommendations, final questionnaire was designed. The questionnaire consisted of two main parts which contained close-ended questions.

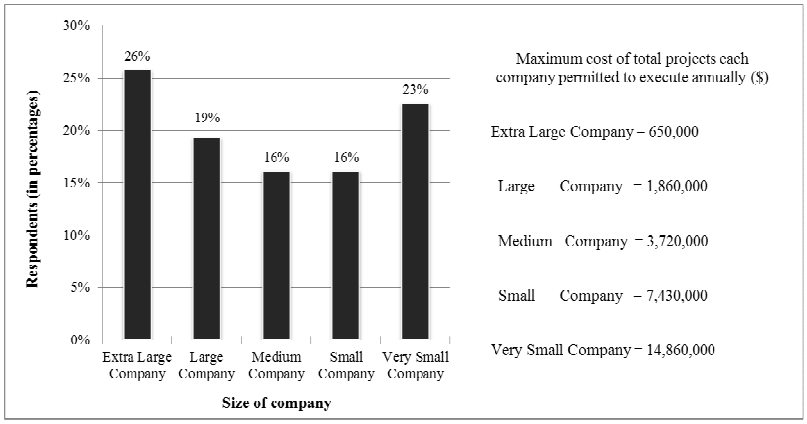

Figure 1 : Percentages of respondents in terms of size of their companies

First part of the questionnaire was divided into three segments. At the beginning personal information of participant were asked for categorizing the data. Then the level of familiarity with PPP was investigated by two simple questions. Regarding to predicted low level of awareness about PPP, a brief definition was presented at the end of the first part of the

questionnaire. Second part had four sections to find out the opinions and tendencies of participants about partnering in public projects. In first section type of projects and phases which participant was interested for partnering in were asked. The next three sections included close-ended questions with Likert scale to evaluate participants' opinions about the level of importance of different factors as advantages, barriers, and success factors in PPP projects. Questionnaires were filled out by face-to-face approach with assistance of a Civil Engineer. Total numbers of 60 questionnaires were sent to 5 Civil Engineers (12 for each one) in three different cities to distribute them among their Colleagues in construction industry's private sector. Respondent companies participated in projects of building construction, transportation construction (e.g. Roads, Railways, and Ports), and pipeline construction (e.g. water and sewage networks). Figure1 shows the percentages of respondents in terms of their company's size and maximum cost of total projects that each company permitted to execute annually. 80 percent of the participants had bachelor degree in engineering and 20% had master degree. In terms of job experience, 48% had less than five years experiences, those with experience between 5 to 10 years were 35%. Participants with experience between 10 to 15 and more than 15 years were 6% and 10%, respectively.

3. Results and discussions

Considering questionnaire's main parts, results were categorized into four parts which will be described. First part was about participants' knowledge about PPP and was followed by questions about their tendencies to partnering in public projects. In second part, according to literature review and characteristics of Iran's construction industry, significant advantages, barriers, and success factors of using PPP were selected. Participants were asked about the importance level of these factors by close-ended questions with Likert scale. As a result, the weighted means calculated for each factor to evaluate overall viewpoint of participants.

3.1 Knowledge and tendencies

To evaluating participants' knowledge about PPP, their level of familiarity with PPP was asked. Twenty nine percent of them were not familiar, and same percent just heard the term "Public-Private Partnership", about 39% were a little familiar and only 3 percent had complete familiarity. The private sector's low level of awareness with PPP and its advantages, in previous studies was recognized as one of the most significant obstacles in partnering which can be obviously seen among Iranian private sector. This unawareness may be the reason that more than half (about 52%) of the participants were not interested in partnering with public sector. The participants were asked about their tendency to partnering with public sector in terms of the type of projects. As illustrated in Figure 2, schools, power plants, airports, and hospitals were ranked at the top of the list. These tendencies interpret by considering the level of familiarity because of the existence of non-governmental (private) schools for about two decades and also the nature of the schools' buildings which is not very complicated, so schools are appropriate projects in terms of constructability and experiences in operation. From respondent's point of view, constructing power plants were ranked as most favorable projects after schools. This is due to easy access and low cost of oil which lead to creation of numerous power plants in Iran and consequently provided valuable experiences for private sector during collaboration with oil industry among these projects.

These experiences and high amount of energy consumption may be the cause of private sector's interest in partnering in these types of projects.

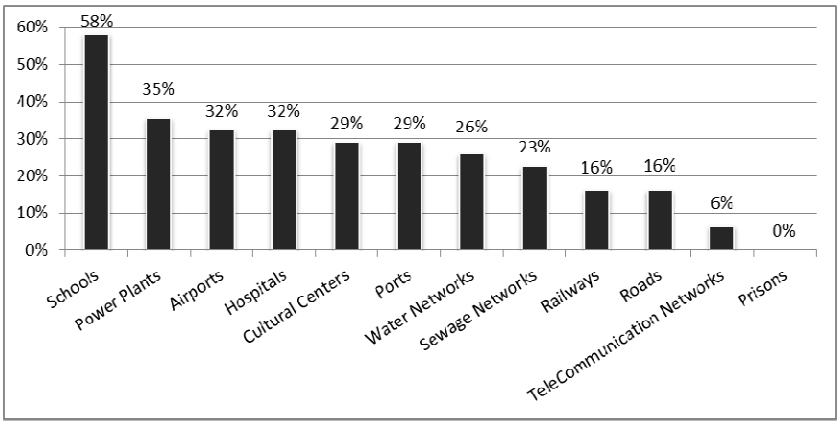

Figure 2: Participants' tendency to partnering in terms of the type of project

Next six types of projects do not differ considerably. The same percent of respondents' tendency to railways and roads (16%) which are half of the airports' amount (32%) show that between different types of transportation projects, partnering in air transportation is more interested for private sector. Telecommunication networks are unknown for construction industry practitioners, and it was predictable that they were not interested in partnering in these projects. Surprisingly none of the participants had tendency to partnering in prison projects, this dislike may have political or social roots. There are different types of PPP projects in terms of the phases included in projects. According to the questionnaire results, participants prefer to join in build, design, and operation phases respectively with 80%, 58%, and 23%. Finance and maintenance place at the last level, each one with about 13 percent.

3.2 Advantages

Six advantages of using PPP in projects which ranked by their weighted means of importance level from participants point of view are showed in Figure 3. Private sector is leader in innovation and using technologies to achieve more benefits (Chan et al., 2006). Public sector can benefit from these capabilities of private sector by partnering them in public projects. "Benefit from private sector capabilities" was selected by participants as most important one with weighted mean of 3.94. Traditional characteristic and inefficiencies of Iran's construction industry and its practitioners are major reasons of this selection. Private sector is very worthy resource for financial support of public projects. By partnering them public sector does not need to invest whole project cost at the beginning, so they can spend their budget for projects with higher priority (Le et al., 2005). Also the problem of low quality which resulted by limited budget will be ignored and projects will be executed with high quality and performance. The second choice of participants in terms of importance was "Provide required financial resource" with 3.65 weighted mean.

It is obvious that allocating appropriate budget, using new methods and materials, and including expertise to project by private sector will lead to higher quality and improved user satisfaction. High quality projects which lead to consensus, improve the value and benefits of projects. This factor ranked third between advantages with level of importance equal to 3.45.

Private sector has better understanding of management usefulness. The importance of consumer satisfaction is proved to private sector and it is demonstrated that better services will lead to consumer satisfaction which will result to more benefits. Partnering private sector in public projects will be very effective to improve service delivery which placed between medium and high importance level by participants with a 3.4 weighted mean.

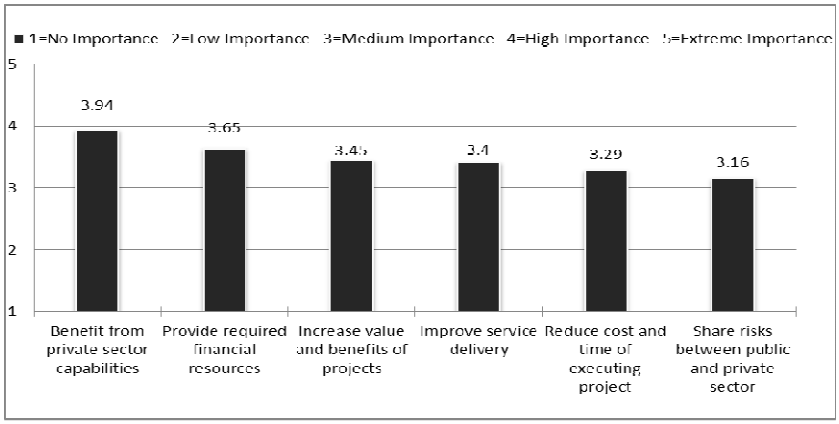

Figure 3: Advantages of using Public-Private Partnership in terms of their weighted means of importance level from participant's point of view

There are two considerations about cost in PPP projects. First, to gain more benefits, private sector has motives to implement project on time and budget to eliminate cost overrun from increasing direct costs or indirect costs resulted from delays. Second, the earlier operation of project, the earlier return on investment. This financial incentive is very significant reason to complete the project on schedule (Grimsey and Lewis, 2004). "Reduce cost and time of executing projects" placed fifth by participants in advantages list. By using PPP, the risks of projects are transferred to expert firms and lead to reduce government risks. Private sector has more efficiency in delivering projects and is reliable to share the risks of project. It does not mean that all of the risks of projects must be managed by private sector; it means that each sector is responsible to risks associated with its duties (Boussabaine, 2007). Although the risk transfer is one of the most significant advantages of PPP, but it was placed at the end of the list in terms of importance. It seems that the concept of risk sharing is not well understood.

3.3 Barriers

The major obstacles in implementing PPP were classified; the participants' opinions about their level of importance are illustrated in Figure 4. "High transaction costs and lengthy lead time" was the most important barrier to implement PPP from participants' point of view. The complexity of PPP Projects and involvement of different parties lead to high cost which might not be economically viable. The high transaction cost may affect the best value for money negatively (Corbett and Smith, 2006). In addition, bidding phase in PPP projects is also costly and time consuming. "Political and social obstacles" stand in second rank. These obstacles may occur in design, construction, and operation phases of projects, for example town planning can affect the design of the project, or environmental issues have impact on construction phase. Most significant problem of private sector is raising tariff to cover the cost of projects; this raising may faces with political and social opposition (Zhang and

Abourisk, 2006). The major political changes like revolutions which transform the macroeconomic policies are other significant barriers to using PPP.

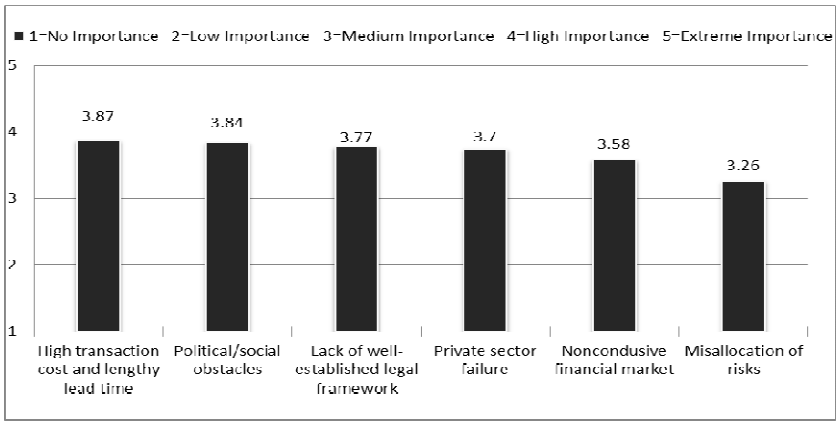

Figure 4: Barriers to using Public-Private Partnership in terms of their weighted means of importance level from participants' point of view

The legal framework has significant role in successful implementation of PPP projects. Iran like some other countries does not have separate legal framework for PPP which leads to increasing potential disputes between parties (Satpathy and Das, 2007). "Lack of well-established legal framework" with weighted mean of 3.77 was third important barrier to using PPP. According to important role of private sector in PPP projects, public sector must be assured about private sector's abilities in financing, constructing, and operating the projects. PPP projects in most cases are complicated projects which require several different experts to execute. Lack of these proficiencies may result in project failure or reconsideration of private partner. "Private sector failure" was forth factor in participants' opinion. The main objective of private sector for partnering in PPP projects is to achieve financial benefits. The unattractive financial market is significant barrier to PPP projects. In order to prevent private sector from facing this problem, accurate financial survey is essential. "Nonconductive financial market" as a barrier has 3.58 weighted mean. Surprisingly, it is observed that the "misallocation of risk" was placed at the end of the barriers list. Regarding to the complexity of PPP projects and involving variety of parties, the widespread range of risks are associated in these projects. For implementing the projects, both public and private sectors must have good understanding about these risks (Sun et al., 2008). Placing this factor as last important barrier to using PPP approves the claim that participants do not realize the importance of risks in these types of projects.

3.4 Success factors

Success factors of PPP projects are illustrated in Figure 5 and are ordered from the highest to lowest level of importance from participants' opinions. Economic viability is very important factor in all types of projects. There are several different methods to evaluate financial viability of projects which can be employed to be assured about beneficial characteristics of projects. In addition, according to long lead time and broad range of risks in infrastructure projects, risk analysis must be performed. Placing "Economic viability" as the most important factor of project success shows the sensitivity of participants on profitability of projects. Private sector tendency to implementing a project regardless of its procurement method

depends on the benefits which will be achieved. As previously discussed, return on investment is very important factor which can motivate private sector to success in PPP projects. Selecting “Favorable investment environment” as second important success factor approves this claim. PPP projects need private partner with experiences in these types of projects because of their unique specifications. Private sector qualifications like experiences, financial afford, and expert personnel play significant role in project success. “Reliable partner with strong technical strength” was placed at the median of success factors.

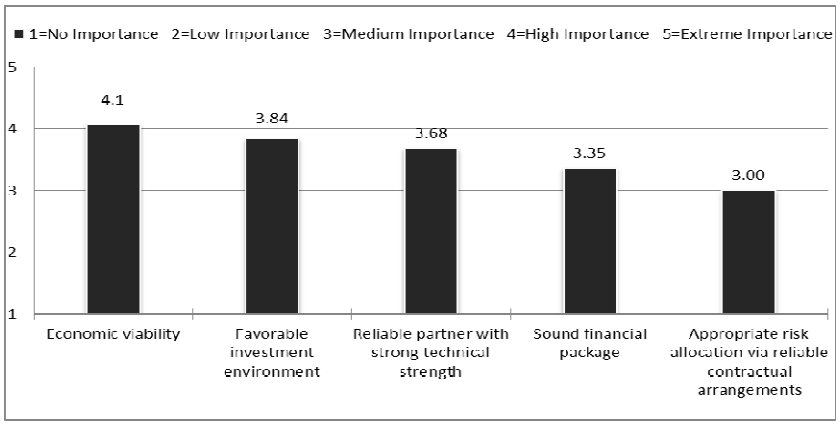

Figure 5: Success factors of Public-Private Partnership in terms of their weighted means of importance level from participant’s point of view

Financial package is one of the most important parts of PPP projects which must be provided very carefully. Financial package must contain several items like, financial analysis, payment, high equity-debt ratio, etc. which can warrant the success of project and ignore potential of budget reallocation. As same as advantages and barriers to using PPP, risk related factor of success was placed at the end of the list. “Appropriate risk allocation via reliable contractual agreements” with 3.00 weighted mean was the least important factor among others. It must be emphasized that these results explain the low level of awareness about projects’ risks between practitioners of Iran’s construction industry.

4. Conclusion

PPP is an efficient and generally accepted approach which has been used in several countries and as time goes by, various outcomes have revealed shortcomings and merits of this method. However, there is lack of enough attention or even acquaintance in Iran which requires an urgent need to measure all aspects and requirements of this technique to develop an appropriate agenda for further actions; in which public and private sectors collaborate more efficiently and enhance their benefits. This paper presented a survey for evaluating several aspects of using PPP in Iran infrastructure projects including knowledge and tendencies of construction parties about PPP, advantages of using PPP, most important barriers to performing PPP, and finally its success factors. The research study presented in this paper has analyzed the perceptions and insights of 60 participants from different Civil Engineering disciplines. By dividing the analysis of this paper in four singular stages, through comparison of factors in the first part regarding to the knowledge and tendencies, the authors found that constructing schools as PPP project is the most desirable one among 12 different options with about 58%. The reason behind this view is that private sectors

constantly were included in construction of schools in Iran and public sector always considered incentives such as tax exempt for attracting contractors. As opposed to schools, telecommunication projects and prisons were respectively ranked by 6% and 0%. Generally, as the projects get more complicated and require more time, effort, and additional financial resources, the tendency of participants' declines.

Second section in this analysis is related to the advantages and benefits of PPP. Six advantages of implementing PPP in projects were selected and ranked which "Benefit from private sector capabilities" became the most important advantage from respondent's perspective with weighted mean of 3.94, whereas "Share risks between public and private sector" was the last advantage with weighted mean of 3.16. Through a superficial comparison between these 6 advantages, it is quite obvious that all respondents were in favor of increasing their profits without paying enough attention to the risks of executing projects. In fact, as Information and data need for accurate planning of time and cost of project in order to acquire precise forecast is somehow uncertain, all stakeholders are exposed to the terrible consequences of project failure or even bankruptcy. Nevertheless PPP cannot reduce the likelihood of undertaking a bad project, but it can help to distribute the risk of projects. So, it is strongly recommended that both parties have to take into account risk of projects in advance and it is totally crucial.

Third stage of this study is presented to describe the barriers and obstacles of implementing PPP. It was observed that "High transaction costs and lengthy lead time" was ranked as the first barrier. The findings reveal that this obstacle was important irrespective of being either in public side or private. Therefore, it can be concluded that this obstacle is pertinent to both parties and they are equally exposed to the time consuming and cost prohibitive aspects of PPP. On the contrary, "Misallocation of risks" was ranked as the least important factor with weighted mean of 3.26. Fourth part of the analysis is dedicated to the success factors of PPP based on five different criteria. According to the results, "Economic viability" was chosen by participants as their first criterion with weighted mean of 4.1. Meantime, respondents selected the "Appropriate risk allocation via reliable contractual arrangements" as the least important factor with weighted mean of 3 which can be concluded that this factor has less influence on success of projects.

While this study was delimited to practitioners in private sector of Iran's construction industry, low level of respondents' awareness about PPP was the most significant limitation which may overshadow the reliability of questionnaire results. To overcome this problem in future works, studying cases of using PPP in Iran's construction industry by interviewing practitioners of these projects is recommended. The structured interviews with practitioners in PPP projects can provide more reliable answers about advantages of using PPP and its related barriers and success factors. In addition, reviewing the records of these projects will be helpful to find out the Iran's construction industry attitude toward PPP projects.

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Social housing design: influences from triple bottom line (3BL) concept

Eduardo Reuter Schneck[1], Andrea Parisi Kern[2], Mauricio Mancio[3], Marco Aurélio Stumpf González[4], Alan Vinicius Hehn[5]

In recent years, there has been a significant supply of housing units through social housing projects (SHP) in Brazil, mostly fuelled by subsidy programs and federal government funding. Therefore, the efficient design and implementation of these projects is an important aspect with regard to optimal use of resources. Under the Triple Bottom Line (3BL) concept - people, planet, profit - it is crucial to understand the decisions taken at the building design stage, when one has the greatest influence on factors that can reduce costs, improve housing conditions and minimize environmental impacts. In this context, the objective of this research is to analyze the environmental impacts, the cost and habitability aspects of housing units in a SHP, based on the 3BL concept. To this purpose, the volumetry of buildings was analyzed and the economic index of compactness (EIC) of the H-shaped buildings used in the base-project was calculated. Then, the building design was modified and two simulations of projects were proposed, seeking to increase the EIC and improve habitability issues. The improved-EIC alternatives had its embodied energy (EE) quantified and compared with the base-project, covering the environmental aspect of 3BL. The benefits that these design changes had in the housing units, as well as the cost impacts of the project as a whole, were also analyzed, thus considering social and economic aspects as well. The results indicate a reduction of production costs of 10% in the proposed projects and improvements in many aspects of habitability, as natural lighting and cross ventilation. Furthermore, there was a reduction of 7.5% in EE, also in favor of the proposed projects with improved EIC. Converting the difference of EE in electric power, for example, the savings generated would be sufficient to supply all the energy needs of 20 housing units (one tower) for 4.5 years.

Keywords: social housing design, economic indices of compactness, habitability, embodied energy.

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1. Introduction

For the first time in history, the majority of the world population is living in cities. However, about a billion people live in informal settlements, as slums, and this number is projected to be about two billion people in 2030. Attracted to urban areas in search of jobs and greater social recognition, many urban migrants are suffering from insecurity, limited access to services such as sanitation and potable water and basic conditions of habitability (SMITH, 2007). Still according to the author, about 90% of the world population has little or no access to most basic goods and services, which demonstrates the urgent need to design and seek solutions for this significant proportion of inhabitants. This scenario characterizes the major cities on all continents, and corroborates with urban violence, poverty, environmental impacts and social exclusion. However, the lack of housing cannot be understood only as a quantitative aspect.

In this context, Brazil has developed initiatives such as the National Housing Plan (PlanHab) and the “My House, My Life” program (PMHML), designed to eliminate the housing shortage by 2022 (MINISTRY OF CITIES, 2010). As a result, the financial support of the Federal Government in recent years has fuelled the segment of social housing design (SHD), with a great participation in the growth of the construction industry.

Considering the large stock of these developments that is forming in the country, the efficient design and implementation of these projects is of utmost importance with regard to optimizing the use of resources. Based on the 3BL concept –(people, planet, profit), we should aim at the best cost-benefit ratio, from the point of view of the government, which acts as an investor, but also from a social and environmental perspective, given the importance of housing in people's lives.

In order to minimize environmental impacts, and corroborate the reduction of construction costs of SHD without neglecting the questions of habitability, it becomes essential to know the relationship between the decisions taken at the design stage and their influence on the final result. The choices made at this stage have the power to define and influence the environmental impacts, the final amount to be spent and the quality of a building. The management decisions have the ability to qualify such characteristics through volumetric solutions differentiated from those commonly found in the Brazilian market (AFONSO et al., 2011).

In Brazil, most SHD approved in the county are very similar to one another. They are generally composed of blocks of apartment buildings with five floors each and four two-bedroom units per floor. The articulation of the blocks with the circulation (routing and staircase) originates an H-shaped plan (Figure 1), which is ubiquitous in such projects. As Siqueira (2008) notes, this type of solution can be regarded as a reflection of the paradigm of economics in circulations, because they are not marketed by real estate. According to this author, due to a lack of theoretical background about the costs of decisions made in the design stage, architects and engineers end up simply adopting those solutions most commonly found in the market. As a consequence, there is a repetition of similar type buildings, which ignores features of the site where it will be deployed.



Figure 1: H-shaped SHD
(http://www.suacidade.com/sites/default/files/images/minha_casa_minha_vida_2.jpg)

This paper discusses the H-shaped building design, largely used in SHD buildings, and aims to analyze environmental impacts, the cost and aspects of habitability of housing units in SHD, from a perspective based on the 3BL concept.

2. Triple Bottom Line concept (3BL)

In general, concern about the qualitative aspects of housing developments denotes not only a fundamental aspect of the quality of life of its residents, but also refers to the concept of social sustainability. Together with the economic and environmental dimensions, that forms the tripod of sustainable development known as Triple Bottom Line (3BL) - planet, people, profit (Silva, 2007). As defined by the WCED (1987), we should be able to meet the needs of the present, but ensuring that future generations can also meet their needs.

2.1 Environmental aspects (Planet)

By producing large physical assets, the construction industry consumes a large part of natural resources and energy produced worldwide. And, in addition, there is the enormous amount of waste generated, reaching about a third of the total volume generated by society as a whole (DEGANI and CARDOSO, 2002).

The outlook of the growth of the construction industry is part of a scenario associated with urban overcrowding, shortage of building materials and environmental impacts. According to Tavares (2006), as a consequence, there has been increased interest in the research and development of alternatives for housing and several studies on energy efficiency and consumption. Briefly, the environmental impacts associated with buildings can be divided into: (a) emissions of greenhouse gases, especially in the production of materials, (b) energy consumption in buildings, from the production of materials to its deconstruction; (c) consumption of natural resources, and (d) indirect impacts such as transportation (TAVARES, 2006).

Among the sectors directly related to construction, the importance of the residential sector in terms of energy consumption is equivalent to the commercial and public sectors taken together, considering all energy sources (BRAZIL, 2005). Roaf (2009) highlights that all construction materials have an impact on the environment, but it is much harder to

accurately assess the total impact of a building. However, embodied energy (EE) may be seen as one of the most important parameters to assess environmental impact, since the use of non-renewable resources directly contributes to the degradation of the environment. According to Gauzin-Müller (2002), EE is the amount of energy consumed for the production of a product, from raw materials extraction to their distribution in the market.

The optimization of processes in the construction industry, especially targeting productivity gains, are being combined with studies and practices in order to reduce waste and minimize environmental impacts (WOLF et al., 2010). Soon, as the same authors state, the issue of sustainability will be incorporated into the processes related to construction. The sector is responsible for significant impacts to the environment, but it is currently seeking to improve its performance and reduce such damage.

2.2 Social aspects (People)

Historically, good examples of SHD are rare in Brazil, given the large number of projects already built or under construction that do not take into account adequate criteria for the habitability of units. Such projects are generally supported by the argument of cost limitation and by a legislation that establishes inferior requirements for the SHD segment, when compared to those established for residential projects outside this segment. As a result, the lack of adequate parameters for SHD, supported by legislation, is a reality in most buildings and minimizes basic requirements of comfort for its users. Lima et al (2011) observe that housing production in Brazil, especially in terms of SHD, has been highly criticized, due to excessive reduction of the areas and using materials of low quality. According to Villa (2009), the architectural quality of these projects is low, although this issue is of fundamental importance since it directly affects the daily lives and livelihood of the residents.

Among the precepts of habitability, passive solutions should be considered in order to meet the requirements of thermal comfort of users and avoid high maintenance costs over the life of the buildings. Thus, most of the solutions should be viable at the stage of design, such as the condition of cross ventilation in the environment and proper solar orientation, as exemplified by Olgyay (1998). Thus, the quality of life within the living space becomes a consequence of compliance with environmental standards of comfort, promoting a space that responds to the quality and function of healthy housing, responding to the concept of housing habitability (Bonduki, 2002).

Therefore, there is complex web of cultural values, ethical, human attitudes and behavior, in addition to environmental aspects, that must be taken into account in the formulation of strategies for efficient solutions, including interests and quality of life for people and local communities (SADAN; CHURCHMAN, 1996 apud SILVA, 2007).

2.3 Economic aspects (Profit)

The idea of reducing costs through the reduction of area is strongly rooted in the construction sector, and the parameter most widely used in Brazil to estimate costs is the BUC (basic unit cost) indicator, which expresses the unit cost per square meter for a

standard project, considering several basic inputs (ABNT, 2006). However, the relationship between design decisions and the total cost of the building must also be considered. Rather than simply expressing the BUC, different studies as Otero et al. (2004), Guerra et al. (2009) and Mascaró (2010) show that there isn't a direct proportionality between built area and cost. That is, reductions in the area of a building do not necessarily imply a proportional reduction in production costs.

Mascaró (2010) relates the financial cost of a building directly to its form, through the so called Economic Index of Compactness (EIC). This parameter is expressed as the ratio between the perimeter of a circle of equal area and the perimeter of the outer walls in the building plan, incorporating edges and curves, since these imply increased production costs. Thus, the higher the EIC, the lower the construction costs, as well as construction waste generation. A higher EIC also tends to reduce costs during use and maintenance of the building (MASCARÓ, 2010).

The EIC is calculated by the formula: $EIC = (2\sqrt{(Sf\ x\ \pi)})/EP\ x\ 100$, where: "Sf" is the surface floor of the building and "EP" is the economic perimeter of the design, calculated by $EP = P + E/2$, where "P" is the real perimeter of the building and "E" is the number of edges. In addition, Mascaró (2010) indicates that the horizontal planes represent approximately 25% of the total cost of a project, the vertical planes 45%, electrical and hydraulic installations 25%, and facilities at construction site about 5%. The vertical planes (envelope) offer numerous alternatives for both the design and for the use of materials, and it can be varied both in quantity and in quality. Thus, when economic factors are essential, the most logical thing to save money is to optimize these surfaces, rather than simply reducing the plan areas of housing units (MASCARÓ, 2010).

3. Methodology

The architectural design of a SHD currently under construction in the south of Brazil has been selected for the case study. The apartment buildings in this project have the H-shaped design that is predominant in Brazil for this type of construction. The blocks were designed in structural masonry, and they are referred here as the base-design study (Figure 2).

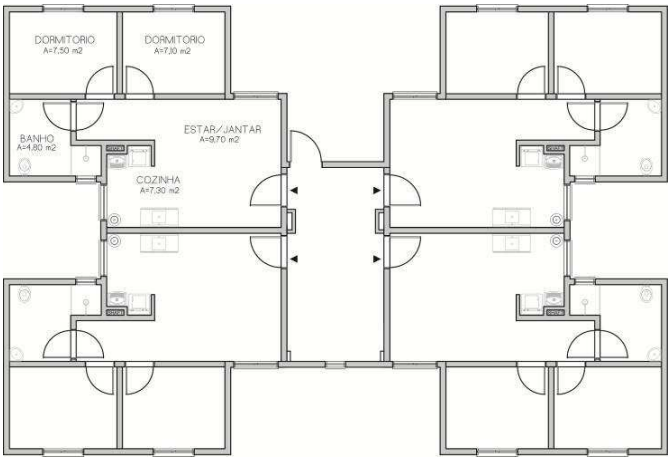

Figure 2: H-shaped base-design, commonly used in SHD in Brazil

Taking the base-design as a reference, changes were made in the building volumetry, seeking alternatives with higher EIC and lower consumption of materials, but always keeping the same total floor plan area (204 m²). Based on the literature, the plant design we seek to achieve is rectangular, having the least number of edges, with the lower length / width ratio as possible in order to improve EIC, as proposed by Mascaró (2010).

After, the consumption of materials of the base-design and proposed designs were quantified using the Revit software with BIM (Building Information Modeling) technology. As a result, alternatives to the base-design were analyzed for total cost and habitability aspects (cross ventilation, better natural lighting and plant flexibility).

The environmental impacts were analyzed comparing the EE of the base-design to the alternative designs with improved EIC, called the proposed designs. The materials budgeting required for construction are listed in Table 2. As the main goal of this research is not to get the absolute EE consumed in each project, but rather to compare the environmental impacts caused by each of the alternatives, some elements were considered as similar for both systems. However, instead of excluding them from the calculation, these values were calculated based on the base-design and replicated in the proposed design.

This study also analyzed the stages of production and transportation of materials and their application in the construction of the building. The stages of operation, maintenance and demolition were not counted because they would be similar for both proposals. From the quantification of the materials, as described in table 2, the total EE values were calculated based on Tavares (2006) research, which provided EE data (in MJ/kg) for materials produced locally.

The item Masonry includes, besides the ceramic blocks, mortar blocks and tiles, roughcast, and plaster. Finally, we included energy from transportation for an average distance of 80 km (TAVARES, 2006).

4. Results and discussion

Figures 3 and 4 show the changes made to the base-design, maintaining the same surface area of the floor plan (204 m²) and the housing unit area of about 39 m².

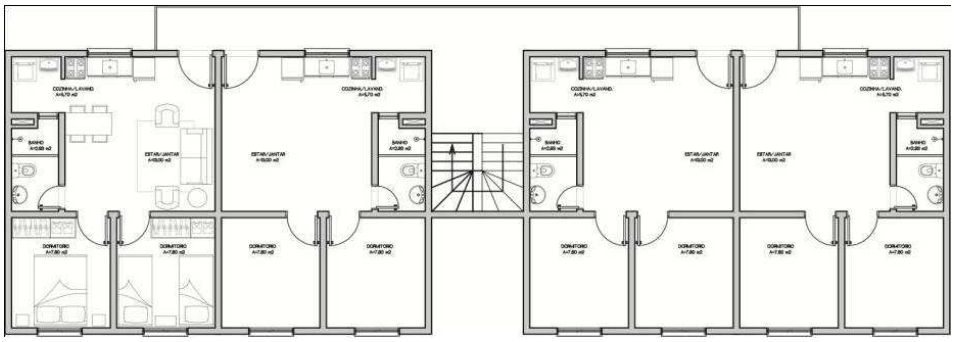

Figure 3: Proposed design A, with open lateral hall and central staircase

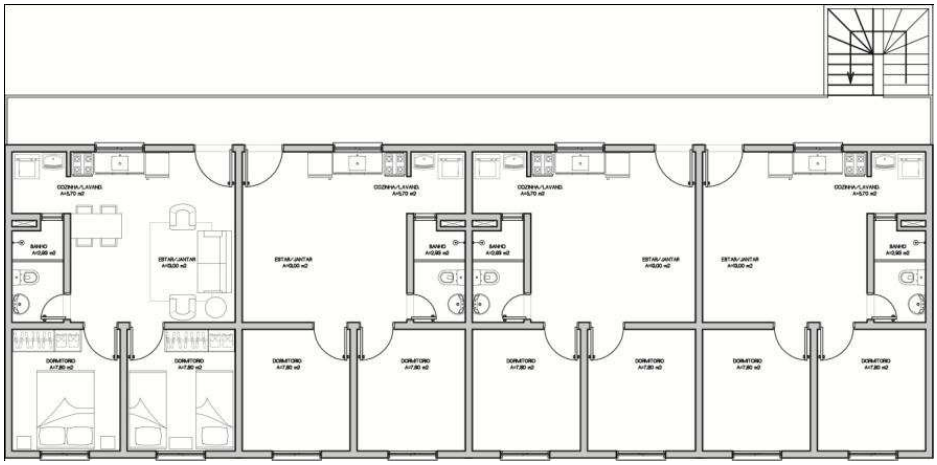

Figure 4: Proposed design B, bar-shaped with open lateral hall

Summarizing the results, Table 1 shows the morphological changes proposed, the design configuration and the EIC obtained for the alternatives developed.

Table 1: Base-design and proposed designs A and B, with their EIC

Typology	Configuration	Total area	EIC
Base-design (Figure 1)	H-shaped design with a vertical circulation serving 04 apartments per floor	204 m^2 x 5 = 1020 m^2	49,6
Proposed design A (Figure 2)	Bar design with a vertical circulation, parcial lateral hall serving 04 apartments per floor	204 m^2 x 5 = 1020 m^2	63,2
Proposed design B (Figure 3)	Bar design with a vertical circulation, total lateral hall serving 04 apartments per floor	204 m^2 x 5 = 1020 m^2	72,3

As described in the methodology, after obtaining the EIC of the designs, the analysis of environmental impact was done through the calculation of EE in the base-design and proposed design with the best EIC (in this case, the proposed design B of figure 3). The material budgeting for each building part, as well as the quantification of EE for the two alternatives, are summarized in Table 2.

Table 2: Material budgeting and quantification of EE for each building

		Base-design			Proposed design B		
Building composition	EI (MJ/kg)	Amount	Total (kg)	Total (MJ)	Amount	Total (kg)	Total (MJ)
1. Preliminary services: lease of the work, siding, temporary shelter		-	-	17567	-	-	17567
2. Structure							
2.1. Infrastructure							
Wood 15mm (5x)	0,5	1,8 m^3	1080	540	1,8 m^3	1080	540
Steel - armor	31	-	1080	33480	-	1080	33480
Waterproofing (3x)	96	-	30	2880	-	30	2880
Medium sand	0,05	6,83 m^3	10350	517,5	6,83 m^3	10350	517,5
Crushed stone	0,15	8,36 m^3	13800	2070	8,36 m^3	13800	2070
Portland cement CP II-E32	4,2	1,77 m^3	3450	14490	1,77 m^3	3450	14490
2.2. Superstructure							
Offset wooden plate 12mm (3x)	8	14,4 m^3	10397	83175	13,5 m^3	9706	77645

Wooden struts d=10cm	0,5	-	19908	9954	-	18900	9450
Steel nails 18x27	31	-	25	775	-	25	775
Steel - armor	96	-	10833	1039910	-	10116	971136
Medium sand	0,05	68,5 m³	103810	5191	63,9 m³	96945	4847
Crushed stone	0,15	83,9 m³	138414	20762	78,3 m³	129260	19389
Portland cement CP II-E32	4,2	17,7 m³	34603	145335	16,6 m³	32315	135723
2.3. Concrete stairs							
Medium sand	0,05	2,84 m³	4312,5	215,62	2,84 m³	4312,5	215,62
Crushed stone	0,15	3,48 m³	5750	862,5	3,48 m³	5750	862,5
Portland cement CP II-E32	4,2	0,73 m³	1437,5	6037,5	0,73 m³	1437,5	6037,5
Steel - armor	31	-	500	15500	-	500	15500
Steel - railing	31	-	29276	780704	-	29276	780704
3. Masonry							
Ceramic block 14x19x29	2,9	235 m³	329000	954100	187 m³	261800	759220
Solid brick 6x11x22	2,9	6,31 m³	8828	25602	7,34 m³	10276	29800
Medium sand	0,05	42,3 m³	64344	2893,1	30,6 m³	46344	2317,2
Hydrated lime CH III	3	9,07 m³	13609	40829	6,75 m³	10113,4	30339,8
Portland cement CP II-E32	4,2	4,77 m³	9292	39028,5	3,34 m³	6535,5	27451,2
White cement (non-structural)	4,2	0,245 m³	478	2006,5	0,18 m³	351	1474,2
Tiles	6,2	490 m²	5880	36456	360 m²	4320	26784
4. Frames							
Wooden door (complete)	3,5	-	6645	23257,6	-	6645	23257,6
Steel nails, screws and hinges	37	-	184,6	6774	-	184,6	6774
Brass – door lock	55	-	710,8	39094	-	710,8	39094
Aluminum – frame and profiles	98	-	9837,5	964075	-	9837,5	964075
Glass	18	-	5675,4	102157	-	5675,4	102157
5. Roof							
Wood – peroba (structure)	0,5	2,44 m³	1756,8	878,4	2,35 m³	1692	846
Steel nails 18x27	31	-	16	496	-	15,5	480,5
Fiber cement tiles-8mm (i=27%)	6	2,05 m³	3935,2	23611,4	2,0 m³	3840	23040
Fiber cemente ridge	6	0,045 m³	85,68	514,07	0,04 m³	76,8	460,8
Gutter - galvanized	33,8	0,185 m³	1450,8	49038,3	0,15 m³	1177,5	39799,5
Canvas (PEAD)	95	200 m²	190	18050	200 m²	190	18050
Bathroom waterproofing	96	-	12	1152	-	10	960
PVC liner (bathrooms)	80	96,4 m²	1253,2	100256	50,0 m²	650	52000
6. Floors							
Tile	5	1212 m²	25246	126230	1290m²	26870,7	134353
Medium sand	0,05	27,56 m³	41756	2087,8	29,7 m³	45071	2253,5
Hydrated lime CH III	3	8,37 m³	12552	37657,4	9,04 m³	13569,5	40708,6
Portland cement CP II-E32	4,2	1,05 m³	2049,4	8607,4	1,12 m³	2181,2	9161,3
7. Installations							
7.1. Hydraulic installations							
Fiberglass tank	24	-	600	14400	-	600	14400
Hydraulic system (PVC)	80	-	546,2	43696	-	546,2	43696
Sanitary ware	25	-	600	15000	-	600	15000
7.2. Electric installations							
Breakers, conduit, eletr wiring, switches		-	-	188245	-	-	188245
8. Painting							
8.1. Interior walls and ceilings painting							
Acrylic sealer	61	2560 m²	399,36	24360,9	2316m²	361,29	22039
Latex PVA paint (2 coating)	65	5256 m²	819,94	53295,8	4736m²	738,81	48023
8.2. External walls painting							
Acrylic sealer	61	83,82 m²	13,075	797,63	75,0 m²	11,7	713,7
Acrylic paint (2 coating)	61	2190 m²	341,64	20840	1278m²	199,36	12161,4
8.3. Frames painting							

Enamel paint	98	486 m²	120	11760	486 m²	120	11760
9. Final works (cleaning)	1			1200			1200
Transport EE (MJ)	0,13			121846,9			107854,2
Overall EE (MJ)				5.280.259,82			4.893.778,62

4.1 Analysis of environmental aspects (Planet)

The difference between the EE of the base-design and the proposed design is about 386481,2 MJ, which represents a reduction of 7.5% in favor of the bar-shaped alternative. This result can be explained by the decrease of material consumption between projects, especially in masonry and painting materials (by decreasing the outer perimeter).

Converting the difference of EE in electric power, we obtain 107,355.94 kWh. Assuming an average consumption of 100 kWh/month (current limit of the intermediate discount bracket of social power rate, as described in BRAZIL, 2010), we have that the savings would be enough to meet the total energy needs of a single unit for almost 90 years, or 20 units (a tower) for approximately 4.5 years. Figures 4 and 5 illustrate the variation of embodied energy (EE) in the buildings as a function of the compactness index (EIC) for each design alternative.

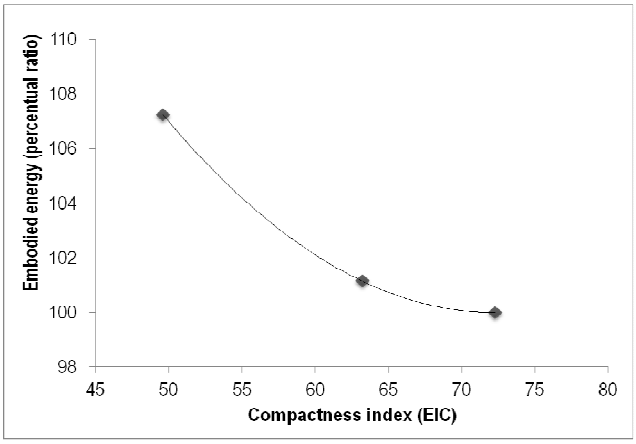

Figure 4: Building embodied energy (percentual ratio) versus compactness index

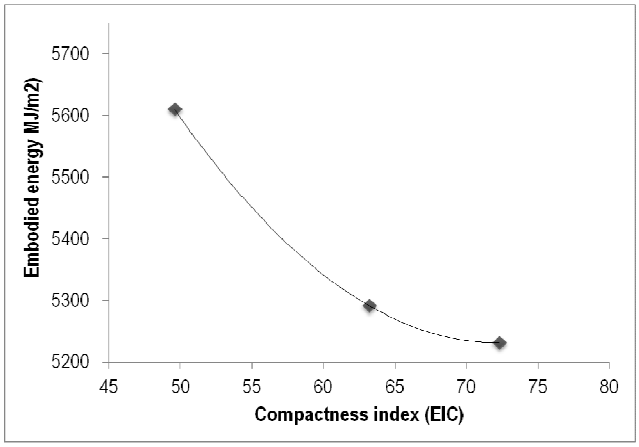

Figure 5: Building embodied energy (MJ/m²) versus compactness index

The first graph shows the relation between the EE and the EIC in a percentual ratio; the second one presents the absolute values of EE in MJ/m². Summarizing, the higher the EIC is, less material is consumed and thereby less environmental impact. It should be emphasized that this condition has been reached only with design changes and morphology optimization, with no changes to floor plan area.

4.2 Analysis of social aspects (People)

Fundamental to the health of individuals, proper illumination and thermal comfort are privileged in the proposed designs, since all housing units are facing the same solar orientation. When feasible due to the implementation on the ground, you can have all dormitories facing better sunlight, which is impossible in H-shaped designs.

This configuration also allows natural cross ventilation, which can provide greater thermal comfort, especially in hot and humid climates. It may also improve energy efficiency in indoor environments, reducing energy consumption, minimizing directly the use of mechanical ventilation systems and air conditioning. In addition, natural ventilation minimizes outbreaks of mold and mildew on the furniture and even walls.

These issues are not answered in the base-design, due to its H-shape. The base-design apartments do not have cross ventilation and one side will always be less exposed to sunlight, which impairs natural lighting and ventilation.

4.3 Analysis of economic aspects (Profit)

Taking as a parameter the economic index of compactness (EIC), there is a cost reduction in the two proposed designs. While the base-design features an EIC of 49.6, the proposed design have an EIC around of 63.2 and 72.3, respectively.

This difference is explained by the decrease of the external perimeter and decreasing edge, directly related to the vertical planes, items of greater direct contribution to the cost of a building. Using the curve relating cost and compactness index (developed by MASCARÓ, 2010) the difference between EICs 50 and 70 corresponds to a reduction of production cost of approximately 10%. This savings can be reversed into improvements such as increased area, larger frames, best quality finishing, among others.

5. Conclusion

The results obtained illustrate important guidelines that can be followed during the phases of conception and design of social housing units. The differences found in the EIC from the base-design in relation to proposed designs indicate that significant savings can be made from volumetric decisions in the early stages of a design.

The savings achieved during the production process can be reversed into benefits and improvements to SHD in order to qualify not only the housing units, but also directly influence the way of life of its users.

In addition, the reduction in EE between the base-design and the proposed design (of about 7.5%) points to a considerable reduction in the environmental impact through the decrease of energy consumption in the production of these buildings.

Based on these results, we question the serial reproduction of typologies commonly found in the SHD segment, without a careful evaluation of the decisions that affect the cost, quality and the impacts of these developments.

Finally, we believe 3BL sustainability aspects such as the ones described here should be extensively discussed by the government and society, and common-sense indexes such as the EIC could be incorporated early into the SHD process in order to cut production costs, reduce environmental impact and improve quality and living conditions.

Architecture has the ability to transform and contribute directly to the improvement of people's lives. More than a quantitative problem, eliminating the housing shortage and providing universal access to basic services should be seen as a serious sustainability challenge that can be better addressed when the 3BL concept is put into practice.

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Purchasing decisions: enablers and barriers to innovation in construction

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Abstract

Innovative construction needs collective capabilities from a variety of firms. The purchasing of new products, i.e. innovations, is complex and involves many people with different interests and motivations. The purpose of this study is to investigate the purchasing decision-making process and its enablers, and barriers to innovation through three construction projects in southern Sweden. Interviews were conducted in three different projects with three different company consortia of architect, contractor and client. The interviews concerned the selection of suppliers, products and services.

The long or short-term nature of the supply chain agreements can act both as enabler and as barrier to innovation. The present study will show that the contractor-supplier relationships in the cases studied were long-term in nature, contrasting previous research findings suggesting the opposite. Furthermore, the study revealed that close relationships between contractors and their preferred suppliers, with customized products and processes, was 'business as usual' in the studied projects. It was also found that consortia select their preferred suppliers at global or local scale based on their internal strategic goals and culture.

The construction industry is constantly evolving. Long-term relationships are paramount to this evolution, due to the fact that co-creation processes require time and effort to develop. Benefits to both parties in long-term strategic partnerships can be achieved through cross-company knowledge management, win-win relationships and product co-creation. Nevertheless, this also creates barriers to innovation due to the aversion to novel solutions designed and specified by architect or a new product coming to market from new suppliers. Contractors tend to disregard innovative suggestions presented by the architects regarding new solutions, suppliers and products. Consequently, the development of new products is often hindered by preferred suppliers with less innovative solutions.

Keywords: purchasing, innovation, supply chain, construction

1. Introduction

Construction requires a wide range of capabilities that rarely can be found within one single enterprise, but require links to technological capabilities of other firms (Gann and Salter,

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2000). Innovation from suppliers is of strategic importance to remain competitive on the market (Teece et al. 1997). Purchasing decisions have a boundary role in capturing innovation from suppliers (see for example, Van Echtelt et al. 2008; Wagner and Hoegl 2006; Wynstra et al. 2001). Throughout the purchasing process from the specification phase to issuing the contract or order, some parties exert more influence than others (Kohli, 1989). The influences are driven by different interests and motivations (Sheth, 1973), which consequently involve considerable complexity (Anderson et al., 1987). The organization of purchasing can therefore be considered having a large impact on the innovativeness of construction projects and the competitive advantage of contractor firms. The purpose of this study is to investigate the purchasing strategies, enablers and barriers to innovation through three construction projects in southern Sweden. Interviews were conducted on projects with three different company consortia of architect, contractor and client. The interviews concerned the selection of suppliers, products and services.

2. Buyer-supplier relationships and the purchasing process

Construction is a project-based business (Winch, 2006), where linkages with other firms differ from traditional manufacturing regarding the interaction between buyer and supplier. Manufacturing has a more transaction-based approach to buy-sell relationships whereas construction implies much more interaction in planning, design engineering, supply and integration, erection and installation of materials, components and technical systems (Gann & Salter, 2000). In a project-based business, people typically work in temporary allocated teams with many other firms and have limited contact with senior management. In these companies, construction materials have typically been ordered by the local project leader from temporary suppliers and sub-contractors (Dubois & Gadde, 2000), which can be seen as decentralized purchasing. According to several authors, e.g. Vrijhoef & Koskela (2000), Cox & Ireland (2002), Cooper et al (2003), Love et al. (2004) and Briscoe et al. (2004), the supply of materials in construction companies is inefficient, mostly due to coordination issues that are argued to depend on the uniqueness of the projects and a fragmented supply chain.

The purchasing process includes a specification phase, selecting the supplier, arriving at an appropriate price, specifying terms and conditions, issuing the contract or order and following up with secure delivery (Van Weele, 2008). When new products are bought, the purchasing process can last several months (Emiliani, 2000). However, in practice most buys are straight rebuys. According to Robinson et al. (1967), there are three types of purchasing situations: (1) new-task situation (2) modified rebuy or (3) straight rebuy. The new-task situation is when a company decides to purchase a totally new product from an unknown supplier. The modified rebuy occurs when the company wants to buy a new product from a known supplier. The straight rebuy, also referred to as routine buy, is when a known product is bought from a known supplier. In general, the straight rebuy is the most commonly practiced approach. The first stage of the purchasing process is the *specification phase* in which two types of specification need to be addressed: functional and technical. Functional specifications describe what the product should be capable of performing. Technical specifications describe the technical properties and characteristics of the product. The functional and technical specifications constitute parts of a set of documents referred to as the purchase order specification. The purchase order specification includes quality

certificates, technical norms and standards, logistics specifications including quantity, time and place of delivery, maintenance services, legal and environmental requirements, and a target budget. The *selection of supplier* is intimately intertwined with the specification phase and constitutes the next step in the purchasing process. In this stage, the borders of subcontracting are determined, the basis of the contract is chosen (i.e. fixed price or cost-reimbursement) and a proposal including references covering previous engagements is requested from a selection of suppliers. Thereafter, the final candidate or candidates (multiple sourcing) are chosen. *Arriving at a proper price* can be conducted through competitive bidding or negotiation. From the buyer's perspective, a fixed price contract is normally preferred from a cost control and budget perspective. Moreover, the supplier is expected to take all the risks. *Specifying terms and conditions* are important and the buyers should ideally specify the company's terms of business. In contracts concerning quality and performance, penalties and warranties are commonly written-in. After the contract has been agreed, the *issuing of the contract or order* takes place. In some cases the contract is the purchase order. When routine buying is applied, call-off agreements are negotiated to cover the supply for one or more years; in this case, contracting and ordering are separate activities. *Following-up to secure delivery* is about documenting experiences with individual suppliers. Documented experiences can be useful for choosing only the best suppliers in future buys. The documentation includes the supplier's quality and delivery record, competitiveness and innovativeness. The purchasing process with its different tasks is illustrated in Figure 1.

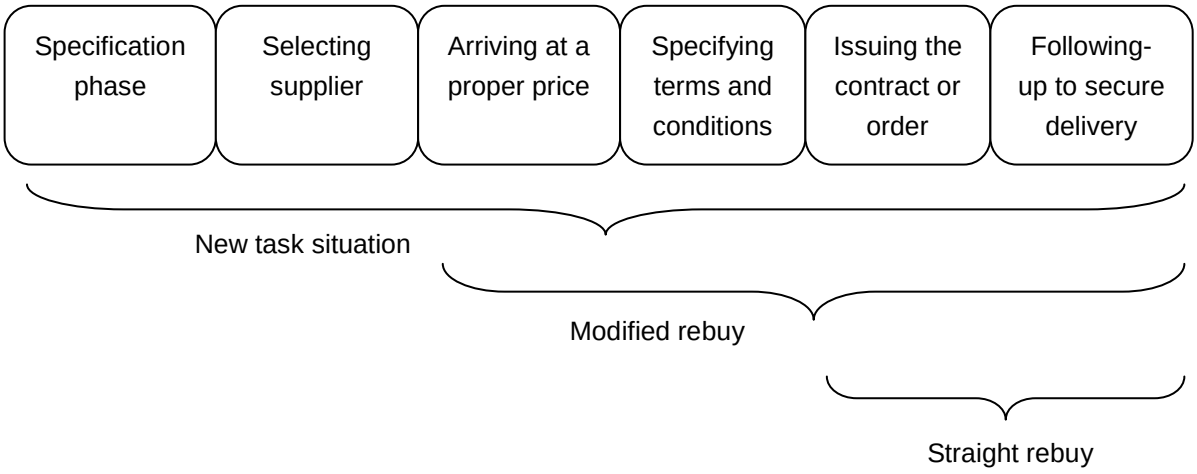

Figure 1: The purchasing process and different situations (abstracted from Van Weele, 2008)

Organizational purchasing processes are complex and involve a group of individuals referred to as the 'decision-making unit' (Robinson et al. 1967) or the 'buying centre' (Webster and Wind, 1972). Webster and Wind (1972) define the buying centre as 'all those individuals and groups who participate in the purchasing decision-making process, who share some common goals and the risk arising from the decision'. The roles in the decision-making process are defined by Webster and Wind (1972) as users, influencers, buyers, decision-makers and gatekeepers.

3. Methodology and case studies

In order to describe and analyse purchasing strategies, enablers and barriers to innovation in construction projects, a case study approach was chosen (Yin, 2008). A case study helps in understanding contextual factors within the specific industry (Johnston et al. 1999) and is considered to provide creative insights, develop new theories and have high validity among practitioners (Voss et al. 2002). Three project organizations were studied, involving the architect, contractor and client. The project organizations were chosen due to geographical proximity and being medium-sized project. The limited size made it possible to follow decision-making of purchases. The data collection consisted of personal interviews with the actors involved and including visits to the architects' offices and the construction sites.

3.1 Case study I – refurbishment of university school building

A university school building was refurbished by remodelling the inside layout for more open spaces, installation of a new ventilation system and new windows. When choosing products for this project, the *architect* used product catalogues to a large extent, mainly digital. There were also printed catalogues available at the architect's office but they are more seldom used. Products could also be selected through advertisements in magazines, although most products are chosen through directed searches. Catalogues can be inspiring in the initial phase, but not so much thereafter. Most information was accessed through searches on the internet. There are search functions for products on the internet but the architect would like them to be improved. Technical information is wanted by architects to get a quick overview of a product. Information about price and how to build is not obtained from catalogues. When it comes to that information, the architect makes personal contact with the suppliers. As the clients want several choices of suppliers (concurrence is considered important by the client), alternative suppliers are suggested by the architect. The architect has little knowledge about technical matters and trusts information given by suppliers; there is no formal agreement with suppliers, but the relationships with them are long-term.

The *client* also uses catalogues to learn about properties of products that are specified by architects. The client gains access to catalogues via the internet or directly from suppliers through meetings or presentations. There are many products in a project. If a product has not been used before, pictures and information about the product are desirable desired with tolerances and material attributes. The choice of suppliers is based on their financial strength and what guarantees they are willing to give. The client emphasizes the importance of guarantees. There are several suppliers for the same products as the client thinks it is important for maintaining competition.

The *contractor* believes that there will be more digital catalogues in the future. However, many still want paper versions as it is difficult to bring computer equipment to the outdoor environment of a construction site. The head office is responsible for the catalogues and distributes them to the different divisions within the organization. Drawings are usually digital and then printed for use on site. The contractor says that a lot of new suppliers are used because every project is unique and price is important and so involves as many actors as possible. A lot of sourcing is from Denmark (50%), but there are also suppliers in, for

example, France and China. The contractor sees no problem in using foreign suppliers; however, different standards can sometimes be a hindrance.

3.2 Case study II – refurbishment of student dormitory

The refurbishment of a student dormitory concerned new kitchens and windows. In this study, a kitchen *designer* was interviewed as well as the contractor and the client. The designer also acts as a principal contractor concerning kitchen installations. The *designer* uses product catalogues to a large extent. Catalogues are, according to the designer, available increasingly on the internet. Even so, suppliers continue to send mostly printed catalogues. There is always a continual search for products. The designer is mainly interested in technical specifications of products. When proposing kitchen solutions to the client, however, the designer says that it is important to show a catalogue with illustrations. Relationships with suppliers are of a long-term nature both in regard to subcontractors and material suppliers. The company has multiple relationships with different suppliers for the same products. Yet, they hardly ever add a new supplier to their supplier base. The materials are all customer-adapted. Products are designed for fabrication in low-cost countries. Foreign suppliers account for 25-30% of total purchases.

The *client* uses product catalogues for inspiration in the initial phase of the project. The catalogues come in printed form from long-term suppliers. Printed catalogues are the preferred basis for obtaining information about products. The client does not search actively for new products. Only 5% of purchases come from new suppliers. Illustrations and technical data are the most important information in product catalogues as far as the client is concerned.

The *contractor* often uses catalogues to find information about products. Catalogues come from visiting sales personnel and the internet. Illustrations and technical information are desired in product catalogues. Paper format is preferred so that information can be easily shared at the construction site. Relationships with suppliers for both products and services are long-term. The contractor has 1-2 years price agreements with suppliers of products and the site manager has to select products from these suppliers.

3.3 Case study III – construction of a new office building

This case study concerned the construction of a new offices consisted of the production of two buildings. One of the buildings is 19 stories high and the other is 14 stories, with a combined total floor area of 9,000 m^2. In this project only the architect was interviewed. The *architect* often uses product catalogues that are in both digital and paper form. Inspiration for new products does not come from the catalogues but from materials used in other projects. Catalogues are more often used when a material has been chosen: the supplier is then contacted. Technical information, as well as the possibility to combine materials, is desired from the product catalogue. The architect mostly suggests products from suppliers with whom he or she has an established relationship. Suggestions from suppliers, which have not been used before, account for 15-20% of total purchases. Relationships with established suppliers have been ongoing for 30-40 years. These long-term relationships are motivated

by concern for cost in the event that something goes wrong when trying new products and suppliers. Danish products comprise 30-40% of specified products. Windows, fittings and armatures are especially desired. Usually the contractor substitutes a cheaper product or one that offers greater discounts. Often these products are inferior.

4. Analysis

To analyze the purchasing decision-making process and its enablers, as well as barriers to innovation, the purchasing process of Van Weele (2008) is used as a model of inquiry (see Figure 1). The various actors interviewed are placed in the model (see Figure 2) and their effect on the final choice of product throughout the process is now discussed. The uniqueness of each product in construction leads more or less to a 'new task situation' for every project. This is because the architect has to specify the products in the design of a new building or the refurbishment of one existing. However, the process is somewhat facilitated by established relationships with suppliers participating in the specification phase. The suppliers contribute their technical knowledge so that the architect and suppliers 'cocreate' building solutions. In the next step (see Figure 2) of selecting supplier, the architect has his/her supplier relationships whereas the contractor has his/her own. The clients want products that are bought at the lowest price through competition between suppliers. Consequently, the contractor often changes products originally specified by the architect. Arriving at a proper price is achieved through long-term price agreements with suppliers of multiple products. It is the contractor that has these price agreements, so 'arriving at a proper price' is the contractor's task. The client stressed that it was important to have guarantees for products and work, which constitutes the next step of specifying terms and conditions. The client and contractor therefore discuss this matter together. The issuing of a contract or order and following-up to secure delivery is undertaken by the contractor.

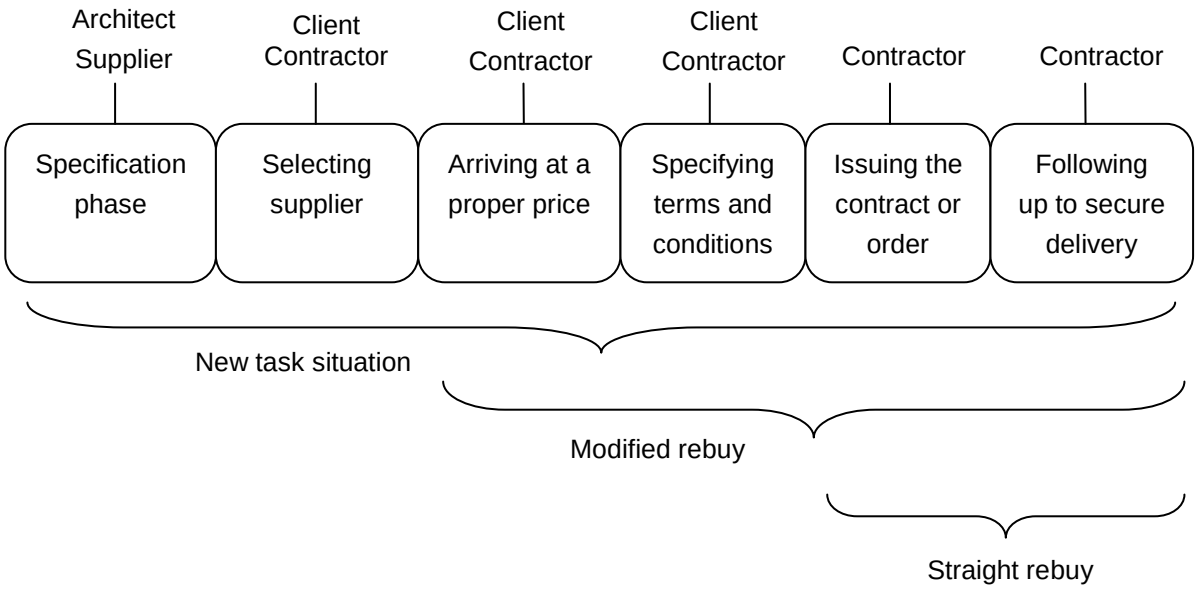

Figure 2: Actors in the purchasing process of construction

The architect can be seen as a driver of innovation and who is continuously in the pursuit of new materials for innovative designs. In the architect's eyes, purchasing is always a new task situation that involves collection of information about design, the context in which

certain materials are used and technical specifications. A new task situation implies new products and new suppliers, which is made for a certain percentage of specified materials. One of the contractors noted that it was unusual that they asked a supplier to develop entirely new products. Most products are a modification of a standard product. When it comes to modified rebuys, a new product is bought from a known supplier. If modified standard products can be viewed as new products, these purchases can be seen as modified rebuys. Some products are, however, true bulk materials and these are delivered by ordering through middlemen for drawn off just-in-time from suppliers with which the contractor has price agreements. These products can be categorized as straight rebuys.

Products used in a project vary between new task situations, modified rebuys and straight rebuys depending on the product. To simplify the purchasing process, straight rebuys offer the most straight-forward approach. However, this hampers innovation as the voice of the architect is not considered. A relating issue is that of the uncertainty of products being allowed under building regulations and whether or not it deters the actors in general from making innovative design solutions. This inhibits purchases from new suppliers, who are unfamiliar. If a new supplier is to be considered, the product from that supplier must be shown in the context of a successful, finished project. Related to new buys is the tendency of sourcing from other countries, which is different between the projects. In the refurbishment of the university school building and the construction of the new offices, a large percentage of materials came from suppliers in other countries. In the case study of the refurbishment of the student dormitory, everything was locally sourced by the contractor; but that was not the case for the kitchen designer (who was also a contractor). A contractor that does not source from overseas is motivated by the uncertainty surrounding products which may or may not be allowed under building regulations. In addition, price agreements with certain suppliers must strictly be followed and no other suppliers are allowed.

5. Discussion

The finding that contractors and architects have such long-term relationships with suppliers contrasts with the findings of Dubois and Gadde (2000) who claimed that the relationships were short-term. There seems to be an overall tendency in the projects that long-term relationships are a matter of business as usual. Moreover, it seems difficult for new suppliers to enter the supplier base. A barrier to entry is to market materials in pilot projects where it may then be difficult to find financing since contractors are reluctant to try new products i.e. to innovate. To solve the complexity of purchasing for buildings, contractors use substitute materials to those materials originally specified by architects. The question here is do these products have the same attributes in quality and design as those originally specified? These consequences would be interesting to study further. The architects seem to do a lot of research in vain in their search for innovative solutions which end-up not being implemented in the building. The architect is not a participant in the subsequent steps of the purchasing or construction process which hinders learning about how the materials are used in reality – the wish to see materials in their context was desired by architects. In the interview with architects, there seemed to be a desire to learn more about materials as most knowledge was transferred to them from material suppliers. The main barrier to innovation is the contractor taking over the choice of product when it comes to the final decision rather than

ordering the product that was suggested by the architect. To overcome such barriers to innovation, the architect needs to participate more in the subsequent stages to learn about materials in their context. This could possibly give the architects more knowledge and power to affect the final decision stages. In a closer relationship between the architect and contractor, the architect could suggest possible new solutions and the contractor could determine whether or not it is buildable. Close collaboration between contractor and architect could then be fruitful from an innovation perspective. Furthermore, the client must be informed about the differences that occur from substituting different products to those specified originally by the architect. The client should therefore also keep more contact with the architect in the subsequent stages of the purchasing process.

6. Conclusions

The purpose of this study was to investigate the purchasing process and its enablers, as well as barriers to innovation. The purchasing process starts with the architect who designs the building and does research into materials which is taken over by the contractor later in the process. Both the architect and contractor have long-term relationships with suppliers. The price agreements that the contractor keeps with long-term supplier relationships is a matter of business as usual in the studied projects. This makes the purchasing process efficient as buyer and supplier do not have to go through all the steps in the purchasing process for each purchase. With common ways of working, the purchasing process becomes more routine-based and supplies are more secure. Clients seem, however, to be more interested in purchasing through competitive bidding between suppliers because they feel better deals are possible.

It can be concluded that architects together with material suppliers are enablers of innovation. The architect can be motivated by the goal of creating something new and suppliers of materials can find business opportunities. Other enablers of innovations are influences from suppliers based in other countries. These established suppliers can offer innovative solutions which can be purchased through modified-rebuys that attract lower risks than in a new-task situation.

The main barriers to innovations highlighted in the study are building regulations and price agreements that substitute innovative products specified by architects. The final conclusion is that long-term relationships lower the risk but also can be seen as a compromise on innovation and innovative design.

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Organized self-help housing: lessons from practice with an international perspective.

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Abstract

There is an urgent need of improving the lives of 100 million slum dwellers until year 2020. The Habitat Agenda has identified self-help housing among other enabling housing strategies. This paper focuses on mapping organizations and different types of organized self-help housing (OSHH) projects since year 2000 with the aim of analyzing important lessons from practice. An international survey was implemented to selected housing experts and practitioners from developing countries; and qualitative data analysis was conducted. Results show that dweller-control over the OSHH process contributes in achieving better quality settlements and homes whilst empowering the urban poor. This process also helps to improve community skills and local construction techniques. Asian CBOs and NGOs have implemented OSHH for slum upgrading and reconstruction after natural disasters. Organized self-help housing has been combined with other support tools such as micro-credit or organized savings, production of construction materials, training and community capacity building. OSHH housing has the potential for fostering the development of social, technical and financial sustainability in human settlements in developing regions.

Keywords: Organized self-help housing, slum upgrading, reconstruction, dweller-control

1. Introduction

There is an urgent need of improving the lives of 100 million slum dwellers until year 2020 as stated by the Millennium Development Goals. In developing countries, governments have not been able to cope with rapid urbanization and housing needs (Jenkins, 2007). The poor have solved their housing needs through self-help housing without technical assistance producing shelter that has been highly affected by natural disasters. Kreimer has highlighted the vulnerability of slum dwellers due to the lack of resources and opportunities (Lyons & Schilderman, 2010). This argument is confirmed when comparing the damage of a 7 magnitude earthquake in Haiti with 80% of population living below the poverty line (Thurman, 2010), with the damage of a 8,8 magnitude earthquake in Chile[3] where only 20% of the population are considered poor.

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[3] In the 8,8 magnitude earthquake in Chile there were less than a thousand deaths. In Haiti, 1,5 million people were left homeless, and 27% of the houses in Port-au-Prince were destroyed (Chege, 2012).

Harris (1999) has tracked the history of aided self-help housing to Sweden in 1904 and then to other European countries for reconstruction purposes after the First World War. Geddes (Harris, 1997; Harris, 1998), Crane (Harris, 1997), Abrams (Abrams, 1969) and Turner (Turner, 1972; Turner, 1976) have argued the importance of two main features of housing and urban development in the rapid urbanizing South; firstly, incremental growth, and secondly, self-help housing. John F.C. Turner proposes three main issues based on his experience in the barriadas in Lima. First, the concept of "housing as a verb" in which he emphasizes the importance of the housing process. Second, he highlights the importance of "what housing does for people" over its physical characteristics. Third, Turner proposes that the value of housing was related to "dweller-control" more than to its physical features; hence, people deserve "freedom to build" (Turner, 1972; Turner, 1976; Marais, 2008). Organized self-help housing[4] (OSHH) has been implemented by CBOs and NGOs as a way of addressing the housing needs of the poor as stated by the Habitat Agenda in 1996 (UN-Habitat, 1996). OSHH as a process has the potential to develop human skills and strengthen community development. The OSHH process is important for *what it does with people* because it also contributes in building the capacity of the community; and therefore, in increasing their resilience when facing natural disasters. There are different terms used to describe organized self-help housing such as community-led housing[5], community-driven housing[6], community-driven development[7], assisted self-help projects, etc. The information regarding OSHH is scattered in different organizations which affects negatively the learning process by different stakeholders. This paper is an attempt of mapping key organizations and identifying the project types in which OSHH has been implemented since the year 2000. The aim of the paper is to analyze lessons learnt from the current practice of OSHH.

1.1 From aided self-help housing to organized self-help housing

Sites-and-services implemented by the World Bank around the world lack "dweller-control" which is considered the most novel contribution of Turner (Harris, 2003). These projects have been structured around state control – recently in South Africa (Marais, 2008); and miss the potential of community development through the process. They are based on a top-down approach in which the community only participates in self-construction activities. There are three negative aspects of the site-and-services approach of the World Bank. First, sites-and-services have promoted urban sprawl due to minimizing investment costs in building one storey housing. Secondly, core housing needed to be built incrementally, but microfinance for subsequent housing improvements has not been available. Finally, the self-help housing process has been focussed on community participation for producing core housing instead of improving the skills of the people and empowering them over the process.

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[4] Organized self-help housing: self-help housing with technical assistance (Abrams, 1969).

[5] See Homes and Communities Agency community-led housing programme in the UK, Community Right to Build, http://www.homesandcommunities.co.uk/community-right-to-build

[6] See Community-driven housing initiatives in South Africa, http://www.afesis.org.za/Sustainable-Settlement-Publications/community-driven-housing-initiatives. See Community-driven Housing by Hunnarshala Foundation, in Bhuj, India,

[7] See Using Community-Driven Development to Rebuild Housing in Haiti, http://pnpm-support.org/sites/default/files/Using_Community-Driven_Development_to_Rebuild_Housing_in_Haiti[1].pdf

UN-Habitat (2005a) recognizes several qualities of self-help housing with technical assistance such as its potential for saving investment costs, how communities acquire important skills through the process, its financial affordability and housing flexibility for incremental growth. For Rodriguez & Åstrand (1996), OSHH is important because "it promotes the enhancement and organization of the resources of the community and institutions involved, to make community development possible". Bredenoord & Van Lindert (2010) argue for new pro-poor housing policies that include the power of self-help efforts of the poor; and provide the institutional, financial and technical framework. Some of the most active organizations internationally that have implemented different approaches to OSHH in the last decade are Slum/Shack Dwellers International, Habitat for Humanity International, Homeless International, and Gawad Kalinga among others. These organizations have been inspired by Crane, Turner and others. In this paper, organized self-help housing is defined as a process that involves the community's active participation and decision making in planning, design, self-construction, and post-project activities with the technical assistance of a facilitating organization.

2. Methodology

An exploratory international survey was conducted to establish the state of the arts of organized self-help housing in developing countries. The study included the following research strategies: a) literature review b) test of a pilot questionnaire c) questionnaire to Housing Development & Management (HDM) alumni, other housing experts and practitioners, d) and Internet survey of shelter federations/organizations. For this paper, three categories of the questionnaire were selected: organization, project type and lessons learnt. The main criteria for the first selection of housing practitioners and experts from developing countries was to have participated in the International Training Programme (ITP) *Organized Self-help Housing: planning and management.* The 137 alumni of the OSHH course are professionals working with housing and urban development in 34 developing countries from Latin America, Asia and Africa; and share concepts and approaches to organized self-help housing. A pilot questionnaire was applied to this target group. Then, a snowball sampling was applied for distributing an improved version of the questionnaire and for the Internet survey. The summary of how the questionnaires have been applied to different target groups from 2008 to 2010 is shown in Table 1. It was possible to obtain primary information from 29 different developing countries through 84 questionnaires. The Internet survey aimed at a) obtaining further information about the organizations and projects referred by the respondents to the questionnaire b) and as validation of the primary information obtained through the questionnaires. This survey focused on websites such as UN-Habitat, Habitat Awards, Asian Coalition of Housing Rights, Slum Dwellers International, Homeless International, and Habitat for Humanity International among others.

Considering that this study is still ongoing, it will lead to more organizations and other types of OSHH projects, approaches and lessons. For the analysis of primary information, the questionnaires were classified by country; and qualitative data analysis was conducted on the following categories: organization, project types, lessons learnt. Questionnaires that failed in providing information about organizations and types of projects were left out of the analysis. The results and discussion section focus on a) discussing the results of the

international mapping with an emphasis on lessons learnt from organizations working in Asia and Africa; and b) the case of Indonesia. There were two main criteria for selecting Indonesia as a case. First, questionnaires have been mostly collected from this country. Second, the scale of destruction of the 2004 tsunami had affected Indonesia heavily and the government supported a people-centred reconstruction process.

Table 1: Details of the international survey

Description	Target group	Date	Number of responses	Percentage	Number of countries	Countries
Pilot questionnaire	137 alumni OSHH courses (2002-2007)	October 2008	16	11,67%	12	Bangladesh (2), Bolivia, Brazil, India, **Indonesia** (2), Nepal, Sri Lanka (2), Swaziland, Tanzania, Venezuela, Vietnam and Zambia (2)
Questionnaire	153 alumni SDD courses (2006-2009)	April 2009	49	32%	22	*Latin America 9 Q*: Bolivia, Brazil, Cuba (2) , Ecuador (2), El Salvador, Nicaragua and Uruguay; *Asia 16 Q:* **Indonesia** (6) , Nepal, Sri Lanka (3), The Philippines (5), Vietnam; *Africa 24 Q:* Botswana, Egypt (2), Ethiopia (2), Kenya (3), Malawi (4), South Africa (2), Swaziland, Tanzania (4), Tunisia and Zambia (4)
Questionnaires	93 housing experts and practitioners	January 2010	19	20%	12	Brazil, Colombia, Cuba, Chile (3), El Salvador, Guatemala, **Indonesia** (4), Nicaragua (2), Nigeria, The Philippines (2), Tunisia, and Uruguay
Total of questionnaires			84			

3. Results and Discussion

3.1 OSHH with an international perspective

The international survey has identified 75 organizations that have implemented different types of OSHH projects; 33 organizations in Asia, 20 in Africa and 16 in Latin America. Organizations such as Habitat for Humanity (United States), Homeless International (United Kingdom), Swedish Cooperative Center (Sweden), German Technical Cooperation (Germany), Universidad de Sevilla and Universidad Politénica de Catalunya (Spain) have supported other CBOs or NGOs in implementing OSHH projects in developing countries. In Latin America, Federación Uruguaya de Cooperativas de Vivienda por Ayuda Mutua (FUCVAM), Fundación Salvadoreña de Desarrollo y Vivienda Mínima (FUNDASAL) and Un Techo para mi País have transferred their experience to other countries in the region. Fundación Promotora de Vivienda (FUPROVI) in Costa Rica and Programa de Desarrollo Local (PRODEL) in Nicaragua have inspired many organizations internationally.

3.1.1 OSHH in Africa

In Sub-Saharan Africa, 62% urban residents live in slum-like conditions (Acioly, 2012). A summary of 20 organizations working in 9 countries, from which 7 are Sub-Saharan Africa is shown in Table 2.

Table 2: Key organizations implementing OSHH projects in Africa where the source of information is specified (Q: questionnaires; and I: Internet)

Organization	Project type	Project summary	Source	Website
Botswana				
Habitat for Humanity Botwswana	New housing	New housing for improving overcrowding (A Hand Up…not Hand Out)	Q	http://adloc.com/hfhb/facts.html
Egypt				
Central government	Aided SHH	Aided self-help housing (Build your Home!-Ibny beetak)	Q	http://www.gopp.gov.eg
German Technical Cooperation (GTZ)	Slum upgrading	Self-help inrastructure improvement (Manshiet Nasser Upgrading Project, Cairo)	Q	http://egypt-urban.pdp-gtz.de1.cc/wp-content/uploads/2010/06/Decision-makers-Guide-for-Action.pdf
Ethiopia				
Habitat for Humanity Ethiopia (NGO)	New housing	New housing, renovations and repairs, water and sanitation.	Q	http://www.habitat.org.et
Kenya				
Pamoja Trust (NGO)	Slum upgrading	Slum upgrading (Huruma Kambi Moto upgrading)	Q	http://www.pamojatrust.org
Jamii Bora Trust	New housing	Micro-finance for new incremental housing, production of construction materials and self-help housing (Kaputiei New Town),	I	http://www.jamiibora.se/
Habitat for Humanity Kenya	Relocation	Resettlement of internal ly displaced persons (Maai Mahiu Project), new incremental housing, organized savings, micro-credit for housing.	I	http://www.hfhkenya.or.ke/
Malawi				
Centre for Community Organization and Development (CCODE) and Malawi Homeless People's Federation (MHPF)	Slum upgrading	Slum upgrading and new housing, organized savings, community capacity development, composting toilets and adobe and compressed earth blocks	Q	http://www.ccode-mw.org
Habitat for Humanity Malawi	Slum upgrading / Rural improvement	Improvement loans for rural and urban housing, new housing for orphans and vulnerable children.	Q	http://www.habitat.org/where-we-build/malawi
The Malawi Alliance, Homeless International and CCODE	Relocation	Relocation housing of slum dwellers, production of bricks (CLIFF Blantyre Project)	I	http://www.homeless-international.org/Files/HOM/PDF/A/A/F/hmint107_cliff_ar12_final_lr_43783_1.pdf
Nigeria				
Habitat for Humanity Nigeria and MTN Foundation	New housing	New apartment units, two bedrooms, self-construction, community capacity building (Karu Project).	I	http://www.habitat.org/lc/theforum/spanish/urbano/Viviendas_urbanas_en_Nigeria.aspx
South Africa				
Built Environment Support Group	Slum upgrading	Slum upgrading and community capacity building.	Q	http://www.besg.co.za
Masisizane Women's Housing Cooperative (CBO) and Rooftops Canada	Slum upgrading / Aided SHH	Housing co-operative for housing improvement in slums, production of construction materials, transfer of skills and community capacity building. Partnership with South African central government to implement one pilot project for the People's Housing Programme -an aided self-help housing programme. (Project Ivory Park Ward in Mindrand, 2002).	I	http://rooftops.digcanada.com/CMSImages/file/Emerging%20Coop%20Housing%20Models%20in%20South%20Africa.pdf
The SDI South African Alliance: Federation of the Urban and Rural Poor (FEDUP), The Informal Settlement Network (ISN), The Community Organisation Resource Centre (CORC), uTshani Fund.	Slum upgrading	Organized savings, enumerations and mapping, self-construction of community toilets, and slum upgrading. (Victoria Mxenge Housing Development)	I	http://sasdialliance.org.za
Habitat for Humanity South Africa	Slum upgrading / New housing	OSHH, organized savings, community capacity building, volunteer management of projects (Employers-Employee model, Orphans and Vulnerable Children Programme)	I	http://www.habitat.org.za
Tanzania				
Habitat for Humanity (NGO)	Slum upgrading / New housing	Micro-credit for housing improvement (Makazi Bora house improvement loan) for supporting incremental housing improvement and/or incremental construction.	Q	http://www.hfhtanzania.org/contact.html
WAT-Human Settlements Trust (NGO)	Slum upgrading / New housing	Micro-credit for incremental construction and/or housing improvement, Housing Support Services (technical assistance for self-construction such as client/artisans technical capacity building); community mobilization and community capacity building for regularization projects.	Q	http://www.wat.or.tz
Centre for Community Initiatives (CCI) and Homless International	Relocation	Relocation project of evicted slum families, housing co-operative, self-construction and mutual help (Chamazi Resettlement Project)	I	http://www.homeless-international.org
Zambia				
Habitat for Humanity Zambia	Slum upgrading / New housing	New housing, renovations and rehabilitation, community capacity building, and the Vulnerable Group Housing (VGH) program for orphaned and vulnerable children and their caregivers.	Q	http://www.habitatzam.org.zm/index.htm
Zimbawe National Association of Housing Cooperatives (ZINAHCO) and Homeless International	Relocation	Relocation housing for slum dwellers, training in loan management & construction to cooperatives (CLIFF Mutare Project, Masvingo Project, Kariba Project, Harare Project, Chitungwiza Project and Bulawayo Project)	I	http://www.homeless-international.org/Files/HOM/PDF/A/A/F/hmint107_cliff_ar12_final_lr_43783_1.pdf

From the 20 organizations, 11 work with slum upgrading and relocation projects for slum dwellers. These CBOs and NGOs implement approaches that include OSHH in combination with other support tools like organized savings, micro-finance, community capacity building, production of construction materials, etc. South Africa has implemented an aided self-help housing programme as part of its housing policy since 1994, and slum dwellers have participated since 1991 in exchanges with Asian Coalition for Housing Rights (ACHR) which has contributed in strengthening their own federations. Hence it is possible to compare the results of a top-down approach with the achievements of the bottom-up approach of the South African Homeless People's Federation. Mandela's housing programme accomplished the goal of building 1 million housing in 5 years, but the housing backlog of 4 million houses in 1994 has been addressed only by 2001. Governmental core houses are overcrowded and sometimes 9 people share one room. Conversely, for the Victoria Mxenge Housing Development[8], women have set their own saving scheme since 1991; they have produced their own blocks and self-built masonry houses up to 72 m^2 with 3 bedrooms according to their saving capacity. The size of their houses is 2 or 3 times bigger than the housing provided by the government. By 2001 the federation has self-built 10,000 new houses (South African Homeless People's Federation, 2001).

3.1.2 OSHH in Asia

The results of the international survey show that organized self-help housing has been implemented mostly for re-construction after natural disasters such as tsunamis, earthquakes, volcano eruptions, tornados and floods in Asia. South East Asia Region (SEAR) countries have the larger number of people killed in natural disasters for the period 2000 to 2009[9]. A summary of 17 organizations implementing OSHH for slum upgrading and reconstruction after natural disasters in India and Indonesia is shown in Table 3. The experience in India regarding approaches and tools developed, and the scale of slum upgrading projects led and self-built by the people themselves with technical assistance of NGOs is remarkable. The 12 questionnaires from Indonesia provided information about the work of 11 organizations whose experience on slum upgrading and organized self-help reconstruction will be discussed further in section 3.2.

Asian CBOs and NGOs have been networking more than 30 years[10]. This exchange extended to South Africa and in 1996 originated the creation of the international network Slum/Shack Dwellers International (SDI) with the aim of stressing grassroots democracy and challenge existing paradigms of development[11]. The effect of long term networking is reflected in a continuous learning process based on development-trial-improvement of

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[8] Victoria Mxenge Housing Development was the first self-built housing project implemented by the South African Homeless People's Federation in the mid 1990s.

[9] According to the World Health Organization, the 11 member countries of the South East Asia Region (SEAR) comprised 62% of the total deaths globally, which means 679,294 people. SEAR countries are Bangladesh, Bhutan, DPR Korea, India, Indonesia, Maldives, Myanmar, Nepal, Sri Lanka, Thailand and Timor-Leste.

[10] Networking in Asia started with the work of Father Jorge Anzorena, PhD in Architecture, J.P. His work has been continued then by the Asian Coalition for Housing Rights (ACHR).

[11] The exchanges of grassroots organizations and NGOs within the ACHR constituted the basis for the creation of Slum Dwellers International (SDI) in 1996 (Patel et al, 2001).

different tools for poverty reduction. The SDI method includes organized community savings, enumerations & mapping, self-construction of toilet blocks, slum upgrading. Community-driven development has been key to develop the capacity of grassroots organizations – through the whole project cycle: planning, implementation (including self-construction), decision making and maintenance. The SDI approach has also improved the position of national slum dwellers federations when negotiating with local governments.

Table 3: Key organizations implementing OSHH projects in India and Indonesia where the source of information is specified (Q: questionnaires; and I: Internet)

Organization	Project type	Project summary	Source	Website
India				
The Madurai Corporation (NGO)	Slum upgrading	Slum upgrading (housing and infrastructure)	Q	www.maduraicorporation.in
Hunnarshala Foundation	Reconstruction	Reconstruction after natural disasters (in India and Indonesia)	I	http://hunnar.org/cdh.htm
UNNATI - Organisation for Development Education	Reconstruction	Reconstruction after natural disasters in Western India	I	http://www.unnati.org
Prasanna Desai Architects, Urban Nouveau, the Society for the Promotion of Area Resource Centres (SPARC) and the National Slum Dwellers Federation (NSDF)	Slum upgrading	Incremental Slum Upgrading (Incremental Housing Strategy, Yerawada slum, Pune, India)	I	http://openarchitecturenetwork.org/projects/dlygad2_insitu_rehabilitation
The Indian Alliance: The Society for the Promotion of Area Resource Centres (SPARC), National Slum Dwellers Federation (NSDF) and Mahila Milan	Slum upgrading	In-situ incremental slum upgrading (Yerwada Slum Upgrading: savings, participatory surveys, design and construction, community capacity building, incremental housing with technical assistance in the plots where shacks are located)	I	http://www.sparcindia.org
The Indian Alliance and Homeless International	Slum upgrading	Slum upgrading, research on incremental upgrading, (CLIFF: Bhubaneshwar, Puri, Pune)	I	http://www.homeless-international.org/Files/HOM/PDF/A/A/F/hmint107_cliff_ar12_final_lr_43783_1.pdf
Indonesia				
Ellacuria Foundation (NGO)	Slum upgrading	Slum upgrading, participatory desigh and organized savings	Q	www.ellacuria.org
Habitat for Humanity Indonesia (Faith based NGO)	Reconstruction	Post-tsunami reconstruction , microfinance for incremental construction (Save and Build Program).	Q	www.habitatindonesia.org
Yayasan Griya Mandiri (Griya Mandiri Foundation)	Slum upgrading / New housing	Slum upgrading and new housing (Community Based Initiative on Housing and Local Development-CoBILD Programme)	Q	www.ygmdiy.org
Yayasan Pondok Rakyat (Action Research Group on Urban Development)	Infratructure improvement	Incremental infrastructure improvement	Q	http://ypr.or.id/en
The Neighborhood Upgrading and Shelter Sector Project (NUSSP)	Slum upgrading	Slum upgrading (NUSSP project)	Q	http://www.adb.org/publications/neighborhood-upgrading-and-shelter-sector-project-indonesia
UN-Habitat and United Nationes Development Programme (UNDP)	Reconstruction	Post-tsunami community-driven approach to reconstruction (People's Process) and Integral slum upgrading (Slum Upgrading Facilities).	Q	http://www.unhabitat-indonesia.org/video/video_anssp.html
TRIACO Consultants	Relocation	Integrated slum redevelopment (Mojosongo Riverbank Project, Central Java)	Q	http://faculty.washington.edu/jhou/rim/2004/papers/AntonioRisianto.pdf
Urban Poor Linkage (UP-Link)	Reconstruction	Post-tsunamy reconstruction, community capacity building (23 Villages in Aceh)	Q	http://uplink.atspace.org/
Government of Indonesia Java Reconstruction Fund (JRF)	Reconstruction	Post-multiple natural disasters reconstruction, paid self-built housing, community capacity building (Rekompak Project or Community-Based Settlement Rehabilitation and Reconstruction-CSRRP)	Q	http://reliefweb.int/sites/reliefweb.int/files/resources/650390WP0JRF0P00Box361555B00PUBLIC0.pdf
Catholic Relief Service (CRS)	Reconstruction	Post-tsunami reconstruction	I	www.crs.org
JUB Uplink	Reconstruction	People-driven post tsunami reconstruction	I	www.youtube.com/watch?v=nx-Dm57aqNE&feature=endscreen&NR=1

Due to the scale of slums in Asia, CBOs and NGOs have developed expertise in in-situ slum upgrading projects with an OSHH component with the main aim of community empowerment and capacity building. The Indian Alliance composed by the Society for the Promotion of Area Resource Centers (SPARC), the National Slum Dwellers Federation (NSDF) and Mahila Milan have implemented successfully in-situ incremental slum upgrading (See Table 3) when "construction and cost escalations made the projects unattractive for commercial contractors...Through economies of scale and self-construction and grant support for learning aspects these projects were possible". The in-situ incremental upgrading of Yerawada slum in Pune is an example (Sparc Samudaya Nirman Sahayak, 2012).

3.2 The case of Indonesia: OSHH for slum upgrading and reconstruction

Slum dwellers are still threatened to eviction from informal settlements despite the right to adequate housing is included in the Indonesian Constitution of 1945 (Centre on Housing Rights & Evictions, 2012). Market forces behind urban redevelopment projects are still stronger that human rights and "over 100,000 people were evicted or threatened with eviction" in Jakarta from 2003-2004 (Du Plessis, 2005). The latter although slum upgrading practice in Indonesia has provided basic services such as water, sanitation, shelter and roads; improving the living conditions of 15 million people through the Kampung Improvement Program (KIP)[12](World Bank, 1996). Conversely, community-driven housing processes have been found to be more effective than contractor-led housing in the last decade. The achievements of bottom-up approaches to slum upgrading projects based on community dynamic planning and organized self-help housing have been shown in projects such as Mojsongo Slum Upgrading Project in Central Java (Risianto, 2004). A key respondent to the questionnaires highlights some benefits of OSHH; *"...[it] creates jobs, sense of belonging/ownership, creating an ACTIVITY that develops community cohesion...OSHH is easier and better in slum upgrading mutual-help activities"*.

Mobilization of community resources, seed capital for establishing a revolving fund and community professionals for supporting participatory processes are vital for the work of CBOs and NGOs when implementing slum upgrading with an OSHH component. Ellacuria Foundation integrates housing and economic development through community organized savings and OSHH for housing renovation (SELAVIP, 2009). From the questionnaires, a housing expert argues that *"...the fluctuation of building material prices due to global recession [2007-2008] has significantly affected the continuity of this project. Finding and adhoc funding scheme is a currently major concern of Ellacuria [Foundation]"*. Griya Mandiri Foundation is the local partner of UN-Habitat and United Nations Development Programme (UNDP) working with "community-based housing" and micro-credit for slum upgrading and new housing. Another key informant from the questionnaires explains some advantages of OSHH *"... [it] is effective and efficient; the cost is much reduced if all works are organized by local people. They feel that the facilities that construct by themselves are owned by them. [OSHH is] integrated and comprehensive in terms of money and the duration of works. However, [there can be] difficulty in coordination in the beginning, and [there can be] social*

[12] KIP improved the living conditions of 15 million people through the provision of basic services such as water, sanitation, shelter and roads (World Bank, 1996).

complications between communities that are not involved directly in terms of works for cash [–working for money]". Another Indonesian housing expert provides data through the questionnaires that support the argument for an organized self-help housing approach in slum upgrading as an effective tool for overcoming poverty: *"I think that many cases in Indonesia show that slum-upgrading and self-help housing can improve the social capital, productivity and health. In Pekalongan, two years after the slum upgrading/self-help housing program was launched, poverty rates reduced by 27%. There was a significant improvement in health and productivity due to better quality homes. The poor could utilize part of their house to support productive home activities. Also self-help housing through micro-credit or rotating funds can improve the community's self-esteem and confidence by providing the opportunity for them to pay back and not a charity case. The participation of the community in the project can also support the sustainability of the program, as they have larger commitment to maintain the housing environment".*

The 2004 Indian Ocean Tsunami following a 9.1 magnitude earthquake killed approximately 129,775 people in Indonesia (Doocy, et al., 2007); with a scale of damages that has had no precedent. In Aceh, this worsened due to another earthquake on March 2005 and from both disasters 167,000 people were reported dead or missing, 500,000 people were made homeless, 120,000 houses were destroyed or severely damaged and 25% of the population lost their livelihood. The approaches to reconstruction from international agencies ranged from delivering turnkey houses to housing by people. Reconstruction after natural disasters has shown to be more complex than slum upgrading. The six first months after the tsunami have evidenced the lack of local institutional capacity for coordinating more than 100 local NGOs and international agencies participating in housing reconstruction (Da Silva & and Batchelor, 2010); and also bureaucracy and corruption in managing huge financial resources from international aid. Through a people-centred and participative process led by the government, 125,000 permanent houses have been built. According to UN-Habitat (2005b), the physical reconstruction by the affected families has contributed to their social recovery because it has fostered community cohesion and development; and it has strengthened networks due to mutual help which is a key aspect to sustainable recovery. Conversely, some international agencies have implemented contractor-build programmes in Aceh arguing that contractor manage speed better than communities self-building by themselves. Da Silva & Batchelor (2010) argue that self-build programmes in Aceh have shown the following advantages: affected families have initiated earlier the recovery process with a sense of ownership and purpose; the process has promoted dwellers control for housing and settlement design, and construction; and, the reconstruction process has contributed to overcome trauma sooner. From the questionnaires, a housing expert emphasizes that *"at the end of the [reconstruction] project, the locals had acquired and remained with all these skills inter alia [make fire cured clay bricks... bend reinforcement bars... set levels... basic carpentry and bricklaying techniques]. They will use [these skills] to repair and renovate their houses, or to outsource their skills for income generation and poverty alleviation... in case of another Tsunami, they could handle their own reconstruction with very little assistance."*

There are several important lessons from post-disaster reconstruction in Indonesia after the 2004 tsunami. First, the recognition of *the power of people themselves* and the technical assistance have been key resources for reconstruction. Secondly, the magnitude and

recurrence of natural disasters has shown the need of local capacity for more coordinated multi-stakeholder partnerships among government, CBOs, NGOs, international and multilateral agencies. Thirdly, the Asian Development Bank highlights that the need of improving the capacity of local communities to provide fast relief and cope more efficiently when facing natural disasters has to be prioritized (Jayasuriya, 2010). Finally, an European survey on the Rekompak project shows that dwellers control provides higher satisfaction because affected families have contributed to housing design, procurement and self-construction process achieving better quality housing *(World Bank, 2012).*

4. Conclusions

This paper concludes that in the last decade, there are many new experiences on organized self-help housing in developing countries. Hence, the need for more systematic research on the OSHH process to provide feedback to the urban planning practice and policy makers in developing countries. The scale of intervention of organized self-help housing projects has increased in the current practice in Asia, demonstrating that 'scaling up' slum upgrading is possible when the processes are led and organized by the people themselves with technical assistance of NGOs. There has been more action in terms of testing different types of OSHH projects than academic debate. This reaffirms the need for generating more systematized knowledge that allows drawing theory from empirical based knowledge, to propose ways of improving current practice and influencing housing policy. The paper has shown that the type of OSHH projects has shifted from new housing for a non-predetermined community to slum upgrading and relocation projects of specific slum dwellers who lead the OSHH process. In a slum, the community has already developed their social capital and networks – social, business, political activities – and this contributes to community empowerment of the OSHH process. Slum dwellers are more affected by natural disasters; but when they are organized and have developed their capabilities they are able to mobilize their own resources to lead and implement organized self-help reconstruction[13] (OSHR) processes more efficiently. Investing in slum upgrading programmes with an organized self-help housing component or approach will contribute in strengthening the capabilities of the communities making them more resilient when facing natural disasters.

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Analysis of seismic vulnerability of structures and estimating the vulnerability of technological systems of the hospitals in the Molise Region (Italy)

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Seismic classification in the Molise Region

In the Molise region by the 1915 earthquake in Avezzano until 1981 all municipalities in the Isernia province and a large number of those of the Campobasso province have been incorporated gradually in areas subject to seismic risk. The earthquake of 2002 struck some municipalities in the Campobasso province that were not included in the seismic classification of causing severe damage and the collapse of a school in the municipality of San Giuliano di Puglia causing many casualties among students and teachers. As a direct result of this event the Presidency of the Council of Ministers issued the Ordinance no. 3274 of 20 March 2003 "First elements on general criteria for the seismic classification of the national territory and technical standards for construction in seismic areas", where, in addition to the definition of new "Criteria for the identification of seismic zones," has been made mandatory control of the seismic resistance of all strategic buildings and infrastructure works that assume an important function during seismic events for civil protection, including hospitals.

Keywords: earthquake, seismic vulnerability, strategic buildings, damage, hospitals

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1. Introduction

Following the entry into force of the new seismic classification and new technical standards for buildings are under the Ministerial Decree of 14 January 2008, the Health Service of the Molise Region has decided to proceed with the implementation of a plan for seismic monitoring of Hospitals regional considered strategic and relevant. To ensure the effectiveness of the action through technical and scientific knowledge in order to achieve the reliability and consistency of the results for an objective evaluation of the risk status of the hospitals the Department of Health of the Region has entrusted the Institute for Construction Technologies the National Research Council of L'Aquila, the task of making the necessary seismic inspections, including surveys and experimental investigations extended to all hospitals and preliminary identification of possible seismic retrofitting required with relative estimate of the costs of intervention. The main objectives were to assess the level of seismic safety of each garrison, and, based on the results of surveys and assessments, identify key structural weaknesses and, therefore, define the possible intervention strategies for the implementation of preventive measures and quantify the economic resources necessary to achieve an adequate level of seismic safety or identify cases where it is appropriate to replace the building.

In addition to the traditional activities such as audit evidence about the structures and investigation of foundation soils was also conducted a qualitative study of the level of vulnerability of the buildings is that of all the non-structural elements and systems that could affect the functionality of hospitals after the seismic event. So also were examined partitions, ceilings, lifts, distribution networks mechanical equipment and medical gases, electrical panels, lighting systems, generators, fuel tanks, gas cylinders, medical equipment and glass walls to a great extent. The analyzes were performed with priority given to services whose functionality is considered to be strategic due to a seismic event. This approach has made it possible to minimize the costs of the checks to the advantage of the funding for the interventions themselves, while taking into account new technical standards for construction in 2008 and to obtain useful results for the regional planning by defining priorities for action and the related cost estimates for assessing the economic viability of a seismic upgrading compared to demolition and reconstruction.

2. Seismic recommendations in hospitals

The hospitals studied were especially prone to seismic risk because of their vulnerability and high exposure lotus (crowding) and also because they were designed and built in seismic areas classified only after their completion. From the regulatory point of view, reference was made to "ATC-51-1 Joint Recommendations United States - Italy for the preparation of emergency plans in hospitals seismic Italian" and "ATC-51-2 Recommendations joint United States - for Italy reinforcement and anchorage of non-structural components in Italian hospitals "and, for each hospital, were given the following information on the non-structural components: general information of a technical nature, including the description of the damage in past earthquakes, specific recommendations for strengthening and the anchoring of 27 different types of components, a guide on the design of devices for the seismic anchor.

The study allowed us to assess the state of the plants and their level of vulnerability and provide the necessary information about the possibility of adapting or replacing structures or facilities. For each hospital has been produced a ranking of vulnerability of the structures and functions of the various non-structural components (from most critical to least critical). E 'was also calculated the cost needed to reduce the vulnerability of the individual components without necessarily proceeding to structural adjustment. From the information gathered it was possible to relate the cost of intervention to the structural and non-structural conditions of the individual hospitals depending on the seismicity of each zone: for hospitals to Isernia, Venafro and Larino will need to act on all the components, Agnone only for a part and Termoli 's intervention may be even more reduced.

For hospitals of Agnone, Isernia, Venafro Larino and for the high structural vulnerability, you should not upgrade facilities without any prior structural adjustment, while the Hospital of Termoli to the low vulnerability of structure and low seismicity of the site it is possible to upgrade the facilities without any preliminary structural adjustment.

3. Hospital "Vietri" of Larino example

In the following, by way of example, shows the summary report of the Hospital "Vietri" of Larino. This hospital complex is housed in an imposing structure located in the peripheral area to the urban center of the City of Larino in an area with low slope (about 8%) that produces a difference in elevation of the ground surface from upstream to downstream of about 12 meters. It 'been possible to find the structural design of the reinforced concrete structure and the preliminary draft on the activities of the post-earthquake of 2002. It 'was then reconstructed the history of the hospital complex that was built in 10 lots, between 1971 and 2000 (year of completion), of which only the first three have involved structural work that was completed in the mid-eighty. The building consists of a reinforced concrete frame in large (about 151.50 x 151.50 m in plan) that is spread over 5 levels to a maximum height of the eaves at about 19 m from the plan 'sets of foundations built on plinths isolated and is designed for vertical loads only. Foundations, due to the morphology of the area, have shares tax very variable.

The covering structure, realized with slabs in RC dimensions of 35 +5 cm, lying on a straight staggered in order to ensure a sufficient exposure to light even to the most internal. The floors are made of inter-a.c. with dimensions 25 +5 cm and are not aligned to the entire surface of the structure. The bearing structure is made up of RC walls and pillars that have a regular grid plan of about 7.2 m in two main directions. Some cases have vertical joints made in part to partial height (joints that start at about half pillar) that continue even on the structures and horizontal coverage and end up on the roof with the probable function to allow for thermal expansion without inducing expected compulsions. For some joints have been provided for the works of solidarization of the vertical elements made of steel hoops to the head of the pillars. Beams, for most AC, are generally generous in size but do not guarantee the connections between all the pillars.

According to the documentation recovered, the site investigation, the geometrical surveys and investigations carried out in the campaign it was possible to summarize the structural

problems encountered: the existence of a plan to 'stilts' in height up to 14 m; presence of pillars in large slenderness (height up to 14 m); irregularities in the distribution of stiffness in plan due to the presence at the first level of pillars with strong difference in height between the upstream and downstream and of baffles in an eccentric position; presence of joints (for most 'closed' by inclusion of works of solidification) arranged in an irregular manner; presence of overhangs large (up to 3.5 m); deformation of the decks in their plan due to the large size of the building plan; septa equipped with armor of small diameter and large pitch; poor shear strength of the structural elements, in particular the vertical ones; the presence of a long corridor with walls made of reinforced concrete supported by beams.

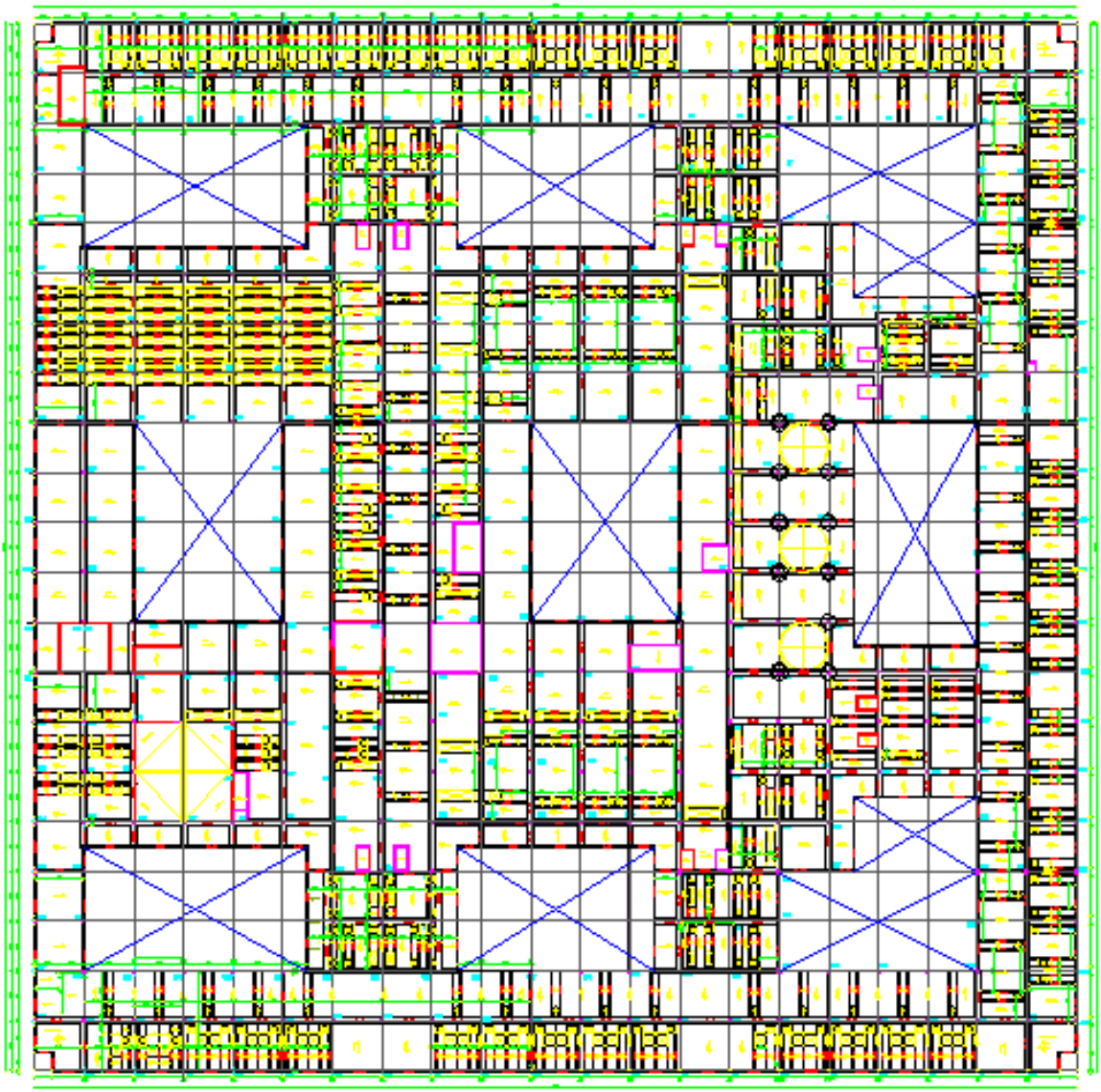

Figure 1: Map of the last level

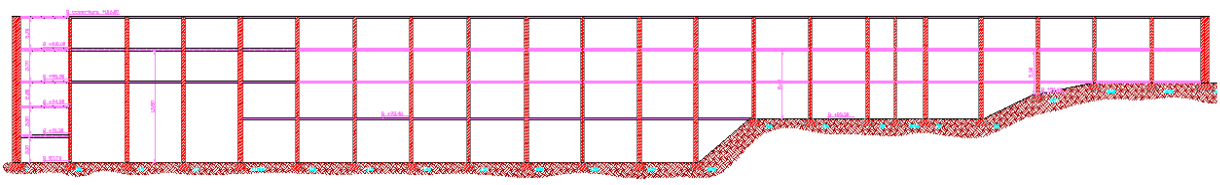

Figure 2: Section

The results of the tests showed the presence of a concrete having average resistance of about 25 MPA N / sq.mm with a value (high) of the depth of carbonation (variable between 40 and 65 mm), little protection of the reinforcement for porosity of the concrete, a high corrosion rate and a presence of corrosion in the pillars and beams.

The brackets of the pillars have variable distance between 20 cm and 30 cm, section 6 and 8 mm while for the beams has the same section with variable pitch between 30 and 40 cm and presence of irons bent. For brackets was used mainly round and smooth and ribbed steel for beams and columns. The fixtures have been sized on the basis of seismic activity related to the second category referred to seismic classification of DM 03/03/75 ag which corresponds to a reference about 0.18.

An intervention strategy for 'seismic retrofit of structures is very closely related to the configuration planimetric and altimetric and weaknesses of the body construction of the building. The survey results showed the presence of a structure not adapted to current seismic code.

To achieve the objective of adaptation interventions are planned consolidation of structures with steel plates, bandages and bracing elements in FRP reinforced concrete or steel. To eliminate the above-mentioned drawbacks construction is expected to reduce the height of the pillars and stabilize the structure with technical joints in places where they had originally planned. To reduce the height of the pillars is possible to provide for the realization of one or two decks intermediate stiffening horizontal or systems that interrupt the height of the pillars.

The technical joints can be achieved through the construction of new piers at a short distance from existing ones. Such intervention to be very invasive and substantially change the appearance and configuration of the structural complex. The realization of the horizontal stiffeners could encourage the creation of new surfaces at the service building. To reduce the costs of intervention was also examined the possibility of realizing an insulation at the base of the pillars with elastomeric isolators.

This project involves the installation of insulators below the altitude of the ground floor, the implementation of a plan to drive this share over tightening intermediate in the light of the pillars with excessive costs.

Alternatively was hypothesis intervention which allows a significant improvement with no high costs is that of providing local works which would improve the response of the structure. They are related primarily to the strengthening of the external nodes, with technical notes that provide confinement with composite material (intervention aimed also to a strict compliance with the instructions given in the regulations), and the introduction of a system of bracing steel posts also in correspondence of the structures to pilotis that would have the dual function of bracing the building and suspend large free spans of inflection of the pillars that constitute a structural inadequacy that evidently has a negative impact on the whole structure.

The level of security achieved with assistance of local reinforcement is equal to 45% of a capacity equal to 0.10 g. To estimate the costs of intervention are referred to the costs incurred for seismic upgrading of public facilities in Molise following the earthquake of 2002 and the estimated cost for the reconstruction of private hospitals in Abruzzo.

Given oh the seismic action hospital complexes and the additional cost due to the presence of complex systems has been assumed an average cost of 800 euro / sqm for the adaptation of structures and 300 euro / sqm for plants for a total of 1100 € / sqm. Were computed in addition to the interventions of high technology for the mitigation of seismic risk as base isolation, the dissipative braces.

The estimated cost for seismic upgrading is approximately € 34,185,046.50 as shown in the table below. The cost of seismic improvement was estimated at about 4 million euro.

4. Summary of costs of intervention and assessment of vulnerability

The table shows the estimated costs of intervention for seismic upgrading of structures and facilities. In addition, it was considered the cost for the recovery of medical implants variable between 20% and 40% of the cost of technological systems in the invasiveness of structural function.

HO	square	techonoligical implants	medical implants	Costs
Agnone	7,393.20	2,217,960.00	40%	887,184.00
Larino	52,062.77	7,809,415.50	30%	2,342,824.65
Isernia	19,350.60	7,840,240.00	40%	3,136,096.00
Isernia	11,517.34	4,606,936.00	40%	1,842,774.40
Termoli	31,046.71	4,657,006.26	20%	931,401.25
Venafro	22,037.00	6,611,100.00	40%	2,644,440.00
Totale	**143,407.62**	**33,742,657.76**		**11,784,720.30**

Table 3: Summary cost recovery medical implants

HO	sup	structures	implants	medical implants	costs	costs mq
Agnone	7,393.20	5,914,560.00	2,217,960.00	887,184.00	9,019,704.00	1,220.00
Larino	52,062.77	26,375,631.00	7,809,415.50	2,342,824.65	36,527,871.15	701.61
Isernia	19,350.60	20,550,600.00	7,840,240.00	3,136,096.00	31,526,936.00	1,629.25
Isernia Dea	11,517.34	11,517,340.00	4,606,936.00	1,842,774.40	17,967,050.40	1,560.00
Termoli	31,046.71	9,314,012.51	4,657,006.26	931,401.25	14,902,420.02	480.00
Venafro	22,037.00	13,222,200.00	6,611,100.00	2,644,440.00	22,477,740.00	1,020.00
Totale	**143,407.62**	**86,894,343.51**	**33,742,657.76**	**11,784,720.30**	**132,421,721.57**	**923.39**

Table 4: Summary cost of seismic improvement

Buildings	Structural vulnerability	Implants e non structural components vulnerability
Francesco Caracciolo Agnone	***HIGH***	***MEDIUM-LAW***
G.Vietri Larino	***HIGH***	***HIGH***
F.Veneziale –Isernia	***HIGH***	***MEDIUM-HIGHT***
F.Veneziale – DEA – Isernia	***MEDIUM-HIGHT***	***MEDIUM***
SS. Rosario - Venafro	***MEDIUM-HIGHT***	***HIGH***
San Timoteo di Termoli	***MEDIUM-LAW***	***LOW***

Table 5: Synthetic evaluation of structural and implants vulnerability

Prevention of Work Related Musculoskeletal Injuries in Construction Trades in Palestine

Adnan Enshassi [1], Eman Al.Swaity [2]

Abstract

Workers in construction trades experience high rates of injuries and illnesses, including work-related musculoskeletal disorders. Musculoskeletal disorders continue to be a major source of disability and lost work time. Understanding their causes that are work-related remains the key to primary prevention. The objective of this paper is to identify the nature of work-related disorders that are suffered by workers and their risk factors. Several construction projects in the Gaza Strip were investigated using a representative sample of 135 persons from the construction workforce. The survey instrument assessed the prevalence of work-related musculoskeletal symptoms and identified job factors that may contribute to those symptoms in construction field. In addition several interviews were held, and pre-site visit forms were filled to support the proposed study. The findings showed that back, shoulders, wrists/hands, and knees symptoms are the most prevalent problems among the workers. Awkward postures and working in the same position for long periods were identified as the leading causes of work-related musculoskeletal symptoms. The findings of this study can be used to formulate appropriate intervention strategies for the reduction of musculoskeletal symptoms for construction workers in the building trades. Strategies for preventing musculoskeletal disorders should be carried out to reduce the burden of high physical workload and repetitive work in construction projects and especially in masonry industry.

Keywords: Construction, disorders, ergonomics, musculoskeletal, strategy.

1. Introduction

Construction is a high-risk sector. It is not only affecting a worker's safety, but also his health. While there are well over a thousand workers killed each year in accidents in the construction sector, there are also many more who suffer ill health. Musculoskeletal disorders are some of the most common forms of ill health in construction (Bonde et al 2005). Musculoskeletal disorders are particularly prevalent across a range of construction industry trades which affect the workforces. Masonry industry (which includes brick masons, block, concrete, plastering, and other building construction activities) reports a high prevalence of work-related musculoskeletal disorders (WMSDs). Many of which can be prevented with identifying the reasons of such disorders then making appropriate changes in materials, work equipment or work practices (Geoffrey et al 2008) .

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Construction workers are exposed to many serious safety hazards. Prevention is difficult in this sector because the work environment is constantly changing. Different types of construction work are often associated with different types of injuries. For example, workers who do overhead work, such as painters and sheet metal workers, tend to have many more shoulder and neck problems (Caicoya et al 2010). Trades at the highest risk of shoulder problems include: scaffold erectors, insulators and painters workers who work at floor level and kneel while working, like floor layers and roofers, sheet metal workers and insulators have many more knee problems. Carpenters and other trades that require constant use of hand tools, have more hand and wrist problems. Tendonitis in construction workers is most common among roofers and sheet metal workers and masons. Working as a labourer or scaffold erector where heavy lifting and carrying is common, is associated with back problems. Each of these types of work exposes the construction worker to a different type of risk factor. Risk Factors are activities, actions, conditions or exposures that can increase the chance (risk) of developing a musculoskeletal disorder (Jim et al 2005).

Masonry industry workers perform many different jobs and tasks. The work is physically demanding, involving stocking and laying of block and brick, stocking and setting of tile, mixing and stocking of mortar and grout, and assembling scaffolds (Choobineh et al 2007). Lifting and carrying of materials is common, as well as repetitive motion, high hand force, reaching overhead, and bending of the back or neck, for certain tasks. These exposures can lead to WMSDs (Davis, 2002). Since Masons working with concrete masonry unit block have high rates of work-related musculoskeletal disorders associated with repetitively lifting and buttering heavy block, the focus of this paper is on the concrete and masonry workers. This study is limited to housing construction projects. This paper aims also to investigate the implementation of a guidelines-based intervention and to determine whether it is effective for reducing work related musculoskeletal injuries.

2. Literature review

The term musculoskeletal disorder denotes health problems of the locomotors apparatus, i.e. of muscles, tendons, the skeleton, cartilage, ligaments, and nerves (Alwin et al 2003). This was stated in other words by Lura and David (2004) that musculoskeletal disorders include a wide range of inflammatory and degenerative conditions affecting the previous parts. These include clinical syndromes such as tendon inflammations, nerve compression disorders, osteoarthritis, less well standardized conditions, low back pain and other regional pain syndromes not attributable to known pathology (Nimbarte et al 2010). Body regions most commonly involved are the low back, neck, shoulder, forearm, and hand. Musculoskeletal disorders include all forms of ill-health ranging from light, transitory disorders to irreversible, disabling injuries. The musculoskeletal disorder, which are included or aggravated by work and circumstances of its performance are supposed to be caused or intensified by work, though often activities such as housework or sports may also be involved (Denisa et al 2008).

Work-related musculoskeletal disorders (WMSDs) are defined as impairments of bodily structures such as muscles, joints, tendons, ligaments, nerves, bones or a localized blood circulation system (Podniece, 2008). WMSDs are a common health problem and a major

cause of disability (Geoffrey et al 2008). As a result there has been an increasing effort in recent years to investigate the causes of WMSDs and to take action to prevent them. This has led to increasing recognition from workers, employers and government agencies that a strong relationship exists between factors within the working environment and the development of WMSDs. These conditions result in significant sickness absence and reduced productivity (Buckle, 2005). WMSDs can interfere with activities at work and can lead to reduced productivity, sickness absence and chronic occupational disability (Podniece, 2008).

Construction workers across most trades are at significant risk of musculoskeletal injury. The physically demanding nature of the work, awkward and static postures, vibration, harsh outdoor environment, and related risk factors help explain why strains and sprains are the most common type of work-related injury in construction (Pamela et al 2007). The physical job features that are frequently cited as risk factors for MSDs, based on both experimental science and epidemiologic investigations which include rapid work pace and repetitive motion patterns (Laura and David, 2004).

The cost to the worker of WMSDs is pain, along with loss of income through being unable to work (Ronald et al 2010). This results in significant cost to organizations through sickness absence or ill-health retirement, and to the government, that may have to support a person unable to work. Musculoskeletal disorders (MSDs) are widespread in many countries, with substantial costs and impact on quality of life (Silverstein and Clark, 2004). Working in the building and construction trades has been linked to serious and costly health risks, including risks for musculoskeletal disorders. Schroeder (2009) stated that in the United States it is estimated that the total economic cost of work-related injuries is $160 billion per year. In 2005, $80 billion was spent on wage and productivity replacement, $31.3 billion in medical costs, and $34.4 billion in administrative costs. In 2005, 60% of work injuries were musculoskeletal disorders (MSD).

Prevention and management of MSD in the workplace has been given much attention over the past years. The term “ergonomics” is sometimes used to describe the approach for addressing musculoskeletal disorders (Gervais et al 2003). Many approaches have been implemented by employers in an effort to control the costs associated with MSD. Using a physical therapist to develop and implement an ergonomics and first-aid program was successful in preventing and managing MSD. It illustrates how a combination of ergonomics and improved injury management tactics reduced clients MSDs by 75% and has maintained this reduction to the current date (Schroeder, 2009). Significant ergonomic improvements may be achieved by decreasing brick/block weight. Raising the brick/block supply and mortar supply off of the ground has been shown to significantly reduce lumbar compression, biomechanical stress, and energetic workload, while increasing bricklayer comfort (Henk et al 2005).

3. Research methodology

This research was conducted as an exploratory study. Potential participants for this study comprised 135 individuals, randomly selected from 7 building construction sites and were

interviewed. The criteria adopted for selecting the working site was based on diversity of activities that were held. The interview sought information on demographic characteristics (including age), lifetime work history, current self-reported physical, psychosocial, organizational and environmental factors, and various health conditions. The present research reports only the data which was defined as the presence of any existing or acquired trouble (aches, pains, discomfort, and numbness) during the last two years. Binary choice (yes/no) questions were used to associate WMSDs with seven anatomical regions: neck, shoulders, elbows, wrists/ arms, back, knees, and ankles/feet. Seven job activities and related tasks performed by prevalence construction industry were identified. It includes formwork, building, concrete, tiling, plastering, transportation, and electrical activities. Several construction projects were randomly selected for this study. In-depth semi-structured interviews were conducted with construction workers, contractors, subcontractors, or inspectors working with specific construction projects selected for the study. The interviews were conversational and open-ended. The visit includes identifications of the work places, the principal factors of the risk, and the analysis of the work environment and the observation of the activities performing way in the building construction sites.

For each task, participants were asked to identify the following usual and variable features of the WMSD risk: (1) the body areas at risk for developing WMSDs and specific risk factor if possible, (2) the methods used in the scope of pain reduction, (3) the source of each risk factor, and the task conditions affecting the intensity of the risk factor (if it is not possible observation will take place). To perform the task effectively pre-site visit forms were prepared. These forms included the mentioned three parts of information in tabulated format. A suitable space was allowed for any additional comments from the participants. The collected data were analysed using SPSS for Windows 18.0 software package through descriptive analysis, relative importance index and ranks.

4. Results

4.1 Prevalence of MSDs for each body region

Table 1 presents the prevalence of MSDs symptoms in different body regions of the workers. As illustrated in Table 1, the highest prevalence was for the back (50%), followed by the neck (28%), shoulders (27%), knees (16%), wrists/arms (11%), and legs (7%). The lowest prevalence was for the elbows (3%).

According to the interviews with workers, the majority of workers across all seven occupational groups affirmed that the back, neck, and shoulder pains are the prevalent form of musculoskeletal pain that often came from performing their job tasks. However, the locations of pain such as wrists, elbows, and legs were rarely mentioned by workers. Welch, et al. (2009) has more common results. In their study 38% of the respondents had an upper-body musculoskeletal disorder, 37% had a low-back condition or sciatica, and 26% had lower-body musculoskeletal disorders. Another study conducted by Sobeih, et al. (2009) also has similar results; the highest prevalence was for the back (38%), but followed by the Knee/legs (14%). The neck and shoulders symptoms were not significant (7%).

Table 1: Different locations of pains as reported in occupational groups

Occupational group of workers		Body parts location of pains						
Occupational group	Number	Neck	Back	Elbow/s	Shoulder/s	Leg/s	Knee	Wrist/Arm
Formwork workers	40	17	20	1	11	0	4	2
Building works	16	0	8	0	6	1	0	1
Concrete workers	37	15	18	2	5	1	5	4
Tiling workers	4	0	3	0	1	1	2	0
Plastering workers	13	4	5	0	4	2	0	3
Transportation workers	20	2	9	1	8	4	8	2
Electricians	5	0	4	0	2	0	2	3
Total	135	38	67	4	37	9	21	15
Percentage		28%	50%	3%	27%	7%	16%	11%

4.2 Methods used to reduce pains

In the interviews, workers have expressed several control measures they used or applied in order to reduce or even prevent the musculoskeletal pains that interfered with their work. These measures are listed in Table 2 below. Many of those measures mentioned by workers are common to most of the seven occupational groups. Other control measures that came up in the interviews seemed to be significant to some workers groups, and not at all mentioned by other occupational groups.

Table 2: Methods used to reduce pains by the interviews with construction workers

Method used by group of workers	Occupational workers groups / Number of workers							
Control measures	Formwork	Building	Concrete	Tiling	Plastering	Transporting	Electricians	Total
	40	16	37	4	13	20	5	
Physical exercise after work	2	3	0	0	0	6	0	11
Rest on weekends	25	2	15	1	5	8	2	58
Keep upright work posture	5	3	3	1	3	0	2	17
Pain killers intake	5	5	7	1	2	2	1	23
Work rotation/change	1	1	3	0	0	2	0	7
Massage therapy	1	2	4	1	3	2	0	13
Others	0	0	5	0	0	1	0	6

These are some of the solutions or best practices applied in the construction workplace that have been known for reducing or eliminating the work-related musculoskeletal problem among workers. The results show that (43%) of the workers rely on weekend rests to reduce the effect of

work pain. However, (17%) of them prefer to use pain killer as fast and effective mean and (13%) of the workers used message therapy.

4.3 Observed work-related risk factor

According to the interviews, workers have indicated that there is a delicate balance between work requirements, the control over them and the resources available to achieve those work demands. Workers have expressed that work demands were often large while the human resources (construction workers) to achieve these demands are sometimes limited due to absenteeism within occupational groups working on the site in small numbers.

Table 3: Observed Work-related factors influencing health in occupational groups of workers

Work-related factors	Occupational workers groups / Number of workers							
Control measures	Formwork	Building	Concrete	Tiling	Plastering	Transporting	Electricians	Total
	40	16	37	4	13	20	5	
Awkward work posture	25	8	17	2	6	5	1	64
Weight handled	0	1	4	1	0	15	0	21
Lack of variation	3	2	0	2	3	7	1	18
Work cycle duration	19	3	6	0	4	4	2	38
High Work place	3	4	3	0	3	1	1	15
Little Work space	1	0	0	2	1	1	0	5
Inadequate work environment	0	1	1	1	4	2	0	9
Age factor	2	2	9	0	0	0	0	13
Improper work equipments	3	0	0	0	0	0	0	3
Heavy work load	5	6	2	3	0	7	0	23
Other factors	0	1	0	0	0	0	0	1

As illustrated in table 3, the majority in each group of workers awkward work postures had an impact on their musculoskeletal health. Working above shoulders, working on knees and static work led to awkward work postures. Some workers expressed that some awkward work postures are due to cramped workspaces or/and lack of appropriate hand tools and mechanical aids which restricted workers from performing their work tasks in a good work posture. The following risk factors were the long work cycle duration and heavy work load. The next factor was the handling of heavy materials since all workers groups except the machine operators stated that manual material handling was still a problem to their musculoskeletal health. These results are compatible with studies held by Jennifer et al. (2010). However, several workers in all occupational groups have acknowledged that

recently there has been a decrease in manual material handling due to more mechanical aids (such as lifts, cranes, carts, trolleys) being brought in on construction sites.

4.4 Respondents previous experience with WMSDs

135 workers who were interviewed, it was found that only 6 workers participated in previous events affected their life. Three masons had a history of back surgery; two of them returned back to work but not to their previous activities; they are now doing easier jobs. Unfortunately, the physical treatment and surgeries didn't achieve the perfect desired results. The third one has been stopped practicing work for 4 years and up to date he didn't come back to work. On the other hand, three participants were in work site and they are suffering from chronic disabilities. Their bend back were the main evidence of musculoskeletal disorders. Finally, the contractors and subcontractors in general complained from the repetitive absence of some workers. The majority of absentees ask for rest due to their chronic pains.

5. Conclusion and recommendations

Tasks commonly performed by block, brick and tile workers in the masonry industry were reviewed, and those tasks with potential work-related musculoskeletal disorder (WMSD) hazard exposures. Hazard control examples for reducing these risk factor exposures were identified. The implication of this paper is to help employers and workers comply with the new rule by identifying masonry-specific WMSD hazards that may exceed the limits specified in the rule, and to suggest possible controls for those hazards. The study showed that symptoms from the musculoskeletal system were common among the construction workers studied. Back, shoulders, wrists/hands, and knees symptoms were found to be the most prevalent problems among the workers. High rate of shoulder problems could be attributable to awkward posture and high rate of back problems could be related to the long awkward posture of this region. These implies that any interventional program for preventing or reducing musculoskeletal problems among the workers should focus on reducing physical exposure to the MSDs risk factors of these regions.

Based on the results there were various factors that have been investigated as work-related ergonomics stressors for disorders, but it is the physical factors that are suggested to contribute most to incidence of symptoms. In respect of the physical factors, there is medium evidence of a causal association for kneeling/squatting and heavy lifting. The results also demonstrate that awkward working postures and repetitive work were found to be the major risk factor that the workers were encountered. Since the postural problems have been found to be largely causing factor, the following corrective measures could be taken in consideration for reducing exposure level and consequently preventing WMSDs among construction workers: using seats with appropriate heights, conducting workers training program on working posture and devising an appropriate work-rest cycle.

Based on the findings, it was concluded that WMSD occurred in high rate in construction work. Workers' level of exposure to WMSDs risks was high. Taking corrective measures for reducing risk level into consideration seemed essential. Any ergonomics intervention

program in the workplace should be focused on eliminating awkward postures of shoulders, back, and neck.

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Maturing workplace culture in the context of evolved ethical agency

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Abstract

Culture is a concept and a descriptor of concrete examples of cultures within which man stands as the embodiment and the maker of culture and morality. This presupposes he is a self-reflective agency capable of decision-making and with the capacity to act independently. Geertz described culture as a system of uniquely human controls, a consequence of which is that morality or ethics reasoning is fundamental to culture. Kohlberg outlines an invariant progress towards ethics reasoning in a universal context, passing though the early stages of reasoning; self-interest, group interests and rule-following. These earlier stages negate autonomous action in favour of heteronomy, a rationale based on internal and external constraints.

Workplace cultures are necessarily dynamic, comprising multiple agents continuously entering and departing the matrix. The safety aspect, often defined as "the way we do things", is substantially more and deeper than a simple behaviour pattern. It is the outworking of reasoning at all levels and the perception of agency by stakeholders. Culture and ethics are identical in this model and in identifying cultural maturity the authors found that maturity is evolved cultural/ethical agency, simultaneously transpersonal and interpersonal.

The authors' ethics reasoning research with undergraduates on the BSc Quantity Surveying programme found the level of reasoning necessary for independent decision-making lower than expected and that students' actions were guided by heteronomous reasoning that is at best morally ambiguous and at worst capable of lending itself to workplace practices that sacrifice safety for profit. Expanding the work of Kohlberg and Eckensberger this paper develops the ethics reasoning research, linking it to culture and the maturity levels of individuals and organisations to illustrate the efficacy of formal intervention to develop the cultural and ethical maturity of professionals and the positive affect on their occupations.

Keywords: Workplace Culture, Ethics Reasoning, Maturity.

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Introduction

Globally the construction industry has a reputation that generally falls well below what can reasonably be called ethical, being as it is an environment where competition between contractors leads to a low price mentalities, fierce competition and paper-thin margins and thus to quality and safety reductions to cut costs and save time, (Hamzah Abdul-Rahman et al. 2007, 2010). Hamzah et al (2007, 2010) summarised research in Australia and South Africa that identified several unethical conducts and ethical dilemmas in the construction industry such as; corruption, negligence, bribery, conflict of interest, bid cutting, under bidding, collusive tendering, cover pricing, frontloading, bid shopping, withdrawal of tender, and payment game. In 2003 the Cole Royal Commission (cited in McCarthy 2012) reported on a general disregard for the law in the construction and building industry and the Building Industry Task Force in 2005 and 2006 reported that the "industry remains plagued by a culture of civil disobedience, coercion, intimidation, threatening behaviour, and the contempt for the law". Construction Forestry Mining and Energy Union (CFMEU), however refuted the Cole Commission process as being contrary to natural justice and the particular assertions of 'thuggery',on the part of workers in the industry (Roberts 2003).

Some four years into the global recession in which construction has suffered badly as a result of the cancellation or suspension of major infrastructure projects, negative equity housing and the banks calling in of loans from small contractors, competition and reduced margins remain a central feature of a landscape in which the International Labour Organisation (ILO) World Congress on Occupational Safety and Health [Seoul 2008] predicted that such a climate would have a direct negative impact on the safety and welfare of workers as employers sought to minimise losses to the bottom line (McAleenan and McAleenan, 2010). It is this latter aspect of the industry's culture, it's "safety culture" where workers face the risk of harm, that had become the focus of attention of those working in the field of occupational safety and health.

A range of approaches have being adopted to manipulate that culture to achieve improved outputs in safety compliance, reduced accidents and a positive safety leadership from senior management and board teams. However the issue is problematic, not least because there is no universally accepted definition regarding what constitutes a "safety culture", much less what it should look like.

Culture

A common phrase used to explain safety culture is "it is the way we do things here"; but this is simplistically inadequate in that it describes no more than the subjective actions of workers in the workplace without consideration of the contexts in which that work occurs and the motivations of the workers to perform in that manner. It is fundamentally a behaviourist approach without an appreciation of the character of the individual workers, their system of motivations which underlies but is not identical with their behaviour, (Freud cited in Fromm 1947). Thus to an observer looking at a site where work is apparently being carried out in compliance with safety procedures, he cannot, without deeper analysis, determine whether he is observing a "safety culture" or merely a momentary culture of work being done safely,

of safety being an incidental output of other motivations. Geertz (1973) refers to this basic statement of what is happening as a Thin description of culture. Culture is not just about behaviours, though conscious behaviours are a cultural phenomena. Freire (1973) has described culture as man's transformation of nature by his work. This transformation is the outworking of a conscious relationship with the world in which man "organises himself, chooses the best response, tests himself, acts and changes himself in the act of responding". He is both in the world and of the world. In this there is a dialectical relationship in which man is both the embodiment of culture and the maker of culture, a duality that negates definitions of culture as abstract matrices in which man merely moves.

Geertz (1973) described culture as a system of uniquely human controls. A consequence of this is that morality, which embodies controls, and ethics reasoning, which informs a rational understanding of what man should or should not do, are fundamental to culture and, following Freire, this presupposes that man is a self-reflective agency capable of decision-making and with the capacity to act independently. Geertz's (1973) thick description of culture is that there is a duality between the manifestations of culture, which he describes as signs and symbols to which meaning must be assigned, and man's interpretation and application of meaning to those symbols. This leads to a position whereby culture is not only uniquely human, but is unique to each human in that each person experiences and interprets culture for himself. What appears to the casual observer to be a shared culture, whether at the level of society or of sub-groups such as workplaces, is in fact a synthesis of multiple manifestations of culture that below the level of the observed is a permanent dynamic that objectively gives meaning to the observed phenomena.

This observed workplace culture is itself also necessarily dynamic, comprising multiple agents continuously entering and departing the matrix, each bringing new interpretations, abstracting from and assigning different meanings to the environment in which they are working. Thus contrary to the idea that culture is shared it is more appropriate to consider culture as being experienced and evolving in a shared place that leads to similar but non-identical responses to the phenomena of work.

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Morality and ethics reasoning

Culture and morality are inseparable (Lemburger 2011) and man as a moral agent is by definition self-reflective and autonomous (Körner 1995, citing Kant). The function of morality/ ethics is that it is concerned with guiding behaviour such that at a fundamental level that behaviour is non-injurious to others and in its more evolved forms it actively contributes to the good of others (Fromm 1947). This distinction illustrates a differentiation between a morality that is mandatory, "you must not harm others", and thus an absolute negation of autonomous agency, and one that is desirable but ultimately non-obligatory, "you should do good", a partial recognition but not full acceptance of autonomy. Reconciling this apparent contradiction is a necessary prerequisite to holding that each is accountable for their actions (Eckensberger 2007). Hegel held that freedom of the will is the appreciation of necessity; that is the capacity to make decisions with the knowledge of the subject (Engels 1894). For Engels (1984) this consisted in man's control over himself and of external nature, a control founded on natural necessity and emerges as a result of historical development. Jean Piaget and later Lawrence Kohlberg (Partington 1997) explored the development of moral reasoning in children and young people to understand how their moral choices were arrived at. Piaget saw two distinct stages of heteronomous or constrained morality and autonomous reasoning that takes place within a social context. Kohlberg's advanced Piaget's work (Crain 1985) and his stages of development of ethics reasoning commences with pre-conventional reasoning amongst young children informed by fear of punishment then of self-interest.

Conventional moral reasoning stems from tribal/ group and latterly societal conformity. Post conventional reasoning is based at the penultimate stage on the recognition of universal rights and abstract moral principals and at the ultimate level morality is based on the recognition and acceptance of equal existence of all living beings. Rules for moral behaviour are no longer necessary as the dignity of each individual is given due consideration, in all circumstances (Coverston n.d.). In this we see the transition from constrained moral choices to autonomous decision making, albeit not until the highest stage is arrived at.

Eckensberger developed Kohlberg's stages from 6 to 11 in four levels (Crain 1985). He introduced two social interpretation spheres, interpersonal defined by concrete interactions with concrete persons and transpersonal, determined by functions and roles. As a level of maturity the latter is indicative of the moral agent reasoning beyond personal considerations towards universal principals, where-as the former necessitates empathy and reciprocal respect and is akin to the ultimate stage identified by Kohlberg. Criticism of Piaget and Kohlberg's theories (Partington 1997) centre on their position that moral reasoning develops in an invariant sequence (across all cultures) and once a level of reasoning is attained is irreversible. Partington (1997) illustrates the negation of non-reversibility by reference to societies that have degenerated from more enlightened periods into fascistic and totalitarian states ultimately leading in some cases to the end of that society. He also holds that the universality of the theory is not supported when one considers other cultures where non-rational philosophies are dominant. His former point is in error in that he has conflated the coherent consciousness of the individual with the dialectical interrelationship of multiple consciousnesses that make up society. The fact that the dominant forces in a society reason at an immature stage compared with less dominant members does not nullify the theory but in his error has exposed the dichotomy between the maturity of individuals and the maturity of the group or groups to which they belong.

Cultural maturity in organisations

McAleenan and McAleenan (2009) have been developing an analytical process for determining with a high degree of accuracy the cultural maturity of organisations. A number of core criteria are identified that are considered in their totality, the absence of one or more of which will severely impair the company's sustainability in times of economic crises and which have a negative impact on its ability to remain viable relative to competitors in times of economic stability. The criteria are Corporate Social Responsibility, Innovativeness, Resourcefulness and Autonomous Decision-making Units. Notwithstanding the OECD (2004) Principles of Corporate Governance requiring corporations to conduct their business with financial integrity and in a manner that respects their key stakeholders interests, it is an indicator of cultural and moral maturity that businesses no less than individuals act morally and from optimum levels of reasoning. The fact that some businesses do not act in this fashion is not a negation of the integrity and maturity of the many individuals that comprise that business at any given point. The dominant forces in a business are the owners and shareholders. Their experience and interpretation of cultural manifestations are as unique as those of employees but with the added qualifier that their decisions and actions carry a force that outweighs those of "subordinates". The worker is constrained by the decision making authority of the employer and those he appoints to manage on his behalf. This negates the

fourth criteria, that the organisation recognises and supports the decision making capacity of autonomous agency within the workforce.

Though required to balance self-interest with social interests, it appears counterintuitive to employer and employee alike, that this should be the case in workplaces, hence the activities of workers are determined by external as well as internal constraints. It does not follow that the requirements of the employer are followed unthinkingly or in agreement, thus pronouncements to work safely are interpreted individually in the context of time pressures, perceptions of employers, budgetary constraints and a host of other cultural signs in the environment. Kohlberg's (cited in Crain 1985) and Eckensberger's (2007) stages of moral development are universal (at least within the culture where they were developed) and applicable to all individuals. By this rationale employers and their agents are capable of attaining those highest stages of universal moral principals that support the universal rights of all. However research conducted from the 1950s into the biological roots of ideology was summarised in 2003 in the paper "Political conservatism as motivated social cognition", (Psychological Bulletin vol.129, p339, cited in Graham and Estes 2012). It "*concluded that some of the defining aspects of conservative ideology - resistance to change and justification of inequality - were motivated by deep seated psychological needs to manage uncertainty and threat*". It follows that as uncertainty increases, as in the present economic conditions, so too will the resistance to change and the justification of inequality.

Though less well researched a liberal ideology is defined by such characteristics as open-minded, creativity and curiosity. The world is not polarised into these two ideological positions, it is much more complex with individuals holding ideological positions that are more conservative on some matters and more liberal in others, for example libertarians may tend to economic conservatism but be socially liberal. Nor is it a question of either position being necessarily false. However these ideological difference extend to moral judgements with liberals more likely to be offended by inequalities and suffering and conservatives by betrayal of in-group disrespect for authority and tradition, (Graham and Estes 2012). Businesses, particularly large corporations which are influential on smaller companies, are structured along and succeed as a result of conservative practices. The organisational structure defines the roles and responsibilities of managers, defines the relative status and norms of behaviour of staff and line functionaries, mechanisms and processes for allocation of resources and in general sets the rule for the game (Ghoshal and Bartlett 1995). Those most likely to rise in the business world are those whose world view is conservative, at least in the sphere of economics.

Conversely in times of uncertainty it is these qualities of the business and those who run them that are least suited to effecting the necessary changes that will meet the challenges they face, thus many companies have failed during times of economic crises. McAleenan and McAleenan (2010) in exploring strategies for success found that though they may be successful, to a point, they are fundamentally flawed in that when circumstances change or new conditions manifest themselves the strategies will fail. What was required was evolution on an ability to develop novel strategies, and this it appears lies with those of a liberal ideological root, that is [ordinarily] those who are not at the helm of organisations. An illustration of the point is Semco (Semler 1999), a large company facing closure during

Brazil's recession in the 1980s. Semler (1999) was given the business by his father and brought to it a more liberal agenda developed in an unconventional youth. As a result of the radical ways in which he restructured the company and the autonomy he recognised and encouraged, Semco was one of the success stories of that period made possible by the innovativeness and resourcefulness of his workforce.

Conclusion

McAleenan and McAleenan (2011, 2012) have been developing programmes with undergraduate design students that are aimed at developing their stages of ethical reasoning, a critical aspect of their professional development/ personal maturity, in preparation for their eventual management and/ or control of companies operating in the construction field and beyond. The success of a company, whether it is in economic terms or in meeting its social obligations to those who work for the company, is dependant upon the company achieving cultural maturity levels akin to the optimum levels of ethical reasoning developed by Kohlberg (Crain 1985) and Eckensberger (2007).

Culture is a poorly understood concept within the safety profession, who tend towards viewing it as a concrete object-in-itself capable of manipulation to achieve particular ends; e.g. improved performance and zero accidents. However this tendency is not an amenable conceptionalization of culture to shed meaningful insight into the ills of the construction industry (Gajendran et al 2012). Culture is the context in which man exists, no less so in the workplace than in society at large. The individual will interpret cultural manifestations, behaviours, institutions, instructions and so in, and respond in his own unique fashion, even within the constraints imposed by the circumstances. Though superficially it may appear that many are responding identically, fundamentally that is not the case. Programmes that enhance the ethics reasoning of professionals, those who will be influential in the organisation and running of businesses are a pre-requisite to the development of ethical and cultural maturity of companies. Integral to this is the need to recognise, value and thus support the autonomy of workers and managers without which there can be no mature agency.

As the research and programme development at student level progresses the next phase is to design research programmes to assess the transformational potential of the maturer reasoning professional on their professions and the companies they work for.

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Elements to Classify Subcontractors Production Systems

Ricardo J. Oviedo Haito[1], Francisco F. Cardoso[2]

Abstract

Subcontractors are heterogeneous firms that are active in different competitions. They are usually hired on the lowest price bidding basis, disregarding their distinctive characteristics, except in cases of construction projects with unique problems. This condition, coupled with the fact of them being mostly micro and small enterprises, causes the bankruptcy of 50% of them in their fourth year of operation. Past researches discussed the characteristics required in their procurement process. However, little is written about how they are organized and how their role in construction projects alters the way they execute their specific building trades. Our aim is to discuss some elements to classify the Subcontractors production systems. Accordingly, 38 companies of different sizes from Brazil and Spain were interviewed in a qualitative research, analyzing elements from their production systems and from their relation to the phases of construction projects. As a result, some classifications of Subcontractors production systems are proposed. Those classifications can serve several purposes, including: (i) Incorporating Subcontractors different characteristics in the Contractor's procurement process, or (ii) for developing differentiation elements in Subcontractors' specific competitions.

Keywords: Subcontractors, Production Systems in Construction, Competitive Advantage, Brazil, Spain.

1. Introduction

1.1 Subcontractor environment

Subcontractors are fundamental actors to achieve better outputs in the Construction Industry. The notion of subcontractor is related to all the firms that perform building trades and have not been awarded with the main construction contract. They generally perform their building trades in different subcontracting tiers (Oviedo Haito, 2010), as specialty contractors, trade contractors and their subcontractors. They are the main participants in a Construction Project –almost 80-90% of the construction work– (Hinze and Tracey, 1994). Also, in developing countries, such as Brazil, where the construction industry represents 8.9% of the Brazilian GDP, subcontractors are an important source of employment.

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Regardless of the differences between subcontractors' services and building trades, they are generally contracted on a basis of lowest-price bid in a competitive tendering process (Dainty *et al.* 2001). Along with these features, subcontractors are characterized for been mostly micro, small and medium enterprises (SME) with lack of resources and competences and low power to change their competitive positioning (Oviedo Haito, 2010). In emerging economies, such as Brazil, subcontractors receive poor condition to work at the construction site and poor contracting conditions (Oviedo Haito, 2010). This, joined to the lack of resources and competences of many of them being SME, lead them to have little capacity to fit their competitive environment; as a result, 50% of them go bankrupt on their fourth year of activity (Sebrae-SP, 2010).

Thornhill and Amit (2003) discussed the importance of having the right resources and competences to the success or failure of a firm. For Amit and Schoemaker (1993), those are the strategic assets of the firm. There are several classifications to those assets. For Empson, (2001) the assets are: reputation, experience, skill and knowledge of the employees are the essential resources. To Anvuur and Kumaraswamy (2008) the capitals are: Physical Capital, Human Capital, Structural Capital and Social Capital. To Oviedo Haito (2010), the strategic assets of a subcontractor are: Physical asset, Financial asset, Human Capital, Organizational Capital, Relationship Capital and Reputational Capital.

Regarding Relationship or Social Capital, the latest efforts in construction collaboration and partnering (Smyth and Pryke, 2008) must be important to change this antagonistic environment. Nevertheless, the relationship between subcontractors and their clients is mostly adversarial and distrusted (Hinze and Tracey 1994, Kumaraswamy and Matthews 2000). This relationship could be improved if their clients recognize the heterogeneity of subcontractors and transform this into an alternative selection process, in contrast to the dominant lowest-bid based on competitive tendering criteria.

A way to do this is by identifying some differences in subcontractor's production systems.

1.2 Manufacturing and production systems in construction

Discussions led by the current concern about the sustainability of the Building Industry revives the interest of the industrialization of construction - and their manufacturing and production systems - especially by increasing the offsite manufacturing at the expense of traditional onsite works (Ekholm 1996, Taylor 2008, Kamar *et al.* 2009, Azzi *et al.* 2011, Taufiq 2011, Jonsson and Rudberg 2012).

This discussion may be decomposed into two main aspects: the product to be built and the process to build that product. On the Product aspect, Cardoso (1996) discussed 3 places of producing parts and components of a building: Offsite and Onsite; dividing onsite in: other installations and the frontline. In those places, Jonsson and Rudberg (2012) distinguished four types of manufacturing systems in construction: Component manufacture & sub-assembly, Non-volumetric pre-assembly, Volumetric pre-assembly, and Modular Building.

Thus Jonsson and Rudberg (2012) defined: "**Component manufacture & sub-assembly**: the traditional approach in construction in which raw materials and components are used for building on-site; **Non-volumetric pre-assembly**: "two-dimensional" elements pre-fabricated off-site and assembled on-site; **Volumetric pre-assembly:** Volumes of specific parts in the building are produced off-site, and assembled on-site within an independent structural frame; and **Modular Building**: in which much of the production is made off-site, with modules fabricated to a high level of completion. The only work performed onsite is the assembly of the modules and finishing operations".

To Kamar *et al.* (2011), these components are the basis for migrating from traditional construction to more efficient ways to build. In this sense, they described three ways: **"Modern Method of construction (MMC)**: Number of innovations in building most of which are offsite technologies, moving work from the construction site to the factory; **Non-industrialized innovative solution**: is the use of an innovation method that has been verified in other industries; **Industrialized building system (IBS)**: is an innovative process of building construction, using the mass-production concept of industrialized systems, produced at the factory or onsite within controlled environments, it includes the logistic and assembly aspect of it, in proper coordination with thorough planning and integration". The relation among these concepts and others is presented in Figure 1.

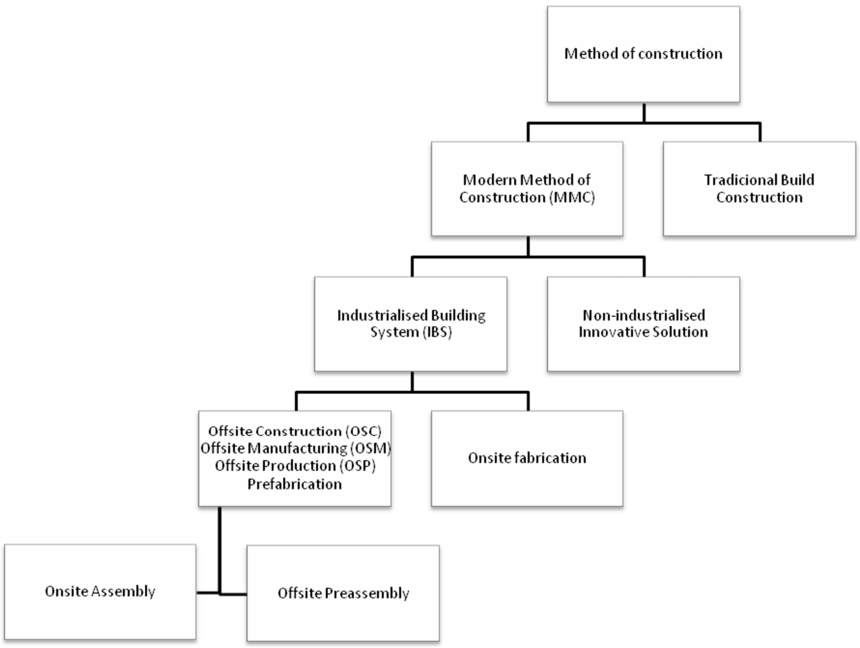

Figure 1: IBS and other Terms to describe industrialization in the method of construction (Adapted from Kamar et al., 2009)

Regarding the Process aspect of Production systems in construction, Sabbatini (1989) discussed concepts of industrialization and rationalization of the construction process. He defines industrialization as an evolutionary continuous improvement process of the organization of a holistic and systematic 'mode of build', characterized by the use of principles of manufacturing or industrial organization (PDCA approach), by the use of other facilities onsite for intermediary transformation, assembly or prefabrication and or offsite

manufacturing and prefabrication of components and elements of the building, by the mechanization of operations, and by the incorporation of technological innovations that improve the overall performance of the product and their production process.

For Sabbatini (1989), rationalization is an intermediary stage between traditional and industrialized modes of build, which constitutes an innovation to the traditional mode. It is related to the improvement of a traditional 'mode of build' by turning it rational, incorporating management principles from the industrial organization, moving the knowledge from the craft of construction activity to design, planning and control stages; by the use of onsite prefabrication or assembly of building components and by, when required, the mechanization of the operations, mainly regarding transportation activities. Adversely, Traditional 'mode of build' is a craft dependent mode of build characterized by the absence of a systematically organized and well defined work process.

Complementarily, Cardoso (1996) defines the Production Process of a Building as the set of stages arranged over time, from concept to operation, in that several agents (from client to subcontractors) interact to carry out the whole Construction Project. He also defines the Building Production System as being a part of a Production Process in which physical and managerial (including, among others, logistics and procurement) operations are articulated and integrated around Product Design and Process (construction) Design. Cardoso's (1996) approach, based partly on Sabbatini´s (1989) work, implies that the ´mode of build´ must be rationalized as a process, defining competences, methods, the managerial approach and the organization of building before beginning onsite construction operations.

In other words, the rationalization and industrialization of a (traditional) 'mode of build' is materialized by incorporating the construction knowledge at the early stages of the Building Production Process, mainly in the Design phase and by designing an efficient mode of build. This proposition is represented in Figure 2.

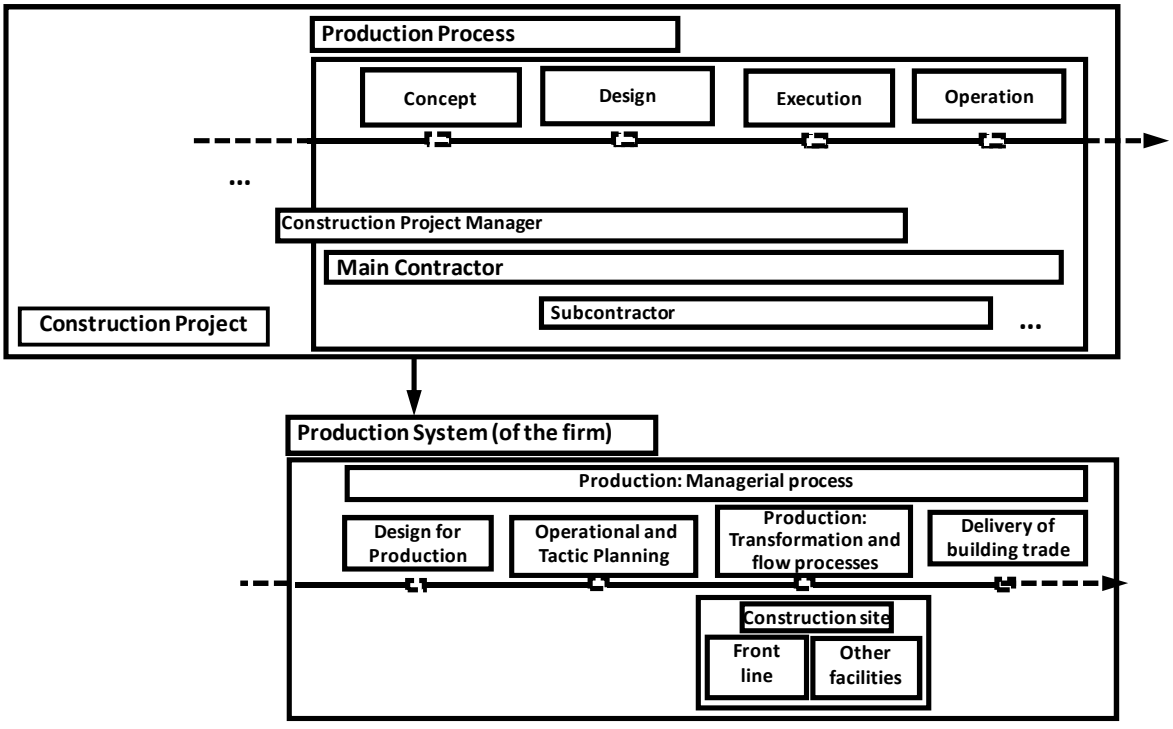

Figure 2: The Concept of Production Process and System of a building trade (Adapted from Cardoso, 1996)

Winch (2003) also discusses that the process flow of a Construction Process can be divided into Concept, Design, Planning, Manufacture, Assemble and Control stages. At a General Contracting system, Design and Planning stages, as a rule, intentionally exclude any subcontractor participation (except for some specialty and trade contractors such as Cladding and Mechanical systems). In emerging countries, as is the Brazilian case, there is little time between the awarding and the beginning of subcontractors' building trades, leaving the latter with little time for planning their production.

However, planning is different from the construction project level, when compared to the level of detail required for the operations of a subcontractor. In a traditional construction project organization, information is detailed up to the work package level, producing rough estimation of work. This information is useful for the tendering process for selecting a subcontractor to do the work, but insufficient to describe the mode of build, transferring this task –and the related risk– to subcontractors.

As shown in Figure 2, this system approach uses the Design for Production approach. In this sense, Maneschi and Melhado (2010 p.9) said: "in civil engineering, product design aims to define the product conceived, being a graphic and descriptive recorder of the product that will be built, while design for production aims to define how to produce the product".

Design for Production (Manneschi and Melhado 2010) is a tool been used in Brazilian Building Construction, mainly to ensure the transmission of information with enough detail to the trade builder do their work as a process, assuring quality on the execution of building works made by, in several cases, disqualified labor. For Sabbatini (1989), Design for Production is a mean to ensure the transmission of construction knowledge , reducing – among others - the need of labor qualification.

Also, Kamar *et al.* (2009, p9) discussed that the "...degree or level of industrialization is also associated with the scope of work in the construction process or life cycle. As compared to the traditional method, the prefabrication scope of work involves more planning".

As highlighted by Vargo and Lusch (2008), the scope of work in a service, or the value proposition of a firm can be described as a function of the valued resources the firm deploys to do their service. This is based on the seminal work by Penrose (1959), who said "it is never *resources* themselves that are the 'inputs' to the production process, but only the *services* that the resources can render" (pp. 24–25; italics as in the original version).

Hence, Oviedo Haito (2010) discussed several scopes of subcontractors' work, all of them associated with six strategic assets: Physical asset, Financial asset, Human Capital, Organizational Capital, Relationship Capital and Reputational Capital. An Australian work studies differences in services provided by construction suppliers, identifying a set of value-adding activities (Manley and Marceau, 2002). From that, some possibilities we highlight are Design, Project Management, Supply, Manufacturer, Distributor, and Installation.

As a result of this literature review, we identified some Elements for Classifying the Subcontractors' Production System, as shown in Figure 3.

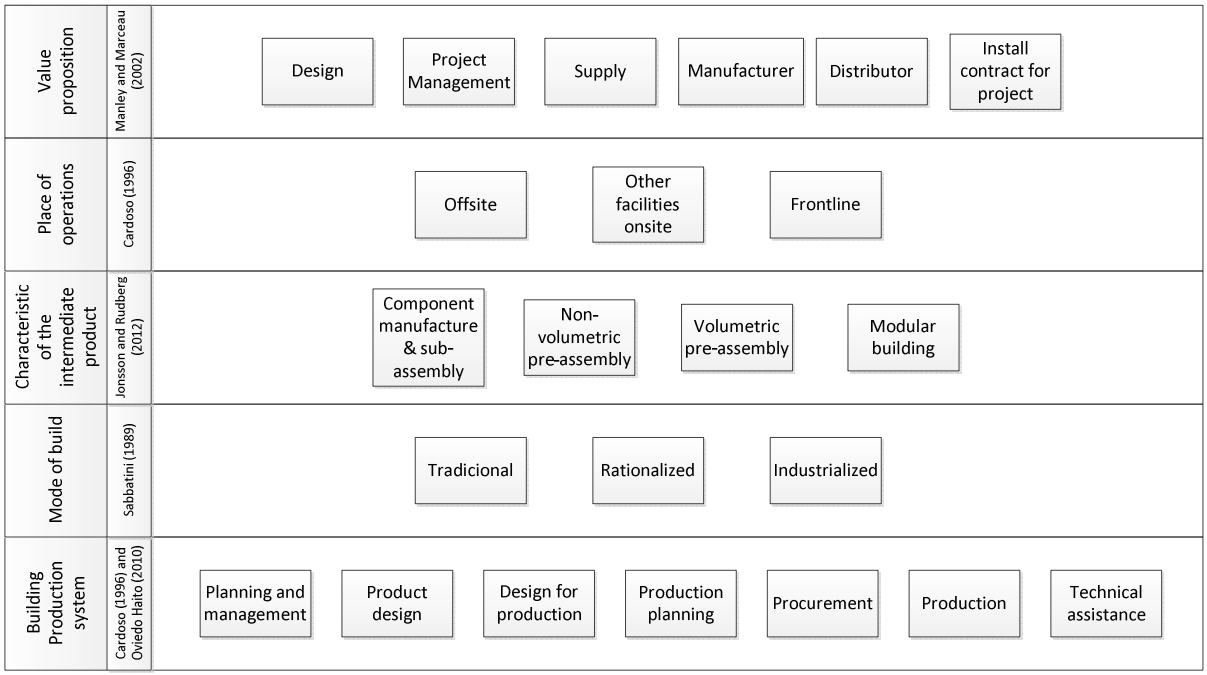

Figure 3: Literature-based elements for Classify a Subcontractors' Production System

2. Objective

The aim of this paper is to discuss some elements to classify the production systems into Subcontractors. A classification *per se* is not the objective, but a means to interpret the characteristics of the subcontractors as a function of the elements identified.

3. Methodology

To accomplish the objective, a qualitative research was performed. In-depth interviews were conducted with 38 subcontractors from Brazil and Spain, selected by purposeful sampling and snowball technique (Patton, 1990). They were asked about the means used for their production process and characteristics of their building trades. The questionnaire was based on the work by Oviedo Haito (2010). Data was collected and compared with the categories taken from the literature review. Accordingly, data was compared and sorted, as shown in the next item.

4. Results

Based on the literature revision, five major categories were identified to compose a classification, shown in Figure 3: Value proposition, Place of operations, Characteristic of the intermediate product, Mode of build, and Production system. As a result, Table 1 shows how these characteristics fit the subcontractors interviewed.

Table 1: Elements for Classifying the Subcontractors' Production System identified in 38 subcontractors

Firm	Building trade	Firm Age (years)	Number of employees	Value adding possibilities				Place of most operations			Characteristics of the intermediate product	Mode of build	Product Standardization	Component Standardization	Production System						
				Design	Project Management	Supply	Manufacturer	Offsite	Other facilities	Frontline					Planning and Management	Product Design	Design for Production	Production Planning	Procurement	Production	Technical Assistance
1	Masonry, internal and external coating, and subfloor	15	200		1				1	1	CM	R	H	H	1		1	1	1	1	1
2	Masonry, internal and external coating, and subfloor	12	295		1	1			1	1	CM	R	M	M	1			1	1	1	1
3	Masonry, internal and external coating, and subfloor	3,5	96			1			1	1	CM	R	H	H					1	1	1
4	Fenestration, doors, frames and hardware	2	46	1	1	1	1	1	1	1	NV	T	M	H	1	1	1	1	1	1	1
5	Masonry	4	376		1	1	1		1	1	CM	R	H	H	1		1	1	1	1	1
6	Electrical wiring and communications	17	11		1	1				1	CM	T	H	H	1		1	1	1	1	1
7	Foundations	75	400	1	1	1		1	1	1	CM	R	H	H	1	1	1	1	1	1	1
8	Water proofing systems	26	200	1	1	1			1	1	CM	R	H	H	1	1	1	1	1	1	1
9	Exterior coating and Concrete structures (including Prestressed Concrete structures)	20	1250		1	1			1	1	CM	R	H	H	1		1	1	1	1	1
1	Water proofing systems	17	180	1	1	1			1	1	CM	R	H	H	1	1	1	1	1	1	1
11	Laminate flooring	13	17		1	1			1	1	CM	T	L	H	1		1	1	1	1	1
12	Masonry, internal and external coating, and subfloor	6	13		1				1	1	CM	R	H	H	1			1	1	1	1
13	Laminate flooring	18	15		1	1			1	1	CM	T	L	H			1	1	1	1	1
14	Gypsum Plaster	16	20		1	1			1	1	CM	T	L	M	1			1	1	1	1
15	Laminate flooring	5	41		1				1	1	CM	T	H	H	1			1	1	1	1
16	Dry Wall	4	37		1	1			1	1	CM	R	L	H	1			1	1	1	1
17	Dry Wall	2,5	30		1	1			1	1	CM	R	M	H	1		1	1	1	1	1
18	Electrical maintenance	3	3		1					1	CM	R	M	H	1			1	1	1	1
19	Fenestration, doors, frames and hardware, glass and glazing, and metal panels	7	29		1		1	1	1	1	NV	R	M	H	1			1	1	1	1
20	Laminate flooring	8	8		1				1	1	CM	T	L	H	1			1	1	1	1
21	Fenestration, doors, frames and hardware, glass and glazing, and metal panels	37	24	1	1	1	1	1	1	1	NV	R	H	H	1	1	1	1	1	1	1
22	Dry Wall	1	100		1	1			1	1	CM	R	M	H	1		1	1	1	1	1
23	Masonry, internal and external coating, and subfloor	15	500	1	1	1			1	1	CM	R	H	H	1	1	1	1	1	1	1
24	Masonry	11	350	1	1	1	1		1	1	CM	R	H	H	1	1	1	1	1	1	1
25	Painting & Decorating	30	350		1	1				1	CM	T	L	H				1	1	1	1
26	Precast concrete facade panels	16	65	1	1	1	1	1	1	1	MB	I	H	H	1	1	1	1	1	1	1
27	Maintenance of civil infrastructures and gardening	25	200		1	1		1		1	CM	R	L	H	1			1	1	1	1
28	Foundations and structures of reinforced concrete	11	50		1	1			1	1	CM	T	M	H	1			1	1	1	1
29	Industrial paintings	18	200	1	1	1	1	1	1	1	CM	R	M	H	1	1	1	1	1	1	1
30	Brickwork, masonry and general workforce	12	150		1	1				1	CM	T	L	H	1			1	1	1	1
31	Concrete forms	28	200	1	1	1	1	1	1	1	CM	R	H	H	1	1	1	1	1	1	1
32	Steel rebars	25	120		1	1	1	1	1	1	CM	R	M	H	1			1	1	1	1
33	Machinery: general and transportation	9	1100			1				1	n/a	n/a	n/a	n/a	1				1	1	1
34	Machinery: cranes and special vehicles	22	45		1	1				1	n/a	n/a	n/a	n/a	1			1	1	1	1
35	Brickwork, masonry and general workforce	10	60			1				1	CM	T	L	H	1				1	1	1
36	Electric and electronic facilities and maintenance	14	8	1	1	1			1	1	CM	T	M	H	1	1		1	1	1	1
37	Earthwork	50	55		1	1			1	1	CM	R	L	H	1			1	1	1	1
38	Hydraulic systems	5	35		1	1				1	CM	T	L	H	1			1	1	1	1
	Total			11	35	32	9	9	29	38	-	-	-	-	35	11	18	35	38	38	38
	%	-	-	28,95	92,1	84,2	23,68	23,7	76	100	-	-	-	-	92,1	29	47	92	100	100	100

LEGEND

	Key	Description	Total	%
Intermediate product	CM	Component manufacture & sub-assembly	32	89
	NV	Non-volumetric pre-assembly	3	8
	MB	Modular building	1	3
Mode of Build	T	Traditional	13	36
	R	Rationalized	24	67
	I	Industrialized	1	3
Product standardization	H	High	15	42
	M	Medium	10	28
	L	Low	11	31
Component standardization	H	High	34	94
	M	Medium	2	6
	L	Low	0	0

Following the results presented in Table 1, concerning the 5 categories evaluated, we can state:

- **Value (adding) Proposition:** Out of the subcontractors interviewed, only 29% offer Design. 24% offer manufacturing services and almost all of them offer Project Management (92%) of their specific building trades and the majority (84%) offers services related to supply (mainly material acquisitions).
- **Place of most operations:** All of them work in the frontline. Only a few (24%) offer offsite operations. Most of them use other facilities onsite to intermediate transforming operations (76%).
- **Characteristics of intermediate products and components**: None of them works with Volumetric pre-assembly. Most of them (89%) work with component manufacture & sub-assembly, showing how much they depend of onsite operations and how far they are to have an industrialized mode of build. Confirming that, only three subcontractors work with non-volumetric pre-assembly; and only one works with modular building.
- **Processes integrating their Production Systems**: Following the Cardoso's (1996) Production System approach, Production, Procurement and Technical Assistance were identified as the core processes of the interviewed firms (100%). Managerial processes (Planning and Management of the firm) as well as Production planning where performed in almost all the interviewed (92%). Design for production was a significant 47%, being consistent the 63% of the firms who said to have rationalized modes of build. Despite of this, most of them said that they produce an unsystematic instruction of work, not a detailed Design. Confirming the initial premise, only 29% of them participate from Design (and planning) stage of the Construction Project. Is necessary to comment that even those who said they were participating from the Design phase of the Construction Project highlighted that their involvement is infrequent.
- **Modes of build**: as said in the former item, most of them (63%) work with rationalized modes of build. 34% of them work with traditional modes of build, and only one firm builds with industrialized modes. Industrialization is also related to Standardization. Notwithstanding, an important 59% work with low or medium standardization on the product they build; contrasting with 64% of subcontractors that work with medium standardized components. Complementary, 94% of them work with highly standardized components, in contrast to only 42% of them who has highly standardized products.

5. Final remarks

There are several elements to classify subcontractors' production systems. Among them we found five elements related to: 1) the work produced; 2) the components and 3) their manufacturing process, contributing to the understanding of the subcontractors' Production Systems.

Most of the interviewed firms participate only in Construction Phase. This conjuncture reflects the little period of time to them to add more value into a Construction Project.

On this sample of subcontractors we identified they were characterized by:

- Having value propositions oriented to the Project Management of their building trades, without participating on early stages of Construction Projects, in a classical Design-bid-build contractual arrangement.

- They mainly integrate they building trades onsite and they generally use as input component manufacture and sub-assembly.

- The product they build is mostly not standardized, adding uncertainties to Design definitions. Half of them have the competence to transform the Product Design in a more detailed instruction of work. Design for production is not properly used, and by the little time subcontractors have to prepare their production, prolonging rough estimating practices of work to be built.

- Even though most of them said they work with rationalized modes of build, most of them do not have a systematic and well defined process of work. Much of the organization of their operations is made by subcontractors' foremen. So the rationalization of the operations of them depends more on foremen and labor competences than on a systematic process. In despite of their good reputation in market, most of them are craft-directed organizations.

In regard of limitations on the sample studied, we identified the five elements of the subcontractor's production systems theorized early in this paper existing in the interviewed subcontractors. Even though, further analysis with bigger and more varied building trades is desirable.

5.1 Implications on subcontracting practices

Subcontractors have little participation in Design and Planning stages. The Construction Project procurement process needs to be modified, allowing subcontractors: 1) to have time to study and planning the production and manufacturing. This planning would add more value to subcontractors insofar they had enough details to reduce decisions made into the construction site; 2) to reduce risks related to present subcontractors practice to planning a roughly estimation of the work; 3) to participate in early stages of the construction project, imputing knowledge of the ´mode of build´ their building trades into the overall planning process. For them, managing these 5 elements is a way to formalize and improve their production systems.

For contractors and other subcontractors' clients, the five elements identified of subcontractors' production system could be incorporated in Design and Planning stages, as well as in tendering criteria, mainly to identify allies –and their attributions and responsibilities– in collaborative arrangements such as partnering (Smyth and Pryke, 2008).

Towards rationalization and industrialization of construction methods, subcontractors can improve their practices by developing a managerial approach on it. As discussed by Sabbatini (1989) and Cardoso (1996) industrialization of construction is an organizational process. The PDCA approach is fundamental and tools as Design for production is important to improving quality and productivity on building trades, combining the effective early use of construction knowledge and an efficient mode of build in a Construction Project and, to subcontractors' in their own building trades.

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Offsite Construction: Sustainable Innovation Futures Using SMART Approaches

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Abstract

Offsite manufacturing has been advocated as a potential lever for addressing the increased emphasis placed on construction stakeholders to meet the challenges of sustainable construction. These challenges include a myriad of issues ranging from green agenda-driven polices and initiatives, through to new strategies and formal mechanisms that are purposefully aligned to meet sustainable metrics and indicators. Whilst it is acknowledged that construction (*inter alia*) has been somewhat entrenched in a raft of potential 'ways forward', the resurgence of new collaborative approaches using technology – especially Building Information Modelling and SMART components provides promising opportunities for exploitation. This research presents an illustration of the potential to integrate design, development and delivery of products and services using offsite construction as an exemplar. The research methodological approach adopted employed a mixed-method research design, which included a series of discursive on-line interviews with domain experts to collect primary data, followed by a workshop to validate findings. These findings emphasised the importance of providing information 'transparency' in order to fully maximise and exploit offsite manufacturing technologies and processes to not only leverage success *per se*, but also enhance the collaborative working practices of (seemingly) disparate stakeholders.

Keywords: Modern Methods of Construction, Offsite Manufacturing, SMART Components, Process, Technology

Introduction

The terms "manufactured construction", "off-site construction", "off-site manufacturing", "industrialised building systems" "off-site fabrication" and "modern methods of construction" have all been used interchangeably in extant literature to describe pre-fabrication within construction. Whilst it can be argued that some have these terms have distinct differences

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(Gibb and Pendlebury, 2006; Nadim and Goulding, 2011), ostensibly, the underlying focus of these 'umbrella' terms is to capture the message of moving some of the construction effort into a controlled environment, using manufacturing facilities. Notwithstanding these differences in nomenclature, offsite manufacturing (OSM) has been acknowledged as being able to procure specific benefits, which include higher speeds of construction, enhanced quality outputs and tolerances, lower costs, and reduced on-site labour re-work (Schuler, 2003; Mullens and Arif, 2006). These espoused benefits have been evidenced in a number of countries, not least Japan (Gann, 1996), the USA (HAC, 2012), the UK (Taylor, 2010; Buildoffsite.com; Egan, 1994), Malaysia (CIDB, 2006), and Australia (Hampson and Brandon, 2004).

However, despite all these espoused benefits and supportive global initiatives, the uptake and pervasiveness of offsite manufacturing is much slower than expected, with a market share in the UK being reported to be around 6% (Taylor, 2010); yet the UK the construction industry sector contributes approximately 8% of the country's Gross Domestic Product and has over 250,000 enterprises, with an annual turnover of £100bn (ONS, 2012). This GDP relationship broadly proportional to other countries over the world, which therefore suggests that the market has potential to benefit from OSM approaches. In addition, extant literature advocates an increased need to employ cutting-edge technologies to address the emerging challenges introduced by the global Architecture Engineering Construction (AEC) projects. Acknowledging this, it is also important to note here that information and communication technology (ICT) has revolutionised production and design (Cerea, et al, 2002), which has led to dramatic changes in terms of production materials and labour (Fruchter et al, 2000; Akintoye et al, 2012). Moreover, the increased use of ICT tools within design and construction now enables designers to experiment and experience OSM decisions in a 'cyber-safe' environment in order to mitigate or reduce risks prior to construction (Goulding et al, 2012). This rapid growth of technology adoption and absorption has been widely evidenced in several other industries; but the same cannot be said for the construction industry with its disparate supply chain and on-site/off-site information flows. However, there are some promising emerging ICT enabled approaches, e.g. Building Information Modelling (BIM), which could support a comprehensive digital representation of all construction information for various stages of the project lifecycle and also enhance team collaboration/project integration (Gu and London, (2010). Given these developments in ICT and OSM opportunities, Taylor (2010) noted that an industrialised system of construction could provide "affordable quality homes" which may help overcome some of the major problems inherent with the traditional approach to construction. In addition, "There is a growing body of evidence to prove that OSM, Modern Methods of Construction (MMC) and Design for Manufacture (DfM) can impact significantly on waste whilst delivering great architecture with corresponding savings" (Davis Langdon, 2011). In summary therefore, acknowledging these issues, and the potential for offsite production and manufacturing to make a positive contribution to AEC stakeholders, it is posited that there is an exigent need to identify the core preventative barriers to uptake and adoption; for example, culture, demand-supply production models, new business strategies etc. This reflection also needs to embrace the inclusion of SMART components, as the integration of these can help provide meaningful solutions to designers (new options), manufacturers (integration), constructors (flexibility), and the end users (adaptability).

SMART Components and Connectors

The term “SMART” component is metaphor applied to any prefabricated frame, panel, technology or connector engineered to integrate with traditional or proprietary technologies. They can be manufactured from a wide range of materials to suit a variety of particular needs (loading, scale, maintenance etc). SMART components are also uniquely customisable to meet customer-specific applications, as the options they afford provide architects and engineers with maximised design and construction flexibility. Thus, the design and development of the SMART components can be said to combine ambient manufacturing methods with an open system for products and components. This offers direct ‘plug and fix’ capabilities, which from and OSM perspective, provides flexible design solutions of a particular space to cater for the needs of the occupants over time. Thus, when designing systems for offsite manufacture, it is important to engage all relevant stakeholders at the early design stage in order to ensure that the end product meets all requirements. These stakeholders typically include: end-users, clients, architects, engineers, builders and manufacturers. It is also important to consider the varying levels of componentisation or manufacture that is to be taken offsite.

SMART components are therefore distinctly designed to be multi-purpose, multi-functional, and offer maximum in-use adaptability – as the re-configuration of space over time can easily be accommodated with minimal damage to the fabric. The design of these components therefore needs to consider:

- The holistic design process - specifications and performance levels must be determined prior to development;
- Cradle to grave thinking - building lifecycle (circa 1500 years?);
- Standards and technical conformance – certification and conformance often varies from country to country;
- Performance – stakeholder requirements (delivery, constructability, in-service use, maintenance, demountability, disposal etc).

One of the major challenges with pre-fabrication and OSM is not the components themselves per se, but rather, the interface between different elements of the system. For example, re-configurable spaces can be made for changing needs thorough such products as Push Walls and the Demountable Walls, fixed by pressure which can be easily moved without specialist skills or tools. Materials such as fibre reinforced plastics (FRP) have been successfully used in the construction sector from the early 1990’s, and have been widely used in the transport and aeronautical industries. FRP’s consist of a polymeric matrix reinforced with fibres, and are generally made from materials such as carbon, boron and resin. Products include small pre-formed units and structural elements for houses, through to large load-bearing elements of buildings, bridges etc. As FRP is significantly lighter than conventional materials, the use of heavy machinery on-site can be reduced or avoided in certain circumstances. Constructability has also been advocated as being up to 70% shorter than by conventional methods, which can help reduce the incidence of construction-related accidents on site. Examples of this approach include partition walls which do not require a frame or sub-structure, as the walls are fitted to connectors that have been fixed to the

ceiling and floor. Several commercial systems are available e.g. Quicklock Partitions (Quicklockpartitions, 2012), and a variety different connector systems can be used (in many different combinations), including magnetic connectors, plastic connectors, steel connectors etc. Commercially available connectors include several options, from the Keku connector - Figure 1, which can be used to secure trims and cladding panels directly to walls with no wooden subframe; through to Velcro tape (produced by 3M) for rapid assembly and disassembly.

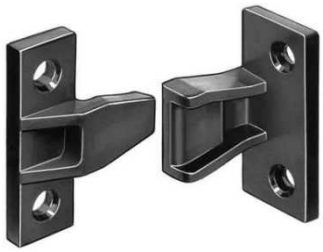

Figure 1: Keku push fit fastener set (©Keku)

Other rapid connectors include Dipple Klick – Figure 2, which was developed by Corus (now Tata Steel) through ManuBuild (ManuBuild, 2009) as a rapid connection solution for offsite (manufacturing and buildability). Dipple Klick is a junction between two cold-formed sections, designed as an interface between wall panels, but extendable to floor, ceiling and roof elements. The main drivers for the development of this connector were:

- Improved flexibility, increased accuracy and building tolerance;
- Reduced tooling (lower capital investment) and reduced setting-out times;
- Higher quality product;
- Accuracy – greater reliability and repeatability of the process;
- Improved health and safety aspects.



Figure 2: Dipple Klick rapid connector (©Tata Steel)

In summary, SMART components offer a range of benefits, not least: greater connectivity options, improved accuracy (tolerance), enhanced flexibility options etc. However, these issues do not naturally seem to have been overtly captured when considering the fundamental nuances of on-site v offsite construction. Given this, it was considered important to investigate these through the Design, Manufacturing and Construction stages, mapped against process, technology and people issues.

Research Methodology

This study specifically focuses on the socio-political-technical relationships that affect the uptake and adoption of OSM. It adopted an interpretive approach to positioning, as it sought to uncover new meanings and constructs. The research methodological approach adopted used a mixed-method research design, which included a series of discursive on-line interviews through three webinars with domain experts to collect primary data. These findings were then presented in a formal workshop, where the results were explored in depth. Initially, the causal problems and key issues that impinged upon the successful uptake of OSM were identified through extant literature over the last 20 years. The temporal timeframe reflects relevance and proximity, and the research lens was open-bounded, thereby not constrained by context, regional or geographical issues. Three areas were selected (Process, Technology, People) cutting across three sectors (Design, Manufacturing, Construction). These six areas were identified as the main units of analysis.

This data collection was undertaken as part of CIB Task Group 74 remit – to investigate new business models in offsite construction. The webinars and workshop were attended by academics and senior executives from companies engaged in offsite construction. These survey participants were 'representative' in order to establish, evaluate and prioritise these nine areas into a draft framework of issues for future uptake. In terms of the methodological approach, this stage followed guidelines for collecting data through focus-group-workshops. Prior to conducting the workshop, the issues of the study were clearly articulated and the questions predetermined (Cresswell, 2009) aligned to the aim of the research. This method is often characterised with its clear use of group communication to generate data and thoughts that would not be easily accessible via ordinary individual interviews (Morgan, 1997; Parker and Tritter, 2006). Hence, this was considered an efficient approach for generating ideas and solutions based on the experts' consensus. Three central 'themes' of People, Process, and Technology (see Davenport, 1992) were used in the development of this study, mapped against Design, Manufacturing and Construction (the three dominant paradigms drivers of offsite).

Research Findings

The research findings presented below highlight the main findings from the three online webinars and formal workshop. These cover the nine interrelationships (Table 1), reflecting *Design-Process*: *Manufacturing-Process:* *Construction-Process*: *Design-Technology*: *Manufacturing-Technology*: *Construction-Technology:* *Design-People*: *Manufacturing-People*: and Construction-People respectively. The primary data was coded and analysed using content analysis to provide the main focus areas. A brief discussion of these relationships follows.

Table 1: Nine OSM themes

	Design	Manufacturing	Construction
Process	Adding Value	Flexibility	New Business Models
Technology	Exploitation	Justifiable Automation	Risk Identification
People	DfMA Skills	Manufacturing Needs	Productivity Up-skilling

Design-Process: Adding value to the business process (multiple perspectives); Process Protocol – lifecycle processes, tried and tested (concentrate on the most important ones); stakeholder analysis is needed; understand the impact of design and process (with business and technology).

Manufacturing-Process: Procedures need to be defined to cope with the variables – will a one-size-fit all model work?. Need to look at other industries re. their business models (not just efficiency over productivity, but also pre and post occupancy). Integration of suppliers into companies needed (and teams). Sustainable business models can be flexible (and tested business concepts can be added). Need to consider what to adopt and what not to adopt e.g. automation v non-automation (is there a happy medium?). Flexibility needed (variable product line).

Construction-Process: Important to consider new business models – which ones?, what remit e.g. house builders, SME's etc. (more than 100 systems and >500 suppliers). How can integration be achieved? (through RFID, BIM etc?). Performance of process - hard data needed (CBA etc). Interfaces between OSP and manufacturing (need to have the right skills?). ISCS report on the future of house building. Emphasis on onsite or offsite construction? Flexibility needed with elements of standardisation (economies of scale).

Design-Technology: Technology embedded in the product (in the factory); technology underpinning the business process; e-readiness of organisations (and the supply chain) – holistic implications on the business; BIM for offsite (product and process) – potential to exploit.

Manufacturing-Technology: Justifiable automation - how much is enough? (optimisation, business case, payback period etc); product and process design – DfM (software and systems development, DSS, integrated product delivery etc); supply chain management – MRP and ERP expensive (inflexible and somewhat limited); modelling and simulation – training needed (systems analysis, discreet event simulation and modelling etc).

Construction-Technology: There is a need to understand what information is created, used and exchanged (Product Modelling Ontology, W3C etc) - common tools from different vendors (integration and interaction); BAE/BAA/IBM systems approach. Granularity of product data could be used better - detailed information e.g. installation, storage, size, mass,

lifting requirements, health and safety issues etc. (BIM is important here). Risk needs to be understood more e.g. i) existing product/process in established application areas, ii) existing product/process in new application areas, iii) new product/process in established application areas, or iv) new product/process in new application areas [as all carry different risk].

Design-People: Traditional versus non-traditional - new ways of working require new skills (especially product modelling.), new thinking, greater collaboration, reassessment of discipline areas, change in individual and company behaviour. OJT and learning needed (industry and academia collaboration). New approach needed to design (key USPs need to be sold re suppliers, assemblers, transport operations etc.) DfMA is an important part of this, along with logistic integration into the design process. Product catalogues, smart connections etc are available.

Manufacturing-People: Mistakes are not openly acknowledged. Multi-disciplinary or interdisciplinary? Mind-set training needed (look at projects rather than products). Decisions have to be modelled in an integrated way (incorporating risk etc.) Shop floor approach needs to change and benefits need to be made clear. Link to disaster management?.Mass customisation – service parts (how to address the various markets). Job roles and functions need re-defining. Integrating people into future scenarios.

Construction-People: Up-skilling of personnel i), so that existing site labour or new trainees can work in the production factory; ii) so that employees know how to install pre-fabricated products and modules on site (this would require training/investment). Healthy and comfortable working conditions could be a key USP (Health and Safety, better working environment, standardised production system etc). Sustainability - social benefits, continuity of employment, economic - stable and long term employment, transportation - pick zones (reduced emissions etc). Productivity - greater efficiency and productivity, no weather disruptions etc. New workforce – greater attraction because of better working conditions, resolution of unskilled labour, no age limit or pre-requisite skills for entering the sector. Perhaps adopt the triple bottom line approach.

Discussion

The findings presented in this paper in many ways reflect the long-term vision needed by a range of stakeholders noted in extant literature. These are however in some respect governed by changes in legislation (which more often than not require more immediate solutions) to prepare the industry for the future, once the market stabilises. From a design approach, the key message is that emphasis should be placed on flexibility (to design out obsolescence), as this reinforces the business case for OSM. Moreover, as OSM can openly demonstrate a much wider range of solution than had previously been made available to the client (customer), there is a correspondingly higher need to understand the requirements of the occupants to design accordingly. Given this, improvements are needed to current business models to reflect the changing requirements of clients and new processes involved. As there are a number of new SMART components and connector pervading the market, increased options with improved flexibility solutions are now available. However, these will need to be integrated. This might for example include creating (or implementing) specific

aspects of the manufacturing user-case business models. In addition, new relationships with the supply chain will need to be fostered and developed. This may involve new procurement routes and contractual agreements, or new production schedules which maximise efficiency, productivity, and logistics. Increased standardisation of products from different sources should also be explored further (e.g. British Standards, EU Standards, International Standards), as this would significantly improve interchangeability from any number of suppliers whilst increasing product selection and market diversification. This would allow different user scenarios to be developed for various typologies (design variations). These holistic issues and interconnectivity can be seen in Figure 3.

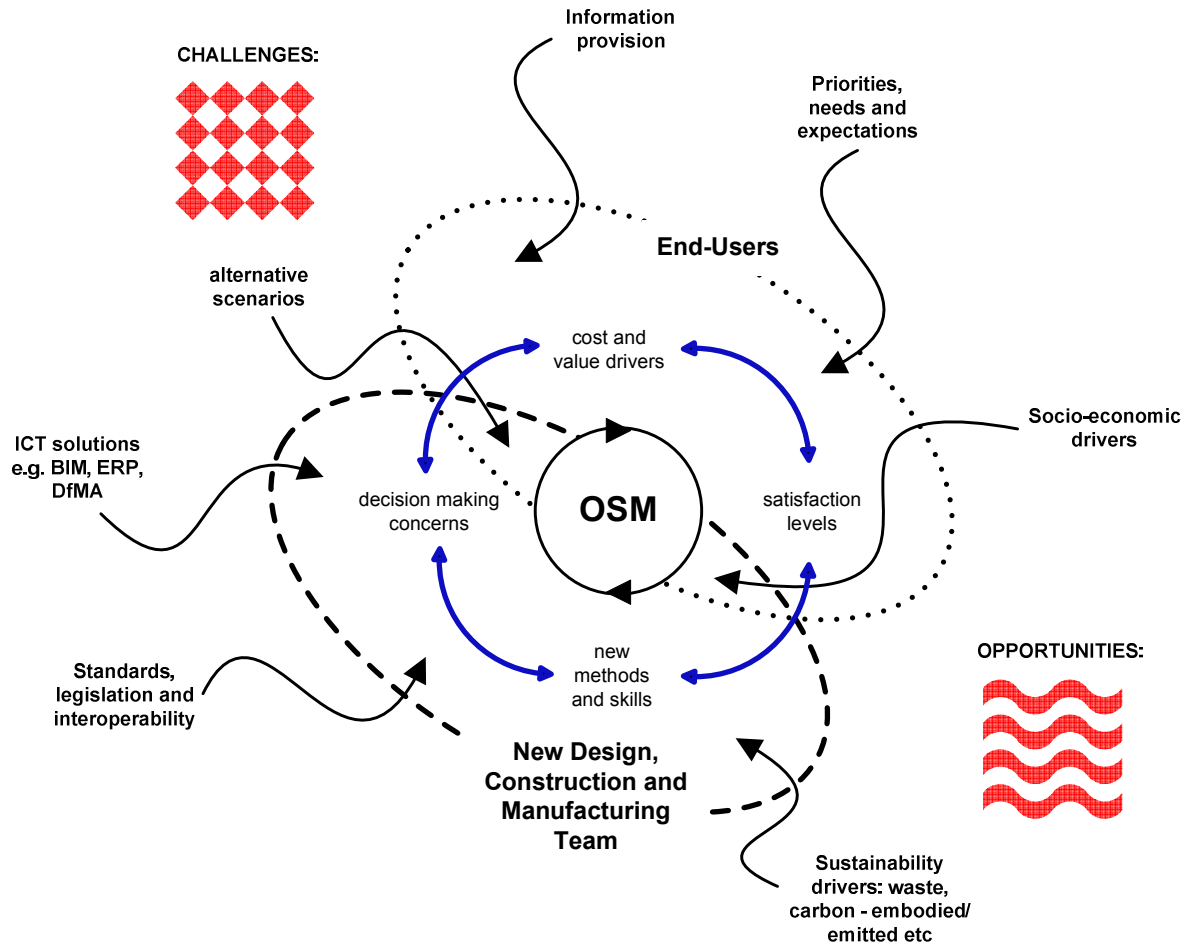

Figure 3: OSM Interrelationship Model

Conclusion

Offsite manufacturing has been on the agenda for quite a while now. It has been offered as a potential solution across a number of areas, not least the 'green agenda' aligned to sustainable construction, but also improved delivery times, higher integration opportunities, improved quality, reduced costs etc. A number of significant and prominent key reports have been produced promoting 'ways forward'. This research presented an illustration of the potential to integrate design, development and delivery of products and services using offsite construction as an exemplar. The research methodological approach included three

discursive on-line webinars with domain experts to collect primary data, followed by one workshop to validate findings. Research findings identified the links between nine areas: *Design-Process*: *Manufacturing-Process:* *Construction-Process*: *Design-Technology*: *Manufacturing-Technology*: *Construction-Technology:* *Design-People*: *Manufacturing-People*: and Construction-People. Research limitations are therefore bounded by this data set. Whilst the interconnectivity of these nine areas provided some meaningful outcomes (especially through the strength of connections and level of granularity of detail provided), one of the main findings that needs to be emphasised is the increased need to provide information 'transparency' in order to fully maximise and exploit offsite manufacturing technologies and processes (as this can enhance the collaborative working practices of the disparate stakeholders involved). Similarly, it is advocated that new employee skill sets which embrace an 'open system' philosophy are needed to drive forward innovative solutions. There is also a need to 'sell' the emerging benefits of offsite manufacturing technologies and processes to these stakeholders. Pivotal to this is the need to create a new culture of OSM/DfMA; from the initial outline design stage, through to the development of the project team, the design and tender process, and full engagement of all stakeholders involved.

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Identification of the Primary Needs for Sustainability and Improvements in Working Conditions on Construction Sites

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Abstract

The construction phase of a building´s life cycle accounts for a significant portion of the environmental impacts caused by the industry, such as contamination, waste, dust emissions and noise. Therefore best practices and technological solutions aimed at rationalising resource use, reducing emissions and increasing the environmental performance and energy efficiency of site equipment and tools, hydraulic and electrical installations, and improving the health, safety and well being of the workers and surrounding community are required. In Brazil, there is a lack of knowledge with regards the primary needs for improving sustainability and working conditions on construction sites. The aim of this work was to identify the priority research areas for improving sustainability and working conditions on construction sites in Brazil. The study consisted of a literature review of the environmental assessment methods to formulate the survey with questions for each possible priority research area allocated within the established themes. The survey was applied to building companies in four cities in Brazil (Salvador - Bahia, São Paulo, São Carlos - São Paulo and Porto Alegre - Rio Grande do Sul). The priority research areas for sustainability and improvements in working conditions on construction sites with special emphasis on low income housing projects were identified. These results are expected to produce guideline proposals for new science, technological and social policies aimed at improving environmental sustainability and working conditions on construction sites with special emphasis on low income housing projects.

Keywords: Sustainable Construction Sites, Health and Safety, Low income housing.

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1.Introduction

On a global scale, the construction industry is responsible for approximately 50% of the CO2 emitted into the atmosphere, 20 - 50% of all natural resources consumed and 50% of all solid waste produced for which the construction phase of a building´s life cycle is largely accountable, causing a series of environmental impacts as a consequence (Probert, 2010, Khasreen, 2009, Cardoso et al. 2006, Pulaski, 2004). The construction process in itself causes several and different environmental impacts (Kilbert, 2005; Polaski 2007, USEPA 2006, Chelma 1997). Large quantities of materials, water and electricity among other resources of various types and origins are consumed on construction sites during the different production activities and by temporary facilities. These activities also generate waste materials and particle emissions that cause a concern regarding soil contamination and air pollution. Water pollution and soil erosion is also a problem. Furthermore, the impacts resulting directly or indirectly from the construction site production activities can create problems related to the health, safety and welfare of site workers and neighbourhood.

In Brazil the impacts resulting from construction and demolition waste and its clandestine disposal have been regulated through the Resolution, number 307, created in 2002 by The National Council for the Environment (CONAMA) which regiments the management and disposal of construction and demolition waste. As a result researchers have given much attention to developing solutions in reducing construction waste generation, management, recycling and its reuse within the productive chain (Evangelista et al., 2010, John, 2000 and Pinto, 1999). However, studies performed by Cardoso et al. (2006) on the environmental impacts resulting from the construction site activities and their respective environmental aspects conclude that environmental impacts go much further than those related to waste generation and include the interferences with the neighbourhood and on the physical, biological and anthropic environments caused by the different construction site activities. Besides this, such interferences with the local environments have received little attention to date from building companies, professionals and academics despite the significant impacts caused by them (Cardoso et al., 2006).

To better understand the relationship between site interferences and impacts, Araújo (2008) created a matrix relating environmental impacts to environmental aspects which were then related according to services performed on the construction site. Many of these impacts can potentially be controlled by the project team during the design and construction phase of a building (Kilbert, 2005; Cardoso, 2006). Further studies include predictions of impact magnitude, indicators for monitoring impacts and guidelines for implementing mitigation measures (Silva, 2007; Araújo, 2008). Therefore, considering the size and importance of the impacts caused by construction site activities, it is necessary that the construction industry addresses issues aimed at improving the sustainability of the construction phase of a building's life cycle. This however, requires a close collaboration among building owners, developers, architects, engineers, contractors and construction firms, facility managers, and real estate professionals. In Brazil, there is a lack of data and knowledge with regards the primary needs for sustainability and improvements in working conditions on construction sites. Several aspects may require research and the development of best practices aimed at rationalising resource use, reducing emissions and increasing the environmental

performance and energy efficiency of site equipment, tools and temporary facilities. Research aimed at improving the environmental quality, such as the health, safety and wellbeing of the site operatives and the surrounding community may also be required.

The aim of this work is to identify the priority research needs in sustainable technological solutions and improvements in working conditions on construction sites. The method of this work is based on a literature review of the different environmental assessment methods of buildings such as LEED (USGBC, 2009), BREEAM (BRE, 2009), and the Brazilian methodologies such as the AQUA Process (High Environmental Quality) and the Selo Casa Azul CAIXA (Blue House Seal from the CAIXA Bank), with particular emphasis on the construction phase of the building's life cycle. From this, a survey was formulated and applied to building companies in four cities in Brazil and their surrounding regions: Salvador - Bahia, São Paulo, São Carlos - São Paulo and Porto Alegre - Rio Grande do Sul.

2.Contribution of the Environmental Assessment Methods towards Sustainability on Construction Sites

Although all assessment methods show differences within their methods of criteria evaluation and their categories and themes in which criteria are distributed, it can be seen that all criteria fall under similar themes forming a flow system related to inputs and outputs (consumptions and emissions) within the physical, biotic and anthropic context of the construction enterprise. This flow system of inputs and outputs was also discussed by Degani, (2003) where the aspects relating to the sustainability of the built environment were subdivided into the following categories: (a) inputs; (b) outputs; (c) relationship with the external environment, (d) internal environment quality; (e) operation and use; (f) maintenance and renovations. Looking more specifically at the contributions of each method towards sustainability on construction sites, it was found that some methods gave more emphasis to this stage of the building project than others.

According to the U.S. Green Building Council guidelines (2009), the LEED method refers to the impacts caused by the construction site activities within its Sustainable Sites category. One prerequisite refers to Construction Activity Pollution Prevention which requires implementation of plans aimed at reducing the pollution arising from construction activities through controlling soil erosion, waterway sedimentation and airborne dust generation. It also emphasises the need to reuse building materials, adopt a materials selection policy using regional and rapidly renewable materials and incorporating recycled content into the new construction. It also requires implementation of a Construction Waste Management plan within its Materials and Resources category. The Indoor Environment Quality category allocates a credit on implementing a Construction Indoor Air Quality Management Plan during the construction phase. Within this credit, considerations must also be made to protecting onsite stored materials and absorptive materials from moisture and contamination. The use of air handlers as temporary heating and cooling systems to protect the well-being of construction workers must be addressed. Four additional credits are awarded for the use of toxin free and low volatile organic compound emitting materials and implementing control measures when materials containing VOC's are used in order to protect the health of installers and building occupants (U.S. Green Building Council, 2009).

The BREEAM method awards credits in an issue titled “Constructors’ Environmental and Social Code of Conduct within the BREEAM Management Category which emphasises the need to recognise and encourage construction sites which are managed in an environmentally and socially considerate and accountable manner (BREEAM Europe Commercial Manual, 2009). According to the manual a checklist divided into four sections is provided: Safe and adequate access, Good Neighbour, Environmentally Aware, and Safe and Considerate Working Environment. The safe and adequate access section provides best practices guidelines regarding car-parking, site entrances and exits, pathways, street lighting, scaffolding, site fencing and road signs. The good neighbour section provides best practices aimed at reducing noise pollution arising from site activities, and both visual and light pollution inflicted upon the local neighbourhood. Energy efficiency, water saving measures, alternative energy sources, fuel spillage, heavy water run-off control strategies and materials and equipment storage are given specific mention within the environmentally aware section. The safe and considerate working environment relates to temporary facilities, PPE’s, health and safety of site operatives and visitors. The BREEAM method also allocates an issue titled “Construction Site Impacts” within the Management Category defined by another technical checklist which outlines best practice requirements related to the CO_2 production from energy use arising from both site activities and materials transport, air pollution, ground and surface water pollution, use of an environmental materials policy and certified timber and implementation of an Environmental Management System.

The AQUA Process is an environmental assessment method adapted to the Brazilian context derived from the French HQE method by the Alberto Vanzolini Foundation (FCAV). It is defined as a process that requires project management to obtain “environmental quality” of a new enterprise or one undergoing renovation (FCAV, 2012). The AQUA process establishes best practices on construction sites within two of its categories: “Integrated choice of products, systems and construction processes” and “Low environmental impact construction sites.” The former relates to materials and product selection based on similar criteria as mentioned in the other assessment methods and the latter is divided into two further subcategories, one of which refers to construction waste management and its reuse and processing within the construction enterprise and the second subcategory requires plans for reducing noise and visual nuisances, nuisances arising from site traffic, particle emissions, dust, mud and concrete Spillage, control measures for air, soil and water pollution and minimisation of resource consumption such as energy and water on construction sites for which many best practices are suggested (FCAV, 2012).

The Selo Casa Azul CAIXA was developed by the Brazilian government owned bank, the CAIXA Econômica Federal and is a social-environmental classification instrument used for residential building projects. It aims to recognise enterprises that adopt efficient solutions applied to the construction, use, occupation and maintenance of buildings by encouraging the rational use of natural resources and improvements in living quality and the building’s surroundings (John et al. 2010). The seal is applicable to all residential enterprise projects that are submitted to the CAIXA bank for financing. The Selo Casa Azul considers the construction phase of an enterprise within the following areas: recuperation of degraded areas, conservation of material resources, reuse of temporary formwork and shoring and implementation of social practices such as educational programs (John et al. 2010).

To identify and compare the contribution of each environmental assessment method towards sustainability on construction sites, the methods were analysed and four generic themes were identified: Resource Consumption; Emissions and Solid Waste; Interface with the External Environment and Intrinsic Quality of the Construction Site. Different environmental aspects which could be allocated within each theme were further identified thus enablinga comparison between environmental assessments (EA) method, as presented in Table 1.

Table 1: Contributions towards sustainable construction sites by EA methods

Generic Themes	Environmental Aspects	Environmental Assessment Method			
		AQUA Process	BREEAM	LEED	SELO CAIXA AZUL
Resource Consumption	Material Resources	X	X	X	X
	Energy Efficiency	X	X		
	Water Management	X	X	X	x
Emissions and Solid Waste	Waste	X	X	X	X
	Air Pollution	X	X	X	
	Water and Soil Pollution	X	X	X	X
Interface with External Environment	Urban / Environment Quality	X	X	X	
	Noise Pollution	X	X		
	Visual Pollution	X	X		
Intrinsic Quality of the Construction Site	Health and Safety		X	X	
	Temporary Installations	X			X
	Innovation		X		X

Here it can be seen that all assessment methods provide best practice guidelines for material resources, waste generation and water and soil pollution. Water management, Air pollution and the urban / environment quality are considered by all but the Selo Caixa Azul. These best practices guidelines provide a means of reducing or completely mitigating the consequential impacts. Those related to resource consumption can be reduced through rational resource use, adopting practices that reduce material losses and selecting materials, products and construction systems with low environmental impacts and low embodied energy considering its whole life cycle process, (Berge 2009). The generation of waste products and other emissions during the different site production activities can be reduced through adequate planning and management. Furthermore, construction waste can potentially be valorised as a raw material or energy source (John 2000). Best practices and technologies aimed at controlling particle emissions during the different site activities can be adopted to minimise risks from air pollution and upon the occupational health of site workers and neighbourhood (Resende, 2007, Kukadia 2003, Usepa 2006). Wastewater produced during site activities can also cause groundwater and natural watercourse pollution, and therefore require plans for water waste management involving infiltration and surface run-off control as to minimise pollution and reduce the risks of contamination (NETREGS 2012). Wastewater and effluents can also cause a loss of the fertile top soil due to erosion which consequently reduces the soil's capacity to sustain local fauna and flora as well as compromising water drainage which can lead to flooding therefore requiring best practices to minimize such risks (Cardoso et al. 2006, Araújo 2008, Pulaski 2004). It is also important to control the impacts caused on the health, safety and welfare of the local neighbourhood as well as the physical, biotic and anthropic environments. By adopting practices that improve

safety and minimise the degradation of the environment including any discomforts and annoyances resulting from site traffic, visual and noise pollution which are directly or indirectly caused by the production activities (Cardoso et al. 2006; Gehlen, 2008). The impacts caused on the health, safety and welfare of site workers must also be considered by installing appropriate collective and individual protections during the different activities (Pulaski, 2004). Improvements on the Intrinsic Quality of the Construction Site such as the comfort and environmental performance of temporary facilities may also be required (Araújo, 2008). Innovative technologies can provide significant improvements on the performance of site equipment and facilities, thus providing sustainable solutions for construction sites.

3.Methods

This work consisted of a literature review, as presented in the previous section followed by the formulation and application of an on-line survey. The survey was composed of two sections: the first aims to identify the respondent company in terms of staff numbers, company age, niche markets within the construction industry and whether it is certified under the ISO 9001 management system or the Brazilian Program of Quality and Productivity (SIAC PBQP-H), ISO 14001 environmental management system, ISO OSHAS 180001 health and safety management system and/or has a building enterprise certified for sustainability. The second section is composed of a series of questions divided into the four aforementioned themes (Consumption, Emissions and Waste, Interface with the External Environment and Intrinsic Quality of the Construction Site). Each theme has an introductory paragraph contextualising the problem to help situate the survey applicant. A question was formulated for each possible priority research need derived from the previously identified best practice guidelines. The respondent was required to attribute a level of importance for the development of research in technological solutions and best practices for each question. Respondents were given five multiple choice answers: 1) Unimportant; 2) Little Importance; 3) No defined opinion; 4) Important and 5) Very Important. For each question a sub-question aimed at identifying whether the company adopts solutions for the research area under question within the routine operations of 50% or more of their construction sites.

Data was collected via online survey applied to 151 building companies and developers in four cities and surrounding regions of Brazil. The stratified sample is as follows: 61 construction companies in Salvador-BA, 27 in São Paulo-SP, 33 in São Carlos-SP and 30 in Porto Alegre-RS. Company profiles per city were characterised and then a comparison made between the level of importance and percentage of practices adopted by respondent companies per city per theme. The Intrinsic Quality of the Construction Site theme was further divided into 3 subareas; 1) Health and Safety (IQ-H&S), 2) Temporary Installations (IQ - TI) and 3) New Technologies (IQ - NT). Results are then expressed per theme, showing important and very important frequencies for each research area and the percentage of companies adopting solutions in over 50% of their construction sites. Research areas were considered most important when the sum of "important" and "very important" frequencies was above 50% and unimportant when less than 50%.

4.Results

Company profiles were characterised per city and its surrounding region as follows. **Stratum 1** – Salvador - State of Bahia: The questionnaire was applied to 61 companies, 22 of which responded, (36% return rate). 55% of responding companies have been on the market for over 21 years and 50% have over 100 employees. The majority work within the real estate market (91%) and 45% work with low income housing (HIS). Results show that 91% of companies are certified with ISO 9001 or the SIAC PBQP-H and 23% have an environmentally certified building. **Stratum 2** - São Paulo - State of São Paulo: The questionnaire was applied to 27 companies, 19 of which responded (70% return rate). Results show that 53% of responding companies have been on the market for over 21 years and 79% have over 100 employees. The majority (74%) work within the real estate market and only 11% work with HIS. 63% of companies are certified with ISO 9001 or the SIAC PBQP-H. 68% have a building certified with an environmental assessment method. **Stratum 3** - São Carlos - State of São Paulo: The questionnaire was applied to 33 companies, 12 of which responded (36% return rate). Results show that 50% of responding companies have been on the market for over 21 years and 25% have over 100 employees. The majority (75%) work within the real estate market and 25% work with HIS. 83% of companies are certified with the ISO 9001 or the SIAC PBQP-H. Only 8% have an environmentally certified building. **Stratum 4** - Porto Alegre - State of Rio Grande do Sul: The questionnaire was applied to 30 companies in the city of Porto Alegre, 44% of which responded (43% return rate). 46% of responding companies have been on the market for over 21 years and 31% have more than 100 employees. All companies work within the real estate market and 11% work with low income housing. Only 46% of companies are certified with the ISO 9001 or SIAC PBQP-H and 15% have a building enterprise certified for sustainability.

Figure 1 shows the level of importance frequencies per city for each theme. Comparing the level of importance shows that research in the “IQ –H&S” theme were considered as most important by all cities, and that the “IQ-NT” theme was considered as least important. All results are consistent within the different regions except for the city of São Carlos which considered research in the “Interfaces” theme most important. Themes with lower important and very important frequencies presented higher number of “no defined opinion” answers, which should be taken in consideration.

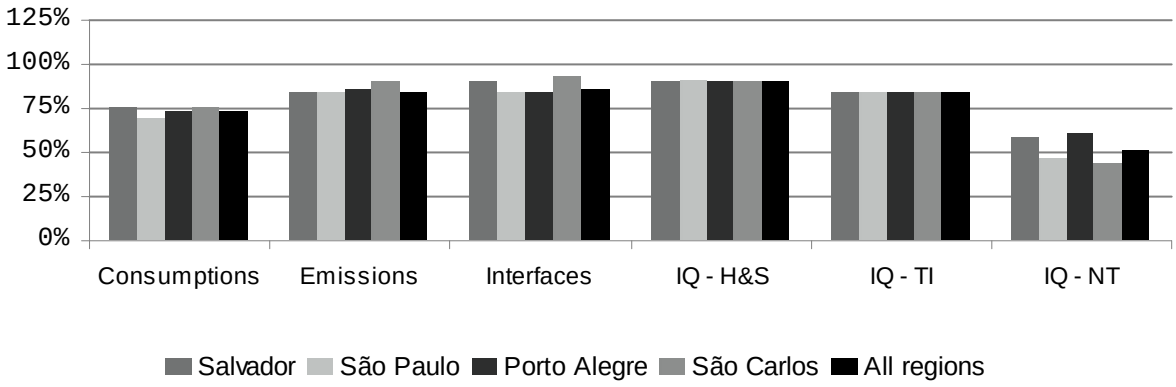

Figure 1: Level of importance frequencies per city per theme.

Figure 2 presents the percentage of practices adopted by construction firms per city and generally per theme where large differences can be observed. The “IQ-H&S” theme presented the highest number of practices implemented by construction firms in all cities, which was also considered as most important, most likely due to the stricter legislations (NBR 18) in place with regards Health and Safety on construction sites. The “IQ-NT” theme also presented the lowest number of practices implemented by companies in all cities. It is important to note that results found for the different themes are consistent among all cities.

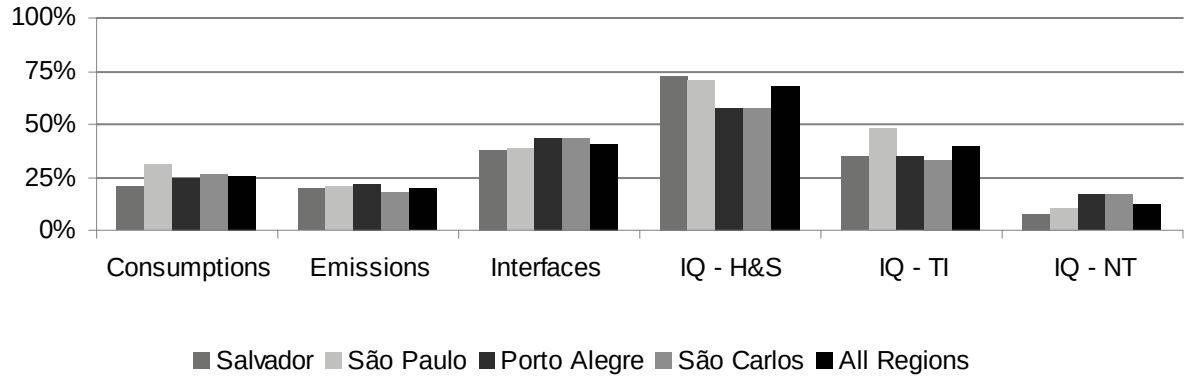

Figure 2: Percentage of practices adopted by construction firms per city per theme.

The following discussion refers to companies from all regions. For the “Consumptions” theme (table 1), research in “reducing material losses during the carrying out of services, deliveries, internal transport, storage and handling of materials in construction sites” was considered as most important (100% of companies), for which 58% of companies adopt practices. Interestingly “Greywater use” and “Use of alternative energy sources, including renewable energy” were considered as unimportant where 0 and 2% of the respondent companies adopt practices respectively despite the former being simple to install, perhaps considered unimportant due to the lack of knowledge on the water economised and how to implement such systems.

Table 1: Important and very important frequencies (I&VI%) and percentage of practices adopted (PA%) – Consumptions theme – All regions

Priority Research Needs - Consumptions	I&VI (%)	PA (%)
• Reduce materials losses during the carrying out of services, deliveries, internal transport, storage, and handling of materials on construction sites.	100	58
• Development of materials, products and construction systems selection criterion from responsible sources that include life cycle analysis information (origin, processing, use e maintenance, durability e disposal) and material properties like technical performance.	95	52
• Improvements of temporary installations with the aim of reducing potable water and electric energy consumption, as also in equipment, lighting and air conditioning systems on construction sites	86	29
• Reduction of Electric Energy Consumption during the Production Activities on Construction Sites	85	18
• Development of a supplier analysis system formalizing aspects related to federal revenues, use of environmental operating licenses, social responsibility, correct use of codes and standards, etc.	85	39
• Rainwater use on Construction Sites	59	5
• Use of alternative energy sources including renewable energy	48	0
• Greywater use on Construction Sites	44	2

For the “Emissions and Waste” theme, all research areas were considered important (Table 2). “Development of technologies and economically viable applications of construction waste materials still without recycling or recuperation solutions (Class C)” was considered most important (98%) although only 16% of companies adopt solutions. This, however depends on research, government incentives and agreements between industrial sectors amoung others. All research areas were considered as important within the “Interfaces” theme (Table 3). Research on “Erosive processes and risks of subsidence” was considered most important and 53% of companies adopt solutions. For all areas at least 27% of companies adopt solutions, thus emphasising the need to identify what is being done by construction firms, where improvements are required and how companies can be trained to adopt more practices.

Table 2: Important and very important frequencies (I&VI %) and percentage of practices adopted (PA%) – Emissions and Waste theme - All regions

Priority Research Needs - Emissions and Solid Waste	I&VI (%)	PA (%)
• Control of generation, quantification, separation, storage and disposal of construction waste on construction sites including Take-back scheme (return of waste products to manufacturers)	97	39
• Development of decontamination technologies and disposal solutions for dangerous construction waste products such as paints, solvents, oils or other contaminated waste products arising from demolition, renovations, radiological clinical repairs, industrial installations among others (Class D)	94	9
• Exploitation and Use of Construction Waste on Construction Sites	91	23
• Development of technologies and economically viable applications of construction waste materials that still have no recycling or recuperation solutions (Class C)	89	17
• Vegetation Preservation methods in construction site areas	85	33
• Sewage catchment and treatment systems and minimization of risks resulting from drainage on construction sites	85	21
• Identification of risks of particle emissions arising from production activities on construction sites and towards the neighborhood	85	21
• Control of groundwater levels, contamination and minimization of risks resulting from its management	85	21
• Characterization, monitoring e control of particle material emissions	74	12

All research areas in the “IQ- H&S” theme were considered as important and over 68% of companies adopt practices. Research on developing and improving “collective protection against falling from heights” “protections against people handling equipment” and “protections against electric shocks” were considered most important for which over 76% of companies implement practices. Although solutions exist, these must be improved. For the “IQ-TI” theme, “Improvements on the work safety conditions” and “health and hygiene conditions inside the temporary facilities” were considered most important (97%).

Table 3: Important and very important frequencies (I&VI %) and percentage of practices adopted (PA%) - Interface with External Environment theme - All regions

Priority Research Needs - Interface with External Environment	I&VI (%)	PA (%)
• Erosive processes and risks of collapse/subsidence	98	53
• Characterization of sound emitting activities and plans to mitigating noise nuisance	92	27
• Management of site access, pedestrian flow, equipment, loading and loading on construction sites	92	55
• Site interferences with local traffic, street conservation and pavements to guarantee accessibility	91	47
• Identification of risks of particle emissions derived from production activities on the neighborhood.	88	30
• Demolition processes and contingency plans	80	29

For the “IQ - NT” the “development of industrialised steel modular temporary facilities (containers)” was considered important by 86% of companies, used by 33% of respondent companies. All regions considered research on “Development of industrialised modular temporary installations in precast concrete, cement slabs or plasterboards for vertical wall systems” as unimportant. No companies use cement slabs, 3% use modular precast concrete and 2% use plasterboard for the vertical wall systems of temporary facilities.

Table 4: Important and very important frequencies (I&VI %) and percentage of practices adopted (PA %) - Intrinsic Quality of the Construction Site theme

Priority Research Needs - Intrinsic Quality of the Construction Site (IQ)	I&VI (%)	PA (%)
Health and Safety – IQ – H&S		
• Collective Protection Equipment against falling from heights on Construction Sites	98	77
• Protections against people handling equipment	98	76
• Protections against electric shocks	98	76
• Safeguards for material handling equipment	97	71
• Machine and equipment protection	97	68
• Protection of excavations	95	70
• National certification system for Industrialized Collective Protection Equipment, similar to existing certification system for Personal Protective Equipment (PPE) on construction sites	79	41
Temporary Installations on Construction Sites – IQ - TI		
• Improvements of work safety conditions inside the temporary installations	97	55
• Improvements of the health and hygiene conditions inside the temporary installations	97	62
• Reuse of temporary installation components and construction systems	92	42
• Improvements in the lighting, ventilation and air quality conditions of temporary installations	89	41
• External visual communication and signaling	86	67
• Improvements in structural safety of the temporary installations	89	41
• Improvements on the connectivity of the temporary installations with water supply networks, sewage treatment, energy and communication lines,	85	35
• Improvements in the operation, use and maintenance of temporary installations	85	29
• Improvements in fire safety of temporary installations	82	41
• Improvements of the water tightness of the temporary installations	82	32
• Furniture and other internal fixed equipment for temporary installations	77	35
• Improvements in the architectural flexibility (lay-out) of the temporary installations	74	32
• Improvements on thermal and acoustic comfort of the temporary installations	73	27
New Technologies – IQ - NT		
• Development of industrialized steel modular temporary installations solutions (containers)	86	33
• Development of industrialized modular temporary installations solutions using wood and its derivatives (eg. OSB)	73	23
• Development of industrialized modular temporary installations using cement slabs in the vertical wall systems	39	0
• Development of industrialized modular temporary installations solutions in precast concrete	35	3
• Development of industrialized modular temporary installations using plasterboard in the vertical wall systems	35	2

5.Conclusion

Priority research areas, number of practices adopted by companies per theme and the percentage of companies adopting solutions for each research area were identified. Research related to “Health and Safety” was considered most important by all regions which also presented the highest number of construction firms adopting solutions, perhaps due to

the stricter Health and Safety legislations in place (NBR 18). Results show that many companies implement solutions for the different research areas. It is therefore necessary to identify what is being done by companies and identify why companies are not adopting practices (lack of knowledge, high cost, lack of available technologies among others). Often, sustainable practices can be implemented without high investments but with planning and obligation. Also, some research areas were considered as unimportant and not practiced such as “greywater use.” Here, solutions are simple but require planning and prioritising within a company’s internal policy. Therefore new government policies should be formed with stricter legislations incentivising the implementation of sustainable practices and technologies on construction sites together with training programs so more construction firms can adopt practices. Interviews are being made with construction managers to validate survey findings, identify solutions adopted and the main difficulties and obstacles in implementing practices. From this, it is possible to identify existing solutions, where improvements are required and where New Technologies should be developed. Some research areas were identified as important, but were given less emphasis within the environmental assessment methods, thus offering opportunities for improvement. The technological solutions and best practice needs identified can help governments, research academies, entity classes and private industries in prioritising funding and resources for further research. Finally, results are expected to produce guideline proposals for New Science, Technology and Social policies aimed at environmental sustainability and improvements in working conditions on construction sites with special emphasis on low income housing projects.

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Public and Workplace Safety and Health in Hydraulic Fracturing

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Abstract

Fracking, a universally recognised term, which refers to hydraulic fracturing of gas bearing rock layers allowing their gas to be released into specially constructed collection wells. Practiced in North America, Europe and Asia the growth of this industry brings environmental and public health concerns to the fore. In April 2012 the UK's Department for Energy and Climate Change released an independent report, focused solely on potential seismological activity, which recommends stricter controls and procedures for developers extracting shale gas in the UK. Also in 2012 a North Carolina conference convened with the following objective; "to facilitate informed discussion to ensure that science-based policy decisions are made on energy development that will best serve the citizens …". A symposium on emerging hazards, at the EU OSH Strategy conference 2012, discussed how existing hazards were reemerging in new industries, particularly the fracking industry. While much has been written and spoken about the scientific and technical aspects of fracking, issues such as public and workplace safety and health need to be thoroughly addressed if the debate and ultimately final choices are to be appropriately informed.

The researchers preliminary scoping found concerns about; increased salinity of water supply adjacent to fracking sites, respirable crystalline silica dust in sand extraction sites, air and water quality, toxicity of drilling fluids and hazardous wastes. In this paper the authors adopt a multi-disciplinary approach involving value engineering, sustainability and ethics; exploring how functional aspects of engineering's societal responsibility; delivering sustainable development through knowledge, skills and professional expertise, are being addressed. In particular it;

- Provides a synopsis of the current 'fracking-related' public and workplace safety and health research, and

- Discusses safeguards drilling companies need to consider in anticipation of the wells finally being exhausted (or becoming uneconomic to operate).

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Key Words: Fracking, Hydraulic Fracturing, Economics, Ethics, Value Engineering

Shale gas and the Practice of Hydraulic Fracturing

US Energy Information Administration (USEIA) (2012) defines shale gas as the natural gas trapped in shale formations, petroleum and gas rich sedimentary rocks; very fine grained sandstone (King 2012). The practice of extracting shale gas [hydraulic fracturing] has been around since the 1940's. And while the practice has been known about since 1800s the first hydraulic fracturing (or 'fracking') experiment was carried out in 1947 and the process became commercially viable in the 1950s (King 2012). Hydraulic fracturing is the practice of drilling a well into the core of the shale, at significant depths, sometimes as deep as 2 - 3km (BGS 2011). A high-volume of highly pressurised fluids[frac fluid], a combination of water, sand and chemicals, is used to fracture the shale rock, which allows for the release of the shale gas. The rate of release of the gas is controlled by the use of a proppant, a substance used to keep an induced fracture (or frac) open.

The frac fluid is not a standard fluid, with many companies using a proprietary substances, for which they maintain a 'commercial confidence' right to withhold the full specification. Concerns are expressed that the nature of the proprietary fluids is such that they could harbor hazardous substances (quantities unknown). There are moves by the Environment Protection Agency in USA to have law amended to require companies to fully disclose their safety data sheets, however at present this is voluntary. A report provided to US House of Representatives (2011) concluded;

> *"[Hydraulic fracturing] has opened access to vast domestic reserves of natural gas that could provide an important stepping stone to a clean energy future. Yet questions about the safety of hydraulic fracturing persist, which are compounded by the secrecy surrounding the chemicals used in hydraulic fracturing fluids."*

A study by Cooley and Donnelly (2012) identified a commonality to the broad range of concerns regarding hydraulic fracturing. Acknowledging their small sample size, although happy with the broad nature of the target groups, Cooley and Donnelly (2012) identified that air and water quality featured heavily in list of concerns. Community aesthetics and increased traffic flows were well represented, while worker health and safety and seismic activity barely featured in the list of concerns. Rich (2009) confirmed in an air monitoring study of several locations in the town of DISH, Texas the presence of multiple Recognized and Suspected Human Carcinogens. Rich (2009) concluded that the identified compounds usually associated with industrial processes such as exploration, drilling, flaring and compression common to the natural gas industry. Lechtenbohmer et al (2011), in a report to the European Parliament, were advocating the need for a reassessment of the full impacts from hydraulic fracturing. They concluded that there were a wide range of conceivable accident risks such as; "*blow out with frac-water spills, leakages from wastewater or from fracture fluid ponds or pipes, groundwater contamination due to improper handling or unprofessional cementing of the well casing*" (Lechtenbohmer et al 2011). And these, they

argue, could be due to inconvenient handling, increasing economic pressures resulting in a speeding up of the process, which has the potential to decrease due diligence in hazards control with the consequent increase in the frequency of accidents. The USA experience supports such an analysis (Lechtenbohmer et al 2011). However their report was not entirely negative in its conclusions, indicating the authors' belief that these risks can be reduced and probably avoided with adequate technical directives, cautious handling practice and supervision by public authorities (Lechtenbohmer et al 2011).

Ewen et al (2012) in a study carried out by a panel of experts in conjunction with ExxonMobil's hydrofracking dialogue and information dissemination process concluded that there was no need for an outright ban on the practice of hydraulic fracturing. Acknowledging that up until now several unknowns exist with regard to the environmental and health impact of the process Ewen et al (2012) suggest proceeding with caution, not whole scale. The following elements, they argue, are necessary if the process is to proceed; "*a defined state of the art; a legal framework that addresses the new risk dimension entailed by hydrofracking; and additional scientific knowledge*". For the time being, they continued; "*all that should be made possible is exploration of gas fields and realization of single model projects, for which extensive safety precautions should be taken and the scope of investigations and testing should be expanded*". Other studies, not so directly aligned to the oil exploration industry suggest a more cautionary approach, calling for further regulatory controls or an outright ban. Wiseman (2009) argues for a comprehensive national survey the environmental effects of fracing that is scientifically rigorous.

Wiseman (2009), acknowledging the good work being carried out by some of the oil and gas companies as technology advances, suggests that, in the light of such concerns and while studies are in progress, Congress should reconsider exempting fracking from the Safe Drinking Water Act. States should review whether general regulation of the oil and gas industry adequately addresses the potential public health and environmental impacts, Wiseman (2009) also argues. Lechtenbohmer et al (2011) indicated that, "*some risk is inherent to uncontrolled fracturing which results in uncontrolled mobilization of fracture liquids*". For instance, they maintain, it is well known that "*small earthquakes can be induced by hydraulic fracturing which might mobilize gas or fluids through "naturally" created fractures*". Seismic activity was explored, following minor tremors were detected near the Presse Hall well near Blackpool, UK. Green, Styles and Babtie (2012) in their report to the UK's Department of Energy and Climate Change (DECC) acknowledging that the seismic activity could be directly attributed to fracking activities, made the following recommendations;

1. Hydraulic fracturing procedure should invariably include a smaller pre-injection and monitoring stage before the main injection.

2. Hydraulic fracture growth and direction should be monitored during future treatments

3. Future HF operations in this area should be subject to an effective monitoring system that can provide automatic locations and magnitudes of any seismic events

in near real-time.

4. Operations should be halted and remedial action instituted, if events of magnitude 0.5 M_L or above are detected.

They further recommended that for any future sites identified for hydraulic fracturing that base line seismic assessments be made prior to any industrial activity commencing. Consequently UK fracking operations are paused (BGS 2011) not banned. UK Government sees no need for a moratorium. This concurs with the work of Williams (2012) where he notes the requirements within the Legislation and Policy Framework for the Queensland Government. It is a requirement that notification be given to landowners prior to commencing and after cessation of operations and that that notice, as well as specifying the chemicals used and the volume of same, must also provide details of completed seismic surveys.

Worker health and safety is largely under represented in the research carried out into the hydraulic fracturing industry operations thus far. Health and Safety Executive (HSE) in the UK have regulatory responsibility for well design and construction, which among other things requires independent verification of the well design. Further scrutiny is afforded through local planning process, the environmental protection agency's consideration of environmental impacts, and the obligation on operators to disclose the content of their fracing fluids. However with issues of public health to the fore along side environmental concerns it is remiss to exclude the health and the safety of those at the 'coal-face'. Bernard Goldstein, a professor in the Graduate School of Public Health at the University of Pittsburgh (cited in Schmidt, 2011) says, "…*published epidemiologic studies relating shale gas production to health are virtually nonexistent*". There are many hazards identified to which the degree of exposure and the extent of appropriate hazards controls ought to be addressed. The Royal Society and the Royal Academy of Engineering (RAE) (2012) consider that health, safety and environmental risks "*can be managed effectively in the UK as long as operational best practices are implemented and enforced through regulation*". RAE (2012) suggest a means of collating and sharing best practice information, the engagement of the regulatory authorities (in UK) and support the use of the Research Councils to further research. The unfortunate omission in the list of priorities was worker health and safety as they suggest research should include "*the public acceptability of the extraction and use of shale gas in the context of UK policies on climate change, energy and the wider economy*" (Royal Society and RAE, 2012). As the debate into fracking progresses and the decision as to whether it should continue research into the ability to control worker safety and health by engineering controls and through managerial procedures must take a higher priority. Such due diligence is a fundamental aspect of the engineers' code of ethics, enshrined in the International Engineering Alliance (IEA)'s Washington, Sydney and Dublin Accords (IEA 1989, 2001, 2002).

Workplace Hazards Associated with Hydraulic Fracturing

Respirable Crystalline Silica and other Health Hazards

In reviews of occupational safety and health hazards associated with hydraulic fracturing, health and in particular worker exposure to respirable crystalline silica was the dominant hazard discussed. Crystalline has long been recognized as a carcinogen (NIOSH 2010). To cause lasting damage the form of silica must be of a respirable particle size to enter the deep lung. The United States Occupational Safety and Health Administration (OSHA) and National Institute for Occupational Safety and Health (NIOSH) have identified respirable crystalline silica as a worker health hazard during the hydraulic fracturing processes (OSHA, 2012; Esswein et al., 2012b). NIOSH began thier worker health exposure characterization effort in January 2010 (NIOSH, 2010). OSHA regulates exposures to crystalline silica via a Permissible Exposure Limit (PEL). Because OSHA PEL's are not updated frequently, NIOSH produces a Recommended Exposure Limit (REL) based on more current toxicological data; thus the REL is more stringent than the OSHA's PEL. In a recent personal air sampling research, Esswein et al. (2012a) took 116 employee breathing zone samples for respirable crystalline silica at 11 hydraulic fracturing sites and found 47% above the OSHA PEL and 79% above the NIOSH REL. In addition they found that 31% of thise surveyed were 10 times above the NIOSH REL (Esswein et al., 2012b).

Esswein et al. (2012a) found that sand can be used in amounts up to 4 million pounds per well, and exposures occurring mostly in cementing jobs, sand transferring, and sand loading. From a review of the Esswein et al.'s presentation (2012a) and the OSHA and NIOSH reports, it does not appear these are new operations. In other words, the fracturing process is simply using a known carcinogen in traditional ways (cementing, transferring, and loading). Hydraulic fracturing operations need to utilize occupational safety and health range of control to solve this known problem. Esswein et al. (2012a) also found worker exposures to other chemicals during the hydraulic fracturing process including the following: diesel particulate; volatile organic compounds; hydrogen sulfide (H2S); hydrochloric acid gas; aldehydes; and lead. Although in their report, it is not clear whether overexposures existed to these substances occurred in any of the worker's personal breathing zones (Esswein et al. 2012a). The findings and recommendations focused on repairable crystalline silica.

Site clearance / preparation

Before drilling and extraction processes the site must be cleared and prepared for heavy equipment to install the hydraulic fracturing systems. Pipelines might also be installed. Potential worker safety and health hazards in this stage would be indicative of those associated with forestry operations, logging, site grading, and trenching (Marcellus Shale Corporation, 2012).

Hydraulic Fracturing Processes / Construction of wells

No specific literature or reports have been found that focus on worker safety hazards specific to the installation of the hydraulic fracturing process, its operation, or decommissioning. The safety and risks of these operations must be further studied to determine if new or unique hazards exist and to recommend control measures to the industry. From a review of the fracturing processes, the risks of explosions, and the general exposures to heavy equipment and truck traffic risks exist. It is not known whether these are

increased compared to general mining and construction activities. Injury attorneys are naturally seeking to get in on the hydraulic fracturing business. For example, one attorney in Pennsylvania, where the large Marcellus gas deposit sits, focuses on injuries and recognizes that the rush for the gas can contribute to worker fatigue. From their website, "The Marcellus Shale gas rush has made a lot of money for the oil and gas companies, as well as local contractors and workers in the fracking industry. Yet too often, worker safety is a secondary concern when there is so much pressure to work fast and keep the gas flowing (Huber and Palsir, 2012). They label these accidents, "*fraccidents*", and go on to describe two recent claims. They "*represented a worker who fell from a ladder onto a drilling unit, resulting in an elbow displacement fracture. In another case, piping was tied down with a snap binder so tight that it exploded in our client's face, causing an orbital socket injury and brain trauma*" (Huber and Palsir, 2012).

Ethics Reflections on Hydraulic Fracturing

Following on from the financial scandals of the early 2000s that saw the collapse of several large financial institutions, [Enron, Worldcom, Anderson] corporations are expected to conduct their affairs in an ethical manner taking into consideration the interests of all their stakeholders, not solely those of the shareholders. To this end the Organisation for Economic Cooperation and Development (OECD) issued in 2004 their Principles for Corporate Governance, which over the subsequent years has come to be the guide for all types of corporations and businesses on their financial and societal obligations. The obligation to manage the affairs of the hydraulic fracturing business, like any other business, in a sustainable manner that ensures continued economic success and growth in the interests both of the company and of the nation is at the core, but in parallel is an ethical obligation to those who are effected by the undertakings of the business; namely customers, employees, the communities in which the business operates, the state and in relevant cases the wider society when it is effected by what the business does or fails to do.

Ethical codes are now a common place in many businesses whether stated as core values, a statement of ethics, or other policy on financial integrity, corporate social responsibility or environmental commitment. The validity of an ethics code is tested against three criteria; that the code, in the context of the whole of the business is self-consistent, that it is good for humanity (Fromm 1947) and that it is capable of universalisation, (Crain 1985, Eckensberger 2007). Self-consistency requires that there are no logical contradictions arising from the various elements of the code, including the company's policies, objectives and mission statements. The fact that a company does not adhere to its own code is not a negation of the self-consistency of that code, but rather evidence of non-compliance and unethical behaviour by the company. Contradictions arise for example when the legal requirements of contracts of employment conflict with the professional duties of engineers to prioritise their obligations to the wider society (IEA Accords 1989, 2001, 2002). Companies expect and reward loyalty and it is considered good ethical behaviour to work (in full compliance with the law) in the interests of the employer. But when the interests of the employer is not fully accepted by the communities in which they operate, professionals seek ways to mitigate the contradiction between conflicting duties. The EUCI Conference on Engineering and Technology Developments (2012) included an agenda item to explore potential risk

management strategies with the aim of avoiding costly permitting delays and for reducing potential litigation risks. Though the outcomes of such deliberations may lead to strategies that will benefit external stakeholders and the environments, the terminology used clearly implied an economic objective on behalf of the extraction companies and that any benefits to other stakeholders or the environment would be incidental. The function of ethics is that it is concerned with guiding behaviour such that at its most basic it will not harm others and in its more evolved forms actively contributes to the good of others. The OECD principles at their core aims to have companies behave with financial integrity and in the interests of their shareholders. But they recognise too that companies in their undertakings have an impact on other stakeholders and that these interests must be considered and acted upon whenever harm is a real outcome. The more directly affected by the undertakings of a company the more their interests become of immediate concern. The nature and extend of the undertakings of the extraction companies is such that large population centres, extensive rural communities, underground and surface water sources extending tens and hundreds of miles from well and quarrying activities are all effected (Blohm et al. 2012, Haworth et al. 2012) and that the key stakeholders constitute a substantial proportion of the current and future populations in countries where these activities are undertaken.

There is evidence that the economic and social advantages to be gained from coal-bed methane extraction (CBM) will be extensive. Many $billions will be generated, tens of thousands of jobs will be created and a key political issue will be energy security for the next generation, (Considine et al. 2011, Tieman et al. 2012). However when these economic benefits compete with public concerns about water contamination, landscape destruction and air pollution (Haworth et al. 2012, Osborn et al. 2011) it is not sufficient to pour money into lobbying the law-makers to pass legislation that favours the extraction companies to the detriment of the interests of local communities. In 2011 a single extraction company spent $1.09m on a single issue compared to $480,000 by the Citizens Campaign for the Environment on all their lobbying issues, (Lerner 2011, Browning & Kaplan 2011). Disproportionate expenditure on lobbying may benefit the shareholder but it leaves the remainder of the key stakeholders to live with the consequences. In Australia one organisation views coal-seam gas (CSG) as but another activity on the land and in the landscape that requires management (Williams 2012). Recognising the potential significant negative impact on water resources, and that protection of the biodiversity and landscape is critical but a neglected national resource issue their proposals are that CSG production and agricultural and forestry protection needs to be approached holistically and managed as part of whole landscape planning, (Williams 2012). There is an element of realism here that recognises that gas extraction is going to be part of the immediate future but that it should not be carried out in isolation from other human activities and needs in respect of the environment, but integrated fully within national biodiversity and social protection measures. Where harm, real and alleged, has occurred independent, objective assessments are required that will determine the nature of the harm, its causes and what will be required to remedy the situation and prevent reoccurrences. The causes of the earthquakes in 2011 near Blackpool, UK, thought o be attributed to direct fuel injection into adjacent fault zones during treatment projected a low probability for further earthquakes. Green, Styles and Baptize (2012) were unconvinced of these projections basing their conclusions on the fact that the earlier reports had failed to identify a causative fault and that details knowledge of

faulting in the area was poor. The recent jailing of Italian scientists (Halsbury's Law Exchange 2012) for failing to predict earthquakes is a salutary lesson that competent objective assessments uninfluenced by political or economic considerations is the minimum that is to be expected from companies and their consultants.

Failure to properly examine the concerns of effected communities and allow extraction practices to continue without adequate regulation will not satisfy the complainant, even when the democratic organs have carried out the assessments. The US's Environment Protection Agency report (2004) into contamination of underground sources of drinking water (USDW) concluded that injection of hydraulic fracturing fluids into CBM wells poses little or no threat to USDWs and that there was no justification of further study at that time. In respect of complaints of contamination, they saw no conclusive evidence that water quality degradation was due to hydraulic fracturing, but that several other sources may be responsible. That report was based on existing literature and on incidents complaints of drinking well contamination. An objective specific study focussing on the particular issue was not commissioned, however by 2011, when over 1,000 complaints had been received the EPA was required by government to fund a new study to examine cases of contamination, (Lerner 2011). A mature ethic requires that where harm is occurring or is alleged, studies into the causes must have as a priority the interests of those on whom the harm is falling. Failures in this regard or partisan approaches to investigations is a negation of ethical behaviour and of the positive economic opportunities presented by they processes.

Ultimately, a code of ethical behaviour must have universalisability, namely that it underscores the fundamental value of equal existence (Kohlberg, cited in Crain 1985) and recognising that that takes precedence over claims to property or wealth rights, or of national energy security issues. Such rights and issues gain validity only in the context of being subordinate to achieving universal equal existence. In this respect it is incumbent upon the industry to consider in their impact assessments how this is to be achieved, how the environment is to be protected, how contamination of the water and air resources is to be prevented and how the production of gases is to contribute to human welfare and sustainability.

Economic Reflections on Hydraulic Fracturing

The extraction of natural gas from shale formations is one of the fastest growing trends in American on-shore domestic oil and gas production (Ground Water Protection Council, cited in Jackson et al 2011). USEIA (2011) estimate that there is 750 trillion cubic feet (tcf) of technically recoverable shale gas resources in 3 regions of USA, North East, Gulf Coast and South West. These current figures [2011] greatly expand previous estimates where it was reported (Moss 2008) that 31 tcf might be recoverable from the Marcellus formation in North East Region of USA, compared with INTEK's estimate or 410 tcf (cited in USEIA 2011). Williams, Stubbs and Milligan (2012) report that while Australia has large coal seam gas [shale gas] potential, exploration is in its infancy consequently resources are, as yet, poorly understood and quantified. Nevertheless Queensland Government has indicated that in their state alone the coal seam gas [shale gas] industry will generate over 18,000 jobs and net annual royalties in the order of AUD$850m. In UK British Geological Survey (BGS) (2011)

has estimated the UK shale gas reserve potential could be as large as 5.3 TCF.

Priddle (2012) reports "*producing unconventional gas is an intensive industrial process, generally imposing a larger environmental footprint than conventional gas development*". Often more wells are needed and hydraulic fracturing is usually required to boost the flow of gas from the well. In the face of all predictions of economic prosperity offerd by hydraulic fracturing the diverse nature of economic benefits claimed the discussion, kept simple, can be advanced by asking the '5W' questions from an economic perspective, namely, Why, What, When, Where and Who. An intriguing tapestry regarding fracking can be created from the simplest premise;

1. Why fracking, well why not?

2. What can fracking provide for humanity from an economic perspective?

3. When will the costs and benefits of fracking be realised?

4. Where does the value to humanity lie in the practice of fracking?

5. Who are the potential winners and losers from the practice?

Why Fracking or similarly why Nuclear or any other form of energy provision; all have potential repercussions if they go wrong but the argument for the use of fracking is that even though it is potentially risky the potential benefits can be argued to far outweigh the potential costs. Considine et al (2011) argues that the US has shale gas reserves large enough to satisfy US demand for decades or centuries to come. The report also postulates that the support activities such as steel, sand and gravel supply and engineering services to the shale gas extraction projects are not easily outsourced to foreign suppliers so the local economy and workforce is largely going to benefit. Considine et al (2011) concludes that shale gas production can offer regions a stream of revenues that doesn't quickly dry up quoting figures of $4,000,000 on average in economic benefits from each well. Compare this with Lechtenbohmer et al (2011) report for the European Parliament that concludes that in a time when sustainability is key it should be questioned whether the injection of toxic chemicals into the ground should be allowed or banned in Europe. This is further reinforced in that the report also indicates that the potential shale gas plays are too small to have an impact on the European gas supply.

This brings the discussion to Cost Benefit Analysis (CBA) as a means of justifying the practice. Who prepares the CBA and for whose benefit and at whose cost? It could be argued that potentially the organisation that prepares the CBA may not be able to be truly impartial due to the specialist nature of the practice. Lechtenbohmer et al (2011) argue that Life Cycle Analysis (LCA) should be mandatory and that consideration should be given to including a CBA as compulsory based on an extensive LCA for each individual project. This they maintain is necessary to demonstrate the benefits for society as a whole.

This also brings to the fore the point of value for money and return on investment (ROI). No government or organisation no matter how wholesome the image they appear to present, are in the business of not getting value for money and a ROI that matches or exceeds their shareholders or voters expectations. Fracking from a headline point of view seems to have very few friends around the world but it is no accident that those who generally are in favour of the practice are those who will benefit financially. Taking a generalist big picture viewpoint on Considine et al (2010) and Lechtenbohmer et al (2011) are at opposite ends of the spectrum, with Considine et al (2010) arguing from a US standpoint, very much in favour of the benefits of and apparent lack of environmental costs of fracking. Lechtenbohmer et al (2011) posting a more guarded cautious approach to fracking within the European Union, concluding that the large gaps in EU regulation with regards to fracking need to be addressed before any decision to move forward in a substantive manner and also highlighting the need for full awareness of the potential massive environmental and human impacts. The US based report (Considine et al 2010) on the other hand whilst identifying possible environmental impacts considers them as such a low risk that when applying CBA techniques they indicate an average cost of $14,000 per well as opposed to $4million of benefits per well. However there is insufficient evidence to corroborate these assertions. The key final recommendation from Lechtenbohmer et al (2011) was with regards to much tighter regulation to reduce the possible costs to the environment and population to a minimum. Lechtenbohmer et al (2011, p.79) concluded that;

> *"Because of the complex nature of possible impacts and risks to the environment and to human health of hydraulic fracturing, consideration should be given to developing a new directive at European level regulating all issues in this area comprehensively".*

One final question is how two relatively opposing viewpoints can exist on the same process, which is simple to answer on the premise that there are a least three sides to every story, namely, the for side, the against side and the real truth somewhere in between. Ultimately then where does the economic truth with regards to fracking lie?

Future Research

The list of questions under each heading could be virtually endless but this only goes to reinforce the need for further critical research into the field of hydraulic fracturing from OSH, ethics and economics perspective. Not surprisingly this preliminary scoping exercise has raised more questions than answers which from a review of the existing knowledge of fracking practices appears to be a practice that for Governments deciding on whether to develop their Fracking agendas should take time to consider and demand independent answers on a case by case basis. Fracking is certainly not a process where one approach fits all or benefits all localities and communities with or without appropriate regulation.

Compared to worker health, there appears to be a gap in worker safety research during the preparation, installation, and operation of hydraulic fracturing processes. The safety and risks of these operations must be further studied to determine if new or unique hazards exist and to recommend control measures to the industry. Researchers should seek opportunities

to work with drilling companies, developers, and workers to adequately describe the nature of safety related hazards and risks in hydraulic fracturing and through a consideration, using the established approaches to prevention through design, value engineering/ CBA and cultural maturity indexing establish the efficacy of elimination or mitigation of OSH hazards. Research should focus on equipment manufacturers and the design of individual wells. In the interim engineering controls, training, and enhanced procedures should be developed and communicated within the industry.s

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Can Darwin show us the way? Improving social housing through an evolutionary design approach

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Abstract

The evolutionary theory of Darwin defends that nature develops through natural selection and in gradual small steps, from specific characteristics in great variety to best-fit specific contexts. This paper builds upon previous research experience on social housing projects in Brazil, to advocate for the gradual introduction of small changes in a standard housing model, as a potential way to improve social housing, through a figurative analogy of the insights offered by Darwin in the field of biology. Cross-analysis of implementation costs and value delivery to end-users forms the basis to validate the proposed evolutionary approach. Darwin further stimulates the study presented here in giving value to detailed observations - in this case, Post Occupancy Evaluation (POE) data - on local social housing. Such data analysis indicates that the present design model needs improvements. Changes should occur in stages, as progressive improvements, through an evolutionary process. Evolutionary change can be tested along the way, avoiding the substitution of an old model with a new, but not yet tried design typology. Value perceived and desired by final users can act as persuasion arguments in the decision making process. The step-by-step approach is useful to convince social housing stakeholders of the true benefit of such improvements and impact on quality of life enhancement. Gradual change is also important for economic reasons, being less costly and technically more viable. Various opportunities for improvement are outlined in this paper, demonstrating that evolutionary, incremental change only needs sporadic larger “mutations”, once simpler elements have been dealt with. As in natural processes, systematic assessments are important after every small evolution, to evaluate if and to which extent improvements were achieved and that they are user- and context-conscious. The discussion on the development of a Darwinian inspired model to improve the design of social housing in the studied context shows that, although mass-produced, this type of architecture can evolve towards more customized, comfortable, sustainable and higher quality homes.

Keywords: Social housing, design improvement, user preferences, value perception, evolutionary design

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1. Introduction

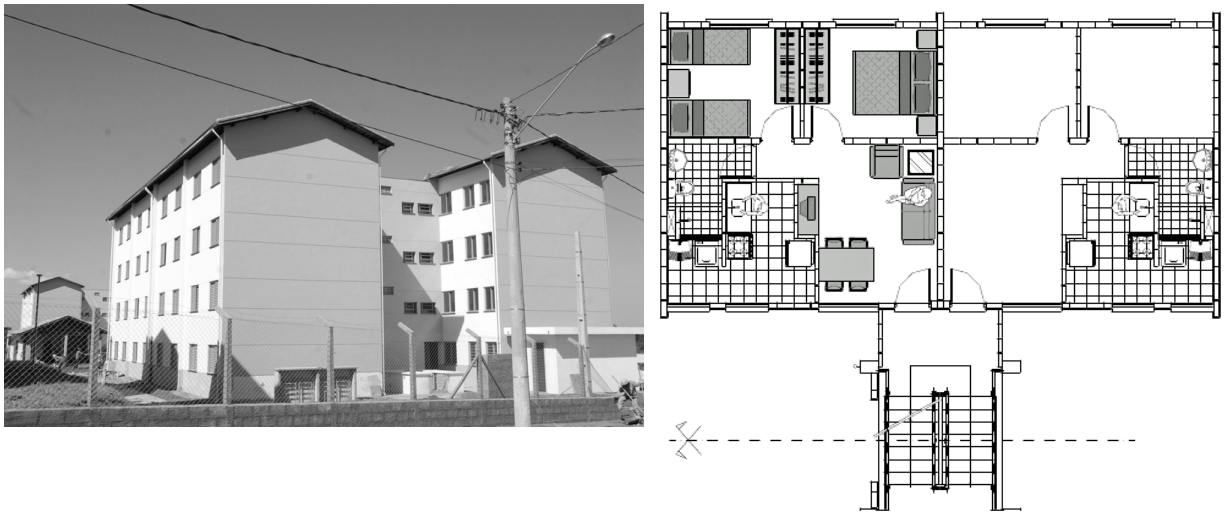
Most of us remember from our high school biology classes something about Darwin and his theory of natural selection, which states that: [the] preservation of favourable variations and the rejection of injurious variations occurs in nature (Darwin, 1859). We also have learned a number of other important things from Darwin, of which few have been applied to social housing or for that matter to architecture or building construction. First and foremost, Darwin shows us the way by advocating the adoption of a more scientific design process, to attain a better fit between desires and delivery in mass housing design. Secondly, the idea of the gradual introduction of changes in a standard housing model is worth to be tested. As shown by Darwin, incremental small mutations can have positive effects in nature. A figurative analogy is herein defended for social housing, using the Brazilian setting as backdrop.

This analogy must be put in its specific context however. The construction industry in general, and housing companies in particular, are conservative and tend to repeat solutions to stay within their comfort zone, being thus adverse to change. Cost is also a major barrier for considering radical modification. Finally, a move towards a new design model should only happen after a thorough multidisciplinary analysis of new proposals has occurred, to allow systematic learning, with an identification of the elements that were successful and those that were not, to avoid the repetition of mistakes in future developments.

2. Social housing in the local context

The housing deficit in Brazil was estimated at 5.6 million homes in 2008, mainly in urban areas. To tackle such enormous figures, many Federal and State programs have been implemented, with massive investments since 2007 to improve housing and urban conditions, including basic sanitation, street pavements and investments in transportation. Design models of social housing have changed little over the last twenty to thirty years in Brazil, and projects developed by the State of São Paulo housing authority - *CDHU* - are used here as the main scenario for pointing out opportunities for improvement. CDHU is the largest producer of social housing since 1986 in the State of São Paulo. Priorities and policies of CDHU are to attend, through subsidies, to the housing needs of low-income level families state-wide. Analogous design principles for similar population strata are adopted, independently of location or size of housing projects.

Many developments are located in smaller cities and thus not especially affected by large urban conglomeration problems, as found in the city of São Paulo, the largest metropolitan area in Brazil. The projects are usually located at the urban fringes, where land value is lower than in consolidated centres. The prime objective is the provision of a large number of housing units, both as detached single-family houses and walk-up apartments blocks. Apartment blocks are primarily H-shaped, with up to 5 walk-up storeys (Figure 1a). A typical floor plan for the residential unit, of some 35 m^2, is shown in Figure 1b. This model is based on providing a minimum culturally accepted set of spaces to families, with two bedrooms, a small living room, kitchen, bathroom and laundry service area. The H-shape allows for cross-ventilation in all apartments, which is an important aspect, given the local tropical climate.



(a) **(b)**

Figure 1: (a) Example of walk-up apartment blocks with surrounding lot fence and small community centre in the background; (b) Sample floor plan of two housing units in a walk-up apartment block.

Minimum standards are applied in relation to indoor space dimensions and construction quality, mainly to attain affordability. The peripheries of such projects will quickly cater to the new population with small shops, bars and everyday services offered in makeshift constructions or adaptations of houses in neighbouring districts. Average monthly income of the population living in typical CDHU projects ranges from one to four minimum wages (around US$300,00 to US$1200,00, in November 2012). Unemployment can be high among such residents, living of informal work and government assistance programs.

Although the projects produced by CDHU can be criticized in relation to the housing quality they offer to end-users, this company has made efforts to improve its standards within the affordability constraints, typical to this context. Construction quality has been the focus of the company's QUALIHAB program, created in 1997. Despite its merits, this plan has not influenced the design model itself. Due to the fact that user satisfaction rates in social housing in Brazil are generally high, changes to the existing model are very slow and not substantial in their impact on housing quality (Kowaltowski et al., 2006). Approval rates of low income families are however not the best indicators of housing quality, since users may have lived in slums or risk areas, paid high rents for poor quality housing or were crammed into borrowed spaces. As legal home ownership status is granted, any degree of housing improvement will be invariably highly rated (Kowaltowski et al., 2006), regardless of its effectiveness. Under these circumstances, little pressure is put on the social housing agents (politicians, housing authorities and construction companies) to invest in new housing designs and to introduce changes to improve social housing for end-users and for urban design quality as a whole.

Literature on housing of the last forty years has criticized design models similar to those of CDHU and shown that retrofit remediation policies are implemented, though with limited success, and that new designs are necessary to avoid repetition of errors and to stimulate

the introduction of incremental improvements. Most studies on progressive improvements of housing in developing countries focus on urban infrastructure. They question the application across the board of global standards, affecting costs and therefore affordability of homes (Choguill, 2007; Ferguson & Navarrete, 2003). Many studies, especially European ones, touch on improvements of the design model as a whole (CABE, 2009_a, 2009_b). In recent years, the literature on building quality assessments has discussed complementary studies to the usual evaluation of satisfaction rates as part of Post-Occupancy Evaluations (POE). The assessment of values that families attach to elements of the home are seen as an important contribution to understand end-user needs, preferences and views related to the built environment (Spencer & Winch, 2002; Benedikt, 2008; Preiser & Vischer, 2005). A study on housing preferences in the UK (CABE, 2009_b) indicated that aspects such as location with good schools and a safe neighbourhood are important, but also external appearance, low maintenance, good quality construction, a private large garden and garage are considered important features of a house or flat. Inside the home, the size and number of rooms and light and ventilated spaces count as positive aspects. The study also showed that architectural style refers to traditional values, although data from e.g. BedZED in the UK, indicate that when a design is well thought through, users will appreciate contemporary aesthetics as well.

3. Social housing design processes

The phases of analysis, synthesis and evaluation were introduced into the field of design when, after the Second World War, designers sought to enter the scientific world, to diminish subjectivity in design, to apply scientific knowledge more effectively and use information technology productively. The methods brought forward by Jones in 1970 were organized according to input (what designers know) and output (what designers want to know) and included a variety of methods still important today. To increase design quality and productivity stakes have been put on design methods in the last fifty years, especially in architecture. The goal in developing design methods was to improve the process and the product outcome. Importance was given to adding structure to the decision-making activity in design. The argument was that, after all, most disciplines depend on tools, techniques, and protocols of good practice, so design and in particular, architectural design should have the same. Figure 2 shows a model of a recommended design process, based on a learning loop, with several analytical and evaluation stages. Figure 3 expands this model to become an integrated process, indicating the specific contributing agents in such a process.

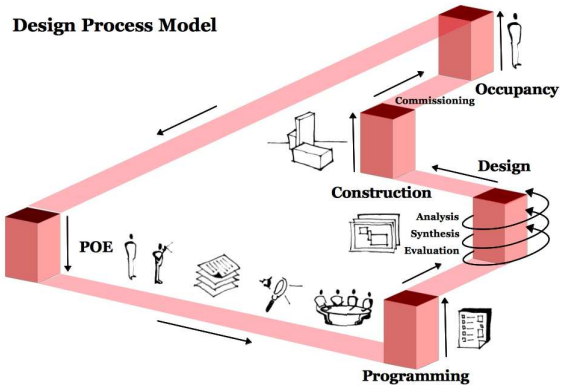


Figure 2. Recommended design process, based on a multi-stage learning loop.

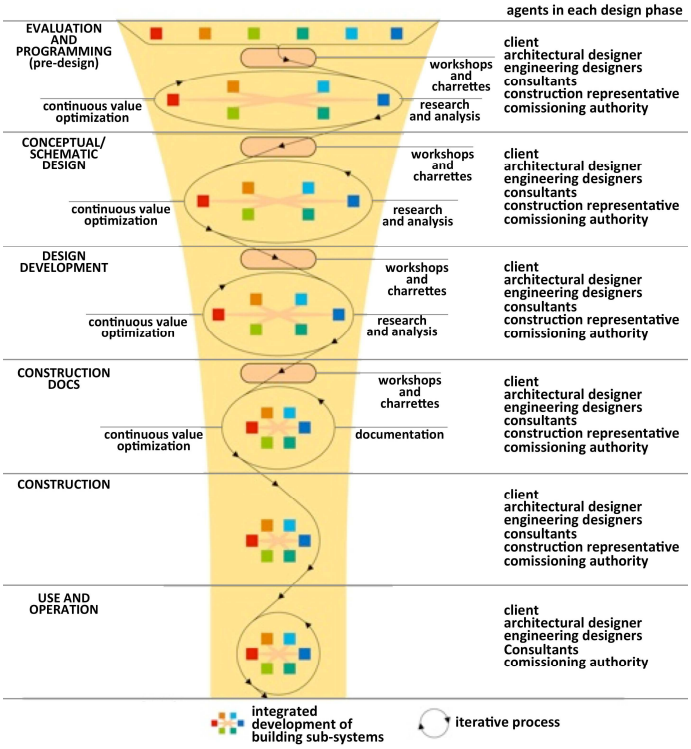


Figure 3. Integrated design process (Figueiredo, 2009)

Many studies have been conducted since the 1960´s, resulting in important contributions to the understanding of the design process. In 1984 Nigel Cross established a division of subjects in design methods and identified each area's principal exponents. Thus, control over the process is the goal of studies by Christopher Jones and Bruce Archer. The structure of design problems - considered as wicked - has been discussed by Peter Levin, Barry Poyner, Melvin Webber and Horst Rittel. Wickedness consists in the continuous redefinition of the problem during the period of its resolution and the impossibility of testing the validity of solutions. The cognitive aspects of design are studied by Ömer Akin, Bryan Lawson, Jane Darke, John Thomas and John Caroll; while the philosophy of design methods is further investigated by Geoffrey Broadbent (1973) and Nigel Cross (1984).

Most studies on the design process in architecture show that it does not follow rigid rules. Designers do not apply universal methods and rarely externalize their thought process. Research in design methods considers the creative process complex, solving what are termed wicked or ill-structured problems (Rittel & Webber, 1973). Thus, design problems are only loosely formulated, at times through a detailed brief or architectural program. A rigid systems view of design cannot therefore be defended, even in the face of losing credibility regarding the design profession, since rationality in design may forget to embrace important concepts such as value judgment, context and uniqueness. In design, as a form of problem solving, reasoning proceeds from objective and functional assessment to means or (product) decisions, but does not follow a formal scientific process in which, by deduction, one reaches a logical result from posed premises. To improve this process, creative methods are seen as important to stimulate original and quality solutions. Jones (1970) already emphasized the importance of methods that aid in the search for ideas in design processes. In such early texts Brainstorming, Morphological Charts and Removing Mental Blocks are mentioned as appropriate tools.

The overview of studies on the process, its principles and methods, as well as the philosophies and theories on architecture and its creative process, shows that design studies are essentially interdisciplinary. From this, an understanding of the rich data coming from the design methods movement is created, which continues to have repercussions in diverse areas, contributing to the development of specific research domains that support professional activities. POE/Building Performance Assessment has gained importance and design quality evaluation methods are being developed, including the ever more present sustainability certifications. Attention to the pre-design phase, or the development of a detailed design brief, has increased in professional activities. Computational support tools, such as Computer Aided Design (CAD), rapid prototyping and applications of artificial intelligence have sprung from the design method movement to enrich and facilitate the design process.

The local social housing process has few of these items. Housing authorities such as CDHU are connected to the local political system and serve the government’s interests. In this context, changes are slow to take effect, since the indicator valued the most by implementing agents is the number of homes distributed during a political term. Costs are reduced to maximise the number of residential units produced and allocated to low-income families. Thus, change in design is avoided since the model in use has already been tried and tested at the lowest costs. There is no feedback loop and the cost of a new design phase is avoided, since old known models are perpetuated and evaluation is superficial. Moments of reflection during the design process are important however, for several reasons. Consultants of various specializations in design and construction can be added to bring their expertise to solving specific problems. Reflection also creates opportunities for more routine corrections, avoiding later retrofits. A reference model for an evolutionary design process for social housing can be constructed as shown in Figure 5. The boxes indicate gradual improvement through step-by-step changes in design or retrofit interventions, which can be assessed and applied until the model is no longer able to incorporate small incremental changes and a larger “mutation” (i.e. design model substitution) is needed, as informed by analysis and feedback loops. End users – or their proxy, from a potential users pool - should

be included in the reflective stages to voice real demands and increase understanding in relation to design solutions, adopted to increase constructive criticism and eventually satisfaction rates. In this way, giving importance to local specifics and opinions, as well as facts, can be part of an improved social housing design and construction process.

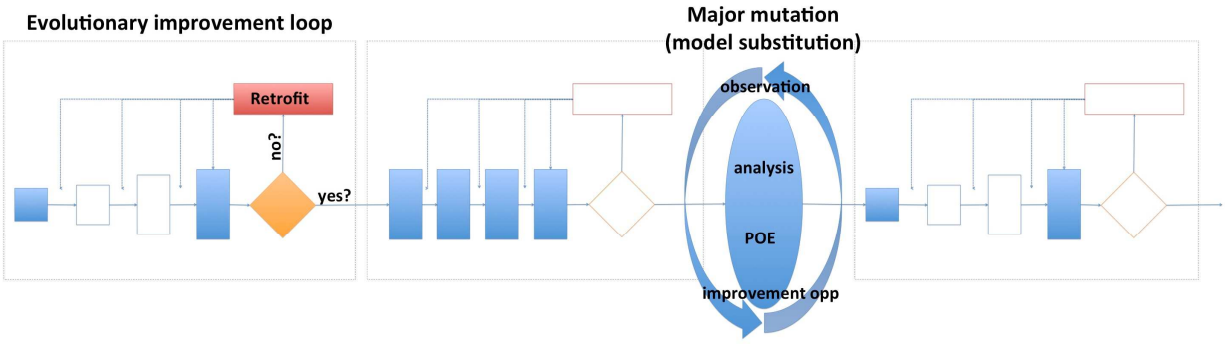


Figure 5. Analogy model for evolutionary change in social housing design

4. Methodology and research approach

The present argumentation advocates for the gradual introduction of small changes in a standard housing model. The paper deploys reasoned previous research experiences by the authors as arguments to promote a figurative analogy between Darwin's evolutionary, natural selection understanding and potential improvements in social housing delivery processes. Kowaltowski & Granja (2011) conducted a study in which end-users of four multifamily social housing projects, based on five storey walk-up apartment blocks, were asked to identify the most valued aspects of housing design. Approximately 200 respondents ranked a list of design attributes, based on the concept of stated preferences. Results of this study are shown in Figure 6. Desired values and user satisfaction rates, especially in the city of Campinas, in the State of São Paulo, were established in earlier research. Cross-analysis of implementation costs and value delivered to end-users initiated by Ruiz (2011) forms the basis to validate the proposed evolutionary approach.

5. Evolutionary change in social housing design

Darwin was not the first scientist to rely extensively, in his scientific method, on compelling evidence of observations and reflections, which made him arrive at new insights and the formulation of theories. The careful and long period of observations and the often simple, but ingenious, tests conceived by Darwin however should be an inspiration in an endeavour to improve local social housing (Boulter, 2009). The many individual observations of housing in Brazil should be organized and characterized to give a scientific base for change. The Brazilian association for technology in the built environment (ANTAC) supports this endeavour through the HABITARE database, where important POE studies are available online.

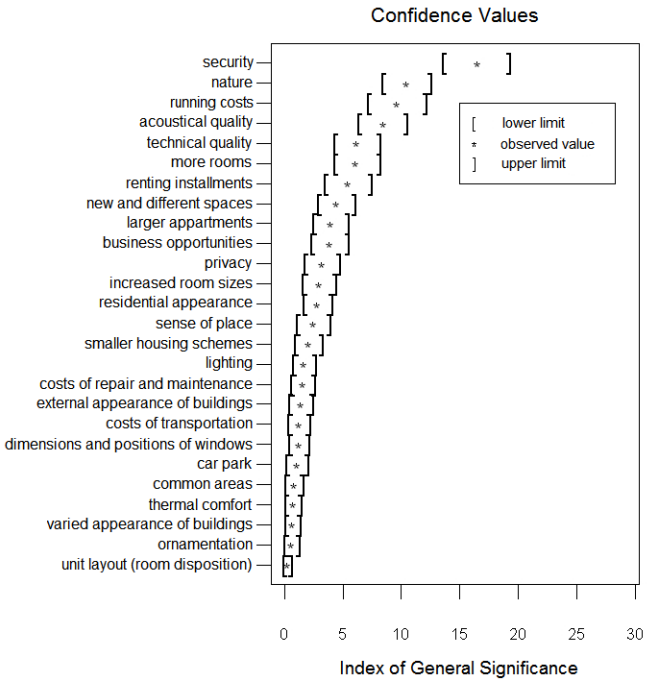


Figure 6: Perceived value of design quality items of social housing projects in Campinas, Brazil (Kowaltowski & Granja, 2011).

The many evaluations in the HABITARE database and data on user preferences (Figure 6) indicate that the current, less than ideal, local social housing design model needs improvements. From the evolutionary theory of Darwin we know that nature develops, through natural selection and in gradual small steps, specific characteristics in great variety to best-fit specific contexts (Dawkins, 1996). This idea can be used as an abstraction of a method to attain a better fit in mass housing design. Changes should occur in stages, as progressive improvements, thus through an evolutionary process. Here it is not nature that determines the positive improvements along an evolutionary process, but user preferences, technical observations and the dynamics of society and the construction industry.

In most social housing developments in Brazil, users are not the instigators of change, since they are typically only heard as far as satisfaction rates are concerned. With very low-income families these rates tend to be high when slum type dwellings or homes in risk area are substituted by social housing options. In the private housing market, users exert some form of impact, and buyers are shown to value specific aspects of housing trends. The market however first has to do its homework and overall assess, run functional tests and validate their financial feasibility, often expressed by (higher profits) sales. Other factors can be used in this scenario, such as: POE studies, retention of users in a specific location, and the increase in financial value of residential developments. In the social housing case, however, these factors cannot be applied, even though retention of families has often been implied as having an importance in this segment as well. Retention in the social housing market is however related primarily to the lack of choices low-income families have.

Other arguments must be found to give improvements an impulse in social housing in countries like Brazil. Security, for instance, is a major issue (Figure 6) and, as crime rates have been connected to negative housing conditions, these factors should be explored. As

few new solutions are tested in social housing and overall project changes are very rare, the proposal of incremental change presents itself as a viable idea to increase social housing quality. The step-by-step approach is important to convince social housing stakeholders (housing authorities, politicians, designers and planners, construction companies and end-users) of the true value in promoting an increase in quality of life indicators for the final users, or homeowners. Also, evolutionary change can be tested along the way, avoiding the substitution of an old model with a new, but not yet tried design typology. Perceived and desired values (Figure 6) can be used to act as persuasion arguments in the decision making process. Gradual change is of further importance for economic reasons, since small changes are less costly, technically more viable and less time consuming during the planning and construction phases of a project.

6. Opportunities for the introduction of improvements

Various opportunities for improvement to the given model were outlined in Kowaltowski and Granja (2011). These are outlined in Table 1 but can improve the existing design model only up to a certain extent. Evolutionary, incremental change only needs sporadic larger “mutations”, after simpler elements have been all dealt with (Figure 5). As in natural processes, systematic assessments are needed after every small evolution, to evaluate if and to which extent improvements are achieved and how user- and context-adapted they are. The discussion on the development of a “Darwinian model” to improve the design of social housing in the studied context can show that, although mass-produced, this type of architecture can evolve towards more customized, comfortable, more sustainable and higher quality homes. The improvements should be related to the perceived values of users as shown in Figure 6. Furthermore, technical observations and assessments should indicate priorities in relation to possible incremental design adaptations. The construction industry itself may bear pressure on changes for technical and productivity reasons.

User desires are overshadowed by security issues in Brazil, and humanization of social housing can only be achieved when urban crime is reduced and people feel safe enough to express other housing related desires, such as access to views with a substantial percentage of greenery, access to a garden to grow food and flowers, as well as having opportunities for healthy leisure activities. Better acoustic barriers on the urban scale and between residential units are also essential, since noise has been linked to aggressiveness in people and therefore creating insecurity.

A previous study conducted in housing developments of CDHU suggested site-planning changes at the design stage, which do not affect costs per residential unit, but allow for the introduction of small and incremental perceived improvements (Kowaltowski et al., 2006). Urban design that optimizes orientation of the built mass and bedroom windows, in particular, to reduce solar gain in a hot and humid climate can improve thermal comfort conditions and operational energy use at no construction cost premium. Also, reducing paved areas, but providing small car parks, with a vehicle space allocation for each housing unit, cannot only improve the urban landscape and vegetated open spaces, but also the form and location of land reserved for schools and other public services.

Table 1: Opportunities for improvement in CDHU housing projects in Campinas, Brazil

#	Improvement opportunities	Contributions toward:
1	Introduction of ceiling panel in bathrooms [Problem = visible sewer pipes of upstairs neighbour]	Privacy; Acoustic quality; Technical Quality
2	Personalized floor materials	Ornamentation
3	Plaster decoration detailing	Ornamentation
4	Exchange of Type of Front Door [Solid wood door = preference]	Security; Acoustic & Technical quality; Privacy & Ornamentation
5	Add a veranda to residential units as add-ons	Nature, Privacy and Thermal Comfort; Increase transitions spaces, improve shading conditions, allow outdoor activities, gardening
6	Allow openings in external end facades [Permit surveillance of building surrounding, parking lots, playgrounds, entrance to housing development; Permit joining buildings and creating various types of apartments (2 to 3 bedrooms)]	Security; Variety; Individualization
7	Installation of fence [Around compound and individual buildings]	Security; Sense of place- territoriality; Smaller housing scheme
8	Small business centres; Child care centre & Health centre Job opportunities [Security guards, Concierge; Small business owner; Employees of health and child care centre]	Business opportunities
9	Increase distance between windows of H-shaped buildings	Privacy; Acoustics; Dimensions and positions of windows
10	Elevate the ground floor apartments by 50cm above the entrance level	Security, Acoustics and Privacy
11	Introduce vegetated barrier between entrances and residential units at ground level	Nature, Privacy, Security, external Appearance, Ornamentation
12	Introduction of transition space in front of apartment door [Solution = Circulation removed from front door; Space for flower pots, personal decoration etc.]	Privacy; Security; Nature
13	Improve detailing of steps of stairs [Rough edges may cause accidents; Poor looking finishing]	Technical quality
14	Open the common stairs [Problem: lack of visibility – feeling of lack of security; Take out dividing wall]	Security; Common areas
15	Replacement of “community centre” by Barbecue area; Playground; Benches and Landscaping project	Nature; Ornamentation; Common areas
16	Individualize exterior of buildings through colour schemes	Ornamentation; Varied & Residential look; Sense of place
17	Permit door openings in party walls [allow joining of adjacent apartment spaces]	Larger apartments; More rooms, Increased room sizes; New and different spaces; Unit layout (room disposition)
18	Motorcycles (and bicycles) parking [Problem: burns from exhaust pipes]	Security; Car park
19	Site planning changes [Optimization of Orientation (sun and wind) of building blocks Optimization of community services will impact better building design; Increase urban tree planting; Plan for leisure activities; Optimize paved areas / reduce impermeable areas; Use of light colour pavements & envelope (roof and facades)]	Thermal comfort (increase shade, reduce heat gains); Avoid HVAC use; Sustainable use of energy resources; Improve rating of neighbourhood; Improve aesthetic aspects of housing projects; Increase retention of families

Ruiz (2011) applied value-engineering concepts to CDHU social housing. Since in a previous study (Kowaltowski et al., 2006) users indicated that the small community centre, part of these housing complexes, is rarely used and not considered as an important element in the housing scheme, the cost of this building could be re-allocated to cover the first six items from Table 1, actually valued by users (Figure 6), although not specifically in the same order of priority. Some of the improvements listed in Table 1 can be achieved through retrofitting, while others are more appropriate or more easily achievable with incremental design changes to new constructions. For instance, an additional ceiling panel in bathrooms (# 1 in Table 1) can be retrofitted, but lifting the building 50cm (# 9 in Table 1) above the main ground-floor entrance cannot. The addition of a veranda, though may be considered a rather large increment in change (mutation), is quite possible in existing developments as add-ons and good examples of such retrofits exist. Some retrofits, which support concepts of sustainability, have already been introduced in CDHU multifamily housing. Individual meters for water and electrical energy consumption have been installed. Other retrofits can be envisioned such as: programs for recycling of solid waste; solar water heater installations; shading devices for bedroom windows facing east, west and north; whitewashing exterior walls and roofs; replacing paving material of parking areas; interventions do improve landscaping (shading, green ground cover); rainwater collection from roofs (use for cleaning of exterior paving and watering of garden areas); installation of monitoring sensors; energy efficient lighting fixtures and presence sensor in public areas among others can be suggested.

7. Conclusions

This paper outlined changes that are considered important to be introduced into the social housing model provided by the State of São Paulo housing company, CDHU in Brazil. These propositions are inspired by analogies to Charles Darwin's scientific methods, based on careful observations and analysis. A further metaphor of Darwin's theory of natural selection was also presented. Thus, small incremental changes in the presently adopted housing design model are shown to be feasible in their introduction, even for a construction sector that works on bare minimum costs for provision of the maximum number of housing units. Retrofitting of existing projects is a viable option to improve housing quality on an incremental basis up to some extent, beyond which new designs are needed. Such design changes and improvement studies can be planned to best suit user values, as well as new technical recommendations that arise. Further research is suggested on several fronts. The extensive literature available on POE studies of design models similar to those adopted by CDHU should be systematically analysed, to identify new incremental changes from lessons learned. Secondly, the actual gradual changes occurring in local social housing models should be analysed. The recent large investments by the private and public sectors and the increasing pressures to include sustainability certifications in the construction industry as a whole in Brazil, may indicate interesting contributions toward improved social housing designs. Other studies should identify the limits of incremental change to old design solutions and the need for periodic adoptions of new models (total "mutations") in response to social and cultural dynamics and to significant changes occurring in the building industry. Furthermore, studies on true innovation in the social housing sector in developing countries

are paramount, to avoid the repetition of errors, improve peoples lives and advance in the science of architectural design and building construction as a whole.

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Delay Analysis Methods and Factors Affecting their Selection in the Construction Industry in Gaza Strip

Adnan Enshassi [1], Asmahan Jubeh [2]

Abstract

Delay in construction projects is a global phenomenon. The contracted parties resort to a variety of delay analysis methods (DAMs) to determine the parties responsible for delays. The delay analysis methods have various capabilities and requirements that limit their use in the construction industry. This paper aims to survey the commonly used DAMs and to determine the factors that influence their selection according to contactors and consultants perspectives in Gaza Strip. A total of 100 contractors and consultants were approached, of which 33 participated. The results indicated that, the most commonly used DAM in Gaza Strip is "As-planned vs. As-built". It has been found that, the most important factors which affect DAMs are: records availability, baseline programme availability and updated programme availability, while dispute resolution forum and applicable legislation are the lowest factors that affect the selection of DAMs. This paper stressed the importance of obtaining full records throughout the project life cycle in order to assist the disputed parties to select the appropriate DAM that gives relatively correct results. Training courses covering delay analysis methods and their requirements are recommended.

Keywords: Delay analysis methods, construction, disputes, life cycle, training.

1. Introduction

Most construction projects are executed through contracts which are not easy to comprehend even by professionals. As the size of project increase, the contract becomes more complex and ambiguities causing the project to undergo cost and time overrun, which in turn create ground for claims and disputes (Iyer et al., 2008). Construction projects are composed of many interrelated elements of labour, material, cost, schedule, and other resources, that make it difficult to decide the proximate causes of delay, and the parties responsible for delay (Kim et al., 2008).

Parties to dispute may seek compensation by submitting a claim. The equitable allocation of responsibility for project delays is essential to resolve most construction disputes and claims. Analysis of schedule delay is conducted to find out what happened in the project, when and how delay events impact schedule and which party causes that delay in order to settle the delay claim or dispute without litigation. For this, there are different methods available for schedule delay analysis methods (DAMs) in construction industry. The DAMs produce

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results of different levels of accuracy and the analysts have differences in the way they deal with the issues often in disputes. Hence the selection of the appropriate DAM is paramount (Palaneeswaran and Kumaraswamy 2008).

For this reason, Iyer et al. (2008) developed expert system that could give guide lines to owners and contractors to evaluate their claims before they are pursued. Palaneeswaran and Kumaraswamy (2008) formulated a knowledge- based decision guidance system to help all disputed parties to rationalized their approaches towards the preparation and evaluation of extension of time claims due to delay. Arditi and Pattanakitchamroon (2006) established a selection guide lines for the DAMs by comparing the most common DAMs under different circumstances. Braimah and Ndekugri (2008) have studied the factors that influence the analyst's selection from the DAMs. Adhikari et al. (2006) used the analytical hierarchy process to select the appropriate DAM.

In Gaza Strip no previous researches were conducted on the factors that control the selection of the appropriate DAM. This modest research is an attempt to survey the most commonly used DAMs in Gaza Strip and the factors that influence the analyst's selection from these DAMs. The objective of this paper is to survey the widely used delay analysis methods in Gaza Strip with respect to contractors, consultants and overall, and to determine the factors that influence analyst's selection from these delay analysis methods with respect to contractors, consultants and overall.

2. An overview of common delay analysis methods

The task of investigating the events that cause the project to delay in order to determine the financial responsibilities of the contracting parties arising from the delay is referred to as delay analysis (DA) (Braimah and Ndekugri, 2008). Delay analysis is a formidable challenge since the contracted parties each prone to view most delays as the responsibility of the others which give rise to disputes. Responding to such challenges, the industry has developed techniques used to prove or disprove the claims either in the course of the project, or after completion under arbitration or any other form of dispute resolution mechanisms (Arditi and Pattanakitchamroon 2006). Yang and Kao (2007) reviewed 28 articles regarding construction delay analysis techniques and developed a knowledge map for delay analysis.

The popular and comparatively acceptable delay analysis methods (DAMs) include As-Planned vs. As-Built; Impacted as-Planned; Collapsed As-Built; Window Analysis and Time Impact Analysis (Braimah and Ndekugri 2008, Palaneeswaran and Kumaraswamy 2008, Yang et al. 2006 and Zack et al. 2006). However, no one method is accepted by project participants and suitable for all situations. Arditi and Pattanakitchamroon (2006) excluded the Window Analysis from being a common method, while Conlin and Retic (1997) excluded the Collapsed As-built and Window Analysis methods. The following is a brief discussion of the common DAMs:

2.1 As-planned vs. as-built method

This method compares the activities of the original critical path method baseline programme with those of the as-built programme, assesses the impact of delays on the project, identifies the sequences that actually define the duration of the project and determines the causes and the parties responsible for that delay. The advantages of this method are inexpensive, simple and easy (Braimah and Ndekugri, 2008). Arditi and Pattanakitchamroon (2006) concluded that as-planned vs. as-built relies on common sense, the analysis incorporates both as-planned and as-built schedules, and both contractor and owner delay events which facilitates the ability for recognizing concurrent delays and acceleration. He suggested using it as a starting point in relation to other complex DAMs.

Among the disadvantages, it assumes that both schedules are correct in activity duration and logic relationships sequences, failure to consider changes in the critical path and inability to deal with concurrent delays and complex delay situations (Braimah and Ndekugri, 2008). It lacks a systematic procedure to evaluate the impact of delay events individually (Arditi and Pattanakitchamroon, 2006). This method should not be used by itself except in the simplest cases (Zack et al., 2006).

2.2 Impacted as-planned method

The method uses only an as- planned schedule for delay analysis where delays and disruption are considered as activities into as-planned critical path schedule to demonstrate how schedule completion date is affected by those delays. The difference between schedules completion dates before and after the addition of delay activities will produce the amount of project delay due to each delay event. This method does not need as-built information to operate since it assumes that the planned construction sequences remain the same and does not consider any changes in critical path (Braimah and Ndekugri, 2008). Arditi and Pattanakitchamroon (2006) concluded that impacted as-Planned Method is the least favored method since it has theoretical flaws.

2.3 Collapsed as-built method

This method does not need as-planned schedule where an as-built critical path schedule with all the delays encountered should be ceated. Subtracting the delays from the schedule to create collapsed as-built schedule will indicate what would have occurred but for those events. It produces results of good accuracy (Braimah and Ndekugri, 2008). It is easy to understand by triers of fact and can determine delay impact in case of limited time and resources available for analysis (Arditi and Pattanakitchamroon, 2006). Great effort is required in identifying the as-built critical path, failure to consider changes to critical path and inability to deal with concurrent delays and complex delays (Braimah and Ndekugri, 2008).

2.4 Time impact method

This method depends on the assumption that running a series of analysis on schedule updates can assess the delay impacts to projects. This method is probably the most reliable

technique when data and source documents are available in the required format and in the required time frame (Braimah and Ndekugri, 2008). Although it provides both parties to dispute to an opportunity to scrutinize the delay and reduce disputes, it is considered costly to operate particularly when large number of delaying events is involved and consumes lots of time (Arditi and Pattanakitchamroon 2006).

2.5 Window analysis method

Using as-built critical path schedule, the total duration of project is divided into number of time periods, which are updated chronologically from the as-built information including all delays encountered to get the project delay that occurred during a certain period. The project completion dates resulting from any time period under review is subtracted from that prior to the review. This method takes care of the dynamics nature of the critical path but it is considered as time consuming, costly to operate particularly when large number of delaying events is involved (Arditi and Pattanakitchamroon 2006, Braimah and Ndekugri, 2008).

3. Factors influencing the selection of the appropriate DAM

In the construction industry there is no single, standard and accepted procedure to determine the impact of schedule delay. However in given circumstances, one method can be more beneficial than another (Bubshait and Cunningham 1998. The selection of the suitable DAM depends on the ability of scheduling data, the familiarity of the analysts with the capabilities of the software used in the project, clear specification in the contract concerning concurrent delays and float ownership and time, fund and effort allocated to the analysts (Arditi and Pattanakitchamroon, 2006). Braimah and Ndekugri (2008) identified 18 factors that affect the selection of the appropriate DAM. These factors are: records availability, baseline programme availability, nature of baseline programme, updated programme availability, time of the delay, reason for the delay analysis, the other party to the claim, applicable legislation, the form of contract, cost of using the technique, size of project, duration of the project, complexity of the project, nature of the delaying events, skills of the analyst, the amount in dispute, dispute resolution forum, and the number of delaying events.

4. Methodology

Quantitative research strategy involving the use of a cross sectional survey was adopted. The first stage in questionnaire design process was an extensive review of the literature relevant the most commonly used DAMs in Gaza Strip, and the factors influence their selection. The questionnaire design was composed of three sections to accomplish the aim of this research. The first section is general information about the respondents. The second section is a survey of the most commonly used DAMs in Gaza Strip. The third section requires respondents to score on 5- point likert scale (1 for "very important" and 5 for "not important") the listed factors on their degree of importance in their decision making as the appropriate DAM to adopt in any given situation.

The targeted sample that consists of contractors and consultants was chosen randomly. 100 questionnaires were distributed (50 for consultants and 50 for contractors) and 33

questionnaires were returned (18 for consultants and 15 for contractors). The data was measured at ordinal level. Non-parametric statistics involving frequencies and relative important index was conducted for each selection factor to facilitate their ranking with respect to contractors, consultants and overall.

The relative importance index (RII) of each selection factor was computed using Eq. (1) to facilitate their ranking (Braimah and Ndekugri, 2008).

$$RII = \frac{100\%}{n} * \sum_{i=1}^{i=5} w_i f_i \qquad \text{Eq. (1)}$$

Where fi is the frequency of response; wi is the weight for each rating (given by rating in scale divided by number of points in the scale which is 5; and n is the total number of responses.

The degree of agreement between the contractor group and the consultant group in their ranking was investigated using Kendall's coefficient of concordance (W) as defined by Eq. (2) (Legendre, 2005).

$$W = \frac{12 \times s}{k^2 (N^3 - N)} \qquad \text{Eq. (2)}$$

Where s is the sum of square of deviations of ranking sum of the factors from the mean, k is the number of respondent groups, which is 2 in this case and N is the number of factors ranked.

Eq. (3) is used to determine the significance of W using a chi-square approximation of the sampling distribution with (N – 1) degrees of freedom (LEGENDRE, 2005).

$$x^2 = k(N-1)W \qquad \text{Eq. (3)}$$

5. Analysis and discussion

5.1 Characteristics of the respondents

The contractor's response was 30%, while the consultant's response was 36%. Figure 1 shows the distribution profile of respondent's designation. The contractor's respondents lack the existence of claim consultant and about 60% of them have been acting as project managers and site engineers. About 60% of the consultant's respondent's have been acting as firm managers and office engineers. Besides 10% of them are claim consultants.

Figure 2 shows the distribution profile of respondent's experience. About 60% of the consultant's respondent's have more than 15 years experience, while less than 30% of contractors have more than 15 years experience.

Figure 3 shows the distribution profile of respondent's education. The education of the consultant's respondents is better than contractor's respondent. 92% of contractor's respondents have just Bachelor's degree and none of them have PhD. Degree. 33% of the

consultant's respondents have Master degree and 14% of them have PhD. degree. The results reveal that the consultant's respondents have higher experience and education and hence are more suited than contractors to comment on the delay issues covered in the questionnaire.

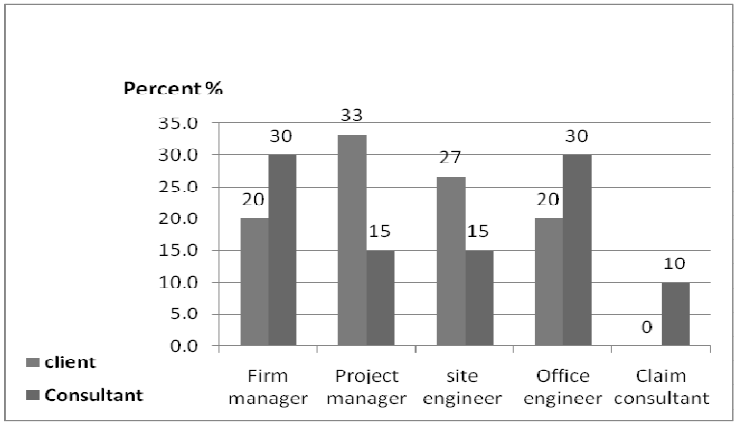

Figure 1: Respondent's designations

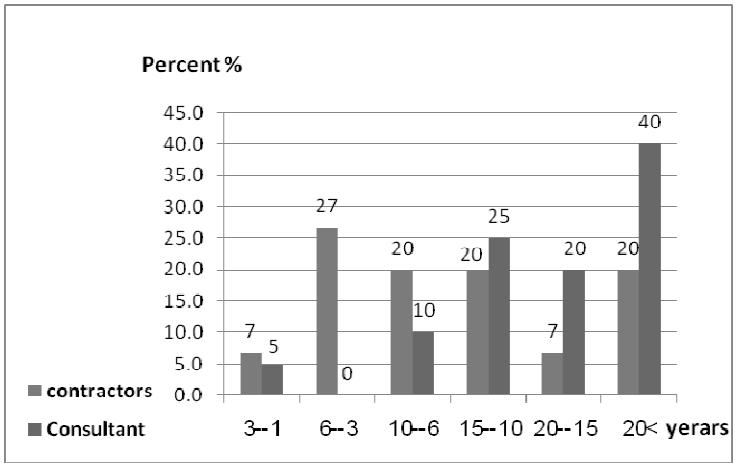

Figure 2: Respondent's experience

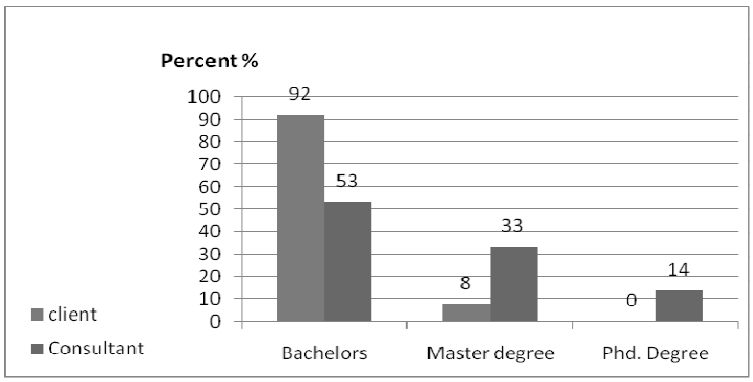

Figure 3: Respondent's education

5.2 The common used DAMs in Gaza Strip

Figure 4 Shows that 80% of the contractor's respondents have consent that the As-Planned vs. As-Built Method is the most widespread method in Gaza Strip. The other methods used in rare situations. 20% of them are recognizable with impact as-planned method and Time impact method.

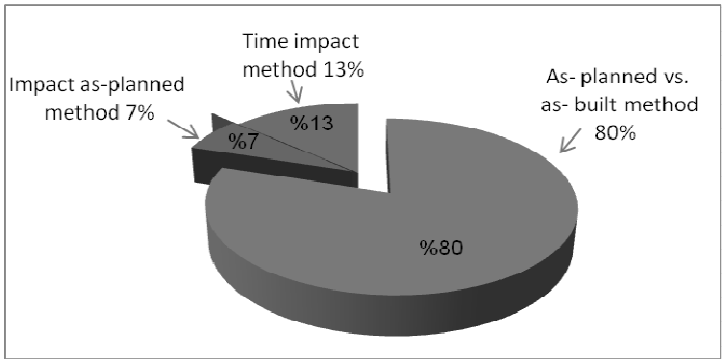

Figure 4: The percentage of the common used DAMs by contractors

Figure 5 Shows that 56.3% of the consultant's respondents agreed that the As-Planned vs.As-Built Method is the most common method in Gaza Strip while the Collapsed as-built method ranked the second common DAM in Gaza Strip according to consultant's respondents. The results indicated that, contractor's and consultant's respondents have consent that the As- planned vs. as-built is the most used method in Gaza Strip. The reason for this is the simplicity of this method since it relies on common sense and the environment of construction projects in Gaza Strip where approximately no complex projects were executed that could force practitioners to resort to the other DAMs.

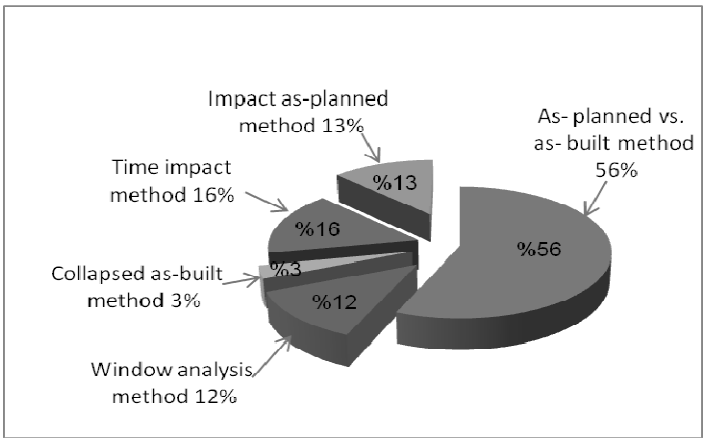

Figure 5: The percentage of the common used DAMs by consultants

Due to the higher level of education and experience to consultant's respondents 44% of them are recognizable with the other four DAMs compared with 20% of contractor's respondents recognizable with Time impact method and Impact as-planned method.

5.3 Relative importance index of factors influencing DAMs selection

Table 1 shows the relative importance index (RII) and ranking of the factors that affect the selection of DAMs for contractors, consultants and overall. The degree of agreement between contractor's and consultant's respondents equal 0.925 and this was statistically significant at 98% confidence level. The ranking of the "records availability" as the most important factor according to contractor's and consultant's respondents was expected, since regardless of the method adopted the analysis depends on the available data, although the amount of records required varies for various DAMs. For example Window analysis and Time impact analysis methods required the existence of certain records to operate, the lack of these project information will enforce practitioners to resort to less reliable methods. The ranking of record availability in the first position is confirmed by Braimah and Ndekugri (2008).

Table 1: RII and Ranks of DAM selection factors

Selection factor	Contractors		Consultants		Overall	
	(RII)	Rank	(RII)	Rank	(RII)	Rank
Records availability	0.666	1	0.880	1	0.788	1
Baseline programme availability	0.574	5	0.810	2	0.708	2
Nature of baseline programme	0.48	16	0.750	6	0.622	12
Updated programme availability	0.6	3	0.760	4	0.702	4
Time of the delay	0.546	8	0.680	14	0.622	12
Reason for the delay analysis	0.56	7	0.740	9	0.662	7
The other party to the claim	0.546	8	0.640	16	0.600	16
Applicable legislation	0.506	15	0.560	18	0.538	18
Type of contract	0.574	5	0.700	12	0.646	11
Cost of using the technique	0.48	16	0.700	12	0.606	15
Size of project	0.534	11	0.800	3	0.686	5
Duration of the project	0.52	13	0.760	4	0.658	8
Complexity of the project	0.546	8	0.740	9	0.658	8
Nature of the delaying events	0.6	3	0.740	9	0.680	6
Skills of the analyst	0.654	2	0.750	6	0.708	2
The amount in dispute	0.52	13	0.750	6	0.652	10
Dispute resolution forum	0.48	16	0.590	17	0.542	17
The number of delaying events	0.534	11	0.670	15	0.612	14
W=0.925	X^2=31.35			df=17 ; X^2 critical =31.7		

Baseline programme availability has been ranked by contractor's respondents in the fifth position, while ranked in the second position by consultant's respondents. Both of them have ranked it within the top five factors. The difference in the contractor's and consultant's respondents ranking is due to the variation in their level of education and experience. In the absence of base line programme the DAMs that rely heavily on it cannot be used. Braimah and Ndekugri (2008) have ranked this factor in the second position as consultant's respondents do in this research which confirms in general the importance of this factor.

Nature of baseline programme has been ranked by contractor's respondents in the sixteenth position, while ranked in the sixth position by the consultant's respondents. As mentioned the As-planned vs. as-built method is the most common method used by contactor's respondents which rely on common sense and doesn't require the baseline programme to exist in the CPM format, thereby the contractor's respondents rank it in the sixteenth position. Braimah and Ndekugri (2008) have ranked this factor in the forth position in the neighborhood of consultant's respondents ranking which confirms in general the importance of this factor. Updated programme availability has been ranked by contractor's respondents in the third position, while ranked in the forth position by the consultant's respondents. Braimah and Ndekugri (2008) have ranked this factor in the fifth position. This corroborates the importance of this factor that enable the use of certain DAMs more than the others.

Time of delay refers to occurrence of delay relative to the stage of the project. The delay analysis can be carried out prospectively or retrospectively. Prospectively refers to analyzing delays when they start brewing or began to occur in order to determine their likely impact on the project performance. Impacted as-planned method is best suited for this situation. On the other hand retrospective analysis required the delay analysis to be done after their occurrence. Collapsed as-built is best suited for this situation. Time of delay has been ranked by contractor's respondents in the eighth position, while ranked in the fourteenth position by the consultant's respondents and Braimah and Ndekugri (2008).

Reason for delay analysis may be either to get extension to project duration or to get compensation. Reason for delay analysis has been ranked by contractor's respondents in the seventh position, while ranked in the ninth position by the consultant's respondents. Braimah and Ndekugri (2008) have ranked this factor in the tenth position. The other party to claim is related to behavior of the opposing party to the claim. When the opposing party to claim is capable to deal with delay issues fairly, the parties to claim usually resort to less expensive methods of DAMs and vice versa. Reason for delay analysis has been ranked by contractor's respondents in the eighth position, while ranked in the sixteenth position by the consultant's respondents. Braimah and Ndekugri (2008) have ranked this factor in the seventeenth position which is too near to consultant's ranking.

Applicable legislation has been ranked by contractor's and consultant's respondents in the fifteenth and eighteenth position respectively. Braimah and Ndekugri (2008) confirm this result by ranking this factor in the eighteenth position as did the consultant's respondents revealing that this factor has a minimum influence on the methodologies that could be used to analyze delays. Type of contract; contract clauses may require the availability of specified type of baseline programme and its updating which facilitate the use of certain DAMs to a

great extent than others. This factor has been ranked by contractor's respondents in the fifth position while the consultant's respondents ranked it in the twelfth position. Braimah and Ndekugri (2008) confirm the consultant's respondents by ranking this factor in the eleventh position.

Cost of using the technique; sophisticated DAMs such as window analysis required the use of powerful planning software which is expensive and a skill person is essential to operate it. When the amount in dispute is relatively small compared to project cost, the parties to claim may resort to use less expensive DAMs. This factor has been ranked by contractor's respondents in the sixteenth position while the consultant's respondents ranked it in the twelfth position. Braimah and Ndekugri (2008) confirm the consultant's respondents by ranking this factor in the twelfth position too.

Size of project; as the size of project increase the number of activities increase. This factor has been ranked by contractor's respondents in the eleventh position while the consultant's respondents ranked it in the third position. Duration of project also influence the methodologies that could be used to delay analyses. This factor has been ranked by contractor's respondents in the thirteenth position while the consultant's respondents ranked it in the fourth position. Braimah and Ndekugri (2008) rank size of project in the fifteenth position and rank duration of project in the sixteenth position. The relatively high ranking of these two factors by consultant's respondents is surprising and need more investigation.

Complexity of project; in complex projects innovative procedures with overlap of phases are often used thereby necessitating the use of certain DAMs to a greater extent than others in case of delay occurrence. This factor has been ranked by contractor's respondents in the eighth position and the consultant's respondents ranked it in the ninth position. Braimah and Ndekugri (2008) confirm the consultant's and contractor's respondents by ranking this factor in the seventh position. Nature of delaying events; the existence of concurrent delays influence the methodologies that could be used to analyze delays. This factor has been ranked by contractor's respondents in the third position while the consultant's respondents and Braimah and Ndekugri (2008) ranked it in the ninth position.

Skill of the analyst; sophisticated DAMs require skill analysts to operate. This factor has been ranked by contractor's respondents in the second position, which is surprising and require further investigation. The consultant's respondents ranked it in the sixth position. Braimah and Ndekugri (2008) rank this factor in the eighth position. The amount in dispute; as the amount in dispute increase, the parties to claim resort to more sophisticated DAMs in order to recover their losses. This factor has been ranked by contractor's respondents and Braimah and Ndekugri (2008) in the second position while the consultant's respondents ranked it in the sixth position.

Dispute resolution forum has been ranked by contractor's respondents in the sixteenth position while the consultant's respondents and Braimah and Ndekugri (2008) ranked it in the seventeenth position. The three parties have consensus on the minimum effect of this factor in selecting the appropriate DAM. The number of delaying events; as the number of delaying events increase, the delay analysis become more complex thereby, necessitating

the use of certain DAMs to a greater extent than others. This factor has been ranked by contractor's respondents in the eleventh position while the consultant's respondents ranked it in the fifteenth position. Braimah and Ndekugri (2008) rank this factor in the sixth position. The insufficient appreciation by contractor's and consultant's respondents of the importance of this factor is attributed to the environment of construction in Gaza Strip.

6. Conclusion

The aim of this paper is to survey the commonly used DAMs and to determine the factors that influence their selection according to contactors and consultants perspectives in Gaza Strip. The most commonly used DAM is As-planned vs. as- built, this is attributed to the lack of complex construction projects in Gaza Strip. Eighteen factors that could assist the disputed parties to choose the appropriate DAM have been ranked according to their relative important index. According to contractor's respondents the top five factors are "Records availability, Skills of the analyst, Updated programme availability, Nature of the delaying events and Baseline programme availability, while the consultant's respondents exhibit that the top five factors are" Records availability, Baseline programme availability, Size of project, Updated programme availability, Duration of the project". The contractor's and the consultant's respondents rank record availability in the first position and agreed on the importance of "Baseline programme availability and Updated programme availability", this is not surprising since programmes are now considered the vehicle for analyzing delays. But they both failed to address "Nature of baseline programme" as an important factor, this is attributed to the fact that most of them are using Microsoft project for scheduling were bar chart and CPM are available. Both contractors and consultants agreed that "Dispute resolution forum and Applicable legislation" are the lowest factors that affect the selection of DAMs. According to contractor's respondents the lowest five factors are " Nature of baseline programme, Cost of using the technique, Dispute resolution forum, Applicable legislation, Duration of the project" while the consultant's respondents stated that the lowest five factors are" Applicable legislation, Dispute resolution forum, The other party to the claim, Cost of using the technique, The number of delaying events".

Both contractors and consultants agreed that "Dispute resolution forum and Applicable legislation" are the lowest factors that affect the selection of DAMs. Ranking the "Nature of baseline programme" as the least important factor by contractors is surprising because bar charts are unable to show critical paths, interrelation and interdependencies between activities which enforce analysts to select certain method of DAMs. The rank of "The amount in dispute" is the sixth according to consultant and the thirteenth according to contractors.

This research stressed the importance of obtaining full records throughout project life cycle or at least at time where a delay dispute is brewing in order to empower the disputed parties to select the appropriate DAM that gives relatively correct results. Training courses covering delay analysis methods and their requirements are recommended. A comprehensive survey should be carried out to confirm the findings of this research and to provide more reliable ranking to guide contractors and consultants how to select the appropriate DAM.

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A Decision Making System for Selecting Sustainable Technologies for Retail Buildings

Zainab Dangana[1], Wei Pan[2], Steve Goodhew[3]

Abstract

The implementation of sustainable technologies can improve the energy and carbon efficiency of existing retail buildings. However, the selection of an appropriate sustainable technology is a complex task due to the large number of technological alternatives and decision criteria that need to be considered. Also, there exist series of uncertainties that are associated with the use of sustainable technologies, but have to be evaluated to achieve realistic and transparent results. The selection of sustainable technology is therefore most challenging.

An earlier study was conducted with UK experienced practitioners including clients/developers, engineers, contractors and suppliers to identify the drivers and barriers for the use of sustainable technologies in UK retail construction. One major barrier identified from the study was the lack of a decision making tool, highlighted by both construction professionals and stakeholders in the retail industry. The large number of alternatives and potential solutions require a decision support method to be implemented. Information data on the economic variables, energy performance and impact on the environment of these systems is presently affected by vagueness and lack of knowledge. To deal with this high level of complexity and uncertainty an evaluation support approach is needed.

This paper aims to develop a decision making framework to assist both retailers and construction professionals to define and evaluate the selection of sustainable technological options for delivering retail buildings. The research was carried out through a combination of a critical literature review and a survey-based study using expert opinions of retailers and contractors. The developed framework of decision criteria should provide a sustainable technology model to assist both construction professionals and stakeholders in the retail industry to systematically and effectively select the most appropriate technology. This approach should make the decision progression more transparent and facilitate sustainable development of retail buildings in achieving the carbon targets set by the UK and other governments.

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Keywords: Sustainable retail construction, Low carbon retail buildings, Decision making criteria, Sustainable technology selection, United Kingdom.

1. Introduction

Sustainability has become an increasing concern for the retail construction industry as construction activities have a significant impact on waste, energy use and greenhouse gas emissions (Ozorhon et al. 2011). Carbon emissions from energy use in non-domestic buildings account for around 18% of total emissions in the UK of which 18% is from retail (Carbon Trust 2009). A large number of new policies and regulations are being introduced to minimize the impact of the built environment and the construction industry on the environment, such as the ambitious targets set by the UK government to reduce carbon emissions by 80% by 2050 compared to 1990 levels (HMG 2010). These pressures are inducing a large amount of product and process innovations across the retail construction industry amongst manufacturers, suppliers, installers, clients, users, and many others. This has led to an increased interest in sustainable retail buildings, which has resulted in pressure to install sustainable technologies in buildings prior to the evaluation of their full life cycle implications.

The study on which this paper reports is part of an on-going research project which aims to optimise the process, energy and carbon efficiency in retail construction by capitalising on sustainable technology. This research project addresses an overarching research question: "How can the use of energy and carbon be reduced for retail construction in a commercially viable way?"

An exploratory study has been conducted with retailers and construction professionals in the retail construction industry (Dangana et al. 2012). The study reviewed the design and construction of sustainable buildings within the context of retail construction; identifying the drivers, barriers and opportunities for sustainable retail buildings and it explored how the UK mainstream retail sector is currently addressing the challenges related to sustainable retail buildings. The study identified the lack of a decision making system for the selection of appropriate sustainable technological innovations to optimize the process, energy and carbon efficiency for retail buildings. Currently, designers, constructors and retailers interested in adopting sustainable technologies in the retail construction industry have no comprehensive evaluation approach to review and select technologies. There is a demand for a systematic and effective evaluation tool for the selection of sustainable technologies (Pan et al. 2012, Devoudpour et al. 2012). The results indicate a big challenge for stakeholders in the retail construction industry to adopt implementation strategies that will support sustainable retail buildings overcoming the barriers for the slow uptake of sustainable technologies.

The results are similar to a study conducted by Odhiambo (2010), which highlights that there is currently no comprehensive standard evaluation process to assist construction professionals to perform a holistic selection of a ST; with most studies addressed from a single issue perspective without taking into account other issues. The current evaluation approaches used by construction professionals for the selection of STs, such as financial

models are inadequate as technology selection is a multi-criteria decision problem. Decision makers are unable to make selections due to lack of value-based decision criteria (Pan et al 2012), and also because some benefits of STs are easily measured (water, energy) while some are subjective, intangible or indirect such as improvements to productivity and health (Huang et al. 2011). Thus there is a great need for a methodology to assist decision makers to systematically select STs which addresses multiple criteria rather than from a single criteria approach to obtain an integrated decision making result (Wang et al. 2009). This holistic approach would allow the selection of STs relative to stakeholders' objectives and consider the total influence on all systems (Belton and Stewart 2002).

The aim of this present paper is to address the gap in knowledge of sustainable technology selection by proposing a conceptual decision making system to assist both retailers and construction professionals to define and evaluate the selection of sustainable technological options. The system is based on the concept of MCDA and sustainable development, in which the technologies can be analysed, evaluated and finally compared to select the optimal variant according to a set of criteria (Huang et al. 2011) based on the objectives of the stakeholders.

2. Literature Review

"Sustainable technology" (ST) is defined as technology that provides for our current needs without sacrificing the future ability of populations to sustain themselves (Hmelo et al. 1995). Sustainable technology is not a new concept but is similar to the theory of "appropriate technology" (i.e. technology designed with special consideration for the environment, ethical, cultural, social and economic factors) that evolved in the1970's, but has recently gained importance due to the increasing negative impacts of human activities on the planet and desire to promote sustainable development (Odhiambo et al. 2010). Sustainable building technologies include concepts and products that provide significant improvements in terms of the use of resources, harmful emissions, life-cycle costs and productivity, and building performance (Hakinenene at al. 2011). STs serve to contribute, support or advance sustainable development by reducing risk, enhancing cost effectiveness, improving process efficiency, and creating processes, products or services that are environmentally beneficial or benign, while benefiting humans (DuBose et al. 1995).

Research conducted for the Intergovernmental Panel on Climate Change (IPCC 2007) estimates that around 30% of the baseline CO_2 emissions in buildings projected for 2020 could be mitigated (avoided) in a cost-effective way globally, at no or even negative costs, if various sustainable technological options were introduced. Similarly, Carbon trust (2009) estimates that reducing the carbon emissions from the UK's non-domestic buildings by 35% by 2020 could result in a net cost saving to the UK economy of more than £4.5 billion using simple and cost-effective building technologies that exist today. The use of sustainable technology emerges consistently as "one of the vehicles to enhance sustainability in the built environment" (Odhiambo et al. 2010) and is used as a strategy by construction professionals to design sustainable retail buildings.

The selection of sustainable technologies is a complex and important task due to the rapid development of technologies, lack of skills and knowledge, uncertainties, risks, and a large number of technological alternatives and decision criteria that need to be considered (Pan et al. 2012, Wang 2009, Dangana et al. 2012). It can have significant implications on building performance and stakeholders' satisfaction; creating long-term problems and hindering the adoption of such technologies. It is therefore necessary to base sustainable technology selection decisions on a clear understanding and a proper evaluation of the full range of implications associated with it. However, designers and clients face significant challenges in the selection of appropriate sustainable technologies due to certain characteristics of markets, technologies, and end-users which inhibit rational, energy-saving choices in the purchase and use of appliances as well as during the life-cycle of a building (HMG 2010, Dangana et al. 2012). Also, the risks associated with the reliability and effectiveness of new innovative products dissuades many professionals from specifying green or sustainable building materials (Pearce and Vanegas, 2002, Hakinene et al. 2011). This lack of enthusiasm may be attributable to clients' risk aversity and the risk-averse culture of the construction industry (Pan et al. 2012).

Currently, a Problematic selection approach is used in which many construction professionals choose to intuitively derive such decisions using their own perceptions of established professional experience. In such cases, the criteria evaluation process is very subjective and relies heavily on a manager's experience and knowledge, as well as intuition (Wang et al. 2009). This has led to bias in the decision making process as it is based on limited issues and the influence on other systems of the building are not taken into account (Odhiambo et al. 2010). A systematic approach is needed for the retail construction industry to identify value-based criteria and establish their relative importance to achieve decision making objectives for the selection of sustainable technologies. The use of new efficient processes and knowledge of decision making phases can assist in the selection of STs (Hakinene et al. 2011), and also overcome the hindrances of using STs (Davoudpour et al 2012).

Multi-Criteria Decision Analysis (MCDA) emerged as a formal methodology to support decisions in many fields and has been valuable in environmental decision making (Huang et al. 2011). MCDA is not a tool providing the "right" solution but an aid to decision making to assist stakeholders organize available information, consider the consequences and minimize the possibility of a post-decision disappointment (Belton and Stewart 2002). Wang (2009) describes MCDA as an operational evaluation and decision support approach suitable for addressing complex problems with high uncertainty, conflicting objectives, different forms of data and information, multi interests and perspectives in order to provide an integrated sustainability evaluation. The MCDA approach will be adapted and used to develop the conceptual framework for this study.

2.1 Decision making for selecting sustainable technologies

Decision-making problems involve the process of searching or finding the course of actions from a given set of feasible alternatives which maximizes or satisfies certain criteria associated to the goals intended to be achieved (DCLG 2009). Decisions are made within a

decision environment, which consists of the collection of information, alternatives, values and preferences available at the time when the decision must be made. Peldschus et al (2010) describes decision making as “a process involving activities that starts with recognition of a decision making problem and ends with recommendation for a decision”. The process can range from highly structured to highly unstructured decisions (Belton and Stewart, 2002) using either an alternative-focused or value-focused approach (Peldschus et al. 2010).

One of the main goals in decision-making for sustainable retail buildings is to identify and choose the most sustainable technological option from among different alternatives. This complex decision problem usually involves a large number of stakeholders with multiple, often conflicting, objectives (Wang et al. 2009). The selection of sustainable technologies requires a highly structured, alternative-focused approach as the decision problem starts with a choice of options and involves the process of selecting a preferred option from multiple alternatives in a structured way.

Techniques such as multi-criteria decision making methods support decision makers when faced with such a problem with a set of criteria on a set of alternatives. The adoption of multi-criteria methods helps to organise the decision-making process and usually includes four main stages: alternatives’ formulation and criteria selection, criteria weighting, evaluation, and final treatment and aggregation (Belton and Stewart 2002). There has been a significant use of multiple criteria decision analysis (MCDA) tools over the last two decades for environmental decisions (Wang et al. 2009, Huang et. al. 2011). MCDA has been successfully applied to solve evaluation problems in various fields such as sustainable energy, quality of service, engineering systems and new product development (Chen et al 2010, Pan et al 2012, Huang 2011).

The evaluation and selection of building technologies has been widely studied, with most decisions based on knowledge-based techniques which take into account economic sustainability (Wang et al. 2009, Krisciunas et al. 2007). Multiple criteria approaches have been used by various authors for evaluating technical, environmental, social and economic aspects (Pan et al. 2012, Chen et al. 2010, Odhiamba et al. 2011). Sawers (1998) applied decision making matrices as a methodology for designers to compare design alternatives, considering both the objective economic traditional criteria as well as subjective factors such as competitive advantage, improved management information or strategic alignment. This approach does not identify project objectives but it illustrates how attributes can be structured into a value hierarchy where each attribute is weighted according to its importance relative to other attributes from the perspective of the stakeholders. Nassar et al. 2003 used multiple criteria for assessing construction methods but constrained the technical processes from the designers’ perspectives. Similarly, Nelms et al. (2005) presented a synthesis of classification systems that focused on the use of technical attributes of building systems and developed a comprehensive framework that incorporated a set of evaluation criteria that built on the work of other authors. Pan et al. (2012) developed a systematic approach for UK house building organizations to identify value based decision criteria and quantified their relative importance for assessing building technologies systematically.

The proposed framework represents an integration and extension of these works and is developed to evaluate and select sustainable technologies from retailers and contractors perspectives for this study. The MCDA approach has been adapted for the development of the conceptual framework and comprises of three steps; problem identification and structuring; model building and use; and the development of action plans (Figure 1). The framework is intended to be holistic, to include the subjective qualities inherent in sustainable technologies and to reflect the retailers and constructors viewpoints as these have been perceived to be the main decision makers.

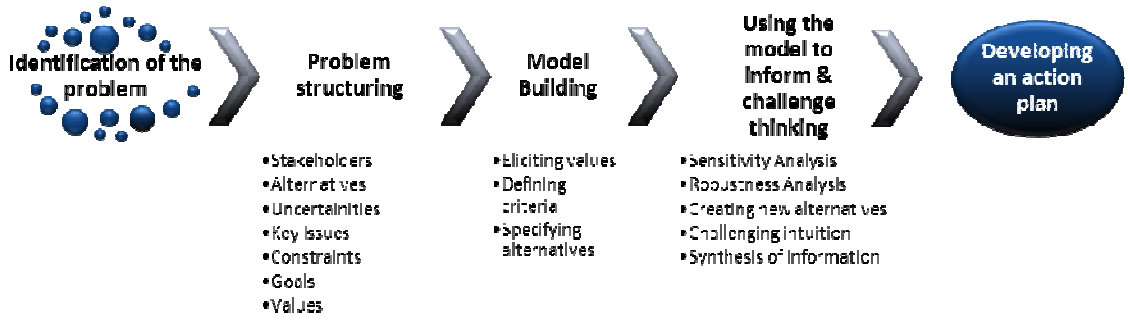

Figure 1: MCDA Approach (Adapted from Belton and Stewart 2002).

3. Methodology

In this study, decision maker(s) or other stakeholders involved in the decision situation are those identifying the nature of the problem and driving the solution procedure towards the preferred direction. Although the two terms are sometimes used interchangeably, for our purposes, decision makers are those assigned with the responsibility to take the final decision, whereas stakeholders is a much broader notion encompassing any single individual or group of people with an interest or concern in the potential problem. When multiple stakeholders are involved in a decision problem, a common understanding of the problem should be achieved through the elicitation of ideas and the sharing of concerns and values. This phase of the study focused on the stakeholders directly involved in the decision problem in order to detect their preferences and values by engaging with those that actually influence the decision (retailers and construction professionals in the retail industry). Hence, the extracted values better reflect concerns and priorities of the people directly affected and were specific, measurable, agreed, realistic and time-dependent (DCLG 2009).

The methodology adopted included a critical literature review and a study using expert opinions of retailers and contractors. Qualitative data was collected using a focus group and semi-structured interviews. The aim was to understand key issues that retail industry stakeholders are concerned with related to the selection of sustainable technologies. Face-to-face semi-structured interviews were carried out with ten senior managers from a leading UK retail contractor company in order to capture the points of view that decision-makers use as a frame for reference in their selection process. The focus group consisted of 12 participants (six retailers and six construction professionals) with experience in retail construction. The CAUSE (Criteria, Alternatives, Stakeholders, Uncertainty, and

Environment) checklist was used to generate and capture ideas to identify the problem of why there was a slow up-take of sustainable technologies (Belton and Stewart 2002).

4. The proposed conceptual decision making system

The conceptual decision making system utilises a set of criteria generated based on the results from the study. It presents a multiple criteria decision analysis problem and the MCDA approach will be adopted and recommended in solving the problem. The key steps of utilising the MCDA process are explained below.

4.1 Identify the problem

This first step of the MCDA process is to identify the issue under consideration, to agree on the focus and the scope of the analysis, and to recognize external constraints such as physical or legislative environments, or time and resources available (DCLG 2009, Belton and Stewart 2002). The identification of the global goal would form the basis for structuring the problem systematically. The issue under consideration was, “The selection of appropriate sustainable technologies to optimize the process, energy and carbon efficiency for existing retail buildings” (Dangana et al. 2012).

4.2 Structure the problem

This is a critical step for the subsequent analysis; it is often said that “a well-structured problem is a problem half solved” (Belton and Stewart 2002).

The triangulation approach was used to ascertain whether the themes identified within the literature review were perceived to be the same by professionals working in the retail industry today; providing a more robust evidence basis for the argument (Bryman 2012).

Based on the study, review and information from industry professionals, a combined list of 22 factors influencing the selection of sustainable technologies for retail buildings was produced. A preliminary coding exercise utilising Nvivo software was used and the 22 factors were grouped under the thematic headings of drivers, barriers and opportunities as illustrated in Figure 2. These factors provide the basis for structuring the problem and represent a fairly complete perspective of the user with regard to the problem. They can be used directly as criteria for evaluating and subsequently selecting the appropriate technology. The next stage involves model building to develop a framework for the evaluation of alternatives.

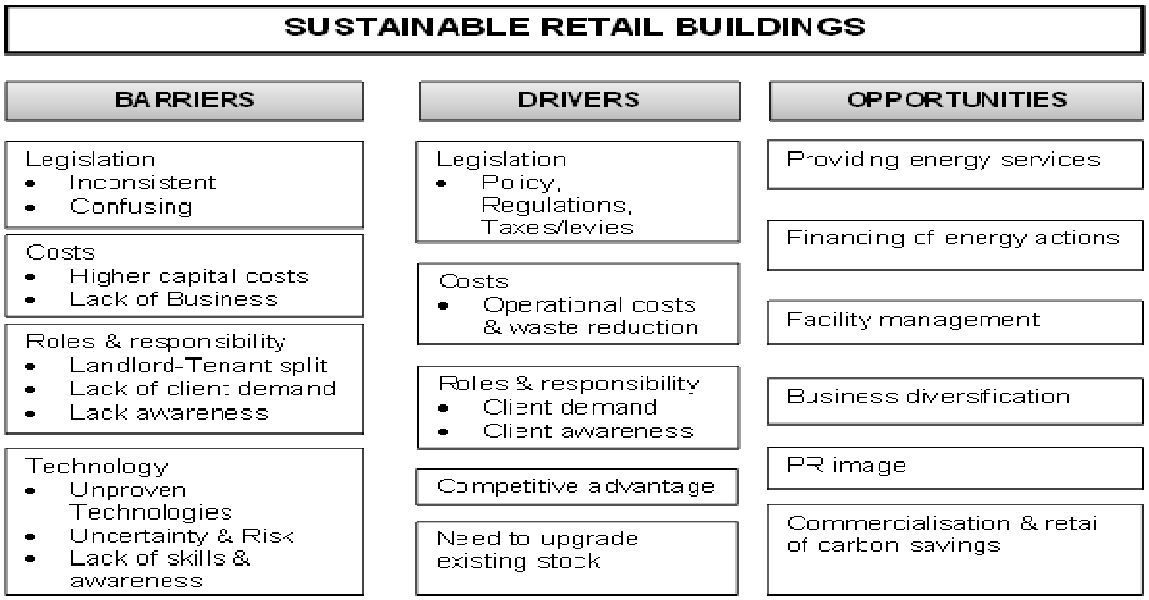

Figure 2: Sustainable retail buildings

4.3 Build the model

This is a dynamic process, both informed by and informing the problem structuring process and interacting with the process of evaluation (DCLG 2009). The type of model used depends on the nature of the investigation and the particular approach to be selected for analysis. The key elements for the model framework are based on the CAUSE framework; the alternatives to be evaluated; the model of values (criteria, objectives, goals) against which they will be evaluated; and how key stakeholders perspectives' on the decision and uncertainties will be taken into account and modelled (Belton and Stewart 2002). A preliminary set of criteria was established by the researcher from the problem structuring phase (Table 1).

Table 1: Preliminary Set of Criteria

Criteria for selection of sustainable technologies.	Reason
Focus on refurbishment & retrofitting of retail buildings (non-domestic buildings)	• It is estimated that by 2050 around 70% of the 2010 building stock will still be in use; it is very clear that low carbon retrofit would have a huge role to play in achieving carbon emission targets (Carbon Trust 2009). • A leading UK contractor which is a good representation of the industry is involved in 95% refurbishment / retrofit projects and only 5% new build. This translates to a ratio of 19:1. • There has been much recent focus on measures to reduce the emissions from new retail buildings; the existing stock remains largely untouched (Dangana et al 2012).
Technologies to focus on optimising process, energy and carbon efficiency for retail buildings.	• Carbon emissions from energy use in non-domestic buildings account for around 18% of total emissions in the UK of which 18% is from retail (Carbon Trust, 2009). Significant cuts in emissions is essential as part of the UK's commitment to reduce carbon emissions by at least 80% by 2050. • Energy costs are typically the second highest operating expense for a retailer, so implementing cost-effective energy saving strategies will have a direct and significant impact on profitability (ASHRAE Website).

	• A 10% decrease in energy costs has an equivalent impact on operating income as a 1.26% increase in sales for the average retail store (Energy Star website 2012)
Early adopter and early majority technologies to be explored	• The technology adoption lifecycle model describes the adoption or acceptance of a new product or innovation. The model indicates that the first group of people to use a new product is called "innovators," followed by "early adopters." Next come the early and late majority, and the last group to eventually adopt a product are called "laggards." • The capacity to innovate – or innovativeness – can lead firms to profitable outcomes, making significant contributions to the performance and efficiency of a business. Innovativeness in organizations can lead to competitive advantage and business performance.

4.4 Identification of alternatives and criteria to be evaluated

This involves the identification of key factors which will form the basis of an evaluation. These are referred to as values, objectives, criteria, points of view (Belton and Stewart 2002). The term “criteria” will be used in this study and these are the measures of performance by which options can be judged. DCLG (2009) suggested two overall approaches for identifying decision criteria: bottom-up and top-down. The bottom-up method is used to identify criteria if options are already given by asking how the options differ from one another in ways that matter. The top-down method is used to identify criteria based on the overall objectives provided by asking about the aim, purpose, mission or overall objectives to be achieved (Pan 2006). In this study the top-down approach was more appropriate for the selection of sustainable technologies using the perspectives of a leading UK contractor and retailers.

The study identified 22 criteria; these were clustered and grouped into several sets that relate to separate and distinguishable components of the overall objective. The main reasons for grouping criteria were: to ensure the set of criteria selected is appropriate to the problem; to ease the process of calculating criteria weights; to help organize the criteria and objectives; to facilitate the emergence of higher level views of the issue; and to highlight conflicts in objectives leading to refinement (DCLG 2009).

The decision criteria at the first level clustered the criteria under the main stakeholders (retailers and contractors) who were perceived to play a key role in decision making for the selection of sustainable technologies. The criteria were then broken down into the second level with 10 broad criteria (Figure 3). The conceptual hierarchy presented will undergo a process of refinement, iteration and modification in the next phases of the study.

The next step involves evaluation and exploration of alternatives to identify the options that contribute to the achievement of the decision objective. The alternatives may be relatively few and explicitly defined or from a large pool of alternatives as is the case in this decision problem.

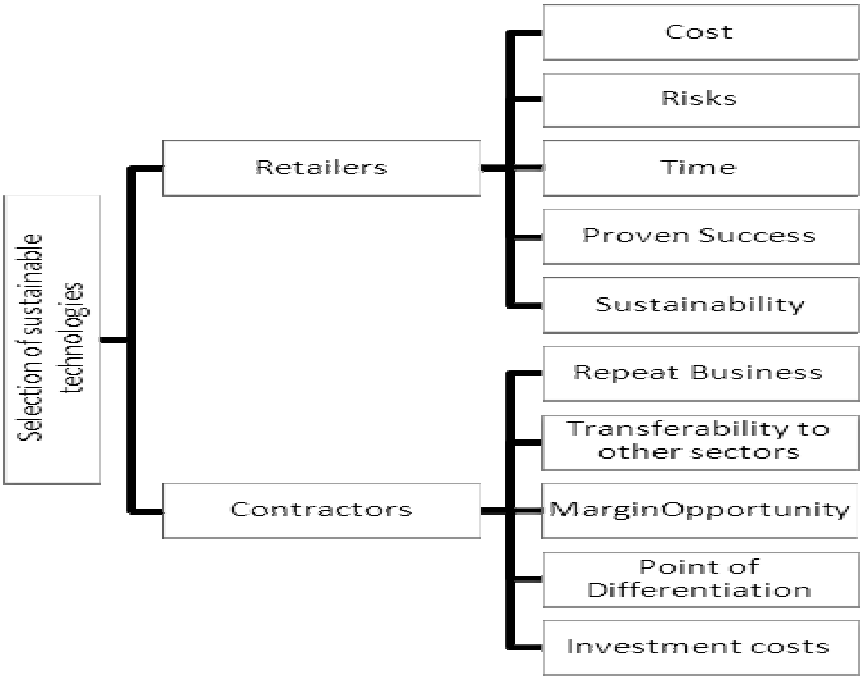

Figure 3: Value Tree of Criteria for Selection of Sustainable Technologies

5. Conclusions and future research

The selection of sustainable technology is an important and complex task due to the rapid development of technologies, lack of skills and knowledge, uncertainties, risks, and a large number of technological alternatives and decision criteria that need to be considered. This can be classified as a complex multi-criteria decision problem due to the high number of alternatives, potential solutions and various stakeholders (clients, professional advisors, end-users) leading to the slow take-up of sustainable technologies.

This paper has developed a decision making system to assist both retailers and construction professionals to define and evaluate the selection of sustainable technological options. This system involved a process of establishing decision criteria, which included clarifying the decision context, establishing decision objectives, identifying, clustering and assessing decision criteria. The study has generated a set of criteria against which sustainable technologies will be evaluated and compared in the next phase of the study. The matrix of criteria would be reviewed and evaluated every year to accommodate the changing needs of the stakeholders.

The decision making system should provide a sustainable technology model to assist both construction professionals and stakeholders in the retail industry to systematically and effectively select the most appropriate technology. From a communication perspective the system will provide a means for all levels of decision-makers to share their concerns and findings. In addition, it will also help to promote dialogue amongst different stakeholders to foster appropriate risk allocation at the outset of the project or before use of the technology. This should make the decision progression more transparent and facilitate sustainable development of retail buildings in achieving the carbon targets set by the UK and other governments.

Nevertheless, it is worth noting that although the aim of this paper is to develop a decision making framework to assist both retailers and construction professionals to define and evaluate sustainable technology selection for retail buildings, the decision making criteria were explored predominantly from the perspective of a main contractor and their clients and supply chains. There are other key stakeholders, such as architects, planning officers, end-users, which also play an important role in the selection of sustainable technologies. The decision criteria which these stakeholders use should also be explored and included in the decision making system, which will be studied in the next stage of the research.

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Offsite Construction Priorities In India: An Exploratory Research

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Abstract

The rapid growth of the construction industry in India has influenced the adoption of alternative technologies that are more addressing time, cost and quality. The rising demand in housing, infrastructure and other facilities have further highlighted the need for the construction industry to look at adopting alternate building technologies. Offsite construction has evolved as an effective alternative to dealing with the under-supply and poor quality in the current age construction industry. This paper presents the priorities for offsite construction in India and presents an implementation roadmap for practitioner and academic community.

Keywords: Offsite Construction, Manufactured Construction, Indian Construction Sector, Implementation Roadmap.

1. Introduction

Offsite construction has been promoted as a new paradigm in construction with the ability to deliver a higher speed of construction, with improved quality, at a lower cost, with reduced labour requirements on-site (Mullens and Arif, 2006). It is important to look at the adoption of offsite construction worldwide. Japan has the world's largest uptake of offsite construction, with companies such as Sekisui Homes producing 70000 manufactured homes a year (Gann, 1996). In the USA there is a separate building code for offsite construction which is referred to as the Housing and Urban Development (HUD) Code for regulating the construction of manufactured homes. Other initiatives include the United Kingdom (UK), where the government identified manufactured construction as a key tenet for improving construction in the 21st century by its inclusion in the Egan (1998) Report. Similarly, the Australian construction industry identified manufactured construction as a key strategy for

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improving the industry over the next decade (Hampson and Brandon, 2004); and countries like Malaysia now have legislation in place which requires the use of offsite in construction projects (CIDB, 2006). This emphasis is growing, which in part may relate to empirical evidence, which suggest that the use of offsite techniques can result in 16% lower labour and material costs (Schuler, 2003). However, despite these benefits and increased global initiatives, the actual uptake and adoption of offsite construction is slow, with a market share in UK being reported to be below 6% (Taylor, 2010). Moreover, in the USA there are approximately 7 million occupied manufactured homes, which make up about 7% of the nation's housing stock (HAC, 2011). Given this, Taylor (2009) related this failure and lack of uptake to the inaccurate public assumptions regarding offsite construction, advocating that the implementation of offsite construction could benefit society in several ways, e.g. reduced build times and costs, better controlled built environments, reduced risks through factory production, enhanced computing and traceability of components, etc. This paper presents an analysis of the Indian construction sector and the roadmap for implementation of offsite construction in India. Rest of this paper is divided into four sections, the next section presents the research methodology, it followed by a section on the development of assessment framework. It is followed by a section on the priorities of the Indian Construction sector and the last section presents a summary of the findings.

2. Research Methodology

In order to develop the overall implementation roadmap it was important to first develop a framework under which the priorities could be documented. In order to set-up the priorities a series of webinars and expert workshops were conducted. Once the framework was complete, it was important to document the priorities for the Indian construction sector. The Indian data collection process included two workshops with senior academics and experts, which was conducted in India and in the UK as part of UK-India Education Research Initiative. The experts included Chief Executive Officers, senior managers and policymakers from both public and private companies. Innovation in most sectors is predominantly diffused through three central 'themes' of People, Process, and Technology (Davenport, 1992). These core themes were considered pivotal for the development of this study, as they embraced the three dominant paradigms drivers of offsite, along with their enmeshed relationships (see Figure 1).

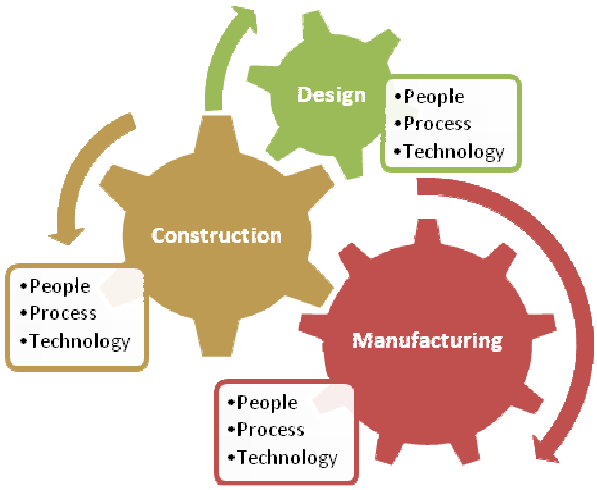

Figure 1: Assessment Framework

Figure 1 presents nine core areas, representing the three major dimensions of offsite construction: Process, Technology and People, and their impact on: Design, Manufacturing and Construction. These issues were informed by discussions in the three webinars. The webinars were also used to populate the nine areas and tease out specific issues within these categories. The framework was first introduced by Arif et al (2012).

3. The Elements of the Assessment Framework

The nine elements of the framework and the topics within each of these elements are as follows:

3.1 Design-Technology

- Technology embedded in the product (in the factory);
- Technology underpinning the business process;
- E-readiness of organisations (and the supply chain) – holistic implications on the business;
- BIM for offsite (product and process) – potential to exploit.

3.2 Manufacturing-Technology

- Justifiable automation - how much is enough? (optimisation, business case, payback etc);
- Product and process design – DfM (software and systems development,
- Decision Support System,
- Integrated product delivery etc);

- Supply chain management – MRP & ERP expensive (inflexible and somewhat limited);

- Modelling and simulation – training needed (systems analysis, discreet event simulation and modelling etc).

3.3 Design-Process

- Adding value to the business process (multiple perspectives);

- Process Protocol – lifecycle processes, tried and tested (concentrate on the most important ones);

- Stakeholder analysis is needed;

- Understand the impact of design and process (with business and technology).

3.4 Technology-Construction

- Need to understand what information is created, used and exchanged (Product Modelling Ontology, W3C etc) - common tools from different vendors (integration and interaction); BAE/BAA/IBM systems approach. Granularity of product data could be used better - detailed information e.g. installation, storage, size, mass, lifting requirements, health and safety issues etc. (BIM is important here). Risk needs to be understood more e.g. existing product/process in established application areas;

- Existing product/process in new application areas;

- New product/process in established application areas;

- New product/process in new application areas [as all carry different risk.

3.5 Manufacturing-Process

- Procedures need to be defined to cope with the variables – will a one-size-fit all model work?

- Need to look at other industries regarding their business models (not just efficiency over productivity, but also pre and post occupancy);

- Integration of suppliers into companies needed (and teams). What a business model would look like? Sustainable business models can be flexible (and business concepts could also be added).

- We have to consider what to adopt and what not to adopt e.g. automation v non-automation (is there a happy medium?). Flexibility needed (variable product line).

3.6 Construction-Process

- Important to consider business models – which ones?, what remit e.g. house builders, SME's etc. (more than 100 systems and >500 suppliers). How can integration be achieved? (through RFID?);

- Performance of process - hard data needed (Cost Benefit Analysis etc);

- Interfaces between OSP and manufacturing (do we have the right skills?). ISCS report on the future of house building. Focus on UK or overseas? (global agreed). Emphasis on onsite or offsite construction? 5 years, 10 year roadmap (up to 2050 agreed). Flexibility needed with elements of standardisation (economies of scale).

3.7 Manufacturing-People

- Multidisciplinary or interdisciplinary? Mind-set training needed (look at projects rather than products);

- Decisions have to be modelled in an integrated way (incorporating risk etc.);

- Shop-floor approach needs to change and benefits need to be made clear;

- Link to disaster management? Haiti house? (along with cultural issues);

- Mass customisation – service parts (how to address the markets);

- Job roles and functions need re-defining. Integrating people into the model.

3.8 Design-People

- Traditional v non-traditional - new ways of working require new skills (esp. product modelling.), new thinking, greater collaboration, reassessment of discipline areas, change in individual and company behaviour. OJT and learning needed (industry & academia collaboration);

- New approach needed to design (key USPs need to be sold regarding suppliers, assemblers, transport operations etc.);

- Design for Manufacture and Assembly is an important part of this, along with logistic integration into the design process;

- ManuBuild (design process, manufacturing process, construction process, sales office) - link to the supply chain and the customer ("buy-in"); (for more details on ManuBuild see www.manubuild.org);

- Product catalogues, smart connections etc are available.

3.9 Construction-People

- Up-skilling of personnel

  i) so that a site labour or a new person to the industry could work in the factory;

  ii) so that they know how to install prefabricated products and modules on site (this would require training/investment);

- Healthy and comfortable working conditions could be a key USP (Health and Safety, better working environment, standardised production system etc);

- Sustainability - social benefits, continuity of employment, economic - stable and long term employment, transportation - pick zones (reduced emissions etc);

- Productivity - greater efficiency and productivity, no weather disruptions etc;

- New workforce – greater attraction because of better working conditions, resolution of unskilled labour, no age limit or pre-requisite skills for entering the sector.

4. The Implementation Roadmap for India

Using the same assessment framework used for the developed world, a roadmap for Indian offsite construction was carried out. The summary of the Indian data is presented in Figure 2. In order to identify any issues that were not covered in the framework, participants were given an opportunity to add any issues they felt needed to be included or excluded.

From a People Driver perspective, the main focus was placed on “Design:People” [High], followed by “Manufacturing:People” [Medium], then “Construction:People” [Low]. The “Design:People” category was classed as high priority and should be addressed within the timeframe of 0-5 years. Participants realised that there was a need for an altogether different kind of design paradigm. This area was perceived to be behind the developed countries, and more awareness needs to be created for this area to progress. Within this, the three areas of focus were: P1 Importance of DfMA and logistics; P2 Need for new approach to design; and P3 Need for new skills. The “Manufacturing:People” category was classed as medium priority and should be addressed within the timeframe of 6-10 years. Within this, the three areas of focus were: P1 Improving integrated decision modelling, P2 Maximising training impact, and P3 Alignment of new job roles (to new requirements). The “Construction:People” category was classed as a low priority and should be addressed within the timeframe of 6-10 years. Within this, the three areas of focus were: P1 Promoting sustainability, P1 Upskilling personnel, and P3 Improving Health & Safety. There was consensus of opinion that there needed to be a significant increase in the training and educational provision of the country in order for this area of prosper.

From a Process Driver perspective, it can be seen that the main area of focus was placed on “Design:Process” [High], followed by “Manufacturing:Process” [Medium], then

“Construction:Process” [Low]. The “Design:Process” category was classed as high priority, but was placed within the timeframe of 0-5 years as respondents classed this as an important area to address. Within this, the three areas of focus are: P1 Adding value to the process, P2 Improving the impact of design/technology, and P3 Better lifecycle process analysis. This sequence is exactly same as that of the developed countries. The “Manufacturing:Process” category was classed as medium priority and should be addressed within the timeframe of 0-5 years. Within this, the three areas of focus were: P1 Learning from other industries, P2 New business models needed, and P3 Identifying breakeven point for automation. The sequence of priorities was also the same as that identified for the developed world. The “Construction:Process” category was classed as low priority and should be addressed within the timeframe of 6-10 years. Within this, the three areas of focus were: P1 Integration of process with BIM, P2 Greater flexibility needed, and P3 Improving the interface of OSP.

From a Technology Driver perspective, it can be seen that the main area of focus was placed on “Design:Technology” [High], followed by “Manufacturing:Technology” [Medium], then “Construction:Technology” [Low]. Whilst the “Design:Technology” category was classed as high priority, which should be addressed within the timeframe of 0-5 years. Within this, the three areas of focus were: P1 Enhanced design improvements, P2 Greater BIM adoption, and P3 Clearer supply chain benefits. Design technologies will also have regulatory impacts and involvement of regulatory bodies would be important. The “Manufacturing:Technology” category was classed as medium priority, which should be addressed within the timeframe of 6-10 years. Within this, the three areas of focus were: P3 Simulation and modelling tools needed (to help predict outcomes), P2 Business cases needed for software (selection), and. P3 Optimisation of manufacturing payback. The “Construction:Process” category was classed as high priority, respondents determined that this should be addressed within the timeframe of 6-10 years. Within this, the three areas of focus were: P1 Identification of technology support tools, P2 Better understanding of risk analysis, and P3 Improving product modelling flow. The priorities are summarised in figure 2 below.

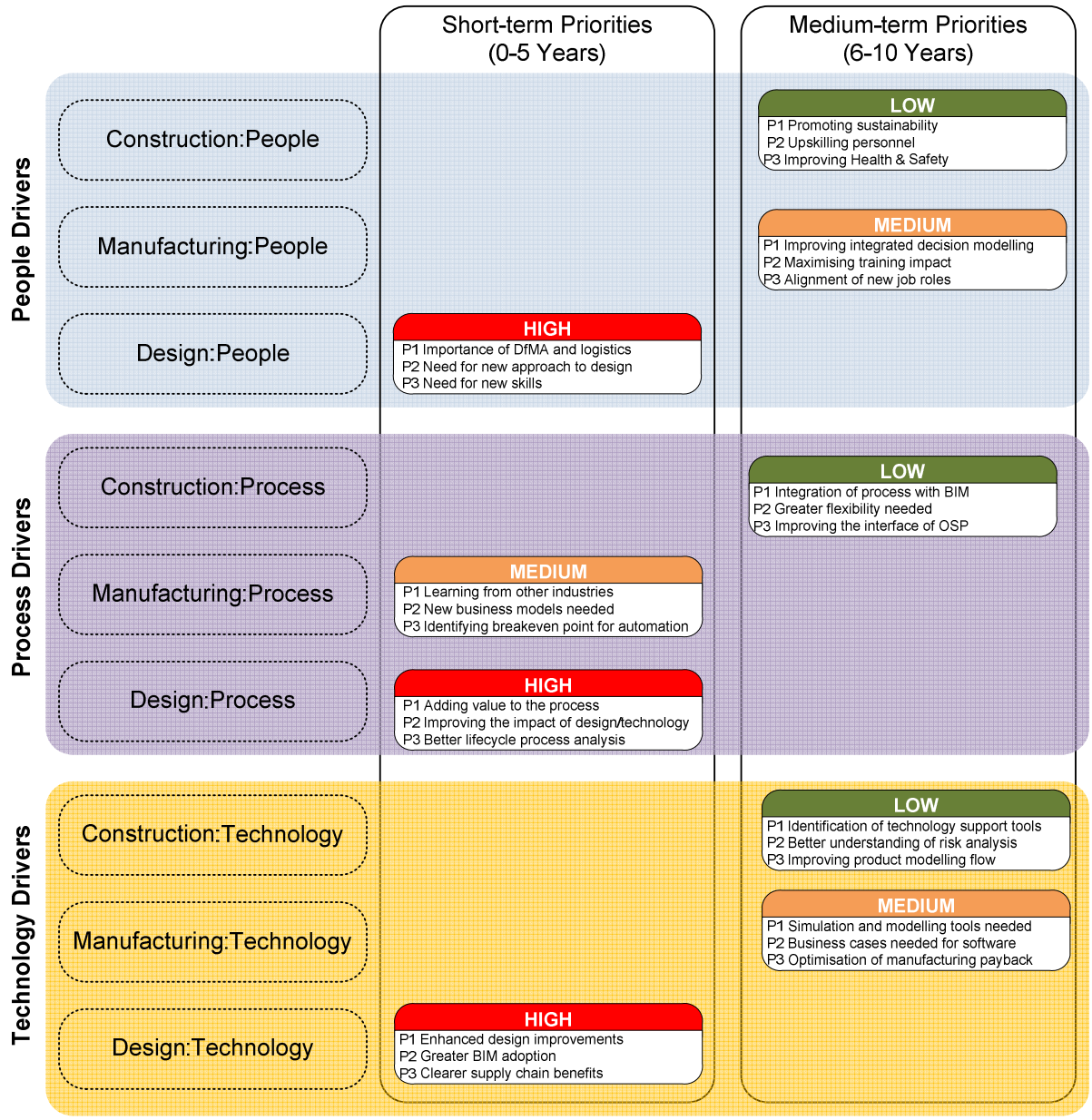

Figure 2: Prioritised Offsite Production and Manufacturing Research Roadmap for India

5. Discussion and Conclusions / Recommendations

In summary, the roadmap presented in Figure 2 presents the industry with a series of focal areas that need to be addressed over the short to medium term. Short-term priorities should therefore focus on disentangling all the three dimensions of Design: people, process and technology. For Design:People category the top priority is the emphasis on communicating the importance of DfMA and logistics. This new way of thinking is important for realising efficient 'manufacturable' designs. Architects and designers should therefore be cognisant of this. The second priority is to understand other issues to keep in mind when designing for manufactured construction. The last among these is the development of new skills and hence the need for newer educational and training programmes in this area. Design:Process is another important short term priority. For this category the priorities in their order of importance are adding value to the process, improving the impact of design/technology, and

better lifecycle process analysis. Design: Technology is the other dimension of design that was regarded as high priority in the short term. For this category priorities in their order of importance are enhanced design improvements, greater BIM adoption, and clearer supply chain benefits. Other short-term priority need to focus on “Manufacturing:Process”, regarding learning from other industries, identification of new business models to operate manufacturing in the construction sector and the least important among this category priorities being the identification of the breakeven point for automation. Given the availability of cheap labour in India, this particular item is rated lowest among the manufacturing process priorities.

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Design Process and Stakeholders Management in Airport Construction

Hasan Wahab[1], Mohammed Dulaimi[2]

Abstract

This research explores the challenges associated with managing the design process in complex construction projects. The study focuses particularly on large airport projects, and their inherent complex stakeholder management during the design phase. The aim of this research is to propose a framework that integrates Design Process and Stakeholder Management in the context of Airport construction. The methodology adopted revolves around Modelling and Case Study techniques, to observe and analyse the existing situation and define the model's variables. In order to develop such a model, an in-depth analysis is carried out of the processes and design approach currently employed. The Process Protocol Model is adopted, albeit with necessary modifications, to address the research objectives. The validated and enhanced model provided a powerful tool for the design manager to administer and archive the information flow in airport projects as well as a framework for managing the stakeholders' requirements.

Keywords: Design Process, Stakeholder Management, Complex Projects, Airport Construction, Process Protocol

1. Introduction

The design of modern Airports Construction worldwide is considered one of the most complex construction projects nowadays. In such projects traditional design and construction management methods would be challenged to deal with the variety of Airport project components along with the advance technology used for airport operation. Adrem et al. (2006) add that airports design management difficulty is in handling the tremendous amount of information flow in all design stages, dealing with the various disciplines involved in Airport projects, managing the variety of stakeholders input and feedback in different projects' stages, and dealing with complexity of design and implementation of the project. Schaar and Sherry (2010) described Airport stakeholders as sophisticated with various interests in the airport building. Each stakeholder involved in the design of airport is seeking specific goal and objectives which put significant pressure on design managers in their attempt to balance between, sometimes, conflicting requirements. The technical complexity of an Airport project has a significant impact on the design process; Airport projects usually involve numerous and highly developed systems which require multidisciplinary teams' involvement in the production of the final design product. Managing communication networks during Airport

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design using more traditional management techniques usually results in considerable number of incidents of missing information and miss-coordination that could have a negative impact during construction. The handling of a complex project creates a challenge of managing a number of interlocked mini projects. Moreover, such projects generate many issues raised between the different departments representing different disciplines within the client organisation that need to work together to deliver the project. Wood and Ashton (2010) explain that such projects create difficulties in communication and handling of the flow of information generated as a result of the project complexity. It is argued that there is a need to have a generic framework that facilitate the management of the design process and the different stakeholders involved in this design process during the complex project life cycle. This study examines the main principles of design management in complex project, and focuses on airports design management process and stakeholder interface challenges in the various design stages.

2. Aim and Objectives

The aim of the research is to examine how to effectively integrate stakeholders' interests and requirement into the complex design process in Airport projects construction. The research objectives are:

- Investigate how information flows in the design of Airport construction project.
- Investigate the value and input of different stakeholders involved in the design process of Airport construction.
- Evaluate the effectiveness of an integrated framework of design and stakeholder management in airport construction as complex projects.

The research's proposed framework shall be able to:

1. Provide clear understating of different relationships interacting within complex building design process
2. Provide a guide for designers to consider the correct design criteria prior executing the design process of the project's elements which is called Design Task.
3. Provide a framework for managing design tasks and stakeholders requirement, and
4. Provide a base for interface stakeholders and their requirements within design process in order to achieve all parties' satisfaction.

3. Literature Review

The design process in both manufacturing and construction consists of solving series of problems and sub-problems (Cross 1989). Kagioglou et al. (1998) suggested viewing construction design process from the point of new product development process in order to improve the practices in construction such as coordination and communication between parties. Newton (1995) developed the Analytical Design Planning Technique (ADePT) methodology. ADePT provide a model for the Building Design Process indicating design activities and their information dependencies. Such data is linked by a dependency table to a Dependency Structure Matrix (DSM) analysis tool to define design process iteration and schedule the activities with the aim of getting optimal task.

Cooper et al. (2005) developed the Process Protocol (PP) based on contemporary problems facing construction sector. PP has six key principles developed from the manufacturing industry. These principles are related to recognised problems in construction where improvement is required and they are: whole project view, a consistent process, progressive design fixity, coordination, stakeholder involvement and teamwork, feedback. The PP model consists of 10 stages grouped into four broad stages as following: Pre-project stage, Pre-Construction Stage, Construction Stage Post construction stage. The PP groups the project participants into 'activity zones'. These zones have multi-functional role and represents structure sets of processes and tasks that direct and maintain work in the direction of a common objective

Gidadio (1996) explains that complexity in construction is characterized in the need to develop many details to reveal how to execute the work. Moreover, complexity needs a logical link between the different activates as a complex projects always run into a number of modification through the project construction. Without studying the link between different activities it becomes hard to update the programme successfully in the most competent way. Gidadio (1996) goes into more details and organizes the source of complexity factors that affects the objectives of managers in construction into two groups**:**
Factors A: that interacts with the inherent components in the operation of individual task and initiate from the environment or resources employed. Factors B: that handles the components originated from bringing different parts together to form a work flow. Wood and Ashton (2010) categorized complexity factors in five themes as following: Organisational (people involved/ relationships), Operational and technological, Planning and management, Environmental, and Uncertainty.

Airport Construction as Complex Projects: Adrem et al. (2006) investigated the characteristics that makes airport different from other construction projects. Usually the specific project is owned by certain facility management organisation within the airport that is responsible for managing and developing all the airport's building and land. However, to execute the project input from several key stakeholders in the organization is needed. Such stakeholders would be concerned with optimizing the design according to their own, sometimes conflicting, priorities. Security elements are the most challenging obstacles facing airport project during construction. Adrem et al. (2006) explained the issues of logistics inside the airport, driving vehicles, security checks for equipment, safety regulation, restricted working hours, work notification procedures, and many other construction factors which should be planned during design.

Chinyio and Olomolaiye (2010) evaluated the Design Process Model and stakeholders management, they found that effective stakeholder management improves capability in relational issues and reduces risks therein. Delivering a successful project requires design managers to manage the multiple stakeholder interests throughout the complete process of project management (Sutterfi eld et al. 2006). For successful management of stakeholders in complex projects Carroll and Buchholtz (2006) suggest the need for clarity on who the stakeholders are, what stake they have in the project, and, the opportunities, challenges or threats do they present, what responsibilities we have towards stakeholders, and finally the strategies or actions to engage our stakeholders. Clarkson (1995) emphasised the importance of having processes and modes of behaviour that are informed of the concerns

and capabilities of the different stakeholder and, consider a fair allocation of the corporate benefits activity among them. Moreover, it is very important to acknowledge the potential conflict between the expected roles of the different stakeholders through open communication.

Airport Stakeholders Perspective: The nature of airport terminal stakeholders has significant influence on the design process due to the long list of stakeholders and the variety of their requirements Schaar and Sherry (2010) presented a model (figure 1) that shows a complex network of the relationships between airport stakeholders. The model consists of airport organization which consists of Airport Management and Operations and Airport Infrastructure. The service providers are the main entity that deals and interact with the airport infrastructure while passengers use this infrastructure to interact with service provider. The model provides two outlines to the airport: Airport organizational boundary and airport service boundary, in addition to that, capital improvement bill payer-'s' boundary, local economy and community boundary; Airport's organizational boundary defines the limit of what is controlled by airport management. Schaar and Sherry (2010) explained that this can control the design matters related to configuration of airport infrastructure and the operational procedures and efficiency of its own organization.

The research would argue that advanced design management models such as AdePT and PP have the potential to address the challenges of design process in complex construction projects, such as airports, with numerous number of building components.

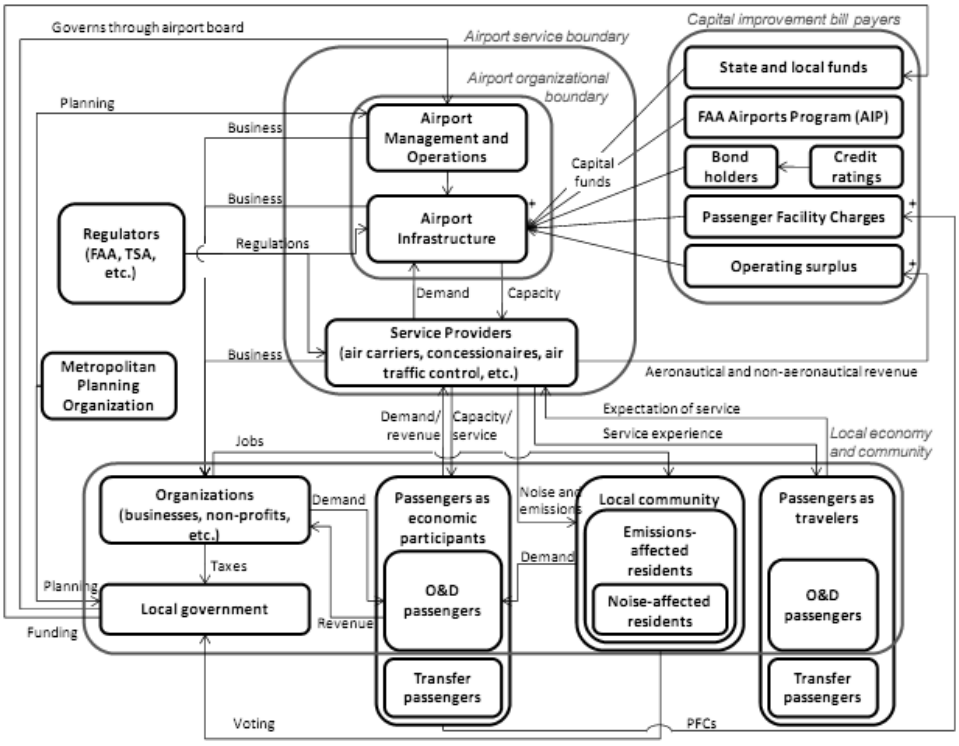

Figure 1: Relationships between Airport Stakeholders (Schaar & Sherry 2010)

4. Research Methodology

The research has reviewed current practise in Airport design management by examining documents, conducted interviews, and sought the opinion of professionals and practitioners who were involved a newly completed passenger terminal project and are currently working on existing expansion of the an Aircraft Concourse project. The interviewees included Architects, Engineers, Construction Managers, and an Airport Operation manager. These Interviewees were from the Airport Construction Authority, the Consultant, Contractors, and Airport Operation Managers. These interviews produced narratives, provided direct observations and allowed detailed document analysis. Later, these narratives are presented again to the participants to verify the narratives findings. The results were used justify the adoption of a model that facilitates the effective design process.

5. Case Study Brief

The case study analysis is conducted in a Construction Authority (CA) responsible for constructing and delivering one of the largest Airports in the Middle East. The findings are taken from this organization experience and interviews conducted with 10 staff and managers working inside this organization, 5 Engineers working with the consultants, 6 Engineers working with the contractors and suppliers who are working with this organization and having a wide experience worldwide in working in the construction of international airports. Moreover, 7 managers from the stakeholders in that particular airport are interviewed as well. CA role is a combination of providing approvals for the buildings inside airport premises as well as the project management role of the airport projects. The CA goes more in-depth in the details of design, procurement and implementation of the project, and CA is the government representative for project finance and payments.

Based on the knowledge built in the literature review, the analysis of the case study is conducted through series of questions developed in order to examine how the airport as complex project is handled in the Construction Authority.

The questions are focused on the following:

Complexity Management: the management of a large number of airport building components, dealing with different design packages interdependency, dealing and managing the sources of complexity

Design Process Management: the framework of the design process, management the design process between different departments, the overall design process of the project and collecting the project's data

Design and Organisational Structure: the role of the different departments and their relationship to the design process as well as with the consultants and stakeholders

Design Management Discipline: the role of the design manager in the CA, how far it extends beyond the traditional design management tasks.

Stakeholder Management: the roles, responsibilities, and requirements of the stakeholders.

During the interviews further ideas and examples are identified and considered.

The accessibility to project documents is possible through the direct involvement of the researchers in the project.

6. Analysis of Existing Practices in Managing Airport Construction

The analysis of the design process followed in this case study seems to suffer from the following Problems:

Early Involvement: The process to develop the design is restricted to the design team without involving the CA's Construction department nor other contractors or suppliers. Several incidents showed that the formal involvement of such parties is required but in practice such involvement occurred informally through the personal relationships between designers with the suppliers.

Document Control: Document control part is only limited to the formal correspondence while most of the disputes or arguments tend to happen through informal channels. Moreover, it is agreed during interviews that using emails and minutes of meetings have their limitation in terms of the ability to retrieve the data from the archive.

Design Process: It is noted that there is no description for the processes taking place inside Development & Master Planning department and consultant. Interviewed managers could not show a clear description of how the design of a particular part of the building is executed nor a manual on how to handle the different parts of the design components. Although emails, design brief or minutes of meetings might describe the design considerations that need to be addressed during the design of that part of the building, however retrieving what decision was taken about a particular part is not an easy task. In conclusion the design process lack of clear updated manual or criteria for designing airport project elements.

Role Definition: The role of each department is not defined clearly. Many of coordination tasks happen on many levels therefore there is overlap of responsibility in taking decision. One of the Architects gave example of deciding the procurement method which is officially the role of procurement department while all other parties such Construction department, D&MP and Engineering have an input in such decision. It is concluded that the coordination between different departments and disciplines is executed but not identified.

Design Phase Flexibility: In terms of dealing with design phase flexibility, the implemented process shows sequential approach to the design process which means that each stage is rigid and its requirement shall be fulfilled before proceeding to the other stage. However the real practice is not like that as explained by the Architecture manager. CA tries to overcome this concept by issuing conditional approvals to make the design stages flexible.

Handling the Source of Complexity: The way the design process was set does not identify the sources of complexity in the project and doesn't address how to deal with it in the design process; such as detailed coordination process between disciplines, administrative procedures and documentation. Moreover, there is no clear description of such procedures in other documents.

Organizational Complexity: The process suffers from organizational complexity shown in the complicated relationship between the different parties, the large number of stakeholders, and the complicated decision making mechanism that needs input from many departments. This is observed in the long time required to release official document for design submissions.

Managing Complexity: The documents and manuals do not address the planning and management complexity such as handling the large number of elements in the project, handling the timeline of the project and managing the acceleration of the project.

Defining Requirements: There is no guideline for defining the project requirement and design criteria at the project initial stage; which Chief Architect explained to be critical for project success..

Stakeholder Management: End-user approval of design is essential part in the design process. However the level of end-user involvement in the design process sometimes does not help the smooth running of design process, moreover it is not clarified what the end-users are specifically approving. Establishing design criteria and end-users requirement is not given adequate attention at design brief and not organized, Airport design standards sometimes are limited in establishing such criteria as the operational requirement might be changed between airports. Documenting the followed design criteria based on stakeholder decision is essential and is in the favour of all parties. However it is observed that there is limitation in the traditional implemented practices such minutes of meetings and emails

The above identified problems necessitate the introduction of a framework that facilitates a coordinated action for an effective design process.

7. Design Process and Stakeholder management Model

This research faces limitation in applying ADePT from Airport sub-project perspective stakeholders' management, and the organizational framework of complex project. The application of PP model on the case study provides a solution for the generic frame work of the case study and it would represent a very useful tool in different levels such as the organizational, knowledge management and managing multidisciplinary from one side, and it provides an area for Stakeholders management integration within the design process, and managing design tasks. It was found that PP model can be adopted considering the following additions and modifications:

Replacing Facility Management with Stakeholder Management activity zone: Having facility and operation managers within the design process is very costly to the CA;

The tasks related to stakeholder given to Development Management zone as explained by Cooper et al. (2005) will be given to Stakeholder Management zone which will extend the stakeholders coordination through the project's life cycle.

Considering Detailed design process: It is proposed that while a designer is working at the task level of the design process, he/she will visit the master list of stakeholders and address the stakeholders affected by his/her design decision as illustrated in (Figure 2).

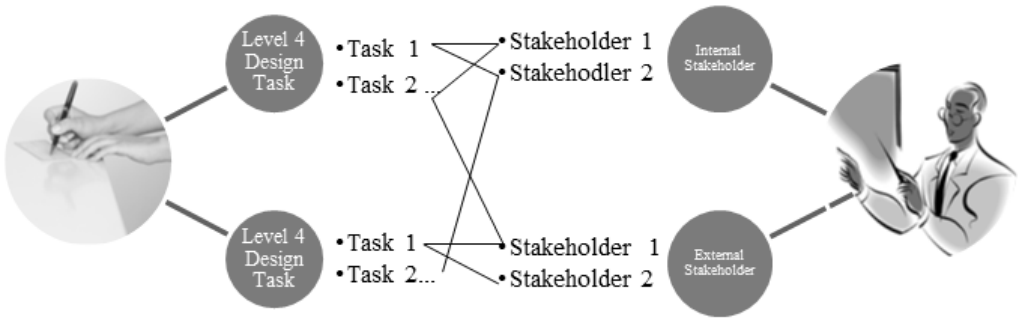

Figure 2: Stakeholder Interaction with the Design Process

While a designer is working on the detailed task level he/she will come up with issues not addressed in the design criteria or design guideline. Therefore, the designer will update the design criteria which will contribute in building the design manual of that part of the project the designer working on. The later designer can send the proposed decisions to the stakeholder managers who will coordinate the approval of these changes. The task of preparing the list and getting stakeholder approval is collaborative work between Design management and Stakeholder management zones. It should be considered that the approval on design decision is judged by balancing the point of view of all involved parties. Once the design decision approved it will be documented in the IT software and added to the design criteria which will be used for similar future projects.

Addressing the Multi sub-projects issues: PP will be considered for each sub-project at the airport terminal to avoid the complication of mixing different disciplines works from technical and procurement point of view. This segregation can take place at Phase 4(Outline Conceptual Design)

Adopting Stakeholder Management Strategy: The Stakeholder management strategy was achieved through: Producing Generic Airport Stakeholder list, Define Internal and External stakeholders to the design process, Develop stakeholder power – interest matrix, Produce design process stakeholder list. Identify stakeholder requirement and needs from the design process, and Define tasks and deliverables of the Design Management and Stakeholders. It is found that stakeholders of the design process in the case study can be classified as shown in Figure 3. The internal stakeholders are the departments who are producing the design and interacting with the external stakeholders to make sure that the design is meeting their requirements according to their power and interests. In this case study, CA is representing the neutral organization which tries to find balance between all involved parties requirements. The power of the involved parties varies according to their needs. The Local airline carrier in the case study is the most important stakeholder since the airport is being built to fulfil the business expansion needs of that entity. Also, the airport operation needs are important in order to meet the business requirement of these stakeholders. Commercial organizations such Duty free are also very important since they provide significant revenue. The government funding authority has a high power since it provides the capital for project execution; however, the design process is not their main concern since it meets the allocated budget. Governmental federations such as the police, immigration and customs are in a similar situation. Business organizations such as food outlets operators and foreign air carriers have an interest in running their business at the airport; although they usually do not have power to influence the design process, it is important to provide them a facility that attracts their business and provide them with adequate facilities. Passengers, communities and NGOs don't have direct impact on the design process. However it is important to keep an eye on these stakeholders since they are providing the data index to the design process.

Based on the case study stakeholders' management observation discussion and literature review, a map of design management and stakeholders' task and deliverables in each design stage is developed. This map is achieved through collaborative work between consultant, CA and stakeholders. This map addresses the issue of pre project activities, design brief and design criteria. Moreover it presents a control point through forms and

reports that can control the project documentation. Table 1 shows a matrix of tasks and deliverables of CA and Stakeholders in the initial phases of the project.

Example of applying the model in preparing initial statement of needs:
This stage is part of Phase 0 which is the demonstration of needs phase. The first task in this stage according to Salford University (2002) is to develop Initial Statement of Needs as Level 1 of the deliverable. Level 3 and dependency stakeholders are shown in Figure 4. In order to define the Level 4 and 5 of tasks involved, a table sheet has been developed in order to identify the lower level of the tasks, time required to complete the tasks, stakeholders' dependency, and result of the conducted task. The example shown in Table 2 shows the Level 3, 4 and 5 of "Discussing Business Requirement" presented at Level 2. It is proposed that this schedule will be linked to a software that records these tasks and stakeholders' dependency and the input of each task will be saved in the project history and the process manager will add the results that come from that task to the initial report of the design criteria which will form a contract between different stakeholders. These design criteria will be developed further through the progress in each phase of the project and it will end up at the end of the project by developing a manual for the design of this airport.
By adding the time to this sheet a planning schedule will be formed and the high level task manager will have an idea about the completion date of the high level task.

8. Model Validation

Model validation is done by organising focus groups to present the developed model to experts who can provide their own judgement as to the comprehensiveness and usefulness of such model. Three meetings are conducted for three groups, where each group consists of 2 to 3 members. All participants agreed that the modified model and the application example showed is generic and describing the complete design process of the Airport design from wider point of view than the existing practice. The described activity zones simulate the discussions conducted between different disciplines in each phase to take decisions about the project however in more systematic manner. The stakeholders' management strategy and the matrix of design management – stakeholders' tasks and deliverables gained the participants acceptance and it is agreed that it represents a clear framework for the relation between stakeholders and design management.

Many participants agreed that the idea of decomposing the design process into documented individual task is a useful way to record the design process and save it in the project history and design criteria which will contribute to solving the issues related to information management and design standard. Some of the participants stated that this model is valid since that the CA is implementing the stakeholder management and design task management using traditional tools without the aid of software that records the design tasks and stakeholders inputs. Issue is raised against the organizational matrix of the different disciplines. The suggested teams seem to be adding additional complexity to the project organization. Hence such implementation requires more studies on the organizational levels. Additional concerns raised regarding managing the complexity of the coordination network between different disciplines and stakeholders when tasks and stakeholder list become more complicated, therefore it is suggested to have a clear framework that describes the IT

solution provided to manage this network and how can this IT software being extended to manage the different activity zones including change management. Some concerns were raised about the culture of the employees in the CA, such model might be resisted by highly experienced staff used to the traditional way. The result of this focused group revealed that the adopted model for design process and stakeholder management is valid and can represent the design of Airport construction as a complex project. Extending the scope of the IT software, studying the organizational implication of implementing the model, and defining the structure of the process documentation framework needs to be developed further

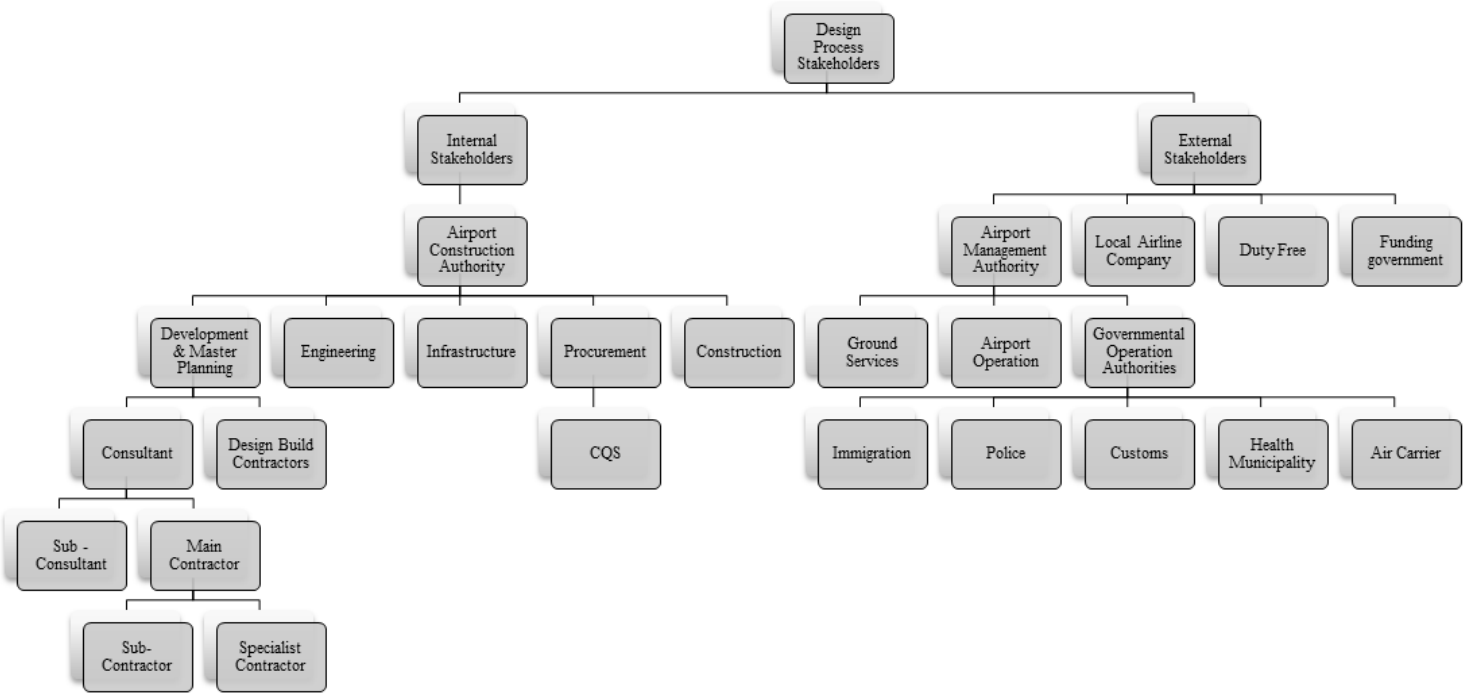

Figure 3: Internal-External Stakeholders to the Design Process

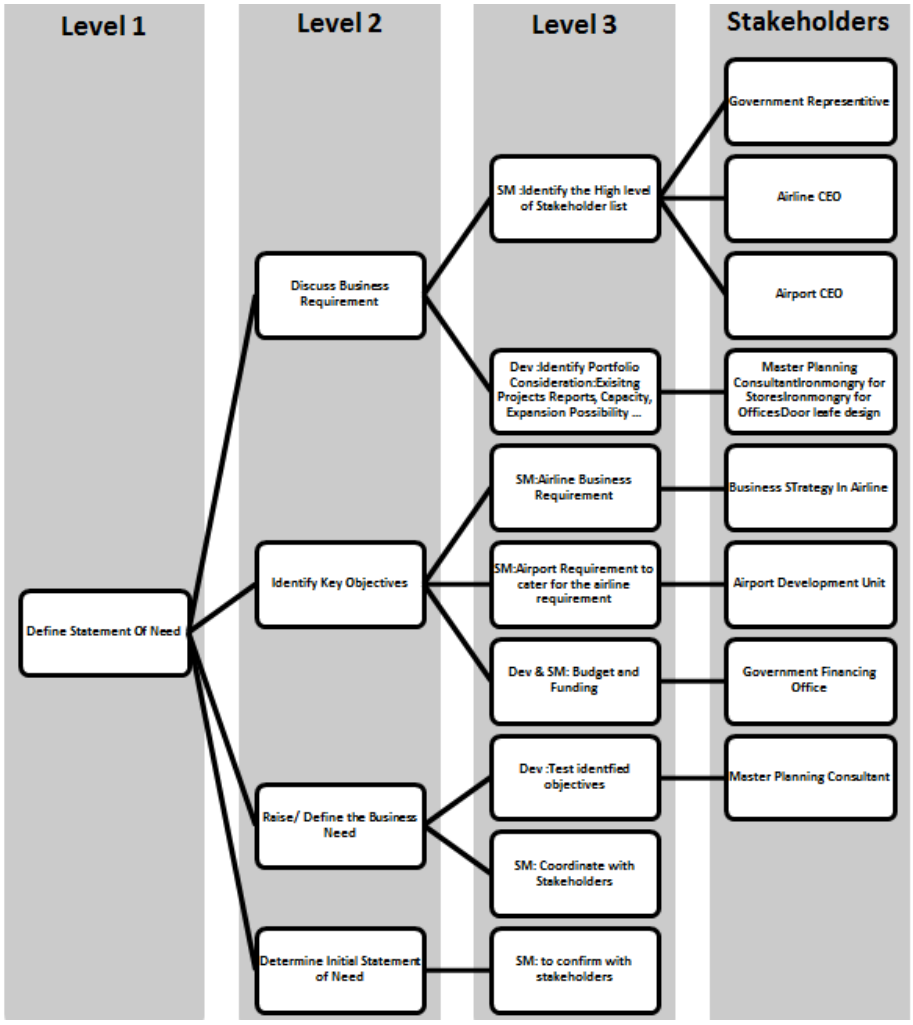

Figure 4: Level 3 of Details and Stakeholders List Matrix

Table 1: Tasks and Deliverables of Design Management Authority and Stakeholders

Stage	Design Management	DM Deliverables	Stakeholder Tasks	Stakeholder Deliverables
1 Identification of Need	Depending on operational or planning requirements arising for DM or stakeholder.	Strategic Brief including 'opportunity identification plan' and early cost	Identification of business requirement through strategic planning or operational feedback	Project initiation letter to DM Form 1
2 Feasibility Stage	• Pre - feasibility Assessment • Collection of data. • Any other necessary pre-conditions • Requirement management • Macro analysis	• Project Charter* • Solution Brief / Project commitment which clearly articulates business scope, cost, business quality and time targets for a solution	• Goals and objectives • Initial commercial input • Business case formulation	Initial Data Report Form 2
	Developing Solution / Project Brief • Feasibility analysis Defining: • Options (strategic choices, strategies, policies…) • Practical solutions (constraints) • Defining direction • What to be constructed? • What is the budget? • Codes, regulations, guidelines and standards governing the solution	• Data Collection Report Report 1 • Feasibility study Report 3 • Project Brief Approval Form 3	• Gathering and consolidation of initial stakeholder input • Production of traffic forecasts (annual/seasonal/design day schedules)	• Data Collection Report (Stakeholders)* Report 2 • Business Case including: ➢ Level of service definition ➢ Operational considerations and regulations input
3 Project Design Brief Stage	• Development of the Design Brief. • Sketch ideas, moods, key finishes and color palette. • Preparation of budgetary estimate and preliminary cash flow forecast. • System consideration (integration) • System optimization • Generating concepts • Evaluating Concepts • Design criteria for project elements	• Project Design Brief Report including design critera Report 4 • Budgetary Cost Report. Report 5	• First level operational simulation • Initial production of facility requirements • Stakeholder review and feedback to the Project Design Brief Report • Review and analysis of Budgetary Cost report	• Consolidated stakeholder feedback on Project Design Brief Report Form 4 • Stakeholder Financial Assessment of Budgetary Cost report. Form 5

Table 2: Level 4 and Level 5 Tasks Sheet

Level 3	Task owner	Time	Level 4	Time	Stakeholder dependency	Result	Level 5	Time	Stakeholder dependency	Result
Identify the high level of stakeholder list	Stakeholder Management	7 days	Define government representative	7 days	Government	Assign VP Funding				
			Define Airline representative	7 days	CEO Airline	VP Business strategy				
			Define Airport organization representative	7 days	CEO Airport	VP development				
Identify portfolio consideration	Development management	7 days	Provide fact sheet about existing facility	7 days	Master planning consultant	Report				
			Study the ability to expand the existing facility	3 days	Development Management Master planning consultant	Level 5	Study apron plot	3days	Infrastructure Department	Report
							Study the capacity of child water utility	3days	Mechanical department	Report
							Capacity of transformer	3days	Electrical department	Report
							Network expandability	3days	IT	Report
							Baggage handling system	3days	SAS	Report
			Study existing operational constrains	5 days	Stakeholder Management	Level 5	Initial report of end-user complains	5days	Service provider	Report
								3days	Airport operation	Report

9. Conclusion

The modified PP model addresses the issue of stakeholder management through presenting the Stakeholder management activity zone which deals in coordinating the requirement of different stakeholders in the project from one side, and identifying the targeted stake holders of the design task from the other side. The modified PP model seems to be able to help addressing the decomposition of top levels of the project into sub-projects that can be further decomposed to different levels according to the sub-project complexity in order to reach the individual design task that helps coordinating different disciplines and stakeholders. The work in this paper although specific to Airport projects the proposed framework can be considered for projects that are technically and organisationally complex.

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Learning from the Past: Analysis of Factors Contributing to Construction Project Disputes in Australia

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Abstract

It is commonly acknowledged that the nature of construction projects is largely fragmented as it is invariably carried out by diverse parties having different aims and objectives. Such a lack of integration typifies the nature of construction industry and arguably makes it prone to project disputes. This paper presents a research study that investigated the key factors that contributed to actual disputes occurred in past construct projects in Australia. The research provides a review of underpinning background knowledge on construction project disputes, as well as their origins. In particular, the research focuses on five main types of disputes: breach, failure to settle and appeal, interpretation, insurance and indemnity and security of payments. Based on this theoretical framework, a qualitative analysis was conducted on 78 court cases data obtained from the LexisNexis database to determine key factors contributing to construction project disputes. The results of this investigation determined that the main factors contributing to disputes were damages, negligence, timing, payments and variations. The 'payments' factor was the highest contribution factor (more than 50%) across all the analysed dispute types. This suggested that most of the disputes originated from a payment disagreement. Additionally, "breach" was found to be the most frequent type of dispute occurred, with 'damages' as the main contributing factor within this type of dispute. The main implication derived from the research findings is that the identified factors contributing to disputes have some element to them that can be specified in the contract and potentially help prevent a dispute, for instance: the amount of general damages that an alleged party can claim; the specification of materials to avoid defective work and thus negligence; the procedure to follow when an extension of time is required; a description of progress and payment claims following its respective legislation; and an appropriate agreement when a contract variation is needed. If these issues are carefully described and understood in the contract, potential disputes can be avoided.

Keywords: Construction, Disputes, Factors, LexisNexis, Australia

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1. Introduction

The construction industry is of great significance to Australia. In 2009, it was reported to employ 9.1% of the country's workforce, making it the fourth largest industry and contributor to Australia's GDP (Gross Domestic Product) (Australian Bureau of Statistics, 2010). Furthermore, Campbell (1997) explains that the construction industry is extensive, formed by diverse types of professions, and fragmented, including different aims and objectives according to the participating parties. Consequently, these characteristics make the industry prone to construction project disputes.

The Australian Bureau of Statistics recorded that in 2004-2005 the construction industry was responsible for almost 50% of all industry disputes. During 2008 and 2009, the dispute percentage compared to the rest of the industries decreased to 27% (Australian Bureau of Statistics, 2010). Such improvement could possibly mean that Australia is embracing various dispute resolution and avoidance methods; however the industry still needs to encourage these approaches further.

Diekmann and Nelson (1985) state that construction industry frequently fails to analyse the actual costs associated with dispute occurrences. For instance, disputes have a great impact on the number of working days lost in the construction industry as opposed to any other industry. The construction industry lost nearly one additional day of work, when compared to employees involved in industrial disputes across all industries (Australian Bureau of Statistics, 2010). Therefore, it is in the industry's benefit to be aware of the factors contributing to disputes to be able to control and minimise any legal expenses resulting from such disputes. In addition, companies need to take into account that there are not only direct financial costs incurred when experiencing a dispute. Hidden costs, including time-value of money, damage of reputation and long-term business relationships, and opportunity costs, among others, should also be considered (Cushman and Carter, 2001). Because of the high cost of disputes identified above, it is important to understand the critical factors that lead to disputes so they can potentially be minimised, or avoided altogether. The aim of the study presented in this paper is to highlight significant sources of disputes that are evident in past construction projects. It is also aimed to provide some recommendations on dispute resolution and prevention methods, as many of the analysed disputes could have been prevented.

The paper details an analysis to identify the most significant factors contributing to construction project disputes in Australia. Although there are a number of past research studies that investigated the similar issue using survey questionnaire and interview techniques, this study took a different approach in determining the most recurrent 'factors' contributing to construction project disputes amongst 78 real-life court cases publicly available from an Australian law database. A qualitative analysis using NVivo 9 which involves the factors' contribution to each court case, as well as their frequency is presented. These factors were analysed to determine how, and the extent to which, they contribute to various types of construction project disputes.

In the next section, a theoretical background related to construction disputes, origins of disputes and types of disputes is presented to establish some key conceptual framework adopted in the study. The methodology employed to carry out the analysis is then explained, followed by the presentation and discussion of the identified factors contributing to construction project disputes. The paper concludes with the summary of key findings and recommendations.

2. Theoretical background

2.1 Construction disputes

According to Black (2009), a 'dispute' is a conflict or controversy; a conflict of claims or rights; an assertion of a right, claim, or demand on one side, met by contrary claims or allegations on the other. Tillett (1991) defines a dispute as something that typically highlights the existence of incompatibilities between the parties. For Morgan (2008), dispute is a contentious issue that the parties to a construction contract disagree upon, or would be likely to disagree upon, and which needs to be resolved by some means or other, either within or outside the contract.

Based on these overarching definitions, and for the purposes of this study, a construction dispute is defined as a disagreement between two or more parties involved in a construction project where litigation is needed. In order for a dispute to arise, an aggrieved party usually serves a written notice either by hand or by certified mail to the party in default. Therefore, it is only called a dispute when all of the parties involved have been notified with the details of the contention (Standards Australia, 1997).

2.2 Origin of disputes

Many problems, arguments and contract variations arise every day in a construction project. The leaders of the project make vital decisions daily to keep the project flowing; these decisions may differ from what the contract specifies. Nevertheless, in most projects the problems are resolved between the people on site, without it becoming a dispute (Campbell, 1997). So, if the involved parties are dealing with these contract changes regularly, what is it that transitions them into a dispute? Construction problems manifest themselves when errors are revealed; changes and ineffective communication create bottlenecks and thereby inefficiency. Cheung and Yiu (2006) summarise specific sources of construction disputes based on an extensive review of past research. Some of the common sources of disputes identified in their research include:

- Variations (due to site conditions, client changes, design errors, etc.);
- Ambiguities in contract documents;
- Failure to comply with payment provisions;
- Timing (schedule delays, delayed design information, delayed site possession, etc.);
- Damages; and
- Professional negligence.

2.3 Types of disputes

Within the context of Australian construction industry, Hollingdale et al. (2009) categorise disputes into five main types: (1) Breach of contract; (2) Failure to settle and appeal; (3) Insurance and indemnity; (4) Contractual interpretation; and (5) Security of payments. Each of these types of disputes is described below.

2.3.1 Breach of contract

The objective of a contract is to represent in writing, the sole declaration of an agreement made between the parties involved. However, the lack of knowledge or understanding of it makes the contract likely to be broken. The primary obligation of a contractor is to carry out the work required, to agreed standards, in a specified time; characteristics that should be detailed in the related contract (Adriaanse, 2005). Therefore, if any of the agreements have not been honoured by one or more of the participating parties on the contract, it may provoke a dispute. The disputes that arise by not following the specifications of the contract are classified as breach.

2.3.2 Failure to settle and appeal (arbitration and dispute resolution)

The construction industry is trying to embrace and encourage alternative dispute resolutions (ADR) as a process to follow in the appearance of a conflict, before or instead of the contractual parties proceeding to litigation. It involves various processes that help prevent and/or manage a conflict between the contractual parties. In order to make sure that the industry is aware of these techniques, it became a compulsory action to be described in the contract. The aim of arbitration and mediation strategies is to make the construction industry realise that the best approach to dealing with disputes is to avoid them altogether (Feld and Carper, 1997). However, the process of managing a conflict is still fairly new to the construction industry of Australia. Therefore, it is reasonable to think that it will take time for the industry to fully recognise it as a primary option before litigation. Nevertheless, there are companies that are already using ADR. Some contracts nowadays dedicate a particular clause for Arbitration and Dispute Resolutions; the breach of such a clause could cause a dispute.

2.3.3 Insurance and Indemnity

In the construction industry it is of common practice to have a management plan for a project; this plan usually includes risk assessment, risk allocation and risk management. The parties to a construction contract carry particular types of insurance that reflect the risks that they are taking on in connection with the project (Hollingdale et al., 2009). The nature of a contract of insurance, commonly referred to as an insurance policy, is that the insurer undertakes to make payments to or for the benefit of the insured on the occurrence of some event (Uff, 2009). Three common insurance policies in the industry are works/property insurance, public liability insurance and workers' compensation. The insurance provisions in construction contracts are closely associated with those for indemnity and care of the works. It is common nature for the contractor to be responsible for the safety and protection of all

the work, temporary work, plant and materials and for any damage to property or injury to the person. A dispute is likely to happen if the responsible party fails to protect any of these previously mentioned elements; consequently the respective party could be entitled to a breach of duty and could face severe consequences for it.

2.3.4 Contractual interpretation

Contractual interpretation, as the name implies, refer to contracts that leave room for personal interpretation. When the interpretation of the contract differs from one party to the other, a dispute is likely to arise. If the contracting parties attach different meanings to the same term, then neither is bound by the understanding of the other. Nevertheless, if one of them knew or had reason to know what the other understood the disputed term to mean, and did not follow their definition, a dispute is probably going to occur. The words of a contract are normally given their ordinary and popular meaning; this is unless the parties use them in a technical sense or if a special meaning is given to them. Therefore, the contract should be drafted carefully to accurately reflect the agreement between the parties, which would also possibly prevent a dispute associated with its interpretation.

2.3.5 Security of payments

There are generally two main participants in a construction contract: the client and the contractor. The client, who proposed a project, expects to see the works specified in the contract in exchange for the agreed amount of money. On the contrary, the contractor expects the payments in exchange for the agreed works. There are generally implied terms in the contract in relation to the payments, their distribution, and sometimes retention of a percentage of it. Given the fact that the parties which are performing the works depend on this payments in order to maintain functioning, a delay or an absence of payment could easily provoke a dispute. Nowadays, it is common practice to withhold a percentage of the payment from the principal contractor to its subcontractor(s) in appropriate circumstances. However, if the principal contractor withholds payment and a request to do so happens to be invalid, they may be liable for breach of contract. Unfortunately, it is not always clear when a principal contractor is required and allowed to withhold part of the payment (Bampton et al., 2011).

3. Methodology

The methodology employed in this study involved an extensive review of relevant literature to provide a theoretical understanding of construction disputes followed by the mining and analysis of qualitative data obtained from real court cases relevant to the Australian construction industry. The details of this analysis and the sample used for the analysis are presented in the following sections.

3.1 Sample

The sample used in this study consisted of 78 court cases extracted from LexisNexis database. The simple selection criterion of the cases was that they had to be relevant to the

construction industry in any State or Territory of Australia. The cases were heard in a number of different courts mainly including the High Court of Australia and the Court of Appeal, Supreme Court and Administrative Tribunal of every State and Territory.

The extraction of the cases from LexisNexis includes 78 cases from 1966 to 2012, involving companies or organisations participating in the construction industry; whether they were contractors, designers, builders, insurance companies, investors, or clients. The court cases used in this investigation have been made public and are available online; therefore, there is no breach of privacy or confidentiality towards any company or organisation. Nevertheless, the cases were only used to investigate the source of the dispute, rather than the outcome of the case. Also the identities of the parties involved in each case are not disclosed in the findings.

3.2 Analysis approach

The data from the selected cases were imported into NVivo 9 to perform a text analysis. NVivo 9 is a qualitative data analysis program that can perform two types of word queries: word frequency and word search. The word frequency feature (Figure 1) allows the user to identify the most repeated words. It provides an option to adjust the search; for instance, the number of letters was increased to a minimum of 4 to avoid common words that were not useful. Furthermore, it allows for deleting words that are of no interest; for example, Australia, Queensland, New South Wales, which were common words and were not needed for this particular query. This feature was used to identify the most significant factors contributing to disputes in the construction industry with reference to the list of factors presented in Section 2.2.

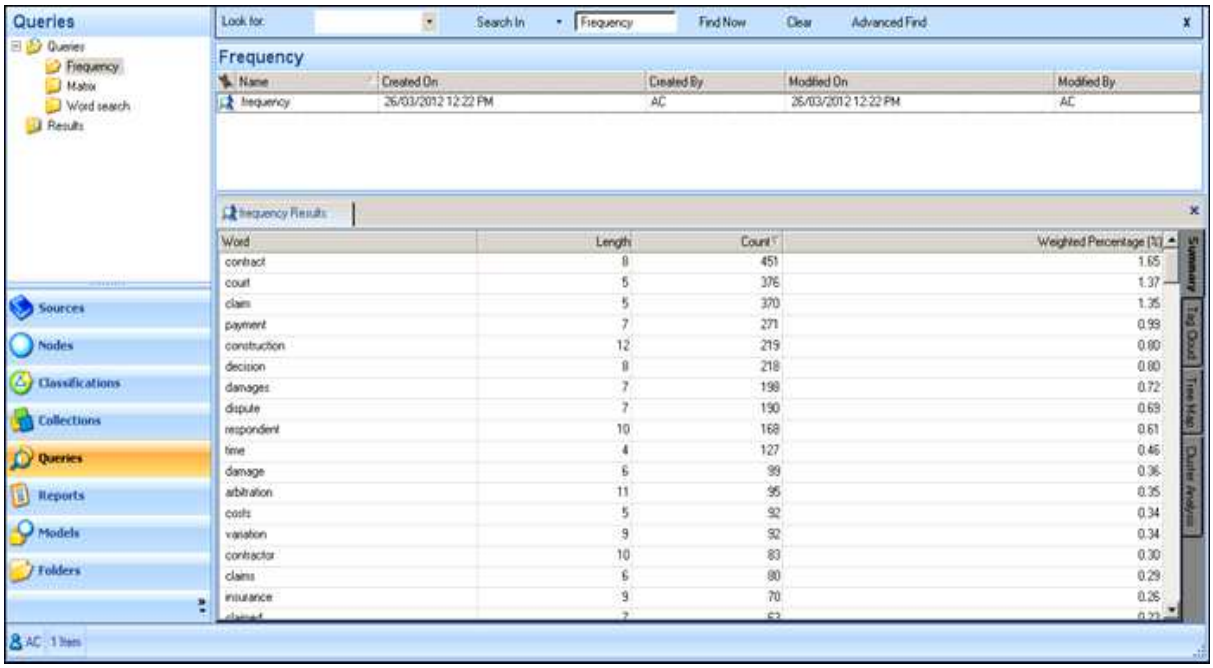

Figure 1: Word frequency queries in NVivo 9

Once the significant (most frequent) factors were identified, a word search was carried out in order to find any cases involving those terms or words with similar meanings. The word search facilitated the coding of the court cases. The coding feature allows each court case to be tagged in a 'types of dispute' and 'factors contributing to disputes', creating nodes and relationships between them. It is important to mention that each case can be tagged (or coded) into more than one dispute type and factor.

Following the coding of all cases, matrix coding was conducted. Matrix coding allows the user to compare items and display the results in a table or matrix. This feature was used to determine the frequency between the five types of disputes (as presented in Section 2.3), and the top five factors contributing to these disputes. Therefore, the matrix consisted of two parameters: types of disputes and factors contributing to disputes. Every court case was also coded into these parameters.

4. Results and discussion

4.1 Overall frequency of factors contributing to disputes

The factors contributing to construction project disputes found in this study were attained from the analysis of the 78 court cases and queries done through NVivo 9. By using word frequency queries, five factors having highest frequencies were identified. These factors are damages, negligence, payments, timing and variations. Word search queries were then carried out to identify how many of these court cases were associated with each of the identified factors contributing to construction project disputes, as illustrated in Figure 2. According to the figure, the most frequent factor was payments, accounting for 50 disputes out of the 78 analysed cases. It was closely tailed by damages (45 disputes); timing (38 disputes); variations (23 disputes); and lastly, negligence (17 disputes).

Not surprisingly, payments dominated as a root cause in more than 50% of the disputes. This is one of the most basic yet critical sources of disputes in the construction industry (and perhaps in any other industries). Fundamentally all of the parties involved in the contract require cash flow to maintain the business operations, whether it is for staff, materials, plant, administration, or any general construction expenses that arise every day. Consequently, and as stated previously, it is critical to describe, in detail, any payment related clauses in the contract. Although this does not guarantee that a dispute will not arise, it may prevent it from happening. Moreover, the factor of payments was also predominantly an additional 'indirect' source of dispute for the rest of the factors contributing to disputes. Some of the cases were not coded into the factor of payments, as that was not the primary source of the dispute. However, it is monetary compensation that parties to a contract generally seek to repair any damage done.

The factor of damages, similar to payments, was a strong factor contributing to construction disputes. Different events happened in the court cases generally came down to damages. In the appearance of a claim for damages, the cases analysed generally proceeded to ask for payment compensation. Therefore, it is recommended to include in the contract the amount

of general damages that the parties to it would be entitled to in case of a claim of damages being needed.

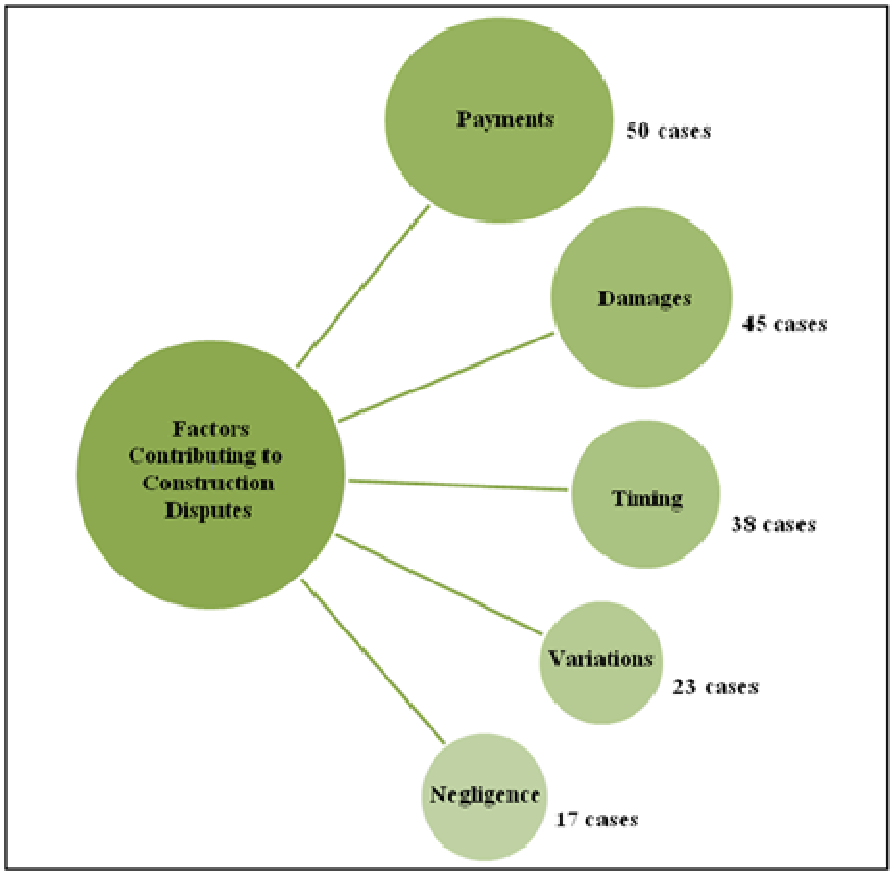

Figure 2: Top five factors contributing to disputes (by number of cases)

4.2 Frequency of the factors contributing to different types of disputes

Following the identification of the top five factors, the court cases were coded into one or more of the five types of disputes described in Section 2.3. Table 1 presents the numbers of court cases (as well as its respective percentage) that were coded into each factor as well as each type of disputes.

Table 1: Frequency of Factors Contributing to Different Types of Disputes

Type of dispute	**Contributing Factors**				
	Damages	Negligence	Payments	Timing	Variation
Breach of Contract	20 (26%)	7 (9%)	11 (14%)	7 (9%)	5 (7%)
Failure to Settle & Appeal	9 (12%)	1 (1%)	11 (14%)	10 (13%)	4 (5%)
Insurance & Indemnity	4 (5%)	6 (8%)	3 (4%)	3 (4%)	2 (3%)
Contractual Interpretation	7 (9%)	3 (4%)	8 (10%)	8 (10%)	5 (7%)
Security of Payments	5 (6%)	0 (0%)	17 (22%)	10 (13%)	7 (9%)

According to the table, it can be seen that the highest number of cases is associated with damages as a contributing factor to breach of contract (26% of the total number of cases). Bailey (1998) stated that any breach will be entitled to a claim for damages. Damages are therefore a major factor contributing to construction disputes because it is commonly involved in the classification of a breach of contract. The party alleging a claim for damages usually receives monetary compensation. Nevertheless, it is also common to request specific performance from the party which performed the breach in order to repair the damages caused (Adriaanse, 2005). The most common form of damages is defective work. This factor contributing to a dispute would usually be dealt with by covering the necessary expenditure to rectify the works plus any consequential losses.

The second highest number of court cases is associated with the payments factor that causes dispute in terms of security of payments (22%). This factor also accounts for reasonably high proportions of dispute cases related to breach of contract (14%) and failure to settle and appeal (14%). Therefore, it can be inferred that the payments factor is as equally important as damages because it can result in a considerable number of litigations across different types of disputes. The payments factor is likely to contribute to disputes as every entity from the construction industry depends on payments in order to maintain the on-going operation of a business. In a construction contract, the contractor is usually entitled to carry out and complete the specified works, as well as required to provide everything necessary for completion. On the contrary, the employer's part of the contract is typically the payment of money. Disputes may arise in deciding when the contractor's obligations are satisfied, what amount of money is payable and at what date. Consequently, all of these elements should be clearly stated in the contract in order to avoid a subsequent related dispute (Uff, 2009).

Similar to the payment factor, but to the less extent, timing factor also resulted in considerable number of cases with disputes related to security of payments (13%), failure to settle and appeal (13%) and contractual interpretation (10%). In the construction industry, numerous variables make it hard to be bound to a definitive completion date. There are endless unexpected and uncontrollable events that could cause a delay on the works. These events could compromise the progress of the works, and therefore prevent the responsible party from not finishing by the agreed date on the contract, making timing the source of the dispute. In an attempt to be reasonable with the respective parties within a contract, the construction industry has modified most current standard contracts in order to entitle the contractor to an extension of time (EOT). However, an EOT would only be granted where the delay was caused by events beyond the control, or reasonable control of the contractor (Bailey, 1998).

Variation factor is present as a cause of dispute fairly equally across all the five dispute types. Although this factor is not the most prominent within the context of this study, variation is one of the most common sources of disputes. The expression 'variation' is commonly used in the construction industry to identify an alteration to the contract, whether this is made by an addition or omission to the works and terms specified in it. Disputes often arise in relation to these variations due to misconceptions as to what the consequence of what appears to be relatively simple changes (Bailey, 1998). Moreover these changes could alter

the scope of works under the contract to such an extent that it could be viewed as creating a separate contract from the original. Therefore, the involved parties should not only thoroughly know and understand their contract, but also any variation that was made to it. Variations to a contract should be given the same importance than the original contract, and therefore both of these should be acknowledged and understood thoroughly. Because these agreements are commonly done through an oral agreement in the construction industry, there is a possibility that the parties could interpret what was said in a different way, or perhaps the person that ordered the variation did not have the power to do so.

Among the sample court cases analysed, 'negligence' appears to be the only factor that resulted in all types of dispute except security of payments. Negligence seems to mainly cause the disputes associated with breach of contract and insurance and indemnity. Negligence, in its tortious context is a breach of duty, which means not taking reasonable care to prevent damage to others from occurring when engaged in anything that requires careful performance a reasonable person would do (Bailey, 1998). It is an action, or omission of an action, that could endanger the life, health, properties, morals or comfort of the public. Nevertheless, negligence can also be found in the context of breach of contract. Common participants in this context are engineers and architects, who can be accountable for carrying out a noncompliant or negligent design or supervision (Uff, 2009). Defective work as a consequence of a negligent design can also be reflected as a negligent act, whether it arises during or after the construction phase of the project.

5. Conclusion

The construction industry, as one of Australia's largest and most important industries is also one of the biggest contributor to disputes. To better understand this issue, the study presented in this paper was conducted to examine significant sources of disputes that were evident in past construction projects and to provide some recommendations on dispute resolution and prevention methods, based on lessons learnt from the past.

By analysing 78 documented historical court cases related to construction disputes, the study determined that the five most frequent factors among the construction industry were damages, negligence, timing, payments and variations. It was also found that these factors were related to each other. Their relationships were identified through a common pattern of events. For example, when the factors of disputes were of negligence, timing and/or variations, a claim for the damages would be justified. Damages as another recurrent factor in construction disputes are usually compensated financially. Thus, most of the cases end up recurring to the factor of payments. Not surprisingly payments was the most common factor contributing to disputes, being responsible for causing more than 50% of the analysed disputes.

Furthermore, the contribution of the factors were also analysed with respect to the classification of disputes, which include: breach of contract, failure to settle and appeal; insurance and indemnity; contractual interpretation; and security of payments. The factor having the highest frequency was damages, particularly, those that caused breaches of contract. However, payments and timing factors were found to have a broader effect,

causing disputes fairly equally across multiple types of disputes. Negligence and variations factors appeared to be less prominent within the context of this study.

Based on the above findings, practical implications can be drawn. All of the identified factors contributing to disputes have some element to them that can be specified in the contract and potentially help prevent a dispute. For instance, the amount of general damages that an alleged party can claim; the specification of materials to avoid defective work; the procedure to follow when an extension of time is required; a description of progress and payment claims following its respective legislation; and an appropriate agreement when a contract variation is needed. If these examples are carefully described and understood in the contract, then both parties will appreciate the consequences of failing to comply with any of them. Although this may not help to completely prevent disputes, it would significantly help reduce the likelihood of them. To better understand and prevent disputes, future research can build on the existing study by examining the dynamic relationships between the identified factors. Such research would help to depict a more complete network of dispute sources to which relevant project stakeholders can refer in order to develop preventative strategies to effectively reduce and manage dispute risks.

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Finite Element Deletion and Topology Optimisation for Building Structural Optimisation

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Abstract

Buildings would not exist without a structural design. Although mechanical, electrical, and computer facilities now often put a much higher burden on the financial costs of a building than the structural design -related to both engineering and construction costs-, a building structure is unique in the sense that structural issues cannot be permitted, as they are life-threatening. Thus a building structure should primarily be safe, but nevertheless also economical. To help structural engineers with these goals, computer-assisted methods exist to determine the stress distribution in structural designs (e.g. the finite element method) and to optimise design components (e.g. topology optimisation). However, research on the optimisation of (complete) building structures is still relatively rare. In this paper, two methods for structural design optimisation have been compared for the application to complete building structural designs. This via a so-called research engine, in which spatial designs are transformed in structural designs, and vice versa, to investigate preliminary design processes. The two methods are compared for their effectiveness of optimisation, which shows that the method topology optimisation is more effective than the method element deletion, and if structural optimisation is used for exploring a solution space and evaluating the design process outcomes, this is an important conclusion. Besides, during topology optimisation a structural design remains stable, whereas element deletion may render the design unstable. However, when structural optimisation is used to study the primarily design process (e.g. via the research engine), the qualitative effects of both methods can be compared, and element deletion is computationally more efficient. Because even an unstable design will be usable in the research engine, for this case the method of element deletion is preferred.

Keywords: Building Structural Design, Topology Optimisation, Primarily Design Process, Finite Element Method, Finite Element Deletion

1. Introduction

Building (structural) engineers are used to the fact that design solutions are a product of a creative process: Not by working from a single problem towards a single solution, but by a very complex exploration of problems, requirements, and solutions simultaneously, as

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illustrated by a model and case studies by Maher (2000). The complexity of this type of design processes has led to three fields of research, related to dedicated computer tools that support the designer to explore a solution space and evaluate the design process outcomes, as described below.

The first field of research develops data models, which describe data and their relationships regarding the design process. Data models have been designed specifically for spatial design, e.g. by Björk (1992) and Borrmann and Rank (2009), and for structural design, e.g. by Weise *et al* (2000). For the interaction between spatial and structural design, Sause *et al* (1992) present an object-oriented approach to unify structural product and process models. Making use of the same object-oriented approach, Nguyen *et al* (1996) developed a concept for a data model, including a prototype program, for architectural design, structural design, and code compliance checking. Similar research was carried out by Khemlani *et al* (1998) and their most important achievement was the explicit formulation of the "space-structure dilemma" and a possible solution they proposed was a so-called "split-edge data structure" concept. Another proposition for a data model including structural and spatial information can be seen in the work of Matthews *et al* (1998). Eastman and Jeng (1999) took into account that the necessary modification of data models during the design process requires a specific data model set-up. They demonstrated this by a spatial, structural, and physical view of a building design example. Then Rivard and Fenves (2000) proposed a data model slightly later that incorporates both an object-oriented data model, and two design evolutionary capable abstraction levels for multiple views, again illustrated by a spatial-structural example. Mora *et al* (2006) worked out a very detailed data model, explicitly for spatial and structural design aspects, which was loosely based on the work of Rivard and Fenves (2000) mentioned above. This finally led, by the same authors, to an advanced design system prototype by Mora *et al* (2008).

The second field of research develops methods for actually generating spatial or structural design solutions for buildings. For spatial design, space-allocation, shape grammars, e.g Kotosopoulos (2005), and related methods, e.g. Oxman (1997), have been developed. For structural design, research has been carried on methods that actually generate a structural design, e.g. Rafiq and MacLeod (1988), Maher (1985), and Shaw *et al* (2008). Probably spanning the largest group of supporting tools within the field, finite element programs should be mentioned, which allow a detailed analyses of the stress distribution in a structural design, Zienkiewicz and Taylor (1988). Often using these finite element programs, also an enormous amount of research exists that optimises an existing structural design (component) by means of several possible optimisation methods, an overview is given by Kicinger (2005). It is remarkable that these optimisations methods are often used on two-dimensional problems regarding only components of a structural design. Literature in which three-dimensional problems are presented, incorporating a complete building structural design, can be found, Rafiq et al (2003), but only occasionally. This is the background for one of the contributions of this paper: Investigating the use of optimisation methods applied to complete building structural designs.

Most of the research projects mentioned above assume, explicitly or implicitly, that after the design of a preliminary spatial design, a preliminary structural design is developed, and this

more or less subsequently. This does not correspond to the idea of exploring problems and solutions simultaneously, with which this section was started. However, a third field or research exists, that addresses exactly this idea: a strong interaction between disciplines, e.g. Maher (2000), Haymaker *et al* (2004). Inspired by this third field of research, a so-called research engine is under development, which develops and modifies a spatial-structural design through a number of cycles *N,* with each cycle numbered from *n* =1 to *N*, Hofmeyer (2007), figure 1. More specifically, a cycle consists of four steps: (1) a transformation from a spatial design (2*n*-1 in figure 1 on the right) to a structural design (2*n*-1); (2) the optimisation of the structural design (2*n*-1), which results in a new structural design (2*n*); and step (3) and (4), which interpret the new structural design as a spatial design (2*n*) and modify this spatial design such that it complies with the design requirements again. Hereafter, the cycle may be repeated, with integer *n* increased by 1.

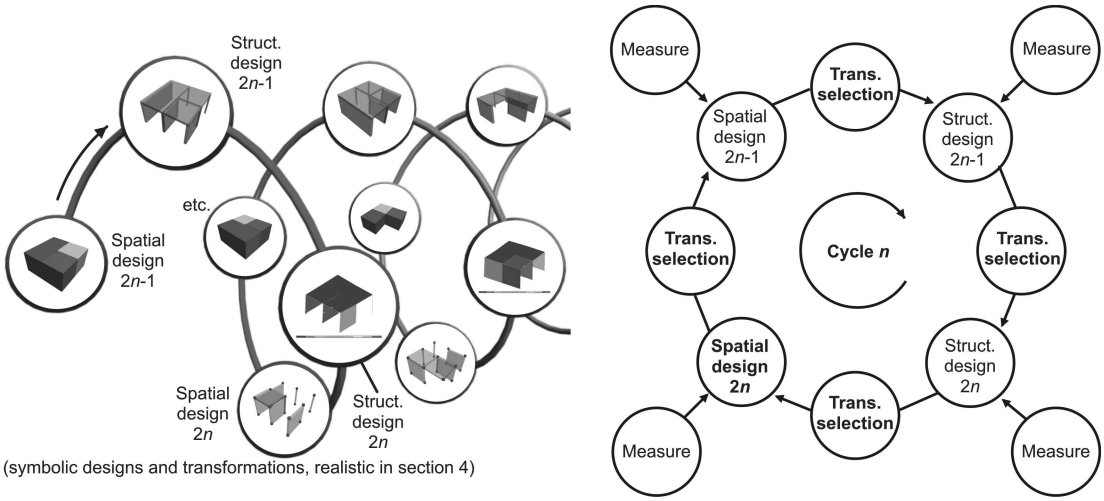

Figure 1: Research engine, symbolic on the left, schematic on the right

Several useful applications and interpretations exist for the research engine, Hofmeyer and Kerstens (2008), and in this paper it is used as a framework to study two possible methods for the structural optimisation of complete building structural designs. The first optimisation method, (finite) element deletion, has been specially developed for the research engine and its non-complex set-up fits the primarily design character of the engine. The second method, topology optimisation, is a frequently used, formal and more complex method, mostly used for two-dimensional problems related to structural design components, Bendsøe (1995).

After this introduction, in section 2 the element deletion method is explained, but this is only possible with a brief presentation of the research engine. Then, in section 3 the principles of topology optimisation are elaborated. Section 4 presents case studies using both optimisation methods; thereafter conclusions can be presented in section 5.

2. Element deletion

As the method of element deletion has been developed with the research engine in mind, and the research engine is used as framework in this paper, first the research engine will be presented here, although very briefly and only for the relevant parts as shown in figure 2. References will be given to allow for a more elaborated description.

The research engine is initiated for its first cycle (n = 1) with the input of a spatial design 2n-1, which consists of rectangular spaces. Zoning, the first process in figure 2, then searches for all possible zones, which are rectangular sets that consist of one or more spaces. Then all possible solutions for constructing the spatial design out of these zones are found, see for more details (also on a possible combinatorial explosion) Hofmeyer and Bakker (2008). Formulated differently, the spatial design is redefined from consisting of spaces to consisting of (larger) zones, which is believed to resemble the working method of a structural engineer: Searching first for geometrical information (gridlines, openings, etc) on the larger scale of a structural design.

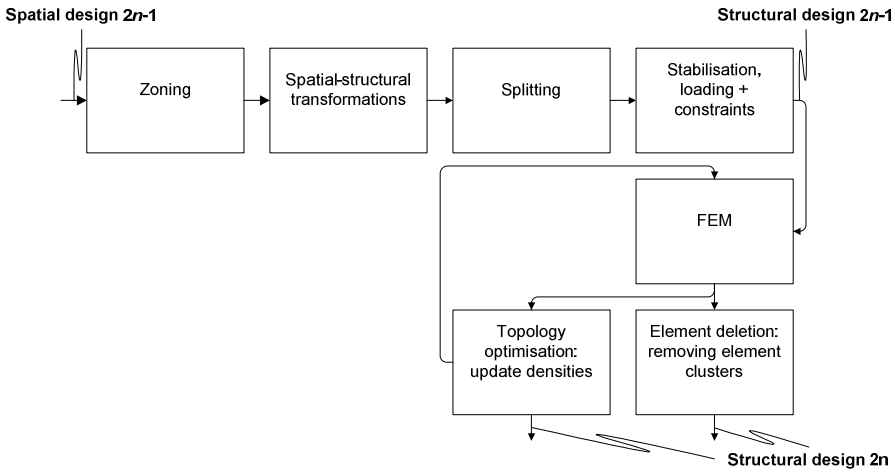

Figure 2: Research engine, process model of first two transformation steps

Hereafter, the second process in figure 2 applies spatial-structural transformation rules to the zoned spatial design. This implies that for every zone, depending on its geometrical properties, some structural elements -like shear walls, slabs, and columns- are added, Hofmeyer and Bakker (2008). For the resulting structural design two issues exist. First of all, the design is possibly not conformal, which means that once it is meshed using the finite element method, it may result in finite element nodes which are not connected, figure 3.

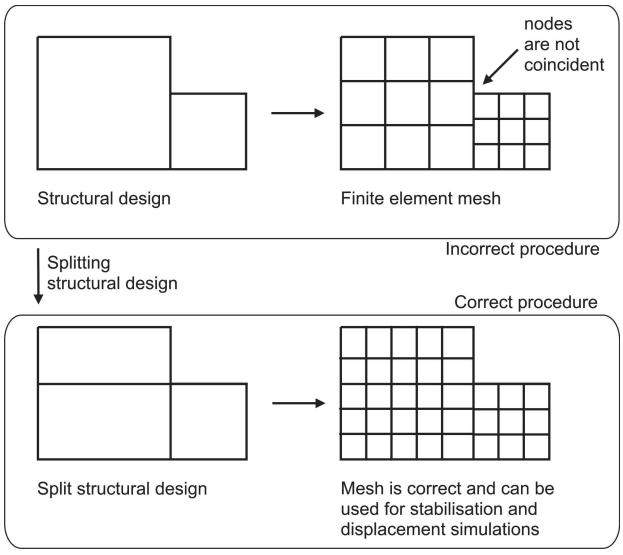

Figure 3: Structural design should be split to assure a correct finite element model

Therefore, the third process in figure 2, splitting, makes the structural design conformal, Hofmeyer *et al*, 2011. Secondly, due to the fact that structural elements are simply added to the zoned spatial design, without any further considerations, the resulting structural design is not necessarily stable. This is solved by using a dedicated stabilisation process, shown in figure 2 as the fourth process. During this stabilisation process, carried out by means of a finite element method, structural elements are added to the structural design until the structural stiffness matrix (used in the finite element method) is regular, Smulders and Hofmeyer (2012). Besides, this process also adds constraints (like boundary conditions simulating the foundation) and loads, after which structural design 2*n*-1 has been developed, as shown on the top right in figure 2.

The first step of the element deletion method is a simulation by the finite element method, as shown by process "FEM" in figure 2. The finite element method is based on approximating the complex displacement field over a continuous structure (e.g. a shear wall or slab) by a simple displacement field for a small part of the structure, an element. Relating all element displacement fields yields a system of linear equations, which once solved, results in an approximation of the displacements, stresses, strains, and strain energies in the structural design. When specifically the total strain energies of the elements are observed, naturally the elements will differ in their energy values. Given this fact, if a structural design should be made more efficient, it is then suggested to remove elements which show very low energy. This because if a structural element has low total strain energy, it either bears low forces (a quadratic relation exists between forces and energy) or shows high deformations (with a linear relation) and does not contribute significantly to the distribution of the applied loads.

For the method of element deletion, three aspects should be discussed. In the first place, for every optimisation method, it is the load case that almost completely determines the outcome of the optimised structural design. Because a structural design should not be optimised for e.g. a single wind direction -making it completely non-optimised in another direction-, several load cases have to be used. For each load case the finite element model is applied, where after for each element, the maximum total strain energy value among the load cases is selected for further processing. The load cases used are shown in figure 4 on the left. On the right, the load cases for topology optimisation are shown, to be presented in section 3. Further details on the selection of the specific load cases can be found in Hofmeyer and Davila Delgado (2012).

The second aspect concerning element deletion is the question how the elements to be deleted should be selected. For this, the K-means algorithm or Lloyd’s algorithm is helpful, MacQueen (1967). This method sorts the finite elements in a number of groups specified by the user. Each finite element is put in the group for which the mean value is closest to the finite element total strain value. As such, the method generates groups with elements with similar energy values. In the currently used research engine, it has been found that grouping the finite elements in eight clusters yields workable results, however, future work should include a rigorous parameter study on the number of clusters to be used. Then, the user can decide how many clusters are to be removed, and hereafter a new optimised structural design 2*n* has been developed, as shown in figure 2 on the bottom right.

Finally, the third aspect is that a structural design 2*n*, as developed by the method of element deletion, is possibly not stable anymore. This is the case because finite elements have been deleted on the basis of their total strain energy level only, without taking into account any other argument, including that of stability of the structural design. It should be noted that for structural optimisation as a solely process this is indeed a problem. However, in the research engine structural design 2*n* is also a precursor for a new spatial design 2*n*, and this new spatial design can be developed from an unstable system without any problem. As such, for research engine applications, this latter drawback of element deletion does not exist.

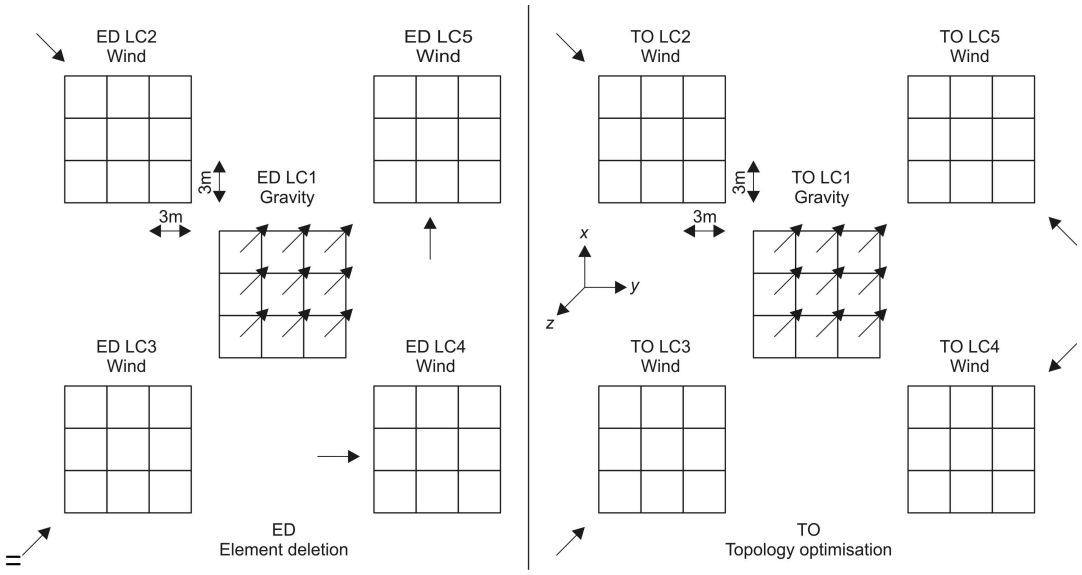

Figure 4: Load cases for element deletion on the left, for topology optimisation (in section 3) on the right

3. Topology optimisation

Topology optimisation is a more formal method, and due to its iterative character, presumably more effective than element deletion. For the topology optimisation method as presented in this paper, a method has been used exactly as described by Sigmund (2001). However, for completeness, a brief explanation will be given in this paper, with inevitably repeating some formulae. Just like for element deletion, also topology optimisation starts with a finite element simulation as shown in figure 2 on the right. Because topology optimisation is best explained using a formal notation, the finite element simulation will be formulated as:

$$\mathbf{KU} = \mathbf{F} \quad \text{Sigmund (2001)} \tag{1}$$

K is the structural stiffness matrix, **U** the displacement vector, and **F** is the force vector. Different from a normal finite element simulation, for topology optimisation **K** is assembled from element stiffness matrices $\mathbf{k}_e$ that are each multiplied with a so-called relative density. This relative density is a scalar x_e that can have a value between 0 to 1, and this makes it possible to lower or higher an element's stiffness. To enable calculating the sensitivity of an

element to the objective to optimise, the relative density is powered by *p*, which is a value equal for all elements:

$$\forall_e \left\{ \mathbf{k}_e \rightarrow x_e^p \mathbf{k}_e \right\} \tag{2}$$

Topology optimisation is started with equation (1), with the same x_e for each element (for example 0.5). Hereafter, the objective to optimise is calculated, in this case the total strain energy:

$$c(\mathbf{x}) = \mathbf{U}^T \mathbf{K} \mathbf{U} = \sum_{e=1}^{N} x_e^p \mathbf{u}_e^T \mathbf{k}_e \mathbf{u}_e \quad \text{Sigmund (2001)} \tag{3}$$

Assuming elements of the same size (volume), better x_e-values (leading to a lower objective) can be found as described by Bendsøe (1995):

$$x_e^{new} = \begin{cases} \max(x_{\min}, x_e - m) \text{ if } x_e \sqrt{\dfrac{-\partial c(x)/\partial x_e}{\lambda}} \le \max(x_{\min}, x_e - m) \\ x_e \sqrt{\dfrac{-\partial c(x)/\partial x_e}{\lambda}} \text{ if } \max(x_{\min}, x_e - m) < x_e \sqrt{\dfrac{-\partial c(x)/\partial x_e}{\lambda}} \le \min(1, x_e + m) \\ \min(1, x_e + m) \text{ if } \min(1, x_e + m) \le x_e \sqrt{\dfrac{-\partial c(x)/\partial x_e}{\lambda}} \end{cases} \quad [35] \tag{4}$$

with *m* a constant with the aim to limit the maximum shift of the x_e -vector **x** and:

$$\partial c(x)/\partial x_e = -p x_e^{p-1} \mathbf{u}_e^T \mathbf{k}_e \mathbf{u}_e \quad \text{Sigmund (2001)} \tag{5}$$

Using a bi-section method, the λ factor in equation (4) can be calculated such that the volume of the optimised structural design (the volume being a function of the new x_e vector **x**) is the same as during the initial run (with the initial x_e values equal to 0.5 in this case).

For certain reasons, as explained in Sigmund and Petersson (1998), it is useful to use a mesh-independency filter. This filter could be seen as partly averaging the element sensitivities over a certain domain (defined by value r_{min}). This filter modifies the values of equation (5) as follows:

$$\frac{\partial \hat{c}(x)}{\partial x_e} = \frac{1}{x_e \sum_{f=1}^{N} \hat{H}_f} \sum_{f=1}^{N} \hat{H}_f x_f \frac{\partial c(x)}{\partial x_f} \quad \text{Sigmund (2001)} \tag{6}$$

with

$$\hat{H}_f = r_{\min} - dist(e, f), \quad \{ f \in N \mid dist(e, f) \le r_{\min} \}, \quad e = 1, \ldots, N \quad \text{Sigmund (2001)} \tag{7}$$

dist(*e*,*f*) is equivalent to the distance between the centre points of (finite) element *e* and *f,* and r_{min}, being a user input, is the maximum distance between the element and other elements that should be considered.

Using the updated sensitivities of equation (6), a new prediction for the x_e-values can be made, where after the topology optimisation process is repeated until the change in x_e-values is sufficient small related to a user inputted threshold. This cycle is also shown in figure 2. And like the case for element deletion, also here a structural design 2*n* results.

4. Case studies

With the two optimisation methods presented above, case studies have been carried out, for which the results will be presented in this section. All case studies have been made fully automatically using the research engine as follows. The initial spatial design 2*n*-1 has a ground plan as shown in figure 4, with 3 × 3 spaces of each 3 × 3 meter, and a building height of 3, 21, or 60 meters, corresponding to 1, 7, or 20 levels with a level height equal to 3 m. The first process in figure 2, zoning, is instructed to develop a zoned spatial design by transforming each single space in a single zone. This seems to be the least advanced or interesting method of zoning, but to compare two methods of structural optimising, in this way a regular and fine grid of structural elements can be produced, and this in turn will enable the optimisation to reduce elements on the basis of a regular and fine grid as well. Therefore, spatial-structural transformations are used that add to each zone 4 shear walls and 1 slab on top of these shear walls. Due to the specific spatial design 2*n*-1, and the very specific settings for the zoning and spatial-structural transformations, the third process, splitting, is not necessary.

The fourth process, "Stabilisation, loading + constraints" is carried out completely, although stabilisation may not necessary due to the same reasons mentioned above: A regular and fine grid of shear walls and slabs is used, which makes the structural design stable naturally. Loading is applied as shown in figure 4. For element deletion, the five load cases are applied on the left. For topology optimisation, the load cases are applied as shown on the right, as explained in more detail by Hofmeyer and Davila Delgado (2013). For both methods, constraints are applied by fixing the lowest points of the structural design in all three independent directions *x*, *y*, and *z*, thus simulating a foundation.

Hereafter, one of the optimisation methods is applied as presented in section 2 or 3. In the finite element simulations, each structural element (i.e. a shear wall or slab) is meshed by 6 x 6 flat shell elements, which have a formulation as described in Batoz and Tahar (1982). After assembling the structural stiffness matrix, the system of equations is solved by BiCGSTAB, Eigen (2012).

Table 1 presents the case studies by their indentifying number and C value, which represents the number of finite element clusters (out of 8) that are removed. Figure 5 shows a typical run, in this case simulation A11, with from left to right in the top row: (a) spatial design 2*n*-1, (b) structural topology, and (c) structural design 2*n*-1 with clustered finite elements; every cluster is shown with a different grey. In the bottom row, from left to right: (d)

optimised structural design 2*n*, (e) spatial design 2*n*-1 with the spaces to be removed coloured slightly more dark, and (f) spatial design 2*n*. The last two spatial designs are only shown here because they are produced automatically after structural design 2*n*-1, however, they will not be discussed in this paper.

Table 1. Case study identifier (left), number of element clusters removed (middle), and effectiveness of optimisation eo (right)

		Topology optimisation			**Element deletion**		
	LC1 Gravity load	A1	C3	2.27	A2	C3	1.45
Low-rise	LC2 Wind load	A3	C2	2.27	A4	C1	1.88
(1 level)	LC1,2,3,4,5 Combined loads	A5	C3	2.00	A6	C3	1.45
	LC1 Gravity load	A7	C2	3.03	A8	C2	1.23
Mid-rise	LC2 Wind load	A9	C2	4.76	A10	C2	2.27
(7 levels)	LC1,2,3,4,5 Combined loads	A11	C2	2.77	A12	C2	1.23
	LC1 Gravity load	A13	C2	3.57	A14	C2	1.27
High-rise	LC2 Wind load	A15	C2	6.67	A16	C2	1.30
(20 levels)	LC1,2,3,4,5 Combined loads	A17	C2	4.35	A18	C2	1.56

To compare the two different optimisation methods, each simulation of each case study is evaluated by using the following measure of effectiveness (*e*) of optimisation (*o*):

$$eo = \frac{E_{2n-1} * V_{FE;2n-1}}{E_{2n} * V_{FE;2n}} \tag{8}$$

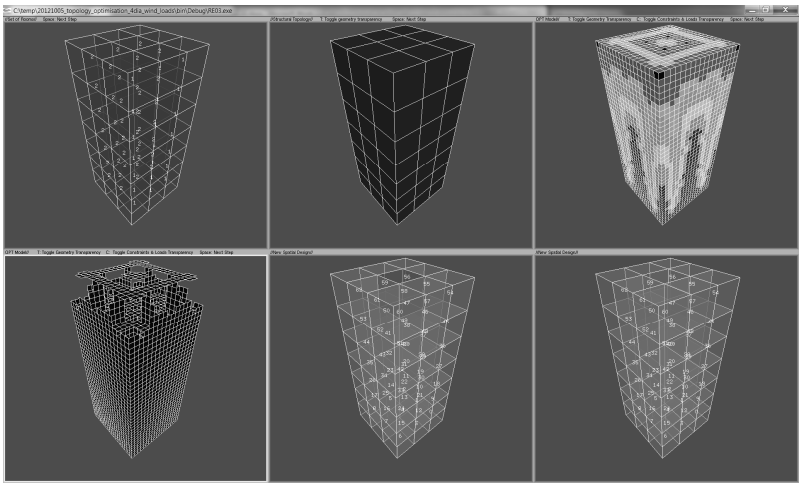

Figure 5: Research engine, typical run for case study A11

In equation (8), *E* stands for the sum of all finite elements' total strain energy, for structural design 2*n* and 2*n*-1 respectively, whereas V_{FE} is a variable that represents the total volume of finite elements used in the simulations, again for either design 2*n* or 2*n*-1, indicated by the subscript. Note that the measure of equation (8) is sensitive for both optimisation methods. If low strain elements are removed with the method element deletion, the total volume of finite elements will decrease for design 2*n*, whereas the total strain energy level will not change significantly, thus leading to a higher *eo* value, which indicates improved optimisation. For the topology optimisation method, the total volume of finite elements will be constant,

however, here the total strain energy will decrease for design 2*n*, again increasing the value of the effectiveness of optimisation. More extended case studies, including more realistic building forms can be found in Hofmeyer & Davila Delgado (2013).

5. Conclusions

If table 1 is studied, it can be seen that topology optimisation is always more effective than element deletion, and even more significantly for taller designs. This can be explained by the fact that topology optimisation is an iterative procedure, whereas element deletion is only carried out once. Furthermore, a taller building implies more degrees of freedom in the finite element simulation, and topology optimisation benefits from higher numbers of elements.

If the specific load cases are taken into account, the case studies show that both methods perform better for LC2 Wind load than for other cases, in most situations. This is because a single wind load results in a strongly non-equally distributed strain energy field in the design, which enables a better optimised design more easily.

The effectiveness of optimisation measures shows that topology optimisation is more effective than element deletion, and if structural optimisation is used for exploring a solution space and evaluating the design process outcomes, this is a deciding factor. Besides, during topology optimisation a structural design remains stable, whereas element deletion may render the design unstable. However, when structural optimisation is used to study the primarily design process (e.g. via the research engine), the qualitative effects of both methods can be compared, and element deletion is computationally much more efficient. Because even an unstable design will be usable in the research engine, for this case the method of element deletion is preferred.

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The meaning of time in a cross-disciplinary arena project

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Abstract

The lack of long-term strategies regarding energy efficiency of multi-family buildings in Europe has resulted in acute need of renovation of these structures. To meet sustainability targets and speed up renovation, the Swedish Government granted time-limited funding of collaborative energy-development projects. A longitudinal case study (2008-2010) of one of these projects, aimed at establishing a cross-disciplinary knowledge arena (researchers, practitioners and regulators) to enhance knowledge concerning energy efficient renovation of multi-family buildings is in focus. The aim of this paper has been to explore how conceptions of time, e.g. as idea, constraint and resource, are manifest in the unfolding of the arena project. The study draws on qualitative analysis of 18 in-depth interviews with actors from the participating disciplines, observations of meetings and close-reading of project documents. The paper discusses prevalent contradictions between conceptions of time within the various social practices and mindsets of the involved parties, and how these have implicated the outcomes of the project.

Keywords: energy efficiency arena, knowing, practice, renovation, time, Sweden

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1. Introduction

As a result of many years' neglected maintenance, a majority of the Swedish multi-family buildings constructed between 1965 and 1975 are in imminent need of extensive renovation. Today, these buildings have an average energy consumption of 185 kWh/m2/year, which needs to be extensively lowered in order to meet the governmental target of reducing the total energy use by 50% until 2050 (Swedish Energy Agency, 2010). How to address this challenge is prioritised among researchers, practitioners and policy makers.

The main problem is not that energy-efficiency policies and strategies are lacking, but rather that these do not take into account local contextual circumstances, i.e. adhere to the building science and technology logic. Little attention is also paid to practitioners' knowledge and how their actions relate to and influence various systems, structures and established conventions (Gluch and Räisänen, 2012; Whyte and Sexton, 2011). In addition, the area of energy efficiency research is largely influenced by anecdotal data, urban myths, vested interests and conflicting arguments (Oreszczyn and Lowe, 2009). Yet, little effort has been invested in trying to understand the complexity and dynamics of the social and political facets that frame energy-efficiency decisions and practices (Guy and Shove, 2000). One of these facets is the dynamics of time. How is time conceptualised within different social systems, and what happens when these systems have to collaborate in a project? How do different ontologies, epistemologies and ideologies of time implicate the development and outcomes of a collaborative knowledge arena project for energy efficiency endeavours?

Over the last decade, the Swedish construction industry has invested much effort and resources into developing technology and implementing various control systems to make buildings energy efficient (Malmqvist *et al.*, 2011; Swedish National Board of Housing Building and Planning, 2010; Thuvander *et al.*, 2011; Toller *et al.*, 2011). This development has largely been driven by governmental regulation and policies, self-regulation activities (through standards such as ISO14001, LEED) and R&D collaboration between industry and research institutions (e.g. E2ReBuild, 2012; Lågan, 2012; Tofield and Ingham, 2012;). One such initiative was the 2007 Swedish Energy Agency grant program aimed at stimulating R&D initiatives for sustainable renovation of apartment buildings (Cerbof, 2011). Due to this grant it was possible to initiate a arena project in 2008, later entitled the *MILPARENA,* an abbreviation of the three words "MILlion", "Program" and "ARENA" where the million program refers to the approximately one million apartments that were built in suburban areas of the major cities in Sweden during a rather short period in the 1960-70s. The arena project's aim was to develop a forum for cross-disciplinary interaction and sharing between various types of professional actors engaged in energy-efficiency and renovation endeavours and also to enable mediation of practical knowledge from ongoing projects to researchers (Dalenbäck and Mjörnell, 2011).

The development and implementation of the *knowledge arena* was studied over a period of three years (2008-2010). Results from the case study have previously been presented in a two papers (Gluch et al, 2012; Johansson and Gluch, 2010) and in a dissertation (Johansson, 2012) where focus has mainly been on knowledge sharing in and across organisational borders. In this paper the focus lies on the concept of time and its

manifestations as the project developed. We discuss the ways in which time is conceptualised e.g. as idea, resource and constraint. The paper probes prevalent contradictions between social practices and conceptualisations among involved parties and identifies tensions at the interfaces of practitioners, researchers, funders and stakeholders.

2. Theoretical framework

The study reported here is framed by a practice-based perspective in which knowing and doing are dynamically intertwined activities that take place in situated contexts through practices (e.g. Lave and Wenger, 1991; Gherardi and Nicolini, 2000). Seen from this perspective, knowledge in general and knowing in particular are not contextualised abstractions or generalisable "rules" stored in a knowledge repository to be accessed when needed; rather they are embedded in the people, processes, methods and tools of a particular practice (Gherardi and Nicolini, 2000). A practice can be described as an institutionalised 'doing', which has been socially and culturally constructed over time within a social system of relations. In this system, agency may be distributed between individuals as well as artefacts. Practice and knowing emerge, are maintained-for-now, and change through an ongoing mutual influence, a duality of structure (Giddens, 1984) between agents (the collective carrying out activities within a practice) and the practice as such. The practice compels particular behaviour and actions of the actors while adjustments and developments among agents in turn develop the practice (Heiskanen *et al.*, 2010; Gherardi and Nicolini, 2000; Gluch and Räisänen, 2009; Gheradi, 2009).

Knowing in a given practice takes place when individuals collectively engage in activities in which they have strong commitment or vested interest. It is in these activities that information is exchanged and knowledge is shaped, re-shaped and shared. In such a relational shaping process, notions of, for example, energy efficiency and climate change may be verbalised in the discourse of a particular party, but these notions also need to be translated into the relevant discourses of other parties before the notions may be appropriated and made sense of by all parties (Füssel, 2005; Stenberg and Räisänen, 2006). Knowledge sharing across disciplinary boundaries can, according to Teigland and Wasko (2003), be facilitated through participation in social networks, informal meetings and workgroups.

Furthermore, governing entities may act as enablers for knowledge sharing across these boundaries by mobilising incentives for collaborative endeavours and mutual engagement to solve societal or organisational problems (Brown and Duguid, 2001). Based on a study of a zero-energy residential building project, Brown and Vergragt (2008) concluded that higher order knowing within a project community was achieved when there were overlaps of the interpretive frameworks and practices held by the participants, such as developer, urban planner, architects and energy analysts. These meaning-making processes also require proactive and ongoing attention to the dimension, of time and space as characterised by Nonaka's notion of $\beta\alpha$, where time and space are merged (Nonaka and Konno, 1998). This conceptualisation of time, in our view, is crucial to the success of a knowledge-sharing arena with the aims mentioned above. Although research tends to be prescriptive concerning indicative factors for successful knowledge sharing in cross-disciplinary projects, there are

insufficient empirical studies concerning the conception, experience and use of time. In interdisciplinary arenas, it is therefore important to pay attention to how engagement and knowledge sharing within communities evolve in terms of time.

3. Method

The empirical data were gathered using qualitative methods: observations, interviews and document analysis. Over a period of three years (August 2007 – May 2010) two workshops at the initial stage of the arena project, five planning meetings, two open seminars, one reference-group meeting, two company presentations, which included construction-site visits, and three site meetings of a pilot project within the arena, were studied. Field notes of formal and informal interactions, and talk provided a contextual understanding and helped to make sense of the interviews.

Eighteen interviews, lasting between 1 to 3 hours, were carried out. The interviewees were selected from the arena's contact list of 50 individuals. All the interviews were recorded. The interviewees were divided into two groups: *researchers/experts* (8 interviewees: R1-8) and *practitioners* (10 interviewees: P1-10). R1-8 were employed either at a Technical University (TU) or at a Research Institute (RI). Interviewees employed within municipal housing companies, a local energy company and the local governing authority made up the P1-10 group. We, the authors, were positioned as academic observers trying to understand and interpret the dynamics of the arena, with as little direct participation as possible.

For the purpose of this paper, a content analysis of the interviews was carried out focusing on the interviewees' interpretation of events. The interviews were summarised iteratively to compile representative stories, depicting different views and attitudes toward arena events and activities. Documents produced within the arena, such as meeting protocols, information leaflets and seminar material were analysed and served to create a "formal" timeline.

4. Findings

4.1 The arena project

Researchers from a Technical University and a Research Institute in the western part of Sweden initiated the knowledge-sharing arena. A professor in building energy technology took on the role of self-nominated arena leader without apparent resistance from fellow researchers. Together, these actors wrote and were also awarded an Energy Agency grant to develop the arena in collaboration with interested municipal-housing companies practitioners. The arena objective, as formulated in the application, was three-fold: 1) *to share knowledge between researchers and practitioners* (clients, contractors and consultants), 2) *for researchers to gain knowledge from real-life projects* and, 3) *to disseminate this knowledge to future projects*. A central idea was that participants in the forum would create and share knowledge by interacting with each other in common forums where particular and relevant mediating tools would be devised and used. The underlying assumption reflected in the arena objective seems to have been that knowledge and knowing are automatically generated and shared when people from different knowledge

fields within a particular subject domain meet and interact around a shared interest and/or activities.

At the initiation of the arena, scant reflection concerning the nature and interpretation of the term *knowledge* occurred, and there seems to have been no effort spent on attempting to assess the "actual" knowledge needs and social paradigms of the prospective participative disciplines. Time was limited to the project duration of three years and no specific time plan or communication plan was established.

The subject domain of the arena was renovation of multi-family housing, which gathered local authorities, housing companies and energy suppliers to join forces with the researchers to develop the arena. Altogether, six municipal housing companies, one local energy company and the local governing authority were co-opted as partners in the shaping of the arena community.

4.2 Perceptions of time and of energy-efficiency as a knowledge domain

Table 1 presents a short-form of findings from the analysis (for a more comprehensive description see Gluch et al, 2012). It shows how the two groups, R1-8 and P1-10, perceived the topic "energy-efficient renovation of buildings".

Table 1: How energy-efficient renovation of buildings was framed by the interviewees.

	Researchers	**Practitioners**
Scope	Integrated on a societal level.	Limited to local interest within a specific type of business organisation or renovation project.
Time frame	Long term perspective (10-50 years)	Short term (now - 2 years forward)
Conceptual frames	Zero-energy, passive housing, sustainable solutions, socio-technical approach, societal values.	Reduce energy use per m^2, technical solutions, performance, return on investment.
Technical frame	A systems approach in which change toward energy-efficient renovation of buildings lies in the managing of system structures.	A practice-oriented approach in which energy-efficient renovation of buildings lies in fine-tuning existing systems and changing technical details.
Problem solving approach	To influence system structures through full-scale socio-technical experiments (pilot projects). Provide normative guidelines.	To influence practice by identifying technical solutions through one-off development projects (pilot projects). Use of tools.
Collaborative approach	Peer collaboration and practitioner participation.	Interaction with peers to identify best practices.
Collaborative space	Pilot projects	Pilot projects

The researchers spoke of energy efficiency in housing as a concern that implicated society as a whole, both current and future generations, and must therefore be dealt with in a *long-term* perspective. In their view, particular and immediate technical solutions would only marginally impact the societal imperative of developing sustainable energy consumption. Achieving energy-efficient renovation demands a socio-technical approach, involving the collaboration of actors at various levels and spheres of society and using a variety of integrated technologies and artefacts. They thus perceived change towards energy-efficient housing built into the handling of system structures, i.e. the way technical structures and/or society is able to support change toward using less energy, energy reuse and small-scale production of 'clean' energy such as solar panels and waste energy delivered to the grid. In order to be able to influence system structures and systems thinking, researchers preferred working in pilot projects (full-scale socio-technical experiments) in collaboration with other researchers and with industrial partners (practitioners). They also tended toward a normative and prescriptive research ideology to influence and underpin regulatory measures to support funding of large-scale development of energy technology. They saw themselves as the propagators of research-based knowledge beyond their own institutes to professional and practitioner communities. In this way they perceived that they contributed to societal and technological change.

The discourse of the researchers tended to be couched in abstract concepts and technical jargon, e.g. passive housing, and their discourse was oriented toward future possibilities rather than solving day-to-day problems. Time in the researcher mind-set took on an imprecise fluidity extending into an idealised and unspecified future of "zero-energy". Process time seemed more important, in which systems thinking is achieved through collaboration and a socio-technical approach, incrementally over a long time span. The arena project seemed to be viewed as one such increment.

The practitioners manifested a short-term perspective on energy-efficient renovation. Some argued that this was a reflection of the organisation's mind-set, in which the predominant concerns were for financial value, budgetary constraints, revenues and return-on-investments. This delimited time perspective not only framed energy efficiency as being energy use per square meter through fine-tuning the existing systems and changing technical details, i.e. a patchwork approach rather than a holistic one. This short-term perspective constrained their abilities to engage in conceptions of long-term investments and systems thinking in their day-to-day practices.

Key terms frequently used by the practitioners when explaining the notion of energy-efficient renovation were technical solution, reduced energy use and return on investment, which reflected a pragmatic mindset very much oriented toward the present and short, time-determined future. Similarly to the researchers, pilot projects were seen as important for the practitioners, especially if these were carried out in their own organisations. The pilot projects served as reference objects when communicating and explaining the concept of energy-efficient renovation. For the practitioners, knowledge was used as a commodity, consisting of formulated and accessible facts acquired through interaction with peers.

4.3 Joint activities – a matter of time and space

Joint activities formed the catalyst for knowledge exchange between researchers and practitioners. The joint activities in question consisted of the pilot projects initiated by the practitioners, open seminars and arena meetings.

A critical factor for a successful interchange was the possibility of meeting face-to-face and spending time discussing a single issue and its ramifications. Such time was rarely made available in the participant organisations. Many of the researchers and practitioners found the time they spent in the pilot projects self-developing. The former had been eager to collaborate both with each other and with practitioners in order to acquire knowledge of how real-life situations were handled. Practitioners deemed that the time spent collaborating with the researchers on the pilot project enabled them to test their ideas and obtain feedback and evaluation on technical solutions in situ. The pilot project thus provided both time and a space, βα, where individuals that had not been in contact before could interact. Through this interaction, researchers and practitioners gradually developed a vocabulary, which enabled them to make collective sense of energy-efficiency and renovation in their local contexts and to contribute with their individual experience and knowing. As a result of its situatedness, the pilot project did stimulate the creation of aggregated ideas for addressing the challenge of making buildings more energy efficient for the future.

The interviews as well as the observations of arena activities indicated that the researchers and practitioners, through their discussions and dialogue, gradually developed a shared understanding of the challenges that needed to be overcome to achieve energy-efficient renovation of housing. Moreover, the arena participants' awareness of the importance of allowing time for joint activities as a driver of knowledge sharing was enhanced, which can be corroborated by a stronger interest from municipal-housing companies in initiating pilot projects.

Ironically though, the practitioners' interest in the arena slowly increased while the researchers were dissatisfied in the practitioners' lack of active engagement in the activities and in their lack of initiative in availing themselves of the palette of expertise offered. The researchers had expected the practitioners to initiate more pilot projects than the two that were realised. For the practitioners, however, starting a pilot project was a cumbersome process; pros and cons, financing, resource allocation and most importantly the benefits for the company needed to be deliberated carefully, all of which are time-consuming activities with uncertain future outcomes. For a project with a three-year funding scheme, time is a scarce resource.

5. Concluding remarks

Consequences caused by tensions between the short termed mindset of practitioners focusing on day-to-day problems and the long-term technocratic researcher mindset oriented toward future possibilities was rather evident in the study. Different perceptions of time lead to miscommunication and sometimes to distrust as it emphasised the different views on energy efficiency of buildings. These differences in framing the challenge of reducing energy

use in buildings also created barriers between professional and organisational entities, barriers that needed to be bridged in order for knowledge sharing to take place in the arena.

Creating spaces for knowledge sharing takes time, as does building a knowledge-sharing arena. Some people drop out while others join, which means that the 'drivers' of an arena need to have sufficient space and fulfil necessary conditions if they are to stimulate an interactive innovation process. The three years allotted to the arena project proved too short to develop trust and develop a common language and understanding to achieve cross-organisational knowledge sharing. In spite of the advantageous pre-conditions in the form of funding, the perceived need and enthusiastic actors, the creation of an arena community in the form of the initial vision i.e. a driver of sustainability innovation just barely had time to overcome initial difficulties before the projected time span ended. The social interaction that took place within the arena community did not become durable enough to enhance long-term sharing of knowledge to any larger extent.

Creating social relations takes time, which is normally not available as actors enter and leave at different stages in a project. In fact, a perceived shortage of time can be used as an excuse for not seeking knowledge (Johansson, 2012). In the studied arena project, pilot projects were given extra resources such as financial means. Time was allotted to creating social bonds and for establishing a common vocabulary repertoires, tools and documents that would facilitate knowledge sharing; however, already at the outset of the development of the arena project, content focus and types of activities were biased toward the stronger group of researchers thus creating tensions that reified conventional boundaries rather than relaxing them. These boundaries were evident in the divergently perceived arena objectives and their framing of energy efficiency as a knowledge domain. For the researchers, the arena objectives were instrumental, prescriptive and normative; for the practitioners, they were emergent and principally problem-solving. The researchers had a long-term view on renovation of buildings while the practitioners were constrained by the short-term response to contingencies set by their organisations. With such incommensurable epistemological and ontological differences, having the time can easily turn into a serious constraint if experience and knowledge as to how to use it is lacking.

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Dealing with Construction Permits: Implications for the Colombian Case

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Abstract

Construction industry plays a leading role in the economies worldwide, and its performance is significantly related to the welfare of society. This relationship is direct in the developing countries. Thus, obtaining a construction permit is a critical process in Colombian building projects. This empirical study found that in 21 Colombian capital cities the number of phases, time and cost required to complete building permits have negative effects over the construction industry performance; whereas, per capita GDP and municipal transparency index have a positive influence. As a result, there is a need to reduce unnecessary phases and costs in Colombian building permits. Additionally, this study contributes to the understanding of building construction performance predictors and to address the design of more appropriate public policies.

Keywords: Building construction industry performance, construction permits, per capita GDP, Municipal transparency index, public policies.

1. Introduction

Construction industry is a business of large proportions (Currie, 1982; Powell, 1980) that produced $1.7 trillion worldwide. In most countries, this industry contributes at least with 7% of gross domestic product (Kenny, 2007), and it ranks third in gross capital formation (United-Nations, 2007). In this regard, Colombia is not an exception due its construction industry contributed 6.5% to GDP in 2011 first quarter (DANE, 2011).

Despite the economic importance of the construction sector, industry regulations are intricate in most countries, being even more complex in developing countries ; as a result, some builders choose to infringe established law, and frequently consider the possibility to pay bribes for obtain building permits. This situation leads to severe problems related to public control and quality of the projects. Notwithstanding, obtaining the approvals to build is, on average, faster and cheaper in Colombia than elsewhere in Latin America (DB, 2011), though variations exist across Colombia cities. Colombia has been pioneer in Latin America on construction regulations; for instance, it became from two decades ago the first

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country in the region to privatize its building permits. Before that reform, construction companies dealing with Public Planning Offices, and interacted informally with the authorities reviewing their cases (DB, 2010).

Internationally, building construction business is dominated by a diverse set of companies. The large construction projects often attract international contractors; nevertheless, most construction activities are contracted with local companies (Kenny, 2007). Colombia has had an institutional context and industry behavior that has prevented access of international competitors (with variations in its long history), specially within the housing sector. However, since two decades ago international companies are more often involved in infrastructure development projects, and local market is increasingly competitive.

Since there is a considerable amount of activities and actors related with the construction industry performance, it is valuable to study the factors that determine its performance. In reviewed literature on construction project management, there is a group of internal and external factors affecting project performance, and therefore, the industrial performance (Campero & Alarcón, 2003). Conventionally, those factors represent the processes within the project development. Empirical evidence shows that these processes that take place in the early project stages (i.e. conception and feasibility) playing a key role in the project value creation (Echeverry, 2007; Páez, Vargas, Prieto, & Mesa, 2010). According to a bunch of empirical evidence, a central process in this matter is to obtain the building permits (DB, 2011). Hence, without a proper management of licenses, projects cannot be legally performed (Kenny, 2007; Moullier, 2009).

Supported on the evidence above, this study proposes to address the analysis of the relationship between the variables that characterize the process of obtaining building permits and the overall formal construction industry performance. To meet this purpose, a regional analysis within Colombia was performed for the period 2010-2011.

This article is organized in four sections as follow: 1) theoretical background and hypotheses; 2) data sources and operationalization of variables; 3) statistical models results; and 4) discussion and conclusions.

2. Theoretical background and hypothesized model

Previous section shows how processes to obtain a building permit affect significantly project performance. Those processes are carried out by performing a series of steps which are regulated by the institutional regulations provided in each region (Moullier, 2009). The steps are procedures that all professionals involved (i.e. builders, contractors, engineers, architects, and design consultants) must follow to develop a new project, or to modify an existing one. Therefore, the essential legal document of these procedures is the building permit.

In Colombia building permits authorize the execution of construction projects. This license allows authorities to enforce compliance of adopted building codes as part of the legal body that regulates the construction industry, and ensures the public right over the private right

(Ceballos, 2008). This relationship between public and private actors works in a complex interdependence framework (Vargas, 2009). Hence, this complexity stimulates, in some situations, informality in obtaining a building permit. In most developing countries, the estimated proportion of informal housing construction is among 60% and 80% (Moullier, 2009). Further, in developing countries prevail an amount of non-standard processes that promote asymmetric information between public and private actors, thus having a negative effect over the licensing service quality. This situation arises, in part, due to the corruption high levels that are often found in the licensing process (Kenny, 2007).

After this developing countries context, it can be inferred that a significant portion of licensing process has a significant effect over the construction project performance. This means that building projects licensing could have a significant relationship with construction industry performance. Additionally, as institutional contexts within countries vary (Scott, 2011), the relation between licensing and performance must be different across regions. On the other hand, industry performance is not only determined by variables that characterize the process of obtaining a building permit. There are also demographic and economic variables (i.e. population, GDP per capita, poverty, international commerce) at the regional level related with the performance of the sector which were included in this study (Currie, 1983).

According to Doing Business 2011 (DB), a project developed by the World Bank and the International Finance Corporation, obtaining the approvals to build is, on average, faster and cheaper in Colombia than elsewhere in Latin America (DB, 2011), but variations exist across Colombia cities (see table 1); nevertheless, Colombia has been pioneer in Latin America on construction regulations. The ease of obtaining construction permits in Popayán is noticeable enough to rank it higher than 94% of the 183 economies ranked by DB. Regional differences are essentially due to special inspections, land-use certificates and local stamp duties that are required in particular cities. On average, Colombian builders spend 109 days (46 SD), 170% as a proportion of GPD per capital (79 SD), and 14 phases (2 SD) to obtain all the approvals for a construction project.

Table 1: City ranking of easier to deal with construction permits, population (65% of the Colombian capital cities), the number of phases, time and cost required to complete building permits (DB, 2010).

City	Easier to deal with construction permits ranking	Population	Number of procedures	Time to obtain a building permit (days)	Cost to obtain a building permit (%GDP per capita)
Popayán	1	265.702	11	38	85,5
Valledupar	2	403.414	13	89	79,7
Santa Marta	3	447.857	13	43	125,5
Tunja	3	171.082	13	86	104,9
Montería	5	409.476	13	75	116,2
Riohacha	6	213.046	14	48	106,1
Bogotá	7	7.363.782	11	74	402,8
Barranquilla	8	1.186.140	13	91	186,9
Sincelejo	8	256.241	14	85	141,5
Manizales	10	388.525	13	98	209,6
Neiva	10	330.487	14	127	112,8
Pasto	10	411.706	13	140	147,2
Armenia	13	288.908	14	123	122,0
Pereira	14	457.103	14	121	171,6
Medellín	15	2.343.049	13	181	231,3
Cartagena	16	944.250	14	107	293,7
Ibagué	16	526.547	14	217	144,8
Cúcuta	18	618.310	16	96	208,1
Bucaramanga	19	524.112	18	160	126,8
Cali	20	2.244.639	19	146	175,1
Villavicencio	21	431.476	16	151	269,0
Mean		**963.136**	**14**	**109**	**170**
Standard deviation (SD)		**1.583.608**	**2**	**46**	**79**

Based on DB (2010 and 2011) indexes, we propose that the ease of obtaining a building permit is related to the construction industry performance in a positive way at the regional level. Being the ease of the process inversely proportional to the number of procedures, time and cost of the building permit, the relationships of these variables and the industry performance are proposed as negative in next hypothesis.

H1a: The cost to obtain a building permit is negatively related to the construction industry performance.

H1b: The amount of phases to obtain a building permit is negatively related to the construction industry performance.

H1c: The time to obtain a building permit is negatively related to the construction industry performance.

Private professionals known as "*urban curators*" became responsible delegates for the complete and timely review of building permit applications in Colombia. By 1996, the system of private urban curators was up and running and today, with the exception of Riohacha, in

all analyzed cities by DB (2010 and 2011). Due this important change in Colombia regulations, it is interesting to study whether higher number of curators in a city is related to better construction industry performance.

H2: The greater the amount of curators in a city, the greater the construction industry performance.

An efficient regulatory framework is the result of a positive both social and economic history of the region (DB, 2010). As it was explained in the first section, construction industry performance is directly related to the economic welfare of a society. Therefore, it is likely that GDP per capita and the proportion of population with unsatisfied basic needs (NUB) are related, positive and negative respectively, with the construction industry performance (United-Nations, 2007). Thus the following hypotheses are proposed.

H3a: Per capita GDP is positively related to the construction industry performance.

H3b: The proportion of population with NUB is negatively related to the construction industry performance.

One of the economic dynamic indicators of a region are the export and import activities (DB, 2010). These exert a significant influence on the construction industry performance, and stimulate the development of commercial, infrastructure and industrial projects. Therefore, these indicators are positively related to the performance of the industry and could be part of the variables that have a significant effect on building performance.

H4a: The city export level is positively related to the construction industry performance.

H4b: The city import level is positively related to the construction industry performance.

High levels of corruption (Tookey & Chalmers, 2009) and poor transparency processes in obtaining a building permit affect significantly the construction industry performance (Kenny, 2007). In view of this background, it is interesting to study the relationship between perceived transparency of public affairs and construction performance as follow.

H5: The transparency city index is positively related to the construction industry performance.

Statistical methods presented in next section were used to support the hypothesis listed above.

3. Methodology

3.1 Data

This study analyzes the regional level variables of 21 Colombian cities - departmental capitals – representing 65% of the capital cities in the country. Information about these cities

was obtained from four sources: 1) results of the DB 2010 report (number of phases, time and cost to obtain a building permit); 2) demographic and economic information (city population, GPD per capita, construction industry performance, international commerce) published on the official website of the *Departamento Administrativo Nacional de Estadística* (DANE); 3) available information of the official website of the *Colegio de Curadores* (Chamber of Curadurías in a city); and 4) Transparency International data base indexes. In summary, we developed a database that contains information about 11 variables extended between the years 2010 and 2011, and at the regional level.

3.2 Measures

Dependent variable: Construction industry performance is the depend variable of this study, and has a normal distribution. Performance index was considered as the total built area in 2011 first quarter. In order to have an unbiased measure due the population size, constructed area was weighted based on the city population. Due the lack of data to measure the informal construction building sector performance, only the formal sector was included in the statistical analysis.

Independent variables: Hypotheses proposed in this study required the operationalization of nine variables, as follow:

- **Number of procedures:** A procedure is any interaction between an construction company employee with an external entity, including government agencies, notaries, property records, land registry, public service entities, public or private inspectors and technical experts (DB, 2010).

- **Time to obtain a building permit:** Time was measure in calendar days. This captures the necessary average time to complete a procedure. This variable was obtained through interviews with local experts. It is assumed that the minimum time required for each procedure is one day. Also, it is assumed that the construction company does not waste time and performed the procedures without delay.

- **Cost to obtain a building permit:** Due the DB (2010) report international comparability mission, cost is measured as a percentage of GDP per capita. Only official costs were measured. All taxes required for legal building were measured.

- **Amount of curators in the city**. It measures the number of curators´ offices available to each city.

- **Municipal transparency index:** This index consists in three measurement factors: visibility, institutional quality, and municipal control and punishment.

- **Per capita GDP:** This index measures the mean income within an economic aggregate, such as a city.

- **NUB population proportion:** This indicator determines whether the basic needs of the population are covered. Groups of people that do not reach the minimum threshold set are classified as poor.

- **Traditional exports and imports by cities:** Traditional exports and imports by cities measured in thousands of dollars FOB.

3.3 Statistical model

This empirical study was conducted in six stages: 1) the variables selection that explain the industry behaviour for the period 2010-2011; 2) the data collection of the variables at the regional level; 3) the statistical methods development to support the relationships between the variables; and 4) the results discussion and conclusions analysis. Due the variables features, a set of multivariate linear regression models at the regional level (city) were used as follow. Three regression models were developed to incorporate progressively all the variables by typological groups (Hair, Anderson, Tatham, & Black, 1999) as it shows in table 2. Model 1 included the variables that represent the ease of obtaining a building permit from the variables: numbers of procedures, and time and cost to obtain a building permit. Additionally, due the remarkable relationship of the political transparency and economic prosperity on the ease of obtain a building permit (DB, 2011), but without a significant statistical correlation, model 1 took into account the municipal transparency index and the per capita GDP variables. Model 2 included, in addition to the former variables, the proportion of population with unsatisfied basic needs variable in order to support H3b. Finally, Model 3 discarded NUB variable but incorporated traditional exports and imports by cities indexes. Thereby, this final model contains all variables that could have a combined effect on building performance. The general statistical model is shown as follow.

$$CIP = \beta_0 + \beta_1 NP + \beta_2 TOBP + \beta_3 COBP + \beta_4 ACC + \beta_5 MTI + \beta_6 GDPp + \beta_7 NUBp + \beta_8 TEIC + \varepsilon$$

Where CIP is the construction industry performance; NP is the number of procedures; TOBP is the time to obtain a building permit; COBP is the cost to obtain a building permit; ACC is the amount of curator´s offices in a city; MTI is the municipal index transparency; GDPp is the gross domestic product per capita; NUBp is the NUB per capita; TEC and TIC are the traditional exports and imports in a city, respectively.

4. Results

Figure 1 shows the behavior of the key dependent and independent variables of this study. Relevant results from these figures are the following. First, CIP reflects an uneven performance between cities. It is noted that the most populated cities of the country (Bogota, Medellin, and Cali) do not present high levels of construction performance. In contrast, medium cities (i.e. Bucaramanga, Pereira, and Neiva) have the highest levels of this CIP. According to NP variable, cities have a homogeneous behavior. Though, at the national level there is a standard regulatory framework, comparative time and cost invested in these processes show a significantly different situation; so, these variables have considerable

variations between cities. Regarding municipal transparency index, all cities have a homogenous behavior, except for Villavicencio and Riohacha.

Three multivariate linear regression models are presented in table 2. Each one was validated satisfactorily according to the multivariate linear regression assumptions, that is, the weak exogeneity, linearity, constant variance, independence of errors, and lack of multicollinearity in the predictors of the statistical models. First model (R2 was equal to 0.651) includes the variables for ease of obtaining a building permit when testing the relationship between NP, TOBP and COBP with CIP; additionally, takes into account the MTI and GDPp. In addition to the factors included in first model, the second (R2 was equal to 0.624) involved NBUp variable. The latter does not yield a significant relationship with CIP. In the third model (R2 was equal to 0.626), NBUp variable was discarded and TEC and TIC were incorporated.

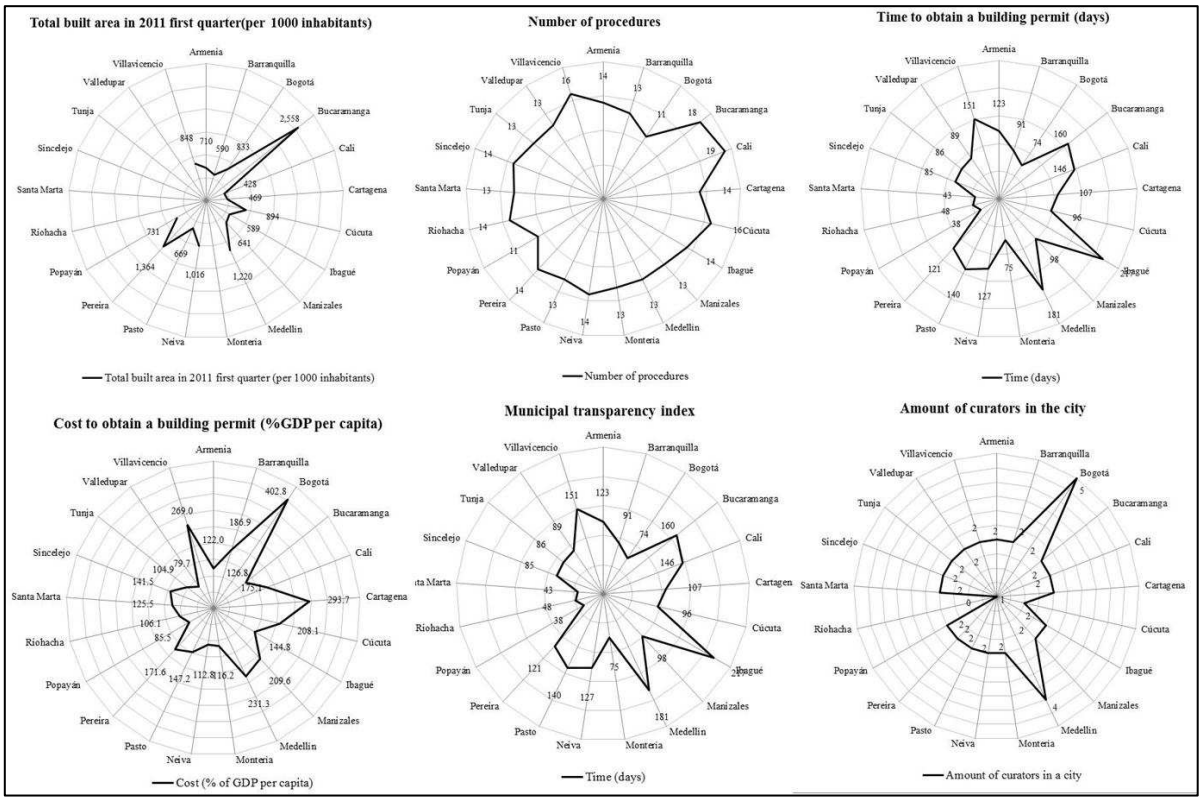

Figure 1: Variable descriptions

Concerning to the hypotheses support, the three multivariate linear regression models have the following results (see table 2). H1a, that proposed a negative relationship between COBP and CIP, was supported by models 1 and 2. H1b, that suggested a negative relationship between NP and CIP, was supported by all models. H1c, that proposed a negative relationship between TOBP and CIP, was not supported by any of the models. As expected, these results indicate that the ease of obtaining a building permits have a positive relationship with CIP.

H2, that suggested a positive relationship between ACC and CIP, was not supported by any of the models. Contrarily, it shows a significantly and negative relationship between those variables. Due the possibility that a greater number of curatorial offices affect negatively the CIP, it is interesting to study the results to revise the regulatory system policies.

H3a proposing a positive effect of GDPp over the CIP, was supported by all models; whereas, H3b suggesting a negative relationship among NBUp and CIP was supported by models 1 and 3. This means that social and economic conditions of a city have a considerable effect on its construction activity.

H4a and H4b proposing a positive effect of TEC and TIC on CIP were not supported by model 3; therefore, it is possible that the effects of such international commercial activities on the CIP are perceived only in the long term. Hence, longitudinal studies must be developed to supports these hypothesis.

H5 suggesting a positive relationship between MTI and CIP was supported by all models. This result shows how a fewer perceived corruption affect in a positive way the conditions to develop construction projects in a city.

Table 2: Multivariate regression models results.

Variable	Model 1	Model 2	Model 3
COBP	-3,401E+00 *	-3,395E+00 [a]	-2,757E+00
	(1,581E+00)	(1,650E+00)	(1,909E+00)
MTI	7,287E+01 ***	7,263E+01 **	7,390E+01 ***
	(1,587E+01)	(1,805E+01)	(1,645E+01)
ACC	-7,126E+02 **	-7,118E+02 **	-6,450E+02 *
	(2,119E+02)	(2,215E+02)	(2,654E+02)
NP	-2,006E+02 *	-2,000E+02 *	-2,035E+02 *
	(8,238E+01)	(8,770+E01)	(9,117E+01)
GDPp	2,400E-04 ***	2,394E-04 **	2,508E-04 ***
	(5,189E-05)	(5,715E-05)	(5,618E-05)
TOBP	2,208E+00	2,181E+00	7,177E-01
	(2,162E+00)	(2,391E+00)	(2,694E+00)
NUBp		-3,169E-01	
		(9,740E+00)	
TEC			5,961E-05
			(1,342E-04)
TIC			-6,337E-05
			(6,204E-05)
R^2 *adjusted*	0,651	0,6240	0,626
N	21	21	21

[a] p < 0,1; * p < 0,05; ** p < 0,01; *** p < 0,001; standard error in brackets.

5. Discussion and conclusions

The empirical evidence provided in this study reinforces partially the conclusions of DB (2010 and 2011). Furthermore, the present article highlights the necessity to review some factors in the processes of construction industry policy design. The conclusions of this cross-sectional study must be confirmed later with longitudinal analysis. Nevertheless, since the variables included reflected the city behavior in the long run, it is not expected to have different results with longitudinal analysis. Thus the principal findings of the study are the following.

First, our results support the background hypothesis that processes located in early project stages have a significantly impact over the project performance. Hence, variables measured by DB (2010) have a significantly relationship with CIP. Nonetheless, to conclude causal relationship among these variables will require a longitudinal analysis. For instances, best positioned cities in the ranking of "ease of obtaining a license", though not in all cases, demonstrate a tendency to show a higher construction activity. Due to variables not included in DB reports, (i.e. Popayán, Valledupar and Santa Martha) a well ranked city did not present high construction levels.

Second, a lower level of perceived institutional corruption contributes significantly to the development a high CIP index. This result corroborates the theoretical framework of Kenny (2007), presented in the first section. Additionally, it highlights the need of a continuous improvement of construction sector regulatory policies.

Third, the welfare of a society plays an essential role in explaining CIP. This result indicates that, beyond good performances of the processes for obtaining building permits, economic welfare of a city generally determines its CIP.

Finally, the exemplary position achieved by Colombia, as a result of efforts to improve the efficiency of the process of obtaining building permits, should be reviewed in the future through a deeper analysis of its institutional context.

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“If you cannot measure it, you cannot improve it”: Measuring health and safety performance in the construction industry

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Abstract

The Australian construction industry has traditionally relied on ‘lagging’ indicators of health and safety performance. Lagging indicators, including lost time injury rates, are limited in usefulness because they rely on after the fact recording of statistically low probability events. They are subject to random variation, which can provoke ‘knee jerk’ reactions immediately following a reportable incident and encourage management complacency when no reportable incidents have occurred for a period of time. An update is provided on the development of a multi-level measurement method, which combines ‘leading’ safety performance indicators and safety climate measures. It is argued that leading performance indicators and climate measures can (in combination with lagging indicators) provide a more comprehensive analysis of health and safety performance in the construction industry. The opportunities for internal (between project) and external (between organization) benchmarking of health and safety performance are discussed.

Keywords: Health and safety performance, measurement, leading indicators, lagging indicators, benchmarking

1.0 Introduction

Sir William Thomson (better known as Lord Kelvin) famously commented on the importance of measurement, stating that “If you cannot measure it, you cannot improve it.” Occupational health and safety (OHS) performance measurement is an important part of the management of OHS. Reiman and Pietikäinen (2012) comment that the management of safety relies on the “systematic anticipation, monitoring and development of organizational performance” (p.1993). OHS performance measurement provides valuable information about how an organization is performing in an increasingly important aspect of business operations. The measurement of OHS performance enables the detection and resolution of problems and provides information needed to evaluate the effectiveness of organizational OHS initiatives.

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Most organizations engage in extensive strategic and operational planning processes, which include the establishment of corporate OHS objectives. Robust OHS performance measurement is critical to understanding whether objectives are being met, and if they are not, to understanding and responding to organizational vulnerabilities in relation to OHS.

This paper reports on an Australian initiative to develop a comprehensive set of OHS performance indicators (the RMIT OHS index). Harms-Ringdal (2009) defines indicators as "observable measures that provide insights into a concept – safety – that is difficult to measure directly" (p.482). OHS is notoriously difficult to directly measure because it is not an outcome in itself. Weike (1987) described safety as a "dynamic non-event" and noted that non-events cannot be counted. However, attempts to characterise safety for measurement purposes have focused on system dynamics and explored how the non-event is created (see, for example, Reiman and Pietikäinen, 2012). Thus, safety has been conceptualised as an emergent quality of a socio-technical system that produces a desired outcome – the absence of harm (see, also Lofquist, 2010).

There is also a general agreement that reliance on a single indicator of OHS performance is not sensible and that different indicators reflect different dimensions of OHS performance, for example, the nature and characteristics of hazards, technical safety features of a work system, safety organization or management systems, aspects of safety leadership or culture and economic outcomes (Harms-Ringdahl, 2009).

The RMIT OHS index comprises a suite of diverse indicators that provide insight into an organization's overall OHS performance. None of these indicators, alone, provides a comprehensive picture of the state of OHS within an organization but, taken together, the indicators enable a meaningful assessment of how well, or otherwise, an organization is performing with regard to OHS. Key features of the RMIT OHS index are the multi-level and longitudinal approach used to collect, analyse and report data. The multi-level approach provides an understanding of differences in OHS performance of sub-units (i.e, projects, contractors or workgroups) within the same organization. The longitudinal measurement provides information that can be used to actively monitor OHS and detect important changes over time.

Several large construction client organizations will soon commence using this system to measure OHS performance of projects within their capital works/construction portfolios. These include an international manufacturing organization, a metropolitan rail organization, a state government department and a publicly owned port authority. This paper describes the components of the RMIT OHS index and explores opportunities for users to benchmark themselves against organizations operating in their own and other sectors of the construction industry, and against other organizations of a comparable size.

2.0 Different types of safety indicator

The safety literature generally differentiates between "leading" and "lagging" safety indicators, with increasing preference being placed on the use of the former. Mearns (2009) defines leading indicators as things "that provide information that helps the user respond to

changing circumstances and take actions to achieve desired outcomes or avoid unwanted outcomes" (p.491). Lagging indicators are the outcomes that result from actions. Similarly, Hale (2009, p.479) describes an indicator as leading or lagging in terms of whether it "leads or lags the occurrence of harm or, at least, the loss control in the scenario leading to harm." Traditional "lagging" measures of OHS performance (such as accident frequency rates) focus on outcomes and are therefore reactive in nature. Outcome measures, by definition, do not tell us about current situations that can impact on future OHS performance.

2.1 The use of "lagging" indicators

"Lagging" indicators, including Lost Time Injury Frequency Rates (LTIFRs), can relatively easily be compared between companies and industries because they are calculated according to standard formulae. For example, *AS 1885.1-1990: Workplace injury and disease recording standard* specifies ways in which OHS statistics should be calculated. The LTIFR is the number of injuries x 1,000,000 divided by the total man hours worked. Lagging indicators have become standard measures of OHS performance in the Australian construction industry. They are useful because they are:

- relatively easy to collect;
- easily understood;
- easy to use in benchmarking or comparative analyses; and
- useful in the identification of trends (NOSHC, 1999).

However, lagging indicators of OHS are limited because they measure the absence, rather than the presence of safety (Arezes & Miguel 2003; Lofquist 2010) and are thus not a direct measure of the level of safety in an organization. Cadieux et al. (2006) comment that, even when there have been no accidents in a workplace, this does not necessarily mean that the workplace is any safer than another workplace at which an accident has occurred in the same period. In fact, when organizations are successful in reducing OHS risk, lagging indicators become even less useful because of random variation. Stricoff (2003) comments that even a stable safety system will produce a variable number of injury events.

Lagging OHS measures record failures 'after the fact.' They do not permit the timely implementation of preventive or corrective OHS measures. Reportable injuries and illnesses have a statistically low probability of occurrence and so measurement based on these events may not be sensitive enough to identify changes to OHS performance. Lofquist (2010) describes how a reliance on lagging performance measures (accidents) led to a failure to recognise the marked deterioration in the quality of safety that occurred during a period of deliberate organizational change in the Norwegian civil aviation industry. Industry participants (pilots and air traffic controllers) had observed a gradual decline in safety standards but no accidents had occurred, leaving decision-makers entirely unaware of the

negative impact of the organizational change programme. Lofquist (2010) argues that the time lag between changed safety performance and the occurrence of an accident can mask an organization's 'drift' to danger and provide an overly optimistic sense of system safety.

Managers' responses to fluctuations in accident rates can also create an 'accident cycle.' When accident rates increase, management expend considerable effort to reduce this rate. However, once the rate has fallen back to its original level, attention to OHS declines and the accident rate rises once again. This cycle of 'knee jerk' reactions to fluctuations in accident rates is counter-productive to continuous improvement in OHS (Stricoff, 2003). Further, a low accident rate does not guarantee that OHS risks are being controlled or that work-related injuries or diseases will not occur in the future because, although the accident rates may be a valid (or true) indicator of past OHS performance, their reliability as a predictor of future events is dubious (Mengolinim and Debarberis, 2008). This is especially true when the probability of accidents is low but major hazards are present in the work environment (HSE, 2001).

Injury frequency rates have sometimes been related to reward systems, managers' performance appraisals, bonus payments or future tendering opportunities. When used in this way, under-reporting is encouraged (Cadieux et al. 2006; Sparer and Dennerlein, 2013). In fact, the greater the emphasis that is placed upon outcome or lagging OHS indicators, the less valid (and useful) these measures may be, because people learn how to manipulate the figures. Under-reporting of injuries is a recognised problem. Indeed, Daniels and Marlow (2005) suggest that the level of reporting of non-fatal construction injuries in the UK construction industry is as low as 46%. Another practice widely believed to impact upon accident rates involves managing workers' injuries to reduce the financial impact on the organization. For example, injured workers are sometimes returned to work on 'light' duties to avoid reporting a lost time injury.

A further problem with most commonly used lagging OHS measures is that they do not accurately measure occupational illnesses with a long latency period, such as occupational cancers or chronic problems like musculoskeletal disorders. Neither do lagging measures assist in identifying the causes of incidents, reducing their usefulness in the diagnosis of OHS problems.

2.2 The use of "leading" safety performance measures

As a result of these limitations, there has been a move away from the exclusive use of retrospective data for the measurement of OHS performance. The use of leading safety performance indicators has become increasingly popular (WorkSafe Australia 1994; NSW WorkCover Authority 2001; DEWR/ASCC, 2005), receiving recent attention in construction safety research (see, for example, Lingard et al. 2011; Hinze et al. 2013). Leading indicators of safety can be defined as indicators that change before the actual level of risk to which people are exposed changes (Kjellén, 2009). There are a number of important advantages in the use of leading OHS indicators. First, leading indicators provide a more direct measure of how well an organization is managing health and safety risk than the occurrence of accidents, which include an element of chance. Leading indicators also provide an

immediate feedback mechanism, enabling organizations to improve OHS management processes, before deficiencies have resulted in incidents, injuries or illnesses (Hinze et al., 2013).

Leading indicators take many forms. In the development and use of leading indicators, what is measured, and how it is measured depend on the developers' theoretical perspective and beliefs about what explains safety (Mohaghegh and Mosleh, 2009; Reiman and Pietikäinen 2012). Assumptions and beliefs about the cause-consequence relationship between work system elements and safety are also important because leading indicators are theoretically positioned as antecedents to organizational safety, rather than consequences of organizational safety (Harms-Ringdahl, 2009).

Much of the safety management literature emphasises organizational safety structures and management systems, recommending third party audits to measure compliance (see, for example, Teo & Ling, 2006). Third party SMS audits are limited because they are costly and infrequent. Further, Zohar (2000) describes the 'implementation gap' that exists between organizational safety policies and procedures (the focus of SMS audits) and "lived" safety practices within organizations. There can be a marked difference between what organizations say they do and what they actually do, which compliance-based audits do not measure. Other disciplines place emphasis on the direct causes of accidents, such as hardware failures or operational errors, and develop metrics to measure these occurrences (Mohaghegh and Mosleh, 2009). Much of the literature has focused on worker behaviour as a causal factor in work accidents, resulting in the development of leading indicators to measure worker behaviour. For example, Sparer and Dennerlein (2013) describe the use of leading indicators of safety in an employee incentive program. The leading indicator measurement method they utilised was based on monthly inspections of a worksite and the expression of the number of physical work practices being undertaken safely as a proportion of the total number of practices observed. This method of direct observation and proportional rating was also used by Duff et al. (1994) and Lingard and Rowlinson (1997) in their analyses of the impact of behaviour-based safety programmes in the construction industry. It is noteworthy that although workers' behaviour is often involved in work accidents, it is rarely the only cause. Indeed, unsafe behaviour can often be traced back to systemic issues, such as excessive workload, fatigue, poor work design, inadequate training etc. Thus, focusing on workers' behaviour in the measurement of safety performance is inherently limited and arguably directs attention away from other important features of a work system.

2.3 Safety climate measurement

The measurement of safety climate is increasingly popular in safety research and practice. Evidence is emerging to indicate that safety climate is a valid leading indicator of OHS. That is, safety climate measured at one point in time statistically predicts the occurrence of accidents or injuries in a subsequent time period (see, for example, Zohar 2000; Wallace et al. 2006).

Safety climate represents the "surface features of the safety culture discerned from the workforce's attitudes and perceptions at a given point in time" (Flin et al 2000, p178). Many

tools have been developed to measure safety climate. However, the measurement of safety climate has been characterised by a lack of consistency in the number of climate components and a failure to replicate climate models across organizations and industries. Notwithstanding this, Flin et al. (2000) note that some common components of safety climate can be observed. These include: (i) management commitment to OHS; (ii) supervisory OHS behaviour; (iii) the relative priority of OHS over production and time pressure; and (iv) the quality of safety-related communication within the organization.

2.4 Multi-level measurement

Mearns (2009) argues that a single level perspective does not adequately reflect OHS performance because organizations are multi-level systems, i.e., micro phenomena are embedded within macro contexts. Within a single organization, research reveals significant variation in safety climate (Zohar, 2000) and the quality of OHS implementation between organizational sub-units (Sparer and Dennerlein, 2013). Thus, it is common for OHS performance to be 'patchy' within large organizations, with some sub-units performing consistently better than others, even when they are exposed to the same OHS risks. For example, significant between-group differences have been found in the OHS performance of subcontracted workgroups in the construction industry (Lingard et al. 2010). Thus, measuring OHS performance at a single macro level (i.e, the organization) can mask subtle but important differences between workgroup OHS practices and performance. It is therefore imperative to measure OHS at different levels within organizations (Zohar, 2008).

Construction projects are subsystems of an organization's larger portfolio of work (Blismas et al. 2004a; Blismas et al. 2004b). Each project is delivered through a temporary organizational structure in which professional services are 'bought in' under a variety of contractual arrangements and construction work is outsourced to a general contractor and a multiplicity of trade contractors. Uniformity of OHS practices cannot be assumed within a single construction organization as work is highly decentralised and local managers (project managers and workgroup supervisors) necessarily exercise discretion in deciding how to implement organizational policies and procedures (see also Aritua et al., 2009). Consequently, to understand OHS in the 'projectised' construction industry OHS performance needs to be measured at the level of the organization, the project and individual work group levels.

3.0 The RMIT OHS index

Given the strengths and limitations of different measurement methods, the use of a hierarchical set of linked measures has been recommended (Arezes & Miguel, 2003; Tinmannsvik & Hovden 2003). The RMIT OHS index adopts this approach. Building on work undertaken at a large civil engineering construction project (reported in detail in Lingard et al. 2011), the RMIT OHS index adopts a hierarchical structure, depicted in Figure 1. The index framework comprises three categories of measurement, including lagging indicators (category one), leading indicators (category two) and safety climate measures (category three).

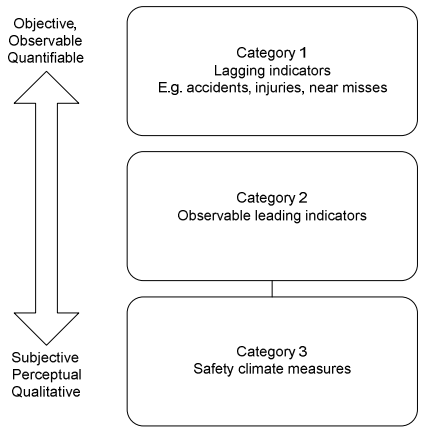

Figure 1: Components of the RMIT OHS index

Lagging indicators included in the index include lost time injuries, medical treatment injuries, minor (first aid) injuries and near misses. Observable leading indicators included in the index are founded upon the model of construction accident causation developed by Gibb et al. (2006). This model was empirically derived from an analysis of 100 construction accidents. The model identifies immediate circumstances involved in construction accidents as well as shaping factors and originating influences that contributed to the accident. Thus, it identifies proximal, as well as systemic causes of accidents. This model has been used in subsequent analyses of construction accidents in Australia and the USA and found to be useful in explaining the causes of fatal accidents (Cooke et al. 2011) and non-fatal accidents (Behm and Schneller, 2012). Leading indicators have been specified for each causal factor identified in the model. For example, leading indicators for "risk management" include "*RM1 A systematic assessment of health and safety risk is undertaken for all work tasks/activities*" and "*RM2 High level risk controls (eliminate/substitute/engineer) are implemented in preference to lower level risk controls (administration/PPE).*" Example leading indicators for "worker health/fatigue" are "*H1 Work hours are monitored to avoid overwork*" and "*H2 Recovery opportunities are built into work schedules*"

The safety climate measurement instrument adopts a multi-level approach in measuring: (i) perceptions of the extent to which safety is prioritised over other objectives, e.g. production efficiency, within the organization (at both client and contractor levels); (ii) perceptions of managers' commitment to safety (at both client and contractor levels); (iii) perceptions of first level supervisors' safety behaviour; and (iv) perceptions of the quality of safety communication within construction projects. These dimensions of safety climate reflect the 'core' dimensions identified by Flin et al. (2000). They have previously been measured effectively in a number of construction client and contracting organizations by Lingard et al. (2012; 2010b). In addition to these dimensions, an additional facet of group-level safety climate has been incorporated into the index relating to coworkers' safety responses. Coworkers exert a cultural/normative influence on safety in workgroups that has been overlooked by a great deal of safety climate research (Lingard et al. 2011; Brondino et al. 2012)

3.1 Benchmarking opportunities

Wreathall (2009) comments that the data produced by safety performance indicators does not, in itself, improve safety. How data is used as important as its quality. The RMIT OHS index can be used in performance benchmarking. Janicak (2010) defines benchmarking as "an ongoing process of measuring one company's safety performance against that of competitors or organizations that are recognized as industry leaders" (p.15). The combination of lagging, leading and climate measures incorporated into the RMIT OHS index provides considerable depth and responds to calls to benchmark more than OHS outcomes. Reiman and Pietikäinen (2012) argue that it is insufficient to benchmark outcome measures only because they do not provide insight into the mechanisms behind the outcomes. It is also important to understand and compare organizational objectives and the way in which these objectives were pursued. Drawing comparisons of "why" and "how" an organization approached safety in a particular way will reveal what should be done to avoid or achieve similar outcomes (Reiman and Pietikäinen, 2012).

Figure 2 illustrates the potential to use the RMIT OHS index to benchmark performance within workgroups or projects within a single organization (as shown in organization 1), between organizations of a comparable size operating in different sectors within the construction industry (as shown between organizations 1, 4 and 6 and between organizations 2 and 5) or between organizations of different sizes within the same sector (as shown between organizations 1, 2 and 3 and between organizations 4 and 5).

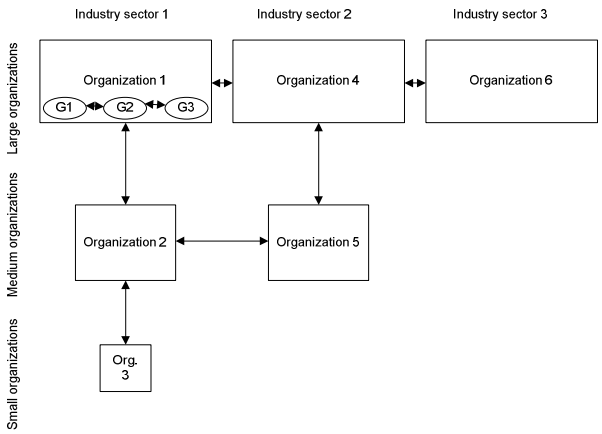

Figure 2: Internal and external benchmarking opportunities associated with the RMIT safety index

3.2 The relationship between leading and lagging safety indicators

Through combining the use of leading and lagging indicators of OHS performance with multi-level measures of workers' OHS perceptions in the climate survey, it is likely that the RMIT measurement model presented in Figure 1, will provide a more comprehensive measure of OHS performance than single indicator measures, such as the traditional LTIFRs.

The RMIT OHS index will be used to measure performance over time. Thus, the measurement of lagging and leading indicators (including safety climate) will occur regularly over the life of construction projects within participating organizations. This provides the opportunity to detect changes in performance over time. This point is important because construction projects are dynamic and OHS commitment and performance have been demonstrated to change over a project's life cycle (Humphrey et al. 2004).

The longitudinal measurement of lagging and leading indicators of safety will also provide a more robust understanding of the relationship between leading and lagging indicators. The relationship between leading safety indicators and lagging (outcome) measures of OHS is often not known. Thus, it is unclear to what extent leading indicators predict future outcomes, such as accidents or injuries. Consequently, the validity of leading safety indicators has sometimes been questioned. For this reason, leading indicators have been recommended for use in addition to (rather than in the place of) traditional outcome measures of OHS performance (DEWR/ASCC, 2005).

The longitudinal measurement will provide an understanding of the predictive capability of specific leading indicators and safety climate measures in construction projects. No research to date has comprehensively demonstrated a link between leading and lagging measures of safety in the construction context.

Øien et al. (2011) argue that safety performance indicators must be carefully evaluated and the validity of measures may change over time. Therefore, in the coming months, the RMIT OHS index will be robustly tested and issues of reliability and validity will be examined. If the early results obtained using the index reveal an inconsistency between leading and lagging performance measures then this would suggest that the underlying model of OHS on which the index is founded could be flawed. If however, leading indicators indicate a high level of safety but lagging indicators reveal the occurrence of accidents, then it is possible that the leading indicators incorporated into the index do not adequately represent the requisite conditions for producing safety in construction projects. Alternatively, a decrease in lagging indicators with no prior change in one or more of the leading indicators would imply that the assumed causal relationship between leading and lagging indicators was problematic.

Ultimately the validity of Category 2 (leading indicators) and Category 3 (climate perceptions) variables included in the RMIT OHS index must be ascertained by the extent to which these measures are significantly correlated with objective outcome indicators of OHS performance, such as injury/incident rates.

4.0 Conclusions

The RMIT OHS index was developed on the basis of work carried out by two of the authors at a large civil engineering construction project in Melbourne. At this project, the index was well received and the general manager of the contracting organization has commented "…*the tool has been fundamental in helping promote positive safety behaviours and accountabilities within our business…the Safety Index has continued to provide an excellent barometer, combining critical lag and lead behavioural elements. It has been central in*

providing genuine impetus for improvement." The RMIT OHS index has been further developed and several large client organizations are commencing use of the index and, in the coming months, its reliability and validity will be comprehensively evaluated. After this evaluation and any further development required, it is hoped that the index will become a valuable benchmarking tool for construction OHS.

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Tree Preservation Orders: A New Vision?

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Enhancing Amenity and Conserving Biodiversity via a Revision of Tree Preservation Orders in Urban NSW, Australia

The purpose of this paper is to explore the history of tree preservations orders (TPOs) in New South Wales (NSW), Australia, commencing with early British legislation leading to a standard set of clauses set down by the NSW State Government. Until recently, TPOs provided a perfect example of slavishly following the British approach. The relevant sphere here is local government. The paper examines the original emphasis on the notion of amenity, which still prevails. It then moves on to opportunities for local government to embrace biodiversity conservation. It will be argued that the current statutory instrument that lays down the TPO provisions that councils must adhere to, demands revision. If the TPO is to serve as a worthwhile tool amongst a suite of conservation mechanisms, significant change to statutory instruments and policy is required.

Keywords: Local government, native vegetation, tree preservation orders, amenity, biodiversity conservation.

1. Introduction

There are various related ways in which private urban open space, namely front and back yards, can conserve local vegetation in residential areas. For instance, the approval of a new building might demand the retention of certain trees on the site. Another example is the replacement of trees that are cut down on the same site or elsewhere. A third approach is utilising the regulatory 'tree preservation order' (TPO) mechanism. This paper focuses on the third notion in New South Wales (NSW), Australia, exploring its historic emergence and current approaches. A major theme will be its evolution from an archaic device to enhance amenity to one that might embrace biodiversity conservation.

TPOs are a hybrid statutory mechanism implemented by local councils under the current *Environmental Planning Assessment Act 1979* (NSW). Their legal history, however, relates to early English legislation. This is no surprise as our planning law structures derive directly from Britain. Original ideas were mostly introduced by British expatriates, such as architect John Sulman who wrote the first book on town planning in Australia, and Denis Winston who held the first Chair in Town and Country Planning at Sydney University (Wright, 2001; Freestone, 1988). Winston was also the first president of the Australian Planning Institute set up in 1951 (Wright, 2001; Freestone, 1988). This first part of this narrative relates

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significantly to statutory history. As Wilson and Game (1998) claim in relation to planning law, 'it is just not possible properly to understand the present without at least some appreciation of how … it developed out of and differs from the past' (p41). But the paper will then move on to the current nature of TPOs in NSW with attention paid to the differences between the initial motives and recent trends.

The context of the paper relates to cities, suburbs and rural townships. It does not extend to the countryside. As a result, the focus is on one small albeit significant aspect of planning law in NSW. It does not extend to either the *Native Vegetation Act 2003* (NSW), which does not apply to cities or towns, or any legislation applying to public land. Nor is there any reference to Commonwealth law whose scope is limited by the Australian Constitution.

2. Historic Background

When it comes to Australian planning legislation, all jurisdictions still reflect the *pre*-1947 British zone-based statutes and plans. Fogg (1985) pinpoints planning schemes made under the UK's *Town Planning Act 1925* and *Town and Country Planning Act 1932* as the 'progeny' to Australian zoning plans (p260). Auster (1985) tracks the beginnings of statutory zoning plans to the pioneering Acts of 1909 and 1919 that comprise 'part of Australian planning history' (p6). The key inspiration, however, was the more ambitious 1932 Act which provided the planning model for Australian State Parliaments to duplicate (Colman, 1971; Whitmore, 1981). Yet several related points must not be overlooked. Firstly, the initial *Housing, Town Planning, etc Act, 1909* (HTP Act 1909) introduced zoning to Britain for the first time (Booth and Huxley, 2012). Whilst many contemporary British commentators and Australian planners might regard it as an almost forgettable statute, it nevertheless provided the initial step of controlling the use of private land. Secondly, a major element of the 1909 statute was introduction of the vague term 'amenity' (Punter, 1986). Thirdly, neither the 1909 nor 1932 Acts created the concept of amenity-based TPOs. As Booth (2003) emphasises, it was the wartime *Town and Country (Interim Development) Act 1943* (UK) (T&CD Act) that presented the option for local governments to adopt TPOs. As will be seen, these mechanisms were soon grasped by Australian local authorities.

The first issue is that the 1909 Act pioneered the making of statutory based 'town planning schemes'. These plans loosely translated early planning movements into law, especially the 'garden city' ethos devised by Ebenezer Howard whose intention involved 'reforming society through environmental improvement' (Freestone, 1989, p15). The phenomenon backed a form of 'green amenity'. This was reflected in the oft-stated pledge by the President of the Local Government Board, John Burns, to the Parliament that the forthcoming Act would 'secure, the home healthy, the house beautiful, the town pleasant, the city dignified and the suburb salubrious' (Parliamentary Debates, UK House of Commons, *Hansard*, Vol clxxxviii, 960-61, 12 May 1908). Such promises received mixed praise. Sutcliffe (1988), for instance, refers to 'tensions' between the garden city and town planning movements (p289). Yet in 1907, the Garden City Association, established in 1899, was transposed into the Garden Cities and Town Planning Association in 1907, which urged for legislative institutionalisation (Beevers, 1988). There nevertheless remained a level of political loyalty *against* regulation of private land. As a result, the HTP Act 1909 was relatively weak. Ashworth (1954) goes as far

as describing it as suffering from ‘still-birth’ (p234). The plans were voluntary with very few reaching fruition. Furthermore, they were limited to areas in the course of development. Yet scholars (see, for example, Herbert-Young, 1988; Sutcliffe, 1988; Ashworth, 1954) observe that contemporary critique of the HTP Act 1909 can be gagged by a temporal perspective. While Cherry (1996) describes the HTP Act 1909 as essentially a ‘house building’ statute (p36), it nevertheless laid down the beginnings of planning law for both Britain and Australia. After a parade of amending statutes, it was the *Town and Country Planning Act* 1932 that enabled planning regulation to cover existing developed areas as well as those handpicked for growth (Cherry, 1996; Cullingworth, 1967). The war-time T&CD Act 1943 went further by bringing land beyond a planning scheme made under the 1932 Act, or subject to the making of such a plan, into ‘interim-development control’ (Wilcox, 1967). In other words, development control was spread across the country. As will be seen, it took a little longer for NSW to follow suit.

The introduction of ‘amenity’ in the HTP Act 1909 is the second point. One member of the House of Commons viewed it as carrying ‘some vagueness and mistiness’ (HC Deb 05 April 1909 vol 3 cc 733-98 at 795). An official report by the UK Minister of Local Government and Planning (1951) depicted it as the ‘hardest-worked word in planning language’ (p138). The term has never been delineated in British statutes (Booth, 2003; Cullingworth, 1967), which is also the case in Australia. Despite this, it is cemented in town and rural planning (Kelly and Little; 2011; Punter, 1986; Smith, 1974). As Cullingworth (1967) observes, ‘amenity is easier to recognize than define’ (p132). The HTP Act 1909 referred specifically to the making of town planning schemes ‘with the general object of securing proper sanitary conditions, amenity, and convenience in connexion with the laying out and use of the land, and of any neighbouring lands’ (s 54(1)).

The third issue the TPO. In the UK, this did not emerge in 1909, 1932 or in between but via an ‘amending’ Act made during the Second World War, namely the T&CD Act 1943. Booth (2003) highlights that unlike common belief, this statute with its several new mechanisms, including TPOs, arose *before* the enactment of the substantial and innovative *Town and Country Planning Act* of 1947. Other than addressing war-time urban destruction, the T&CD Act 1943 introduced amenity-based provisions on protecting ‘historic buildings’ and ‘introduction of the list as a means of identifying buildings of significance’ (Booth, 2003, pp95-6). Yet in considering the Bill, the House of Lords paid minimal attention to the TPO provision. The Lord Chancellor ranked it as falling into the basket of clauses that needed no explanation. Most attention was given instead to interim development control pending the making of planning schemes (Heap, 1991). Power was granted to ‘interim development authorities’, including local councils, to prepare zoning plans subject to Ministerial approval. Previously, the 1932 Act had raised interim control as a voluntary and somewhat complex mechanism (Heap, 1991). The insertion of TPO provisions in planning provisions after the 1943 Act was nevertheless optional. This is also the case in contemporary NSW.

The T&CD Act 1943 at s 8(1) enabled an authority to insert provisions under an ‘interim protection order’ into an existing planning scheme for ‘preservation of trees or woodlands’. In relation to a pre-scheme situation, TPO provisions could be added into the compulsory interim plan. In both circumstances, at s 8(1)(a), the instrument prohibited, subject to

exemptions, ‘the cutting down, topping, lopping or willful destruction of trees’ without consent. This was the birthplace of TPOs in NSW and other Australian jurisdictions.

While the subsequent Act of 1947 was more policy-oriented than its predecessors, it granted local government considerable discretion in determining development proposals (McAuslan, 1985). The stranglehold of zoning provisions was largely left behind. Yet in NSW and other Australian States, it was the stringent *pre*-1947 Acts that clung to restrictive zones and prohibited uses that provided the basis for local plans. These included references to voluntary TPOs.

3. Early Endeavors in NSW

In the same year that the HTP Act 1909 was enacted, the Royal Commission for the Improvement of Sydney took place. Gibbons (1980) observes the substantial influence of the UK’s HTP Act 1909. Improvement of transport infrastructure, such as roads and railways, town planning and beautification comprised the key factors (Gibbons, 1980). The sheer emphasis on aesthetics is also raised by Sandercock (1975), in addition to social and hygienic improvements (Winston, 1957). Whilst these issues might be regarded as writ-small in contrast to the burgeoning British cities, Sydney suffered profoundly from similar problems.

The first comprehensive local government legislation in NSW demanding compulsory municipal incorporation was the *Local Government Act 1906* (NSW), described by Purdie (1976, 137) as serving a ‘limited range of works and services’. Councils had to wait until the *Local Government Act 1919* (NSW) (LGA 1919) for a particular provision on urban amenity. Section 309 and subsequent amendments enabled Ministerial proclamation of ‘residential districts’ (RDs) that prevented obnoxious uses, such as trades, business and advertising hoardings, in designated areas (Wilcox, 1967). Whilst the provision related to uses of land rather than regulation over trees, it served to enhance residential amenity. Green aesthetics coincided easily with protection and planting of trees, especially in Sydney’s wealthier suburbs. This is demonstrated by Proudfoot (1992) in her recognition of RDs as a direct lineage from garden city principles.

The earliest statutory provision relating to TPOs arose from insertion of Part XIIA, entitled ‘Town and Country Planning Schemes’, into the LGA 1919 in 1945. This enabled the first comprehensive land-use system in NSW. As in the UK, preparation of PSOs suffered from lack of interest. The first was the regional County of Cumberland Planning Scheme Ordinance (CCPSO) arising from an amendment to the LGA 1919 in 1951. It related to the geographically extensive Cumberland basin surrounding and including Sydney. The CCPSO was the first and last statutory regional plan of its type. But according to Harrison (1972), the regional Cumberland County Council (CCC) which represented 69 councils was ‘regarded as an agency of the State rather than as a representation of local interests’ (p188).

One crucial feature of the CCPSO illustrated by Freestone (1989) was its ‘classic planning statement in the garden city tradition in post-war Australia’ (p235). Provisions in the CCPSO related to, inter alia, ‘foreshore scenic protection areas’, ‘places of scientific or historic

interest' and, at cl 40, 'Preservation of trees'. Clause 40(1) enabled the making of a TPO 'for the purpose of securing amenity or of preserving existing amenities'. Furthermore, shadowing the UK approach, cl 40(2) stated that the TPO 'may prohibit the ringbarking, cutting down, topping, lopping, removing, injuring or willful destruction of any tree or trees specified in such [an] order'. The emphasis was clearly on enhancing amenity. Perhaps this was the product of strict adherence to Britain's planning laws. Whilst the CCC was dissolved in 1963 due to State political discomfort (Harrison. 1972), the CCPSO was to apply to patches of land for many years. It served to shape zoning patterns and other controls in subsequent plans (Whitmore, 1981). In addition, the CCPSO contained the controversial Green Belt Area Zone around Sydney's periphery, which emphasised aesthetics and scenery. Freestone (1992) describes it as an 'antidote for promiscuous urbanisation' (p72). But while the green belt was to be gradually eroded away, TPO provisions were to persist.

The CCC was replaced by the State Planning Authority (1964) which, in its first Annual Report, referred to the forthcoming power of local councils to 'issue and enforce' TPOs (p19). According to Wilcox (1967), the first local Planning Scheme Ordinance (PSO) was the 1960 Penrith PSO at Sydney's western edge at the foot of the Blue Mountains. There is little surprise that Part VI of Penrith PSO, called 'General Amenity and Convenience', contained provisions for 'Places of scientific or historic interest', 'Foreshore building lines' and, at cl 44, 'Preservation of Trees'. The provision was a virtual facsimile of cl 40 of the CCPSO. Whilst a handful of rural PSOs had already been gazetted before 1960, interest was generally minimal. This might be because planning was then mostly carried out by engineers who suffered 'very low status' (Burdess, 1984, p65). Otherwise, it was due to limited financial resources, community indifference and unwieldy processes.

The State Government reacted to this sluggishness by devising a standard instrument to apply to each council area. The new instrument, in similar fashion to Britain in 1943, was deemed an 'Interim Development Order' (IDO). At the beginning of November 2012, seventeen council areas were fully or partly covered by these prehistoric instruments made before 1980. Walget Shire in outback NSW, for example, still administers an IDO, with TPO provisions that are almost identical to those others raised above.

4. NSW in the 1980s and Beyond: A Fresh Approach?

As a result of the rise or environmentalism, the *Environmental Planning and Assessment Act* 1979 (EPAA) was enacted in 1980. Whilst it overrode Part XIIA of the LGA 1919, countless PSOs and IDOs – such as in Penrith and Walget – were to remain until overtaken by novel planning instruments made under the EPAA. The new local instrument was the 'local environmental plan' (LEP). Considerable discretion was granted to councils in framing their LEPs, subject to Ministerial approval. Some local authorities devised their own TPO clauses to be placed within their LEPs. The majority, however, adopted the *Environmental Planning and Assessment Model Provisions 1980* ('Model Provisions'). These comprised a blanket of sub-clauses put together by the State Government to maintain consistency across the board, including provisions on TPOs. At cl 8(1), the regulatory approach and emphasis on amenity directly followed its predecessors (Kelly, 2006). The emphasis on amenity remained steadfast.

In the late 1980s, the State Government considered redesigning the Model Provisions where TPOs were directed at *both* amenity and nature conservation. Draft cl 28(2) was to require consent for 'any action [to] ringbark, cut down, top, lop, remove, injure or destroy a tree' together with 'an assessment of the importance of tree or trees' with respect to, inter alia, 'scenic or environmental amenity' and 'vegetation systems and natural wildlife habitats'. This indicated confidence that two aspects could coincide. Unfortunately, the draft failed to reach policy or law. Instead, individual councils had to take the lead.

Opportunity for creative and ecologically focused TPOs surfaced with some councils who chose not to follow the archaic Model Provisions. An example is Sutherland Shire LEP 2006 at Sydney's southern suburban edge, where cl 56(1) cites its objective as 'to ensure the protection of trees and bushland vegetation that are fundamental to the conservation of biodiversity'. The provision contains no reference to amenity. Nevertheless, it echoes early TPOs by declaring that one 'must not ringbark, cut does, top, lop, remove or willfully destroy any tree or other vegetation' without permission (see cl 56(3)).The items of vegetation listed for protection are listed in a 'Development Control Plan', which adds detail to the LEP. Sutherland Shire Council's general approach is scarcely unique. The emergence of environmental officers across local government with sufficient resources and community support has assisted the planning system to stretch beyond its English origins. Yet the beauty of Sydney's indigenous flora, such as the angophora costata (or Sydney red gum) that often nestles into the Hawkesbury sandstone, undoubtedly adds to the amenity in the Sutherland Shire and elsewhere. The strength of emerging ecologically based TPOs depends, of course, on staff expertise, adequate financial support and a willingness to take legal action against disturbance or destruction of listed trees and vegetation. The construction of the relevant clauses is paramount.

Unfortunately, the flexibility of TPO provisions has been stifled as a result of insertion of s 33A EPAA into the EPAA in 2006.It sets down a slate of standard provisions that each council must adhere to in preparing its draft new LEP. This instrument, cited as the 'Standard Instrument (Local Environmental Plans) Order 2006', is generally called the 'LEP template'. It is a modern version of the Model Provisions of 1980. The LEP template was preceded by a discussion paper issued in 2004 including a proposed clause entitled 'Preservation of trees' (Department of Infrastructure, Planning and Natural Resources, 2004). Apart from a small mention in relation to pruning, there was no reference to amenity notwithstanding eleven other references throughout the document. Neither was there any specific referral to biodiversity conservation. While there were proposed provisions on 'heritage conservation areas' and a council's 'Significant Tree Register', these scarcely addressed management of local of ecological communities. Moreover, the regulatory language reflected its antecedents by banning a person to 'cut down, top, lop, prune, remove, injure or willfully destroy at tree' subject to consent. As usual, exceptions applied.

The 2006 LEP template substantially reframed the draft 2004 model. The title of (the then) cl 32 was 'Preservation of trees and vegetation', thereby widening the net to shrubs and saplings. Perhaps this was accelerated by progressive councils keen to move beyond traditional formulae. The term had no reference to TPOs. Yet former cl 32(1) stated the objective as 'to preserve the amenity of the area through the preservation of trees and other

vegetation', thereby entrenching amenity as the main goal. The instrument stated that an individual 'must not ringbark, cut down, top, lop, remove, injure or willfully destroy any tree or other vegetation' as prescribed in a DCP, without consent (cl 32(3)). Insertion of the provision was subject to whim of each council. Inclusion of cl 32 was, as usual, totally voluntary. But the prescription, if adopted, remained firm. Any council that was eager to adopt a 'greener' type of amenity had to seek Ministerial approval to amend the 2006 LEP template to suit its own circumstances. The extent of success here, if any, is worthy of further research. Evidence exists of some beneficial and well designed provisions.

Recent alteration to the LEP template appears positive. Clause 32 has been translated into a fresh cl 5.9. The revised overall objective is to 'preserve the amenity of the area, including biodiversity values, through the preservation of trees and other vegetation' (cl 5.9(1)). This recognizes that biodiversity conservation and amenity enhancement might be able to coincide. But in order to achieve this, a council needs sufficient expertise and resources. Many councils are achieving this. A further issue is that adoption of cl 5.9 is no longer voluntary but mandatory, subject to specified exceptions. This is a major step forward for those councils who are keen to see greater protection if not improvement of their local vegetation and fauna.

A curious provision of the LEP template is cl 5.9(5) (formerly 32(5)), which obliquely refers to biodiversity conservation (Kelly, 1996). It asserts that cl 5.9 'does not apply to a tree or other vegetation that the Council is satisfied is dying or dead and is not required as the habitat of native fauna'. In other words, hollow logs where species such as possums and birds, including kookaburras and cockatoos, can receive special attention (Department of Sustainability, Environment, Water, Population and Communities (Cth), 2008). It is clear that this fragment of a sub-provision moves away from the conventional notion of amenity. Creatures living in fallen or burnt logs will be invisible to passers-by apart from scientists and interested citizens. Whilst it heads in the right direction towards retaining biodiversity, its scope is restricted. For instance, what is meant by 'habitat of native habitat of local fauna'? Does a council have the resources and skills to apply it? Even if a council ecologist is adamant to conserve and improve biodiversity on private open space, what might be the view of the elected representatives? After all, most residents may not desire dead logs in their front yards or next door. The answers are far from clear cut.

5. Conclusion

In her survey of TPO provisions in the Sydney region completed more than two decades ago, Mather (1990) submitted that TPOs were 'not simply the protection and preservation of trees' but 'also the enhancement or reservation of the human environment' (p10). This appears as an early recognition of moving beyond amenity. If similar research was carried out today, the reference would undoubtedly refer to biodiversity conservation. The crucial role of local government in conserving biodiversity was receiving critical attention in the late 1980s at both global and local levels. At the Rio Earth Summit in 1992, in addition to the Biodiversity Convention, a statement of intent named 'Agenda 21' adopted by 170 nations, including Australia, raised the vital role of local government in conserving biodiversity (see ch 28). At the local level, the Australian Local Government Association and the Biological

Diversity Advisory Council (1999) produced the *National Local Government Biodiversity Strategy* for all councils across the nation. In addition, high level strategic national and State instruments, plus the *Biodiversity Planning Guide for NSW Local Government* (Fallding et al, 2001) have encouraged councils to embrace biodiversity in their local plans.

TPOs and their modern-named counterparts can play a key role in conserving biodiversity at the local level. But several issues arise here. Firstly, TPOs represent only one of a suite of potential mechanisms. Others include, inter alia, implementing local 'state of environmental reports', improving management plans for vegetated council reserves, designing buffer zones at the boundaries of State reserves, giving saplings to local citizens, carrying out education programmes and coordinating with neighboring councils. In this mass of conservation approaches, TPOs present a mere fragment. This does not mean, however, that their potential should be overlooked. Secondly, residential front and back yards are becoming smaller due to bigger houses (Hall, 2010). At the urban periphery, this is permitted by policy and law. The result, according to Kelly and Little (2011), is 'urban sprawl' pressing 'across far-flung suburbia' (p174) with scant opportunity to maintain green amenity let alone encouraging biodiversity. In established residential areas, infill development applies economic pressure for removal of vegetation. Thirdly, the breach of a TPO (or tree preservation control) is an offence (Ogle, 2011). But clear evidence that a particular person has committed the offence can be difficult to obtain. This demands sufficient resources to support compliance officers and lawyers.

Notwithstanding the above issues, the architecture and application of TPOs warrants change. It is time for biodiversity conservation to come closer to the forefront. Of course, there will be exceptions, such as bushfire prone vegetation. The aim is for amenity and biodiversity conservation to coincide as far as practicable. After all, conservation of urban biodiversity is essential (Ives et al, 2009). Notably, some pre-2006 LEPs are superior to the State Government's 2006 LEP template. There is evidence that in some circumstances, the Minister for Planning has approved LEPs that differ from the norm. It is argued that in order to avoid suffocation of local inventiveness, cl 5.9 should be regarded as the start of the design journey. While the Minister can use her or his power to check against any major intra-regional disparity and assist impoverished remote councils, local government should be trusted to respond to local conservation needs on private open space. Councils are closer to the ground than other spheres of government. Application of the subsidiarity principle is recommended. Indeed, councils with sufficient resources might be bestowed greater power to draft their own TPOs. But should a council fail to achieve this, the Minister might step in and employ the whip hand.

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Factors Threatening the Cultural Heritage- the Windows of Europe

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Abstract

Today, historical windows of Europe are disappearing from the façades in a magnitude that can possibly be compared to the destruction of the building stock during the World Wars. The purpose of this paper is to give a structure to the problematic and to discern factors that contribute to such circumstance. Even though the European legislation generally protects historical buildings since the last 30 to 70 years, the vigour of law seems toothless in favour of market forces and weak insights of the consequences of establishing sustainability policies. One factor that has in recent years grown in significance seems to be divergences of policies between sustainability and protection of the cultural heritage. Another contributing factor to the rate of destruction seems to be economic wealth that correlates to inappropriate change of windows. The paper proposes a more holistic view of the consequences when sustainability measures and decisions are taken. Finally the paper contributes to a proposition how the unfortunate development should be hindered or mitigated.

Keywords: Architecture, Change, Cultural Heritage, Sustainability, Windows.

1. Introduction

Windows are the openings in the walls of buildings, which originally were merely holes. In order to enable daylight entering the inside of buildings and in the same time excluding wind and cold temperatures, transparent material were sought as covering material in the wall openings. The first glass windows were already created in ancient times, when the Romans were capable to produce glass. Windows were a luxurious artefact of a building and grew continuously in importance and contributed with a development of specialized craftsmen in the field. In the middle ages windows of composed pieces of circular (or hexagonal) crown glass with plumb frames was the predominant way of creating a window. From the 17th century larger pane surfaces where sought, which lead to a development of the technique of producing cylinder (plain) glass. During hundreds of years until the last century the same technique of producing pane of glass remained the same, however with increased sizes and refinement. A mouth-blown glass square was produced through a two-step procedure: first a glass-cylinder was moulded in a form. After cooling, it was cut up alongside the height and a second time put into the oven where the cylinder opened to a flat rectangular pane of glass. (also called cylinder blown sheet glass). With this technique it is impossible to create a perfectly flat surface; instead it contributes to an almost inimitable and special character of windows and in a larger context: the perception of the façades. The thickness of glass panes is from 2 to 5 mm that render the panes quite sensible; a minor impact is enough to destroy

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a pane of glass. The cylinder glass windows relates to the architecture that succeeded the medieval building with crown glass. Larger glass surfaces became a significant architectural resource of expression of European architecture; e.g. from Versailles in the 17th century to every common buildings until the 1920s. During the early 20th century cylinder glass for windows were replaced with a number of new techniques of producing considerable large surfaces (e.g. float glass) with a perfection of a flat surface. Uncontestably the new glass production technique contributed together with the development of steel and concrete techniques to the characters of the various trends of modern architecture during the 20th century. However in the beginning of the modernistic era, when perfect plain surfaces were sought, particular unevenness of windows in buildings can be found until the 1930s. The window ratio of the façade area before the 1930 generally was 10% to 50 % and afterwards the span extended until 20% to 100%. This fact suggests that the character of the glass surfaces play undoubtedly a mayor role of how we perceive the architecture of a building. The texture of mouth-blown the glass panes get lost when they are replaces with modern windows. This paper want to raise the question if it is possible to maintain a more subtle and careful way to deal with windows in old houses, that in fact would be more sustainable in a holistic viewpoint and ultimately “is there any willingness to do so?”. (This article is limited to the topic of “Casement window” which is the traditional window of Northern and Central Europe, hence named here merely as “window”)

2. Architectural values

Old windows have generally a frame of timber (rare alternatives are iron, steel or lead), which in particular in Northern Europe have often a very high quality (often heartwood of pine and spruce) a low propensity to decay even if the coats of paint have fallen away. In central Europe hardwood like oak was the domineering material for the frames. Panes of glass are fixed in the wooden frames with small nails and putty. Traditionally linseed oil is an important ingredient in window manufacturing: (1) As impregnation as a primer of the timber frame, (2) As binder for the putty and (3) As binder of the coat of paint. Through the ages linseed oil loses its elasticity through an oxidation process; when it becomes dry it does no longer protect the window. Due to the winter season, parallel frames of windows were common from Northern Europe until the alpine region. In southern Europe sun protection is solved through shutters and blinds. In Northern Europe the whole year’s windows are nearest to the façade and opens outwards. The windows for the cold season are hooked inside with opening inwards. In Switzerland and Central Europe the season windows are often contrarily hooked nearest the façades. Traditional window frames are subdivided into smaller sections because the glass panes were not technically possible to produce large enough for the size of one window frame. The glass panes are separated by slender timber parts; the horizontal are called saddle bar and the vertical bar: stanchion bars. Windows are often symmetrical; a vertical timber part, the mullion, separates the left and right window frames. The timber parts of a traditional window have often elaborated and refined design of profiles (www.buildingconservation.com).

2.1 Irreplaceable qualities

The concept of “Nordic Light” is related to early skills of milling appropriate profiles of timber of the interiors in order to optimise the daylight in morning and evenings and has thus a functional role apart from the decorative appearance. The timber profiles together with composition of multiple uneven glass panes enable daylight to enter a building smoothly without sharp contrasts that occur between shadow and light. The handicraft of windows of traditional windows consists furthermore of elaborated details of metal: fittings, hinges, catches and handles (e.g. Figure 1). All mentioned materials compose together a characteristic element of the architecture of a façade, and are consequently utmost significant for our cultural heritage.

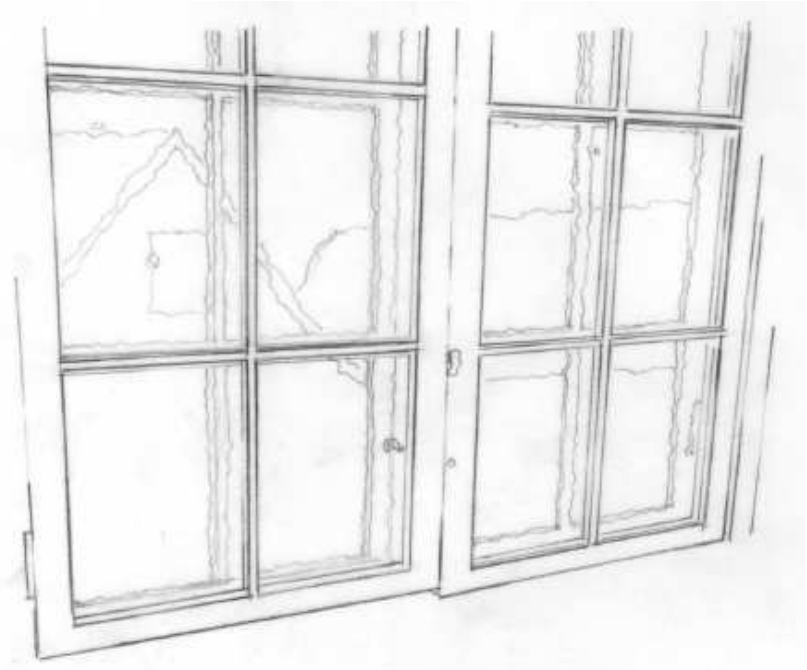

Figure 1. Details and Texture of old windows do not exist in modern windows: Original Window 18th century, Skottbergska Gården, Karlshamn, Sweden

3. Energy Saving vs. Protection of Cultural Heritage

The oil crisis of 1974 gave rise to energy saving requirements in Europe and has since then continuously been a theme in European Governments and Financial institutions, which has given a rise in industry to produce windows with higher thermal insulation. The façades of existing buildings got an additional layer of thermal insulation; the windows were replaced with new windows with better U-value. Since the 1960s, city cores in Europe have endured a time when historical buildings, often several hundreds of years, have disappeared to larger extent than during the world wars. All cities cores in Sweden (that did not even participate in the world wars) must during the 1960s sacrifice an important stock of historical buildings in favour of new constructions for supermarkets (Primarily the chain “Konsum”, politically related to the Social Democratic Party with its ideology of “The People’s Home”) and office

buildings. The remaining historical buildings often have been radically changed from the 1970s due to energy requirements; new facade layers, new roofs and replacement of windows. Undoubtedly large amount of the historical values have thus vanished or been changed to a considerable extent.

3.1 Questionable Vigour of Protection of Cultural Heritage

Since the beginning of the 20th century, governments of Europe have to a various extent created regulations of protecting the cultural heritage; initially building of spectacular value like castles and churches became protection early whereas private buildings (dwellings, factories, offices and commercial building) from medieval to 19th century become protected after WWII. Despite status as protected heritage, changes of windows are frequently made. In the archives of the building authorities the blue prints of façades often have the scale of 1:100, which means that a window with measure of let us say 2 x 1 meter has the size on the blueprint 2 x 1 cm. Certainly on such tiny size, details of a window cannot be seen or evaluated of its architectural or historical quality, nor can a difference between old and new windows be distinguished. In reality, it is undoubtedly a considerable difference between an original window with substitute of a modern window: (1) modern glass panes a perfectly even, which can be easily detected in the mirroring of the glass pane. Instead of multiple glass panes, a single glass pane fill the entire frame where saddle bars and stanchion bars are often mere decoration and fixed inside the glass pane (2) Instead of wooden parts, the windows have frames are often of plastic or aluminium. The profiles of the frames (and the “false bars”) are of standardised form paying no heed to the above mentioned functions of the original windows profile. Furthermore, from inside the frame create a sharp contrast to the daylight instead of the particular character of the subtle light dispersion of old windows.

3.2 Movements of Protection in Academia and Practice

During the 1970s, a wave of demolition of old buildings took place. Voices of protecting historic values arose, often as a protest to market and political forces. The protests against the extensive demolition of historical building resulted in higher academic interests at the architectural schools in Sweden (primarily the Professors Boris Schönbeck at Chalmers and Ove Hidemark at the Royal Institute of Technology, Stockholm) where maintenance of old art and crafts within the building sector acquired new-born interest. Relations to artisans were established that were invited to architectural school to work-shops. One example was Hans and Sonia Allbäck from Ystad, Sweden who specialized in the art and craft of old window at its traditional materials. Hans Allbäck invented a glass-tube that heated the old putty of windows and thus facilitated removal of putty without damaging the mouth-blown glass panes. It must be said that specialists in repairing old windows have in the recent decades found its market segment in Europe. Another example is the firm Glomet AG in Horgen Switzerland (www.glomatag.ch) who as well has a stock of old windows and thus is capable to provide original window parts for their clients. The interests for preserving old buildings have become institutionalised phenomena in Sweden; outside academia organisations like The Swedish Association for Building Preservation (www.byggnadsvard.se) has been established. Contacts to specialised artisans and providers of traditional building material are provided from several sources.

Intermediary solutions between old and new windows were as well of interest; for example in the 1970s the firm EMDE Inredningar, (design Max Dettwiler) in Sweden pursued experiments by preserving the old glass panes and transferring them to new timber frames with an internal additional window frame with a modern isolation glass pane. Contrarily the authorities of building preservation (www.ag.ch/denkmalpflege, Switzerland) recommend a method of replacing old glass-panes with modern glass panes and preserving the timber parts of the windows. There are today some manufacturers of mouth-blown glass pane in Europe that have to reconstruct forgotten techniques of various times; for example the degree of organic pollution in the sand resulted in particular textures that are difficult to reconstruct (www.byggnadsvard.se). Moreover there is a large amount of modern glass panes with market label as “antique”. They are however far from the character of mouth-blown glass panes and cannot function as a substitute.

3.3 Two main categories of old windows

The character of a building in relation to an urban context must be paid better attention where details such as Figure 2 that render historical traces have great significance for the architectural understanding and historic traceability (Schönbeck, 1994).



Figure 2. Details and Texture of old windows do not exist in modern windows: Original Window from 17th century, Dijon, France

Schönbeck (1994) suggests that if changes of a historical building must be made, it should be elaborated with prudence. Distinction is made between restoration and renovation: traditional techniques should be used in repairing measures (restoration); whereas new building parts must pay heed to the character of the place. The Venice charter of 1964

stipulates that new building elements should represent the present time, thus not being a pastiche of past times.

In this paper it is argued to divide the management old windows into two categories: (1). Buildings where the windows earlier have been replaced one or several times (medieval to 19th century) and (2) Buildings where façades and windows have the same age like Figure 3 (frequent example, houses from 1870, art nouveau buildings from beginning of 20th century). According to “The Venice Charter 1964” a new window might have its place in a historical building that have changed the character of the façade throughout the centuries and where the existing windows have little historical and cultural value. The second category however deals with historical buildings where a considerable part of the original surface is threatened; if possible it would have high value if the entire building to a maximum can maintain its original materials. Nypan (2009) compares short life cycle of modern windows and maintenance of old windows; thus put to question the necessity of a change. Dettwiler (2012) conclude that changes often occur without a rational reason and often the change per se can be of nuisance. An example are the art nouveau buildings in Eastern Germany that after the opening 1989 were renovated for symbolic reasons; having now lost their original windows the buildings must probably already have their second generation of plastic windows.



Figure 3. A residential building from beginning last century in Davos, Switzerland where the upper floors have changed to new windows, whereas the lower floor has maintained the original windows.

In several ways, the original windows can in fact have sustainable features: (1) they old windows were repairable, the new windows not, (2) maintenance consists of a layer of linseed oil each fifth year, enabling a quality as a new window (3) societal cost of energy

would be saved by avoiding manufacturing, transport, installation and waste, (4) cultural value would be maintained etc. (Ohlén, 2005).

4. Analysis of Sustainability

In recent decades Switzerland have agreed to achieve a so-called 2000 Watt Society (introduced by ETH in Zurich, 1998), which is a target of energy consumption per head in a future. Such a political target has resulted in requirement of energy savings among the existing building stock. If house-owners commit themselves to transform their houses to new energy standards they receive lower interest rates on the loans. Similarly cultural values seems to be forgotten when it matters of energy saving in historical buildings; methods of renovation is well spread in Germany. It means thus that Financial Institutions and Governments contribute to the disappearance of old windows. The manufacturing industry of plastic windows fulfilling the new requirement has grown and offers easy delivery and replacement of desired sizes.

The Swiss authorities accept that old glass panes of cultural heritage classified buildings are replaced with new glass panes and thus would the timber parts of the window saved (for example www.ag.ch/denkmalpflege). Windows in historic city cores have to a considerable extent been replaced by new windows (often of white plastic frames and false bars behind the glass pane): examples are Appenzell (Figure 4), Zermatt, Zürich, Geneva, Lausanne and more. Being classified as a Unesco Heritage more prudence of window repair and preservation can be seen in Bern.

4.1 Architectural Design vs. Energy Saving

The manufacturing of windows during the post WWII era has been developed from handicraft to large scale industrialisation. The technical qualities of windows has continuous been enhanced in terms of acoustic and thermal insulation. Glass panes have become thicker with a significant more flat texture and can be produced of considerable larger sizes than it is possible with mouth-blown glass panes. Together with steel and concrete as building materials, the technical development of glass production has incontestably contributed as an important material of the architecture of modern buildings. Old windows have poorer thermal insulation however compensated by its minor part of the surface of the façade. Modern windows often have a larger part of the façades with less wall surface. In Northern and Western Europe, the floor surface per capita grown as well as the floor size of apartments has as well continuously grown since WWII. On one hand we have thus an older building stock with smaller surface of windows with on the average small apartments. On the other hand we have an architectural trend of increasing glass surfaces and a design of larger apartments with more floor surfaces per capita. As a part of discussion on sustainability, this observation argues for not studying only the physical aspects of windows as an isolated building element but rather as in ingredient in a larger context in briefing, building physics and architectural design.

Sustainability labels generally do not pay heed on culture values, rather they tend to be directed to incorporate insulation materials and thus attain targets of energy saving. Ohlén

(2005) suggests that old windows in fact can be better than new windows; the differences should be about 4% of the entire heating cost between preservation and new windows. Energy can be saved in a number of other changes in a house like more efficient ventilation, roof insulation, efficient re-use, low energy household equipment etc. A balance with humidity and temperature is relevant; historical timber houses with historical painting layers suffer from damages of continuous level of heating because water evaporates and dry the timber with results of volume changes. It causes cracks and peeling of paint and plaster. The other extreme is too much humidity in the building which often were the case of the additional insulation of the 1970s (due to the oil crises 1973) were the condensation point felt inside the wall through openings in the moisture barrier.

4.2 A Philosophic Comment on Sustainability

It is remarkable that there seems to be a correlation between wealth and destruction of cultural heritage; Dettwiler (2012) exemplifies with the opening of Eastern Germany and how Art Nouveau houses were badly damaged through unskilled renovation. The same can be seen in Switzerland where cultural heritage seems primarily have an image role for tourists; one of the Landmarks of Switzerland; the Kappelbrücke in Luzern was completely destroyed in 1993 through an intense fire. It was originally constructed in the 14th century with 111 paintings from 17th century. A new copy was quickly reconstructed in its place. The newly built Kappellbrücke is still a photographic symbol of Swiss tourism.



Figure 4. A residential building from 17th in Appenzell, Switzerland after a "Sanierung" with a new coat of paint and new windows (NB. Plastic bars, without function, behind a single glass pane)

Furthermore; houses from 15th century until 19th century that are renovated (German: "Sanierung", literarily translated "Cleansing") in Switzerland often got a new perfect facade with new layers of paint and new windows whereas more prudence can be seen concerning old houses in neighbouring countries with lower GDP. During the 1960s the Swedish word

“Sanering” (Cleansing) was as well frequently used when a considerable part of the historical building stock insensitively disappeared and is today avoided due to its negative associations. “Sanierung” is however today frequently used in Switzerland, which implies that there might be cultural differences of the attitude to cultural heritage (Figure 4). Through insensitive restoration the original character vanishes and a have a new “look”; a building with the same treatment of its surface can in fact easily be reproduced elsewhere in the world. It can be associated to newly built city centres aimed for tourist; e.g. the collection of copies of various European old houses in Macao or the copy of Venice in Las Vegas. The question arises “Is it indifferent whether buildings or building parts are original or copies?”

Investments in historical buildings have often a dual character. Buildings in city cores with high symbolic values and rentable surfaces are a subject of investment and speculation. Negative aspects are risks of costly and complicated renovations with restrictions due to protection of cultural heritage. Most frequently old windows of old houses seem disconnected to the value as an old house. The contractors specialised in renovation do seldom want to exhibit a renovated window as an enhancement of value, whereas ornaments of the walls are often new painted or cleaned. The outcome of a renovation is (as the name implies) a new “look”.

It is probably a matter of status of a building if a window renovation should take place. For example, we cannot accept that the glass panes of the royal castle in Stockholm should be replaced by modern glass panes. An extensive and most prudent renovation lead by Professor Ove Hidemark maintained all original glass panes, the oldest from 1741 (www.gardochtorp.se). Auditing of real estates is a fundamental element of valuation and information for real estate archives, where a multitude of physical aspects are documented. In Italy old building parts are included in the auditing process (Bellintani and Ciaramella, 2008). Documentation might in fact be a step to establish a value of old windows and other original building parts. It is a well-known fact that investment and value has a psychological background. As far, old windows have frequently been regarded as a financial burden where the easy solution is replacement. If old windows would be ubiquitously regarded as valuable objects, more balance could be found in the future between change alternatives.

The concept of “sustainability” deserves some analytical remarks. There is apparently a divergence of policies and interests between sustainability and the protection of the cultural heritage. Alternatives of managing old windows are highlighted in Table 1.

One can assume that the targeted 2000 watt society to a large extent is biased not only to fulfil political goals but as well of an emerging industry. If the approach of achieving sustainability would be to cause a minimum of nuisance by a change it is not certain that a manufacturing of new production, and its related processes, like transports would the best alternative. Decision of changes can be related to variables of pro- activeness, re-activeness and weighting of functional and symbolic values (Dettwiler, 2012): We might feel that we have done something good for the environment if we replace old windows by new ones when we actually are influenced by governmental and market goals. In the same time we have invested financial means that result in a new painted façade with new windows (that have a life-cycle of about 25 years and cannot be repaired). Certainly it would be a sacrifice

of renouncing for a short-sighted economic profit in favour of altruistic ideals of preserving cultural heritage for the benefit of coming generations.

A comparison between the two alternatives of managing windows in Table 1 can be further deducted to the utilitarian thoughts of Mill (1863) where a human action should be transferred to a satisfaction, ethics and moral. It is not evident that users and owners of buildings would be immediately happier by preserving old windows with the disadvantages of inferior acoustic and thermal qualities. Shall the mouth-blown glass panes be sacrificed in favour of comfort requirements of today or shall possibly moral and ethics be a means to fulfil conservation aspirations?

Table 1. Alternatives Maintaining existing Windows or exchanging them.

New windows (discharge of old windows)	Maintaining old windows (maintenance and repair)
• Loss of cultural heritage • Change of 10-50% of façade architecture • Improvement of Energy Cost for the building • Improvement of acoustic quality • Risk of humidity damages and contribution to "sick houses". • Limited life cycles, Replacement with another window each 25 years>recurrent costs • Higher Societal energy cost of transporting, manufacturing and waste windows (thus less sustainable?) • Easy to realise accessible on market (Economies of Scale, Standardisation and Supply) • Governmental request of energy saving, promotion through financing • Gives jobs and business opportunity for manufacturing industry • Plastic, Aluminium cannot be repaired	• Maintenance of cultural heritage • Maintenance of façade architecture • Some Improvement of Energy Cost for the building if maintained and repaired • Some Improvement of acoustic quality if maintained and repaired. Otherwise poorer quality than new windows. • Higher energy cost for owners • Undefined life-cycle if maintained and repaired • Recurrent cost of maintenance and repair • Lower societal costs of energy and material (assuming that maintenance and repair is less energy demanding than replacement, thus more sustainable?) • Difficulty to find competent artisans in the field • Timber repairable and easily maintainable. • Growth rebirth of old art and crafts
Sustainability from Political and Market Forces' viewpoint	Sustainability from a scientific viewpoint?

5. Summary: What can be done?

Building authorities are the institution that primarily can promote a more sober and differentiated view on windows. Original windows that are repaired could be entered as part of the value enhancement of a historical building: information to the public has a preventive effect. Such information has a multidisciplinary duty: from historical, architectural values to technical advices and guidance to the few artisans in the field that are capable to repair and maintain old windows. The architectural (and engineering) school might have a course in preservation of cultural heritage and traditional arts and craft as a mandatory theme. An

advice for the future would be more prudence and balance by identifying the real needs and necessary changes.

5.1 Recommendations

Some ideas in the paper that can be transformed to practice:

- Profound investigation whether a certain change must take place. An analysis of consequences can be motivated. What is sustainability in a societal and larger context? Contradictions can be found in a limited context as that of a singular building. More subtle weighting should be made between energy saving and preservation. Finding alternative ways between preservation and fulfilling acoustic and energy saving requirements (like intelligent and variable heating of spaces) are motivated.

- Educational measures: (1) Education of more artisans capable to repair appropriately windows and in fact open a market to the public as an alternative to pre-fabrication window suppliers. (2) Historical values that might be transformed to economic values. Elite of educated real estate investor would appreciate original windows of a real estate. Might such attitudes be spread to a broad category of owners?

- Documentation performed by municipalities, investors and owners as a part of the auditing process and value creation. Better routines among authorities: details of façades should be better protected against changes with higher degree of details in drawings (from 1/100 to 1/20 for example). The development of technologies, ICT, BIM etc. gives large opportunity to manage large amount of data concerning windows.

- Energy savings of old building relate often lower interest rates of loans when original windows of old buildings are replaced with plastic or aluminium framed windows. Probably such rule has caused the high degree of disappearance of old windows during recent years. Governmental financial support of repairing old windows might give balance to the today's financial promotion of replacement alternative.

- Two categories of old windows have been distinguished that lead to various measures: (1) original windows with same age as the facade and (2) old windows, but younger than the facade itself. Repair and maintenance is more motivated in the first category in order to maintain an original facade, whereas the second categories represent another window in a succession of several previous generations of windows.

6. Conclusive Remarks

This paper has highlighted the imminent problematic of the loss of historical building and windows in Europe; in particular the loss of mouth-blown glass panes (cylinder blown sheet glass) has been treated. It is furthermore most remarkable that the institutionalised ideas of energy saving, sustainability labels, political and market targets seem more or less to have been forgotten the architectural and historical values of old windows. Recommendations are made in order to safeguard the remaining part of the old-window stock. A holistic view of the

consequences would be motivated when sustainability measures and decisions should be taken. New windows imply that energy can be saved in a limited perspective but is more doubtful in a larger and societal context. Various alternatives should be considered in the decision process before making a change. Ultimately, it can be said that this paper has an underlying research question: “What is sustainability from a scientific perspective?”

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How Important is Inter-organizational Collaboration to the Success of Construction Project BIM Implementation

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Abstract

The construction industry is always criticized for lack of collaboration and ineffective communication. Building Information Modelling (BIM) is introduced to the industry as a concept that involves a series of changes on organizational processes, tools, structures and policies, as well as the interaction patterns among individuals and professional groups. Proponents claim that BIM will improve the collaboration performance of project teams. However, the performance of BIM in practice fails to achieve more advantages than traditional projects on efficiency and effectiveness. On the contrary a collaborative working environment could be the antecedent of successful BIM implementation. In this paper, the impacts of BIM implementation on the construction process are underlined and a set of key factors of inter-organizational collaboration are explored. Furthermore, the significance of inter-organizational collaboration across project teams toward successful BIM implementation in the construction industry is also discussed, pointing to future study on collaboration theory from a social-technical perspective to evaluate the BIM performance.

Keywords: Inter-organizational relationship, collaboration, Building Information Modelling (BIM), construction.

1. Introduction

Professionals intend to optimize their functions with little attention to others' interests, and they are barely interested in understanding the whole process in construction (Love et al., 1998). Dainty et al. (2006) confirmed that this focus on their own interests is the reason for fragmentation i.e. lack of integration from design to project delivery. Thus, participants focus more on self-protection and economic benefit maximization rather than general project performance. Furthermore, increasing fragmentation facilitates the increasing complexity of projects, and brings more difficulties in project management (Kadefors, 1995). The fragmentation within the project organization is the main barrier to project performance. Construction projects are unique due to temporary collaboration amongst parties.

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Professionals own influence on the decision-making, and the goal of the organization is mixed with their own expectations. From Partnering, Alliancing to IPD, multi-delivery methods are adopted through the process in order to optimize such inter-organizational collaboration (Earl 1996). Nevertheless, both academics and practitioners fail to attain satisfactory inter-organizational collaboration, no matter how they tackle the improvement such as changing organizational structure, adjusting contractual items and adopting new technologies.

Wide use of BIM technology in construction industry has not promoted collaborative relationships within organization thus far. BIM becomes one way to cope with cooperation, integration and coordination challenges in the construction industry, however, current use of BIM technology has not promoted collaborative relationships within organization. Collaboration under BIM creates great opportunities, but also creates new issues that need to be addressed and solved. It is ineffective for BIM adoption if each professional still performs under the conventional contract framework. That ignores the inter-relationship between BIM and Integrated Project Delivery (Ashcraft, 2009). It is necessary to consider collaboration before implementing BIM.

2. Building Information Modelling

BIM is regarded as a critical factor in fulfilling integrated project delivery. This inevitably leads to the restructuring of project organizations and communication processes. Current project management also needs to be changed in order to facilitate BIM implementation. Although the development of Information and Communication Technology (ICT) has improved significantly in the past decades in construction industry, most of the outstanding issues mentioned earlier are still unsolved since Bowley (1966) identified the problems and issues related to the industry (i.e. lack of integration of design and production). Courtney and Winch (2002) confirmed that over 80% of those factors underlying re-engineering issues could also be found in other countries with equal significance.

BIM as a new concept involves a series of changes and adjustments related to organizational process, tools, structures and policies. Further, it changes the style of interactions among individuals and their organizations. The advent of BIM technology takes one significant step forward towards cooperation and communication logic. Different parties may achieve higher level of collaboration through effective communication in addressing problems, deriving solutions and building trust (Hossain, 2004). Collaboration demonstrates communication and cooperation across parties in the organization (Baker, 1992). Nevertheless, BIM implementation on construction sites has gradually forced project teams into partially unnatural and ineffective administrative work routines due to the inflexibility and fixed nature of the BIM system and process (Wikforss et al., 2007). In that way, the potential of BIM for facilitating collaboration at both inter-personal and inter-organizational levels is constrained under such inappropriate implementation strategies.

By working collaboratively, the project organization could achieve process integration, knowledge sharing and relationship maintenance. Professionalism and geographic dispersal are sources of collaboration difficulties. One of the main functions of BIM is facilitating

professions to achieve integrative and collaborative working. BIM can provide such a condition and platform to optimize the inter-organizational interaction. Nevertheless, the quality of collaboration still needs to be improved. How to promote multi-disciplinary collaboration and how to integrate BIM advantages with better collaboration are the key questions to be addressed. Obviously, it will not be successful without considering social and psychological issues which impact inter-organizational collaboration. They also impact the effectiveness of BIM implementation in a project. Gerber et al. (2012) demonstrated BIM collaboration benefits as follows: "1) Enabling concurrent collaboration—compared to sequential workflows of information generation and analysis; 2) Integrating separate tasks—a shared 3D model can incorporate estimating, scheduling, spatial coordination tasks more effectively; 3) Improving separate tasks—direct use of a 3D model facilitates tasks such as estimating, scheduling, spatial coordination." (pp. 22)

Understanding inter-organizational collaboration is necessary before BIM implementation. Currently, the majority of construction professionals lack sufficient training and BIM knowledge. Few people recognise the necessity of encouraging project teams to collaborate effectively. BIM should break down cultural and organizational boundaries by promoting communication and collaboration. Technophobic personnel are one of the challenges to the successful incorporation of value contribution in the BIM process. Thus the satisfaction of current BIM technology is still low and there is a gap between interoperability and functionality.

Through visualization, BIM may analyse and detect clashes that allow professionals identify the potential risk. At the time that people strongly believe that BIM could provide high efficiency and collaboration with advanced technology platform, but professionals still focus on their own organizations and work fragmentally in construction process. Each member only fulfils minimum responsibilities according to the conventional contract signed before. This constrains the potential utilities of BIM and BIM is adopted as a tool only that creates little knowledge contribution and added value (Dossick and Neff, 2010). BIM provides increasing opportunities for project participants to integrate essential project elements, but it cannot fill the social gaps within inter-organizational relationships. This means that the BIM adoption fails to guarantee a better collaborative interaction in the project. We claim that transformations from traditional projects to BIM enabled projects change the way of providing services and the process of delivering projects. Some changes may do harm to process of collaboration. Inappropriate adjustments and implementation strategies may even cause protectionism and conservatism. Thus inappropriate BIM adoption can decrease the collaboration level and lose the advantages of communication efficiency. Previous studies fail to point out the importance of collaboration across professionals. There is no collaboration issue to be considered before adopting BIM. In other words, BIM could detect the clash by analysing building information, but it could not solve the inter-organizational conflicts. Therefore, we don't consider BIM only as a tool that digitally represents buildings with three dimensions and file all essential databases on a collaborative platform. It is not a tool only but also a set of policies, processes and technologies providing a methodology to collaborate all the essential construction outputs through building's life cycle (Succar, 2009).

The adoption of BIM technology as a goal is to accomplish the critical project objectives such as completion on time and on budget. BIM implementation is expected to close the communication gap and increase collaboration. However, the nature change of construction industry could not be brought along by new technology only (Rowlinson et al., 2010). It is necessary to provide a clear pattern of collaboration in construction and analyse the characteristics of inter-organizational collaboration before we move to BIM enabled projects. We need to find a way to embed this advanced technology in order to better fulfil the vision of collaborative working. Implementing the technology is not a challenge, but how to appropriately adopt the technology is the most difficult issue.

3. Collaboration

Collaboration as a word, which the first instance dates from 1860, means working together with others who share common goals and find solutions in order to satisfy all concerned (Kvan, 2000). Mattessich and Monsey (1992) provided a working definition of collaboration as: “Collaboration is a mutually beneficial and well-defined relationship entered into by two or more organizations to achieve common goals. The relationship includes: a commitment to: mutual relationships and goals; a jointly developed structure and shared responsibility; mutual authority and accountability for success; and sharing of resources and rewards.” (pp. 39)

Patel et al. (2012) also defined collaboration as involving two or more people working and interacting within a single task or series of processes. These people worked together towards a common goal. These definitions identify the characteristics of collaboration. The essence of collaboration is common goal, shared responsibility and joint completion at a project level. These characteristics are also the key factors of project success in construction projects. Son and Rojas (2011) explained the evolution of collaboration within inter-organizational networks in the large complex project based team. Xue et al. (2010) claimed collaborative working was recognized increasingly as one of the most important critical success factors in the construction process, and collaborative working became a new management paradigm in the construction community. de Saram and Ahmed (2001) confirmed that collaboration and communication is the key to achieve project objectives. To better understand and analyse it, we examine collaboration in more specific conditions and at different levels.

4. Multi-level Collaboration

Kvan (2000) reported that cooperation was used interchangeably with collaboration as seen in the literature. Overuse of “collaboration” on any type of inter-organizational or personal relationship impedes the practical evolution (Gajda, 2004). Czajkowski (2007) argued that although the term collaboration was interchanged with cooperation and coordination, they represented three different levels of formality and structure in the relationship processes in inter-organizational relationships. In practice, few scholars emphasize the differences among cooperation, coordination, and collaboration. Cooperation exists with informal relationships and without common objectives, structure or planning effort. Each organization retains their authority and shares information when it is necessary. There is virtually no risk and the

resources are as separated as rewards; Coordination is more formal than cooperation on relationship issues. Each organization has compatible missions yet still maintains their own authority, but there is an established communication channel. Resources and rewards are both mutually acknowledged. Risks are increased to all participants; collaboration presents a long-term strategic relationship. Collaboration aggregates different organizations into a united structure with one common goal. In this relationship, authority is determined by the organizational structure. To maintain this relationship, it requires effective communication and comprehensive working schedule. Therefore, each organization shares their outcomes and risks although they contribute their own resources and reputation (Mattessich and Monsey, 1992).

Marchington and Vincent (2004) examined inter-organizational relations at three levels: institutional, organizational and interpersonal levels. This distinction allows us to review the factors that encourage collaboration separately.

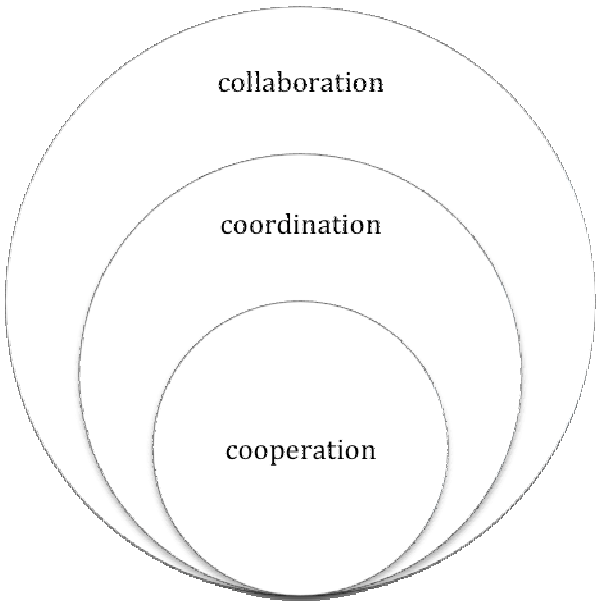

Fig.1 Categorization of Formality of Working Relationship

Phua and Rowlinson (2004a) confirmed that cooperation was vital to construction project success, and they claimed that intra-organizational cooperation was more important than inter-organizational cooperation. Because Intra-organization was more manageable than inter-organization, and individual firm could better control over the work behaviours of their employees in intra-organizational condition. In this paper, we discuss collaboration at project level. Based on the formality of working relationships, we categorize interactions into cooperation, coordination and collaboration (Fig.1). Cooperation allows individuals to share information supporting others for organizational objectives. Coordination is the activities in which different entities share a goal in order to achieve mutual benefit. Collaboration is that different professions give up some degree of independence to realize a shared goal. So the interactions among three categories could be analysed.

Cooperation at the individual level is fundamental to the collaboration. Individual cooperation provides further opportunities of coordination among different parties. Different parties still conserve their independences in the context of coordination. Fragmentations still exist at this level. A collaborative working relationship evolves from individual cooperation to team coordination and then inter-organizational collaboration. Base on the good inter-organizational relationships, project integration is achievable through the construction process.

5. Key Factors of Inter-organizational Collaboration

Gajda (2004), adapting figures from Bailey and Koney (2000), argued that collaboration was a journey, not a destination cross the continuum of integration. Anvuur (2008) analysed four types of cooperative behaviour and its impact on the organization. To achieve cooperative behaviour, he also claimed that four essential factors for optimal working relationships in construction, such as common goals, mutual respect, group interaction and support of the authorities and egalitarian norms were needed. Anvuur (2008) also found that contract types decided the nature of cooperation among organizations, some contract incentives may motivate organizations to cooperate, and some may work against the objectives of the project organizations. Mattessich and Monsey (1992) identified 19 factors that influence the success of collaboration based on six categories. Environment, process, structure, communication, purpose and resources are further developed in their study. Phua and Rowlinson (2003) also claimed that culture as a key factor that impacts inter-organizational collaboration. Cultural differences could moderate the contextual variables such as organizational structure. Cultural differentiation leads to inter-organizational differentiation. Better understanding of the influence of culture of organizational cooperation could improve the management of construction projects. Previous researchers identified collaboration factors from a general level rather than any specific industry. Some researchers analyse collaboration factors more specifically in the context of construction projects. Succar (2009) categorized leadership, infrastructure, human resources and products/services into process fields. In his framework, he used these to distinguish among these sub-divisions in order to define BIM stages in detail. Leadership is combined with management decisions, organizational processes and communication activities. Management decisions represent vision and culture; organizational processes represent management; and communication activities include internal and external communications.

6. BIM Collaboration Framework

Selected practitioners were invited to participate this research. Emails were sent out to the potential contacts. Eight industry practitioners with more than three years of BIM experience replied and agreed to meet. Face to face interviews were adopted to investigate the impact of BIM implementation and the potential for collaboration improvement. The interviewees were invited from three different BIM enabled construction projects. Based on the literature review, further discussion related to BIM collaboration was developed. A conceptual framework was structured accordingly (Fig. 2). Key factors that facilitate better BIM collaboration are identified.

Through the interviews, most practitioners agreed that promoting collaborative effectiveness of BIM is a systematic issue. It is multi-relational and a dynamic evolution through people, process and technology. Managing a successful BIM enabled project requires an integrated and balanced approach to technology, process, and people.

First, technology as the antecedent is the driver for the whole construction industry to embrace BIM implementation. When the current technology can satisfy practitioners to adopt practically, people may take it on board and enhance it. Technology innovation, as an enabler to improve project performance, provides dramatic improvements in documentation, communication and visualization. Thus management of new technology is crucial to implementation. For better collaboration, current BIM technology could do better such as open standard, interoperability and communication. An open standard may integrate different work done by different professionals. Building information and data is core value and product of project service. Exchange of Building information and data among project participants is crucial to the performance. A standardized exchange protocol is the key to communication through new technology. Communications enhance mutual understanding and information exchange improves communication efficiency. Standard and communication both decide the performance and applicability of BIM technology. In order to take full advantage of BIM, project organizations need to optimize the level of interoperability. Lack of interoperability challenges the acceptance of technology and project progress. Therefore, analyses of standards, communication and interoperability are of major importance in promoting BIM application.

Second, a person is even more important than the technology itself considering successful BIM implementation. Implementing BIM requires changes to organizational culture and process. Individuals who are key players of new technology and execution strategy need supporting management skills. Professional knowledge and personal commitment are critical to successful project delivery. A certain degree of professional knowledge and training are essential at the beginning of BIM implementation. No matter how perfect a technology is, it is only a concept until people decide to adopt it. Incentive strategy could further motivate people to experience new technology more widely. Certain incentives can stimulate individual commitment to project team. The more people involve with new technology, more feedbacks and innovative improvements are provided. Since the technological communication became available, people also need to communicate among project teams. A functional communication path can strengthen the collaboration through sharing knowledge and exchanging ideas. They could strengthen the team relationships through communication and increase the efficiency of BIM implementation. Most of our interviewees claim that good leadership is also important to the success of BIM implementation. Leadership could mean a good BIM manager in a project, or it could be a committed project organization that encourages collaboration.

At last, professionals with efficient resources and state-of-art technology are able to provide services and deliver qualified products. However, process change can lead to negative impacts on the final product. Understanding construction process and optimizing process can reap advantages through productivity and efficiency. When technology is applicable and people master the skills, process needs to be revised according to new circumstances. To

implement a more collaborative BIM, construction project needs a new contract strategy that better fulfils the demands of BIM implementation. We found most of the BIM enabled construction projects are still under the traditional procurement system. This impedes the potential functions of BIM. Besides contract issues, organization structure is another barrier to BIM collaboration. Routinized organization structure may also eliminate BIM's potentials. The rigid structure also constrains individuals' authority. Individuals do not expect to take more responsibility and the organization structure decreases the flexibility of project management. Interviewees also suggest optimizing resources to facilitate team collaboration is crucial to BIM success. Each professional has their own resources and advantages, but sharing resources is difficult. In a word, successful BIM implementation relies on the revolutionary change from all the aspects. Industrial participants should have a clear framework before they could implement collaborative BIM successfully.

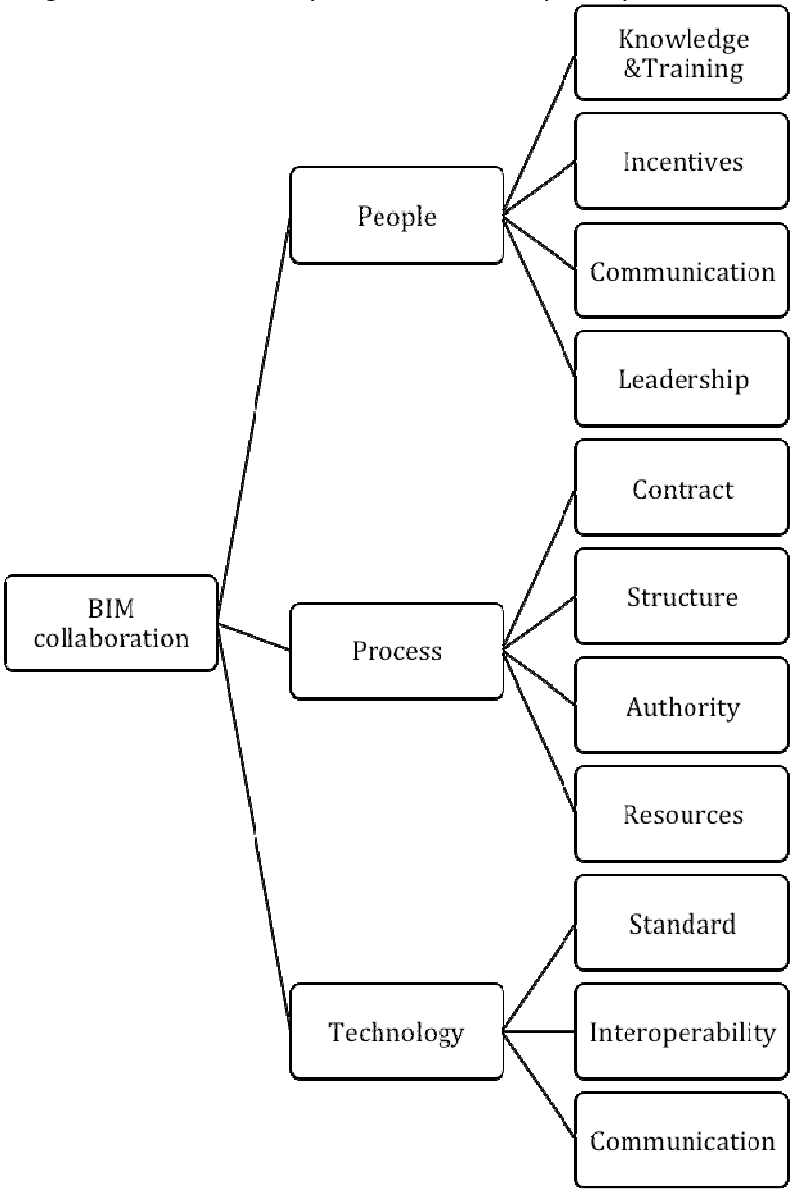

Fig.2 Key Factors of BIM Collaboration

7. Discussion and Conclusion

Multi-disciplinary professionals work together so that projects can be executed accurately. Recognizing that collaborative efforts facilitate achievement of organization objectives, researchers and practitioners attempt to set up strategies that foster a collaborative culture among players. BIM implementation breaks the traditional relationships among clients, architects, engineers and contractors. The roles of participants need to be more flexible, interactive and collaborative in the construction process. Collaboration is capable of empowering individuals and connecting fragmented systems in order to address social concerns (Gajda, 2004). The designers traditionally retain their authority and judge the contractor's performance with their initiatives of project success, and contractors always take compliance with the minimum requirement of contract standards. Even though contractors may have superior knowledge of alternative solutions that may benefit the project, they still choose to process the orders conventionally. These adversarial relationships impede knowledge sharing which offers the greatest opportunity to improve project performance. Collaboration is the key to capture that information (Allen et al., 2005). Collaboration in the construction industry is different from other sectors. First, the project organization is a form of multi-disciplinary representatives who have different objectives, goals and cultures. Second, duties and reliabilities are all project oriented in a short term. Partnerships may conflict with each organization's long-term objective. Last, organizations are dynamic. Some representatives may leave before project completion, but impacts of their previous decisions and actions may affect the final outcomes of the project (Kalay, 2001). Greenwood (2012) tested different degrees of collaborative working that is relative to project performance, and he identified that higher level of collaborative working is more likely to produce higher level of project performance and vice versa. Other researchers also opine that working relationships have positive impacts on project performance in terms of construction time, cost and quality (Larson, 1995, Phua & Rowlinson, 2004).

Gajda (2004) identified collaboration as the most highly developed level of integration. Project team collaboration and inter-professional support are essential to BIM implementation. Interactions within the system and the interactions among project participants are the most important aspects to be encountered (Kvan, 2000). Working collaboratively, professionals can share their knowledge and pool scarce resources in order to achieve an objective that would not otherwise be possible to obtain as professionals working separately (Gajda, 2004). Kvan (2000) concluded that collaborative environment could not be created simply with hardware and software tools, and over-reliance on tools was less cost effective use of resources. AIA (2009) claimed that collaboration increased the efficiency, and the adoption of BIM could enhance collaboration. However, it could not guarantee that such collaboration is best for project thinking and primary principles. Hansen and Nohria (2004) identified five advantages of good collaboration including increased profit by expertise sharing, cost reduction by practice sharing, improved decision making by knowledge sharing, innovation by ideas sharing and improved achievability of goals. Thus, collaboration issue is highly important to the success of BIM implementation and to the project performance finally.

Based on the analysis, this research clarifies the importance of collaboration and identifies the relationship between collaboration and BIM implementation success. In other words, collaboration is the key factor in measuring the success of BIM implementation in a project. Therefore, BIM as the vehicle of project delivery aims to integrate project activities rather than be a simple communication and simulation technology. More importantly, few researchers to date have explored the factors that may encourage participants to adopt more collaborative ways of working. Efficient and effective communications are essential to the successful completion of construction projects. However, this finding needs to be qualified by considering the inter-relationships among people, process and technology. Although technology could create a communication environment for virtual users, it may also hinder the sense of cohesion and satisfaction of interaction, and the interactive links are associated with the effectiveness of information exchange.

Projects as temporary social systems in different contingencies and multiple contexts require further demonstrations. Analysing the recursive interplays among actors, organizational structures and technologies are important. First, BIM implementation changes the traditional working process. Second, the organizational contexts constrain the BIM development. So BIM can improve the inter-organizational collaboration, but this advantage can also be constrained by the existing organization context.

Despite the massive investment in BIM, it is impossible to divorce interpersonal and inter-organizational collaboration from the construction process, which is rooted in project success. BIM tends to break the cultural and organizational boundaries by integrating communication and collaborating team participants. Collaboration is able to achieve greater efficiency, but projects need fundamental change to fit into BIM thinking. In this paper, we argue that the study of inter-organizational relationships is important to project success. But it is difficult to generalize a collaboration theory. It is necessary to consider the different levels of collaboration. This research also identifies the inter-relationship between BIM performance and collaboration. Unlike the studies that have been conducted in BIM, it is clear from our research that technology is not the critical issue to successful implementation and project collaboration. It depends on the factors related to people, process and technology as a whole. Further, how to link the project success with innovative technology is demonstrated. In summary, we have argued that inter-organizational collaboration needs to be analysed before considering BIM implementation. Although it is difficult to develop a collaboration model, significant factors could be identified such as contractual issues and organizational structures etc. This study reviews past research on collaboration within social and behavioural contexts. Further exploring the impacts of BIM implementation in a construction project, we identify the importance of collaboration. With the demonstrated relationships between BIM and collaboration, understanding the fundamental issues of collaboration is beneficial to the decision makers in adopting appropriate BIM strategies in future. The study of inter-organizational collaboration could facilitate people reviewing the initiatives of BIM implementation and strategy to further achieve integration.

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Heart and mind: the role of time in design related decisions

Leentje Volker[1]

Abstract

We make numerous decisions every day. Some decisions are based on a range of explicit and material alternatives, others are constructed from implicit ideas about the options we have in mind. In preparing a construction project, creating a vision on how the future would look like appears to be one of the most important activities. This is usually done through design sketches. This paper focuses on the interaction between people and the alternatives they face when make decisions that relate to the built environment. My argument is built upon two research traditions - valuing design from a cognitive perspective and psychological processes of decision making, and exemplary empirical observations from my previous work. First the concepts of architectural design quality and value dimensions of a product are addressed, bringing us back to the essentials of Vitruvius. Then I show how sensemaking and intuitive decision making do justice to the complexity and ambiguity of making design related decisions. In the conclusion I argue that value judgements should be considered as a result of the interaction between a product and an individual person in the context of a group or society. Consequently value judgements are essential in sensemaking processes leading to decisions. They integrate arguments from the heart and the mind, leading to particular preferences among individuals. Since decisions are often considered satisfactory for the moment, but outmoded the next, time plays an essential role in creating meaning of design related situations.

Keywords: decision making, design, intuition, sensemaking, time

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1. Introduction

We make numerous decisions every day. Some decisions are based on a range of explicit and physical alternatives, while others are grounded in implicit ideas. Somehow we have to find a way to communicate about our preferences and the direction of our decisions. This paper focuses on the design related decisions and the role of time. Many aspects of this process are intangible by nature. Social science can contribute significantly to the understanding of psychological processes of decision making in the context of architectural design. The insights from this field of science identify situational characteristics in the dilemmas that project managers, client representatives and other actors in the construction industry face when dealing with design. My argument in this paper is built upon two research traditions: valuing design from a cognitive perspectives and psychological processes of decision making. In both traditions the concepts of *perception* (e.g. Bell, Greene, Fisher, & Baum, 1996; Tversky & Kahneman, 1981), *intuition* (e.g. Dane & Pratt, 2007; Sadler-Smith & Sparrow, 2008), *judgement* (e.g. Gifford, Hine, Muller-Clemm, & Shaw, 2002; Hogarth, 1988), *expertise* (e.g. Hekkert & van Wieringen, 1998; Hutton & Klein, 1999), and *emotion* (e.g. Desmet, 2002; Simon, 1987) play an important role. These concepts all strongly relate to the use and perception of time. The line of reasoning and choice of research traditions are fed by empirical examples from my previous work on client decision making during architect selections (Volker, 2010). Throughout the text I refer to situations or quotes of decision makers in explaining their behaviour, therewith addresses the concepts of intuition, emotion and perception.

The paper is built around a theoretical argument about the strong influence of time in design related decisions. First I will address the architectural perspective on the dimensions of the value of a product, which can be traced back to the essentials of Vitruvius and product experience. Then I will show how sensemaking and intuitive decision making do justice to the complexity, temporality and ambiguity of making decisions about design.

2. Design judgements

2.1 Quality and value

Discussions in architecture often relate to actual buildings of bricks and stone or to designs as future representations of the buildings. Holistically, design quality can be seen as the achievement of an integrated totality that is more than the sum of the parts (e.g. Bártolo, 2002; Dijkstra, 2001). However, during communication and discussion, design quality is often decomposed. The oldest known operationalisation of architectural quality (about 25 BC) is that of the Roman architect Vitruvius, which distinguishes three aspects: ‘Utilitas (commodity), Firmitas (firmness), and Venustas (delight)’ (Gann, Salter, & Whyte, 2003). This trilogy has been a source of inspiration for architectural theory since then and continues to be so for several contemporary researchers. Every scholar appears to create his or her own version of the list of characteristics of a design, while at the same time these lists basically cover the same things. Macmillan (2006) for example distinguishes between exchange, use, image, social, environmental and cultural value for the built environment while Gann and Whyte distinguish ‘functionality’, ‘build quality’ and ‘impact’ (Gann et al.,

2003; Whyte, Gann, & Salter, 2004). Authors who not only consider the building but also include the development and management of a building often expand this trilogy with contextual factors and future perspectives, such as finances, time and resources (Gann & Whyte, 2003). *Quality* is strongly related to *value*. From this perspective Wandahl (2005) defines product value as the value which an individual places upon an object or outcome. The act of valuing is thus dissociated from the value itself. Also, it becomes possible to allow for the fact that different people may hold different beliefs or preferences based on the same value. Macmillan (2006) distinguishes several comparable main types of value of a mixture of tangibles and intangibles between stakeholder groups. These value types are related to the different building types described by Loe (2000): use, exchange, image and business value buildings. Finally Bucciarelli (1994) concludes that design is a social process and the objective reality of a technological artefact is in fact a social construct. The design object is consequently always alive, beholding uncertainties and ambiguity.

The distinction between quality and value appears to lie in the objective or subjective character of its judgement. Value assessments can be subjective when framed against an individual's values, while quality assessments can be considered objective when the relationship between benefit and expense is compared on a level of fulfilment of requirements (Thomson, Austin, Devine-Wright, & Mills, 2003). These same authors conclude that value is the relationship between positive and negative consequences for an individual (output and input, or benefits and sacrifices). "When a consumer asks him or herself 'is it worth it?', they are making a value judgement in light of their own, often tacit, values and comparing this with the market value assessment (typically expressed as a price)" (Thomson et al., 2003, p. 337). In this sense *value judgements* are seen as rational considerations of individual decision makers at a specific time among the different value types that can be addressed to (future) buildings. Yet, discussions about *architectural design quality* tend to focus on the qualities of the product itself and about architecture in relation to societal value. Functionality, impact and build quality imply a judgement about tangible and intangible product qualities from the perspective of a person experiencing objects in the built environment. There seems to be no real difference between discussions about realised objects or designs as projections of future buildings. In this respect time does not make a difference. However, in real life we do experience these kinds of differences. I argue this has to do with the fact that scholars in construction usually exclude other individuals than themselves in their reflections. This differs from the field of product design experience, which is based on the assumption that value assessments cannot been seen separately from the person perceiving the object. This will be discussed in the next section.

2.2 Product experience

The field of product experience mainly originates from the field of cognitive psychology, emotion and perception (Schifferstein & Hekkert, 2008). In this field the interaction between the individual and the product is the main point of reference. From this perspective three components or levels of product experience are distinguished: aesthetic pleasure, attribution of meaning, and emotional response (Desmet, 2002; Desmet, Porcelijn, & van Dijk, 2007; Hekkert, 2006). At the *aesthetic level* a product's capacity to delight one or more sensory modalities is considered. The degree to which a person manages to detect structure, order,

or coherence and assess a product's novelty or familiarity typically determines the affect it generates. This can be explained by examining the evolutionary basis of the human perceptual system (Kaplan, 1987). In this sense time only changes the result of the interaction and not the character of the interaction. The *experience of meaning* concerns the cognitive processes of recognition, interpretation, association and assignment that attach a meaning to a product. These processes are subject to individual, cultural and physical differences (Hekkert, 2006) and thus dynamic in nature. The *emotional response* relates to the result of a cognitive, though often automatic and unconscious process caused by the interaction of the human with the product. According to Desmet (2002) an emotion is elicited by an evaluation (appraisal) of an event or situation as potentially beneficial or harmful in relation to the person's product concerns. It is the interpretation of an event (or product) rather than the event itself that then causes an emotion. Because appraisals mediate between the products, concerns and emotions, different individuals who appraise the same product in different ways and different times will experience different emotions. Product experience thus largely depends on emotions related to a specific person, a specific time and a specific place.

2.3 Valuing design

Based on the preceding perspectives I argue that design quality actually is as an overall value judgement by an individual person, based on the interaction between a person and an object in the built environment (see Figure 1). The product experience literature teaches us that a judgement includes an assessment about the level of quality as well as an affective response. Only then a product is associated with a certain value. In this sense the product receives its value *after* its meaning is interpreted by an individual. Individuals act in the context of their personal value system of goals and expectations, which is applied during the judgement (Thomson et al., 2003). If assessments are made in groups, a value system is developed among the members of the group, which could again influence the individual value system (Kelly, Male, & Graham, 2004). Furthermore, the individual value system is influenced by personal, social, and external variables of the context. Differences in value judgements can thus be assigned to a difference in the weight of values (Mills, Austin, Thomson, & Devine-Wright, 2009), the amount and use of information during the judgement (Soane & Nicholson, 2008), or a difference in training of the expression or verbalisation of product experience (Hekkert, 2006). I presume that the stage which a product is in – a representation of a future product or a physical object – is part of the information that is available during value judgement. As such the process in time influences the value judgement process.

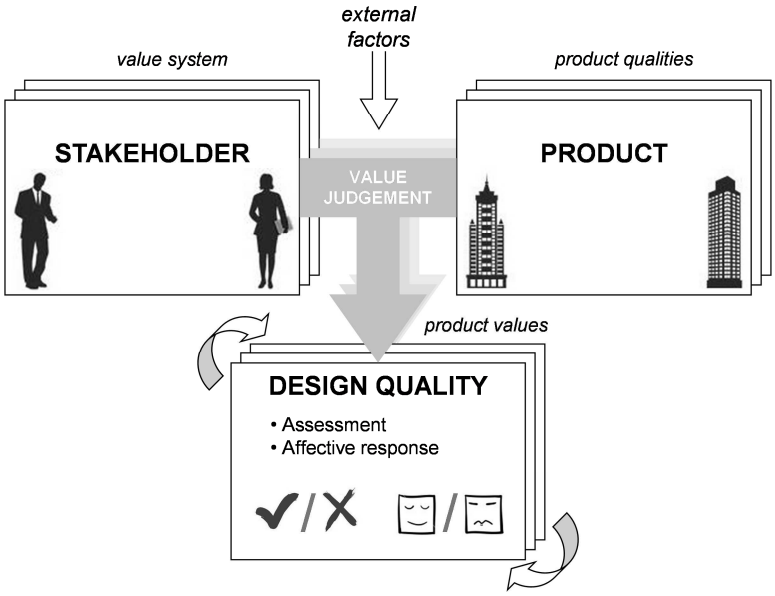

Figure 1: The concept of design quality defined as value judgement

3. Making design related decisions

3.1 From value judgement to decision making

Talking about design related decisions suggests individual value judgement. Yet, real life situations often involve a consensus among members of a group. Following the literature from organisational psychology, decision making is a way to align expectations and needs to reach goals (Hodgkinson & Starbuck, 2008). As also addressed by Tzortzopoulos, Cooper, Chan, and Kagioglou (2006), actors in construction have to make decisions in a strategic, dynamic and elusive organisational context. Decision making in a design environment should therefore be considered as an iterative process of different kinds of value judgements, resulting in different kinds of product values. These values are not easy to sum up and justify as one 'truth' because they are based on perceptions of the group members at a specific time. The theories of *bounded rationality* (Simon, 1997), heuristics (Tversky & Kahneman, 1974), and *intuition* (e.g. Gore, Banks, Millward, & Kyriakidou, 2006) are different explanations of how decisions are made in complex situations with a lot of uncertainties. They show that not every decision is rational and conscious by nature (Hogarth, 2005; Sinclair & Ashkanasy, 2005). *Context and problem structure* play a crucial role in determining the appropriateness and efficacy of judgements (Klein, 2004). Affect, mood and emotion are other reasons that people could behave different from existing theories and models (Beach & Connolly, 2005). The concept of *sensemaking* (Balogun, Pye, & Hodgkinson, 2008; Weick, 1995) attributes to the understanding of decision processes and the importance of the justification of a decision in organisations (Vidaillet, 2008). In this argument I therefore take the concepts of sensemaking and intuition to address time and the iterative character of judgement processes in the built environment. These concepts will be illustrated by empirical findings from four case studies in which clients had to decide on the best architect for their future accommodation (Volker, 2010). These situations can best be compared to architectural competitions in which several architectural firms submit design

proposals in order to acquire a new job (Strong, 1996). The data was collected by (participatory) observations, interviews and secondary document analysis. The purpose of the examples used in this paper is to strengthen the argument and show why and how the concepts of intuition, emotion, time and perception can influence the perspective on design related decisions.

3.2 The role of sensemaking

Sensemaking involves the ongoing retrospective development of plausible images that rationalise what people are doing (Weick, 1995; Weick, Sutcliffe, & Obstfeld, 2005). It has its genesis in disruptive ambiguity and its mixture of retrospect and prospect. Aspects that directly relate to time and the perception of events by a decision maker. "Sensemaking pays attention to how people 'deal with' (whether unconsciously or otherwise) constraints imposed by the information processing limitations and their organisational context, delving into the socio-political nature of organisations to show that the answer to better decision making does not necessarily lie with the provision of greater quantities of 'more accurate', 'objective' and timely data, but rather requires an understanding of the social processes of negotiation involved in decision making" (Balogun, et al., 2008, p. 235). Central questions are how an event comes to happen and what does an event mean. Weick et al. (2005, p. 409) emphasize that sensemaking is about the interplay of action and interpretation rather than the influence of evaluation on choice – "it is a process that is ongoing, instrumental, subtle, swift, social and easily taken for granted". Present, future and past interchange, illustrated by a quote of one of the jurors: *'I finish this project in my mind... It has so much potential'*.

In each case it was found that in the process of selecting an architect in tender the design related decisions consist of four steps: 1) *initialisation* by interaction between the problem definition of the client (a brief) interpreted by the architect, 2) *confrontation* as the proposals of the architect were presented to the clients, 3) *communication* about the preferred parties based on a the perception, value judgement and decision making within the organisation, followed by 4) *confirmation* in case a contract is signed. An urban planner involved in one of the cases explained that interpretation relates closely to expectations of the clients: *'Clients hire an architect to visualise their ideas and therefore they are looking for an architect in line of their thinking'*. Especially between the confrontation and communication sensemaking takes place. Clients are suddenly confronted with a visual response to their requirements. Observations showed that they first started to evaluate how and to which extent the submissions fulfil their personal needs. This is partly done by explicitly evaluating the official tender criteria, but also relies on the positive surprise or affective response towards to the proposal as also described by Desmet et al. (2007). One of the jurors argued that a certain submission *'feels like a caravan exhibition hall'* instead of a faculty building. With a humoristic tone of voice a member of the Christian party described his argumentation to choose for a particular design during the public debate: *'It was love at first sight. First I wandered what it was; a bee hive, a space ship, maybe a centipede. But then I saw it: It is an Ark. The heart was touched...".* These expressions not only illustrate the sensemaking process during the interpretation of the proposal but also the affective response triggered by it and the role of emotion in making decisions.

Balogun et al. (2008) define sensemaking as a social process of construction and reconstruction of meaning that enables individuals through interacting with others to collectively create, maintain and interpret the world. The intertwined concepts of 'framing' (shaping the meaning of a subject and sharing it with others), 'sensegiving' (attempts to influence sensemaking and construction of meaning toward a preferred redefinition of social reality), 'sensereading' (perception of circumstances and aligning of interpretations), and 'sensewrighting' (inheriting, shaping and reflecting the understanding of the world) are all related to the resource, process and meaning of power effects in organisational decision making (Balogun et al., 2008). All elements of this definition show the search of decision makers in time. One of the architect described why decision making is so hard for client organisations: *'A public client is in fact not a single client but a monster with many heads, a conglomeration of clients who does not know what she wants and always tries to find a solution in the middle.'* Yet, to sign a contract this quest needs to end in a clear decision. This is difficult since they *'feel responsible'* since the implications can be large: *'we have to act as decided'*. Fortunately, as an experienced jury members explains, *'almost every jury process eventually leads to a satisfying results'.* The term satisfying emphasises the temporarily and the relativity of the decision.

3.3 Rationality and intuition

An underlying issue in decision theories is the level of rationality of decision makers. According to Simon (1997, p. 84) "rationality is concerned with the selection of preferred behaviour alternatives in terms of some system of values whereby the consequences of behaviour can be evaluated". This means a decision can be objectively, subjectively, consciously, deliberately, organisationally, or personally rational. Etzioni (1988, p. 136) defines rationality as "the concept of a man who acts wisely, and who chooses efficiently the means that advance his or her goals. Rationality entails deliberations; it is not automatic or non-conscious and can vary by degree. It is based on openness to evidence (an empirical orientation) and on sound reasoning (logic)". Yet, *'what sounds logical from one perspective, does not make sense from another'*, as rightfully notices during a validation workshop. Dean and Sharfman (1993) argue that a rational action is feasible if decision makers are in agreement about goals and cause and effect relationships and if they are aware of the environmental and other constraints. Yet, in many situations decision makers cannot rely exclusively upon rational methods due to complexity and uncertainty. Understanding conscious choice requires the knowledge of the perspective of the actor at the time of choice: an action that appears irrational after the fact, might have appeared perfectly rational when the actor chose it (Hodgkinson & Starbuck, 2008). An architect explained: *'one always selects who one trust, who makes one feel right. They just see what happens next'.*

People actively try to influence events in order to make their choice the right choice (Balogun et al., 2008). This results in strategic behaviour. During the jury deliberations a juror said: *'I notice what you are doing and I went along in your direction for a long time, but this is the limit'*. This does not only affect the direction of the decision but also the potential of the personal relationship: *'We will still be friends if you leave this one out but I still think it is a very strong project'*. The observations showed that experts were better at positioning arguments in the discussions. Their frame of references appeared to be more robust than

the novice decision makers, which also reflects on the power of decision makers in discussions: *'I just sat there with my eyes and ears wide open. I am a layman: I did not find time to say anything useful'*. Experts also communicate with little words in underpinning their preferences and posing arguments in favour of a certain submission. They convince each other by using short phrases such as 'interesting', 'not very realistic', or 'attractive scheme'.

According to Dane and Pratt (2007) there are two sets of factors that influence intuition effectiveness: domain knowledge factors (development of schemas by explicit and implicit learning) and task characteristics (intellective versus judgemental tasks, environmental uncertainty). Well-structured problems might be compared to tasks with objective criteria for success within a particular conceptual system, while ill-structured problems seem similar to judgemental tasks for which there is no objective criterion or demonstrable solution (Dane & Pratt, 2007). In tightly structured, intellective tasks in data rich, objectively quantifiable, and computationally complex domains, statistical models perform better than human judges (Sadler-Smith & Sparrow, 2008). It can therefore be concluded that in loose decision structures with moral, political, ethical, aesthetic or behavioural judgemental tasks, ill-structured strategic problems with little precedent and information to draw on and in situations with time pressure, dynamic conditions and experienced participants, intuition is favoured over analytical approaches (Hogarth, 2002; Klein, 2004). Making reasons explicit could lead to inferior decisions and less satisfaction about the decision (Wilson & Schooler, 1991). This is explicated by one of the committee members who openly stated that *'I only used the criteria because you have to be transparent and because you have to explain later on. But I did not look at the criteria during my judgement process; I would lie if I say so'*.

4. Conclusion

Real-time situations in construction are complicated: information is never complete, the context is dynamic and future perspectives continuously change due to increasing insights. Such uncertainties create an urgent need for time to give meaning to events, integrate the input from both the structured and rational-oriented mind and intuitive and emotion-driven heart, and actually make decisions about design related issues.

In this theoretical argument I have made an effort to integrate concepts from architecture, product experience, decision making and organization science and analyse the origin of design related decisions. Empirical exemplary observations have shown the role of affect, perception and emotion in making decisions. In line with Chan (2012) I consequently argue that it is the perception of time that allows people to make decisions in complex and conflictive situations. Whether these decisions have proven to be right is not easily said: an action that appears irrational after the fact, might have appeared perfectly rational when the actor chose it (Hodgkinson & Starbuck, 2008).

The illustrations also supported the argument that without the interaction between a design and an individual no value judgement can be made, and that without judgements decisions do not exist. Sensemaking is essential in interpreting the options and future value of objects in the built environment. Sensemaking is interwoven with time, just as perception is. They are both integrative activities of heart and mind. For people working in construction, it will be

beneficial to take the relativity and time-dependency of decisions into account when preparing and conducting activities. They also need to be aware that it is during the process of decision making that a decision receives meaning for the members of a group. This, in turn, increases the chance that a decision is implemented into action. In my opinion sensemaking it not something we can or should prevent, we can only facilitate. If we all know what to expect, we would not make mistakes.

Despite the fact that this paper provides an important fundament on temporality in construction, more research is needed to explore the differences in task conditions, the role of time perception and the influence of contextual factors. As indicated by Sadler-Smith and Sparrow (2008) due to the significant developments in cognition, neurology and neuroscience, a fruitful dialogue between intuition researchers from several fields is to be expected. Those studies should not only be based on self-report and experimental research, but also use the numerous opportunities for qualitative methods such as ethnographic work and action research. Another promising areas for empirical research is proposed by Dane and Pratt (2007). According to these authors we should look for the practical implications of the interplay between intuition and analysis and the link between creativity and intuition. Many situations in the realisation of infrastructure projects can be labelled as such. This means that the construction industry provides an excellent environment for time related research initiatives.

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An Evidence Based Online Design Platform: Challenges and Limitations

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Abstract

Historically, the problems associated with feedback in building energy consumption are threefold: a) a lack of information, b) a lack of effective use of the existing data, c) a lack of knowledge how to engage more than the interested few to understand and act on building performance. Whilst introduction of Display Energy Certificates (DECs) created a framework for information generation, their intended role is to place the subject building within the context of similar type of buildings but this data can provide little or no insight into the root causes of the energy performance. To go beyond the headline benchmarking of energy performance of buildings and to provide evidence based design advice to various stakeholders such as building designers, clients/investors, facility managers, and users on how their buildings are performing with regard to their architectural, engineering and occupancy characteristics we need an intelligent and rapid feedback tools/protocols.

It is well known that the useful feedback should contain extensive building design and performance data, benchmarked against similar type of buildings, and accompanied with 'do and do not' reflections from all key stakeholders involved especially the design team and facilities managers. In order to facilitate the need for more comprehensive feedback in the UK, a consortium of researchers from industry and academia has created an online Evidence Based Design platform called CarbonBuzz.

Having this in mind this paper describes the development of an Italian Evidence Based Design online platform using the UK based CarbonBuzz as an example. The paper is set out in 3 sections: a) a framework for platform development, analysing the source of data and completeness of records currently in CarbonBuzz in order to inform the development of the Italian platform and b) a data structure review, identifying potential challenges in translating

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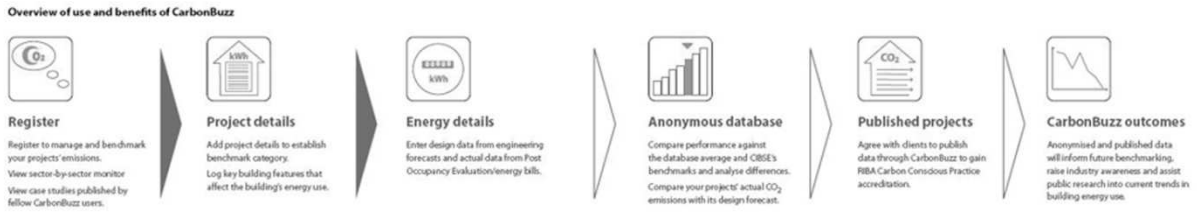
the UK data structure in the context of Italian regulatory requirements, and c) developing prototype, describing the data collection protocol used to inform the development of the Italian platform which follows Evidence Based Design principles with an aim to provide advice on how choices related to design, construction and management of a building impact its carbon emission. The paper concludes by reflecting on these limitations of this development programme and describes some additional features employed by the Italian platform in order to overcome some of these challenges.

Keywords: energy performance, low-carbon design, web platform, post-occupancy evaluation, occupant feedback

1. Introduction

Previous research studies clearly showed that ongoing efforts to deliver low carbon buildings while providing acceptable indoor environmental quality have had little success (Dasgupta et al 2011). The absence of readily available energy use data matched with descriptors for physical forms, indoor environment characteristics, occupant use of space and behaviour affects the accuracy of predicted energy consumption at the design stage and prevents the development of transparent and validated strategy for modelling energy use in buildings. (Prodromou et al 2009). This has been further substantiated by the opinion of 286 UK professionals regarding designing of low carbon buildings, which has clearly identified the inability to predict the actual consumption of buildings as one of the key risks (Dasgupta et al 2011). The discrepancies between operational versus designed performance of buildings have been additionally substantiated by Post Occupancy Evaluation studies (POEs) and as a result the designers and engineers are increasingly under pressure to provide more accurate estimates for energy consumption in buildings and supply guidance to achieve carbon reduction targets. Although essential, the detailed POEs are usually carried out by the interested few in academia and industry, on a small number of buildings involving expensive and time consuming monitoring campaigns, all of which is limiting the possibility to formulate robust Evidence Based Design guidance. Moreover, data collected is rarely collated in a single database and disseminated to inform further research.

To overcome these limitations a number of institutions have embarked on research programmes including: the Building Energy End-Use Study in New Zealand (www.branz.co.nz/BEES); the Energy Efficient Buildings Research programme by the Precourt Energy Efficiency Center at Stanford University in the USA



(http://peec.stanford.edu/buildings/); and a retrofit specific programme in Canada at the Institute for Building Efficiency (http://www.institutebe.com). In the UK, a consortium of partners led by Aedas R&D and supported by the Chartered Institute of Building Services Engineers (CIBSE), the Building Research Establishment (BRE), the Royal Institute of British Architects (RIBA), University College London (UCL) and AECOM, along with other industry partners, has developed an Evidence Based Design online platform – CarbonBuzz (www.carbonbuzz.org). Initially funded under University College London (UCL) UrbanBuzz Programme, CarbonBuzz is a free platform that collects anonymous energy building consumption data to highlight the performance gap between design figures and actual readings of recent projects (Figure 1).

Figure 1: Overview of CarbonBuzz

It is believed that this crowdsourcing data platform would enable researchers and building professionals to map and benchmark the annual energy consumption of a building from design to operation by fuel as well as by energy end uses. In doing so it highlights the gap between design stage predictions and operational energy use and draws attention to 'unregulated' energy use which have a significant impact on achieving expected energy performance (Figure 2).

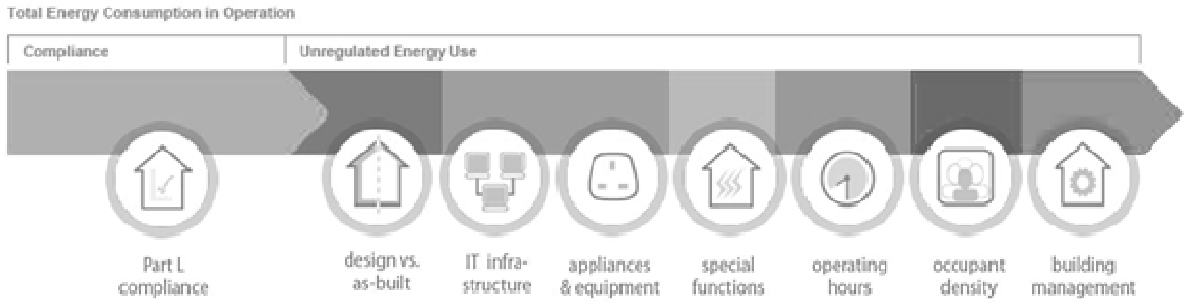


Figure 2: CarbonBuzz – mandatory compliance vs. actual performance

Unlike the UK Climate Change Act (2008) which has committed the UK Government to cut the CO_{2eq} emission by 80% by 2080, the Italian Government adopted lesser carbon reduction targets based on the revised EU Energy Performance of Buildings Directive (EU/31/2010) Strategy 20-20-20 which requires each Member State to reduce CO_{2eq} emissions and the consumption of primary energy by 20% (from 1990 level), and to increase the use of renewable energy supply by 20% by 2020. Within the European Action Plan for

Energy Efficiency, Italy requires benchmarking tools and methods that use actual consumption to verify theoretical estimations. Updating of the legislative framework in Italy (D.Lgs 2005/92, D.Lgs 2006/311, D.Lgs 2008/115, DPR 2009/59, D.Lgs 2011/28) as well as the technical norms (UNI-TS 11300) that introduced standards, methodologies and innovative tools for new construction and refurbishment of public buildings, further action is required to sustain the interventions in this sector. Having this in mind this paper aims to: a) analyse the source of data, completeness of records currently in CarbonBuzz in order to inform the development of Italian Evidence Based Design online platform and b) identify potential challenges in translating the UK data structure in the context of Italian regulatory requirements, and c) describe the data collection protocol used to inform the development of the Italian platform which follows Evidence Based Design principles with an aim to provide advice on how choices related to design, construction and management of a building impact its carbon emission.

2. Framework for Platform Development

To define a framework for the development of Italian platform, a simple statistical analysis was carried out to identify a) type of registered organisations, b) type of registered organisations uploading the energy data, c) type of registered organisations uploading design and actual data, d) number of projects with energy data by building type, and e) completeness of data records. This analysis provides an insight who might be the most interested stakeholders and potential supporters of the Italian platform.

Analysis of CarbonBuzz database shows that the platform had 575 registered users in July 2012, an increase of 42% from 2011 (July 2011- July 2012), across 17 company categories. [Since the time of this analysis the number of registered organisations increased to 674 to November 2012]. The major groups registered: architects (141 architectural practices registered; 23% increase), engineers (82 engineering practices registered; 21% increase) and consultants (59 consultancies registered; 51% increase). An 80% increase in University registrations has to be noted (74 universities registered) which means that 25% of all UK Higher Education Institutions (universities, colleges of higher education and further education colleges that offer HE courses) have been registered with CarbonBuzz (includes university estates as well as research groups). Other organisations include: business management (43), central government (7), computing companies (16), construction (23), local government (14), manufacturers (12), media (2), property management companies (22), quasi-governmental (19) and surveyors (3).

Table 1: Registered organisations contributing energy data

Company Categories	Number of Organisations Contributing Energy Data 2011	Number of Organisations Contributing Energy Data 2012	% Change
Quasi-governmental	8	23	188
Architects	82	100	22
Engineers	18	11	-39
University	2	2	0
Consultants	1	1	0
Business management	4	16	300
Local government	3	1	-67
Total	121	159	31

The overall number of organisation contributing design and actual data has not increased to the same degree as the total number of organisations registered with CarbonBuzz (Table 2). There has been an overall increase of 7%. Consistent with the makeup of the registered organisations and the 2011 data, architects still contribute the highest number of energy records (18 new projects). Table 1 shows large percentage increases in contributions from quasi-Governmental organisations (15 new projects) and Business Management (12 new projects) organisations albeit from a very low base. Note that the reduction in numbers is due to project deletions throughout the analysis period.

Table 2: Organisations contributing design and actual data

Company Categories	Number of Projects 2011	Number of Projects 2012	% Change
Architects	25	16	-36
Engineers	6	6	0
Business management	4	7	75
University	0	1	100
Quasi-governmental	8	15	88
Property	2	0	-100
Total	43	46	7

Table 3 shows that the number of projects with energy data in the database has increased from 299 in 2011 to 381 in 2012, this decreases to 319 if those marked as test are not included in the count. Education is the largest category contributing 42% of the total non-test buildings. 243 (76% of the total) of non-test projects have any energy data (either design or actual electricity or heat consumption data) of these 49 (15% of the non-test projects) have design and actual electricity data and 44 (14%) have design and actual heat consumption data. In total 40 non-test projects (12.5%) have design and actual electricity and heat consumption data for comparison in the database.

Table 3. Projects with energy data by CarbonBuzz sector

Sector	Number of Projects	Number of Projects (not including those marked 'Test')	Percentage of total (non-Test)
Civic & Community	11	11	3
Office	110	85	27
Education	151	135	42
Health	16	12	4
Residential	37	28	9
Retail	21	18	6
Sport & Leisure	20	19	6
Hospitality	6	5	2
Industrial	4	3	1
Other	5	3	1
Total	381	319	100

Of all the projects 96% (306 projects) have a gross floor area figure and 82% (262 projects) have project value associated with the project. However basic building geometry factors are less well represented; circa 15% of projects have a data entry for actual number of storeys and less than 10% have a figure for actual floor to floor height. Less than 50% of projects have figures for actual numbers of occupants and operating hours and almost no projects have detail on facility management arrangements.

Analysis of the data base has identified five types of data entry error: a) format errors, b) unit errors, c) boundary errors, d) category errors, and e) errors with a drop down classification. Most of the above errors can be omitted in the Italian platform through user guidance, adjustment to drop down menus or relational checks being built into the database.

3. Data-structure Review

CarbonBuzz is based on the data structure of the Display Energy Certification (DEC) system, set up as part of the UK's implementation of the EU Energy Performance of Building Directive (EPBD) since 2006. This certification rates operational performance – and the CarbonBuzz tool takes lessons learned from benchmarking actual energy use and applies them to inform design phase predictions. The procedures for a National Calculation Methodology (NCM) for the purposes of production of Energy Performance Certificates (EPC – asset rating) and Display Energy Certificates (DECs – operational rating) are incorporated in software tools developed by the UK Government (SBEM – non domestic and SAP – domestic buildings), however other approved Dynamic Simulation Models (DSM) can be used (IES, TAS, Design Builder). This approach is used for demonstrating compliance with Part L2a of the UK Building Regulations (HM Government 2010). CIBSE TM22 Energy Assessment and Reporting Methodology (CIBSE 2012) data structure represents the foundation of the DEC system and allows for the collection of building information in very general terms from the 'top down', or for users to build up very detailed illustrations of data use from individual loads from the 'bottom up'. The aim of using TM22 as a basis for

collection is in order to provide cross industry coordination and take advantage of data that may already be collected elsewhere.

The current published CarbonBuzz database is split into two subsets: 'Project Details and 'Energy Records'. For a detailed structure of this complex database please register as the CarbonBuzz user. Project Details describe the characteristics of the building and are in turn broken down into:

- Project Details (per project) detailing: building location, building use, number of zones, building ownership and tenancy, design/management teams;

- Project Details (per energy record) detailing: data collection dates, if data comes from a particular data set (i.e. TSB BPE or DEC data), benchmark targets/rating system used, which edition of building regulations applied, embodied energy, any uploaded drawings or images, cost;

- Project Details (per zone) detailing: servicing strategies (lighting, heating, ac, nat. vent etc.), low and zero carbon technologies employed, building fabric details (proportions of glazing, U-values etc.), air tightness, building dimensions, separable or special energy uses, occupancy rates, facilities management strategies.

Energy Records describe the energy consumption associated with the building and are split into Design and Actual data. Each contains:

- Source of data (software if prediction, meter type/frequency if actual);

- Total Electrical Energy use broken down into: Low and zero carbon uses/sources, Building loads (services, lighting), Occupational loads (small power, ICT, catering transport, special or separable functions);

- Total Non-Electrical Energy use broken down into: Low and zero carbon uses/sources, Building loads (services, heating, DHW), Occupant Loads (catering).

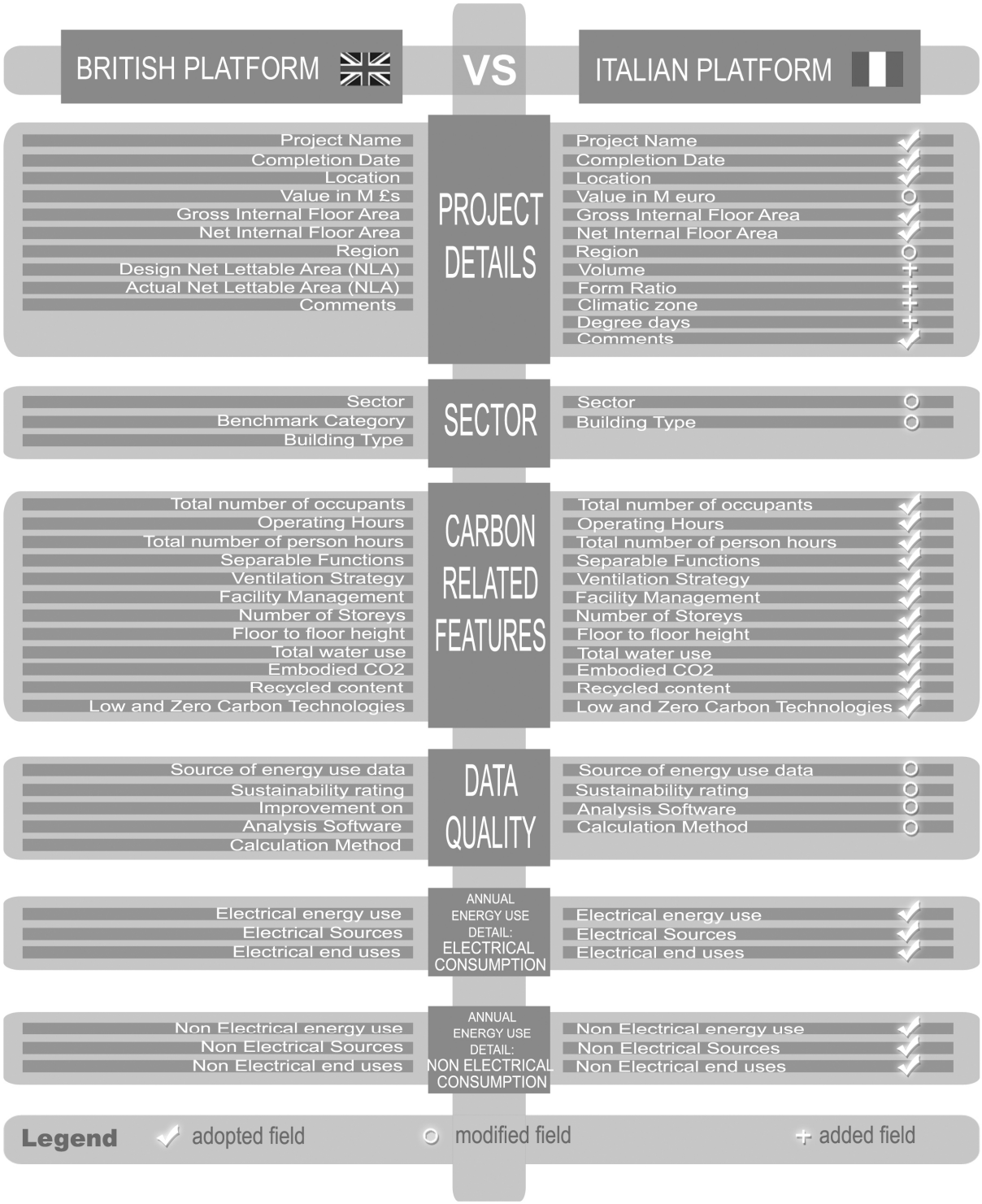
Unlike the UK where users can compare design stage carbon emissions, calculated during the planning and detail design phases against the DEC benchmarks, calculated in kg CO_2/m^2/year (kWh/m^2/year), in Italy the legal limits have been set based on an Energy Performance Index (EPi limit) that is evaluated in kWh/m²/year (for residential buildings) and kWh/m^3/year (for non-residential buildings) which deals with winter heating performance only. The Italian Guidelines for Energy Classification of Buildings (D.M. 26/06/2009) prescribes that the energy class of a building, EPgl (index of global energy performance), is calculated using the following equation (Bianchi et al 2009):

EPgl= EPi + EPacs+ EPe + Epill,

where: EPi: index of energy performance for heating, EPacs: index of energy performance for the production of hot water, EPe: index of energy performance for cooling, and EPill: index of energy performance for artificial lighting. At the moment, the energy class for a building is still determined by the performance index for winter heating (EPi) and hot water production only (EPacs) (Romani et al 2011). For summer cooling, only a qualitative assessment of the building envelope characteristics is required (Boffa et al 2012). The EPi index has to be lower than the minimum fixed value defined by the following parameters; a) heating degree-days for selected climatic zone, and b) surface (external building envelope area) to volume (building volume heated) ratio (S/V). Some regions, in anticipation of the long delayed national guidelines, have developed their own procedures on minimum requirements and the certification of buildings. The Italian platform will incorporate the definition of the minimum requirements and methodologies for the assessment of the cooling energy performance (EPe), also for artificial lighting (EPill), and the regulations on the use of renewable energy technologies in buildings (EU 2008).

Furthermore, the following issues have led to a modification and development of new datafields in the Italian data structure: a) *modus costruendi* (heavy weight continuously supported structure vs. light weight wood/steel frame structure), b) lack of 'cradle to gate' embodied carbon data in Italy: some research has been carried out in this field including the so-called "Accordo di Programma" between the Region Marche and ITACA, l'ITC-CNR and the Polytechnic University of Marche which developed the first institutional database of building materials and products, which follow the CEN TC350 life-cycle analysis methodology developed by the EU, c) a large variety of the environmental sustainability protocols used which are used only in two Italian regions (ITACA Protocol, BREEAM, LEED Italia, CasaClima, Passivhaus), d) lack of regulatory requirements to develop a detailed submetering strategy to quantify energy end uses such as heating, cooling, lighting, small power loads, etc. Figure 3 compares the structure of both British and Italian online platforms.

Figure 3: British vs. Italian database structure



4. Developing Prototype: Data Collection Study

For energy performance feedback to be informative it needs to capture both building design and performance data. Buildings can then be benchmarked against similar typologies and

‘do and do not’ reflections can be added by key stakeholders involved especially the design team and facilities managers. A data collection study was carried out in Rome to identify potential problems in translating CarbonBuzz data structure to the Italian regulatory environment and practice. The work was structured around five key phases:

4.1 Selection of case study buildings

Six buildings were selected to cover a range of ages, building types and building systems. The buildings were listed in three major groups: a) buildings using non-electrical energy sources for heating with no cooling systems or mechanical ventilation (1 case study), b) buildings using non-electrical energy sources for heating with electrical cooling and mechanical ventilation (3 case studies), and c) buildings using electricity both for heating and for cooling (heat pump) or mechanical ventilation (2 case studies).

4.2 Data Collection

The data gathered from the Roma Tre University Estates included the following: a) architectural and morphological parameters (location, orientation, year of construction, heated building volume, usable floor area, building envelope area, S/V ratio, number of floors, floor to ceiling height), b) use of buildings (academic department, number of occupants, office hours, and system operating hours), c) building construction parameters (building envelope characteristics, glazing parameters, etc), d) building services data (heating, cooling, mechanical ventilation, etc.), e) facilities management (energy data, review of energy certificates, interviews with energy managers).

4.3 Inspection of the sample buildings

As part of the data collection the team carried out a series of site visits to verify the information obtained from the desktop study. At this stage further data was collected about mechanical systems via questionnaires aimed at facilities managers. These covered energy consumption patterns and contributing factors including the use of electrical devices, artificial and natural lighting, heating/cooling installations, natural and artificial ventilation.

4.4 Collection of electricity consumption data

Apart from the data obtained from the energy performance certificates the following data was acquired from the energy managers: a) monthly electricity bills and b) half-hourly electricity data for a full year for all the buildings in the pilot. Half hourly electricity data shown in Figure 4 were used in to highlight the limitations of the Italian EPi calculations which according to 2008 implementation of EPBD excluded both EPe: index of energy performance for cooling, and EPill: index of energy performance for artificial lighting.

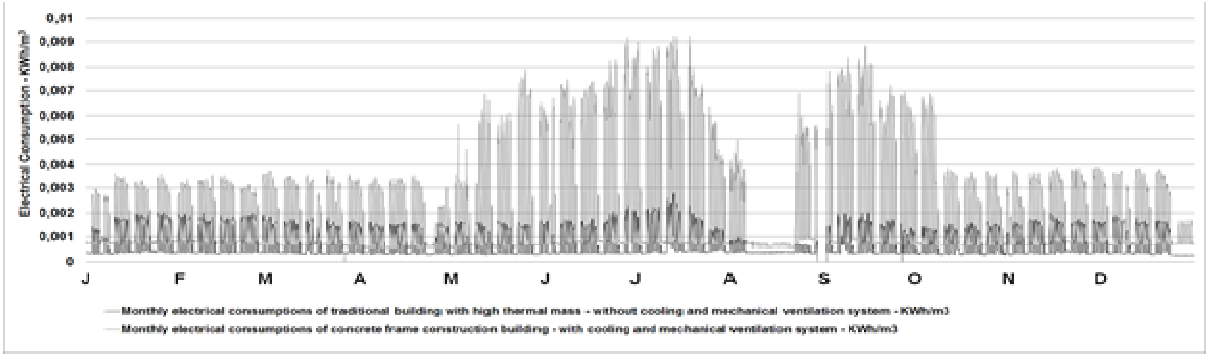


Figure 4: Electrical consumption – naturally ventilated heavyweight building vs. lightweight building with mechanical cooling (half hourly data)

4.5 Non-electric energy consumption

Figure 5 provides the headline energy consumption results obtained from the POEs carried out in 6 case studies. Energy end uses estimated in this way were uploaded into the platform, where it is possible to read either by project or by portfolio.
In this figure and for each case study, electrical and non-electric energy consumption refer to envelope's characteristics (form coefficient S/V represents the ratio between dispersing area and heated volume of the building), structural type (massive building/concrete frame), presence and types of plant systems (heating, cooling, mechanical ventilation).

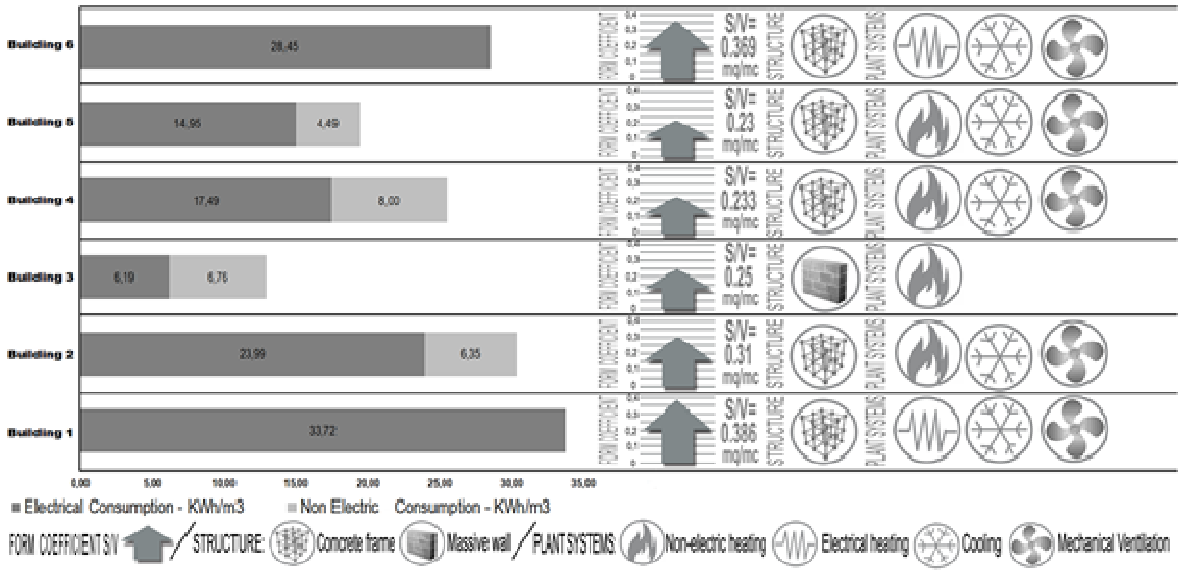


Figure 5 : Overview of energy consumption in 6 case study buildings

Table 4 compares EPi values, which were adjusted to take into account the equipment's intermittence, the building's structural inertia and the equipment's operating hours, with the actual energy consumption and EPi lim values.
For the buildings that have non-electric heating, table 4 compares Epi values (energy performance index) – which derive from energy certificates and were re-evaluated by considering a correction factor due to intermittency of the equipment (which is calculated on

inertia of the building and operating hours) - with actual energy consumption derived from non-electric bills; both values were compared with the limit values of energy performance (Epi $_{lim}$), established by law: in almost all cases the real consumption and the consumptions in the energy certificates were higher than the limit value, but surely the real ones were closer.

Table 4: Actual vs. estimated energy consumption data for 4 case studies (with non-electric heating)

case study	EPi [kWh/m^3/y]	energy class	intermittent factor	revalued EPi [kWh/m^3/y]	non-electric consump. [kWh]	Heated volume [m^3]	non-electric consump. [kWh/m^3/y]	EPi lim [kWh/m^3/y]
2	30,89	G	0,6136	**18,95**	1073337	84476	**12,71**	**7,86**
3	31,03	G	0,7994	**24,81**	119203	17625	**6,76**	**6,89**
4	21,46	F	0,6136	**13,17**	625526	78169	**8,00**	**6,61**
5	35,50	G	0,6136	**21,79**	464198	51645	**8,99**	**6,56**

5. Conclusions

This Italian-UK collaborative research project has reinforced the need for more transparency in reporting energy consumption data to address the lack of evidence and clarity about building performance. It is clear from this study that this data is difficult to get hold of and compare 'like for like' even across a region where this is mandated.

Although the CarbonBuzz has been created to address this problem, a brief analysis of the source and quality of data currently in CarbonBuzz demonstrates that the data available in the public domain is still not sufficient to support the development of an alternative approach (Hawkins et al 2012) for understanding the impact of building design parameters on the energy use in buildings. This is reflected in the fact that only 8% of 575 registered users have contributed both design and actual data. However, the fact that there is a steady increase of architectural, engineering practices using the platform indicates that there is an appetite for this approach. Indeed, the next UK release of the platform has built on feedback from a broad range of stakeholders to incorporate additional functionality to manage and share such data transparently over time and to improve the capture of physical forms, indoor environment characteristics and occupant use of space and behaviour.

The Italian prototype has adopted what were perceived as the strong points of the CarbonBuzz approach including the following principles: a) data structure facilities creation of a database divided into categories where data about CO_2 emissions can be collected and compared like for like, b) facilitating comparison between energy certification and operational energy use (adapted to Italian regulatory context), c) analysis of end use energy consumption, and d) ease of use and accessibility for all users, online sharing of data relating to consumption. The data collection and processing pilot study carried out on 6 university buildings has highlighted how hard it was to get evidence and clarity about

building performance even for new buildings. Capturing project and energy use data from Italian case studies has identified some potential limitations of using the UK CarbonBuzz platform on international projects. These limitations arose from the type of data available, differences in the implementation of EPBD regulations and Italian building types and construction systems. The data collection and processing study provided a very useful insight which has been used to develop a prototype for an Italian online platform which will be presented at the CIB 2013. Further data fields have been inserted into the platform with regard to the following: a) building envelope and its exposure and occupancy to enable implementation of Italian EPBD protocols.

This paper underlined some critical features, together with the necessity of future actions aiming on the one hand to the fine tuning of the system of systematic survey of data and of their informatics management, on the other to the environmental mitigation and infrastructural updating for the energy efficiency of the examined buildings.

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A reflexive capability pathway to commercialisation of innovations using an integrated supply chain: a case study of an innovation in the Australian residential sector

KERRY LONDON AND JESSICA SIVA

A strong innovation culture is critical to the performance of the construction industry. However, the industry has one of the lowest innovation rates of any industry in Australia. The idea of using the supply chain concept to improve industry performance has long been discussed. However there have been limited examples where this concept has had any major impact in terms of performance improvements through the delivery of innovations – or where the improvements have been monitored. The Australian Housing Supply Chain Alliance commissioned a study to investigate the pathway for highly innovative firms seeking to commercialise novel ideas in the housing industry. Eight detailed semi-structured interviews were conducted. A document analysis of organisational records and court reports was also conducted. A narrative analysis was used to map fifty-seven stories from ten key protagonists against the innovation process framework. A critique of the barriers and enablers allowed the development of a structured methodology of 'best practice' for innovations requiring an integrated supply chain approach. Reflexivity theory provided a method to critique the characteristics of the innovator group in how they successfully delivered the innovation to the housing industry. The mapping of the required human capital and the strategizing to develop a cluster of actors whose collective contributions will achieve the design, construction and distribution of the innovation was an important finding. The capacity to overcome barriers relied upon the cluster's adaptability capabilities within the context of an integrated supply chain that enabled them to transform barriers into enablers through the use of human capital. The innovator group had a detailed awareness of the human capital required, its location and ways to access the resources in response to the creation, development and adaptation of the innovation. The importance of this case study is that this was an innovation of national significance. The dissemination of this case study to the housing sector as part of its cultural heritage is important to demonstrate the challenges of innovation within a largely successful innovation implementation.

Keywords: innovation, reflexivity, human capital, case study, integrated supply chain

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1. Introduction

The housing sector has always been seen as an important part of the construction industry. The housing sector generally makes up 50% of the construction industry. In 2012 the

construction sector represented 7.7% of the GDP of an economy (ABS, 2012). In Australia in 2009 the residential sector accounted for approximately $70b and from 2000-2009 the average was 47% of the total spend in the construction industry (ABS, 2010). There are significant problems in the supply of housing in Australia. The Australian National Housing Supply Council (2012) reported that the "housing shortfall (gap) increased by 28,000 dwellings over the year to end-June 2011, taking the cumulative shortage since 2001 to 228,000 dwellings. The Council projects that the national shortfall will increase to 370,000 dwellings by 2016, 492,000 by 2021 and 663,000 by 2031, assuming historic demographic and supply trends continue (the Council's "medium" growth scenarios for underlying demand and supply)." Noticeably, this gap is steadily increasing. The shortfall means we are faced with a crisis in our capacity to plan, design and construct to meet our nations needs unless we act immediately to improve our capacity for a more efficient, effective and innovative supply system. "Housing affordability constraints, cyclical economic factors and barriers to additional housing supply may cause underlying and market demand to diverge considerably" (NHSC, 2012). Housing research in the past has focused on policy and planning problems as the way to address supply challenges (Holmes et al, 2008). To date the housing supply debate has been largely focused on housing demand, affordability and land supply. Lack of innovation in housing supply is considered a barrier to the sector's capacity to meet market demand (NHSC, 2012) and yet very little attention has been paid to challenges experienced by those involved in the design and construction stages of supply. One of the suspected overarching key causal factors of poor housing supply is the fragmented nature of housing supply with numerous actors involved with their own objectives. A lack of coordination and integration between supply chain actors can exacerbate barriers to innovation. It is proposed that a more cohesive supply chain would prove beneficial to all housing sector stakeholders.

The aim of this research was to undertake a detailed case study analysis of successful delivery of an innovation to the Australian housing construction industry. In the 1980s an innovative concrete footing system was designed, tested, developed and constructed to address the problem of high variability in onsite materials management. The need to improve reliability in housing concrete footings was directly related to a business imperative. At the time the state manager of the largest national housing developer was exploring ways to increase revenues through developing efficient on-site materials management. He had observed much waste in materials in the onsite construction processes and vastly differing amounts of materials specified versus actuals used. It is noted that the study makes no comments on whether the innovation actually made a difference to housing affordability and this was not the intention. The genesis of the solution was the 'waffle' slab construction system which was borrowed and adapted from the use of this system for multi story car parks in another part of the country. We don't wish to delve too deeply into definitions of innovations however given that this was not a construction system used previously anywhere else in the world at the time for residential housing footings our study is predicated on the assumption that this was an innovation- ie an application of a new idea to a current problem. As the story unfolded during the study it certainly had all the attributes of being an innovation. The technical innovative aspects were well documented either during the creation and development of the innovation through various engineering technical documents and publications or subsequent to its diffusion throughout the sector. Significantly though, the most important aspect of our study was that the 'human' and 'business' story of

the creation, development and adaptation journey of the innovation had not been uncovered although the technical story was well documented.

This paper explores the innovation journey to create, develop and adapt the concrete footing system. The case study is an example of an innovation that required supply chain participants to behave differently than they had previously. Their conventional norms and practices which were focussed on outcomes and objectives specifically for an individual firm which holds a particular position within the supply chain at each tier for each firm had to be balanced with an overarching a whole of supply chain objective. This research is a first step in addressing the problems of the residential construction market through the "supply chain lens". This paper focuses on the idea that innovative firms seeking to deliver and commercialise novel ideas are constantly responding and adapting their strategies to suit the changing requirements of the innovation process. Firms can deal with barriers and respond to change through the strategic management of human capital including social, cultural and intellectual. The paper begins by briefly outlining the theory that underpins this study which is a combination of innovation diffusion and construction supply chain theories. We fundamentally seek to begin to make contributions through this small study to construction supply chain theory. This is then followed by a brief description of the methodology undertaken for the study in terms of the data collection and analysis methods. A discussion of the innovation pathways methodology is presented in relation to the creation, development and adaptation stages of the innovation process. The interpretive framework is extended from previous work undertaken by London and Siva (2009, 2011) whereby they borrowed and adapted from Bourdieu's reflexivity theory to consider how firms manage a changing international environment. Reflexivity has its derivation in sociological research (Giddens, 1991). It is based in a positive interpretation of change and a continual responsiveness to change by participants in the system. The key similarity is the way in which organisations manage human capital in a constantly changing environment where there are no previous patterns or rules. The findings are interpreted within the reflexivity framework established previously. Finally we suggest future research directions and conclusions specific to theory development.

2. Theoretical framework

2.1 Construction supply chain

The idea of using the supply chain concept to improve firm behaviour and thus ultimately improve sectoral performance through the development of supply chain clusters and targeted project constellations (London, 1999); targeted procurement (Shakantu et al, 2007) or integrated supply chains (McDermott, 2006) has been discussed in the academic research community since the late 1990s (London, 2008). The supply chain concept is very much concerned with firm behaviour within markets. The supply chain is the upstream and downstream contractual relationships between firms who deliver a commodity (product and/or service) related to the core business of a construction project. Subsequently the supply chain once formed creates a flow of commodities, cash and information. The creation of the supply chain is impacted by the location of the individual firm within its competitive market. These markets have unique structural and behavioural economic characteristics.

The upstream and downstream linkages are affected by the characteristics of these markets and in particular the ensuing power relationships which arise between tiers (London, 2008). This provides the central premise for this study.

A central idea of supply chain theory is that holistic supply chain integration relies upon each firm at each tier in the supply chain knowing and aiming for a common objective. Although this fundamental principle is a long standing assumption within the supply chain theorists and active practitioners; it is still one of the most basic problems in relation to developing integrated supply chains and creating holistic performance goals for supply chains. Much rhetoric states that supply chain management will solve problems, create innovations and improve productivity however, there has been little empirical research that deals with the strategic practice of supply chain management associated with creating innovations and solving commercialisation challenges in the housing sector in Australia (London and Siva, 2011). There are a range of tools and techniques that can be applied from other sectors that are 'tried and true' that have been proven to achieve more cohesive supply chains, in particular the well known theory and practices from the Toyota Production System also often referred to as Lean Production. Accompanying lean production is practice and theory to support that practice on supply chains. However, it is critical that an understanding of the sector specific challenges associated with the unique housing sector supply chain problems are considered as well. The investigation of the concept of the supply chain for innovations in the housing sector has not been undertaken in the Australian research community and for that matter in the international research community from the position of 'capital' transformation within the supply chain. It is noted however, that there is an emerging area of research on construction innovation in a more general sense.

2.2 Innovation diffusion

Rogers' theory of innovation diffusion (1962; 1995; 2003) provided an initial framework through which examination of the diffusion of an innovation through construction supply chains was examined. Rogers defines the diffusion of innovations as the process by which knowledge of an innovation is transmitted through communication channels, over time, among the members of a social system. The theory of innovation diffusion has been used in many different sectors including health, information technology and construction. London et al (2007) and Walker et al (2005) explored e-business and information technology adoption in the Australian construction sector using concepts from this theory. Within this framework diffusion is largely measured through the degree of adoption within a system. Adopters are categorised by Rogers' as innovators, early adopters, early majority or laggards. These adopter categorisations are differentiated primarily in relation to diffusion as temporal process whereby diffusion happens in time, whilst the other key elements of innovation; communication channels and social/business systems exert influence upon the temporal diffusion process depending on their specific qualities (London et al, 2007). Further to this there are two key phases in relation to the diffusion of an innovation: first is the creation of the innovation and that process by the 'innovators'; and second, the adoption by others in the industry and the process of diffusion of the innovation.

The adopter categorisation by Rogers is particularly applicable to the second phase of the innovation diffusion process whereby adopters can largely be grouped into one of the four categories of innovators, early adopters, early majority or laggards. This simplistic classification by Rogers, however, places all participants involved with the creation of an innovation into the broad "innovator" group which does not capture the specific characteristics of the different participants within this group and the process undertaken by the different participants to create the innovation. The present research sought to extend the work of Rogers to examine more specifically the characteristics of the different participants within the innovator group and the process undertaken to create an innovation in the housing sector. This research was focussed on the creation phase towards the development of a pathways methodology for the innovator group. The participants in the "innovator group" include those players who were actively engaged with the creation, development and implementation of the waffle footing system innovation process. The innovator group is differentiated from the other adopter groups in that participants are actively engaged in the creation and development of the innovation and they are not simply adopting something which has already been designed, tested, evaluated and implemented. This research aimed to go beyond the identification of factors of adoption within an organisation to explore in detail how the innovator group developed and diffused an innovation in a fragmented industry such as the housing sector through supply chain integration and to understand the characteristics of the collaborative efforts between those firms.

3. Research design

The empirical stage of this study was undertaken through three main phases: firstly; exploratory description of case study: description of the chronological history of the creation and development of the innovation including key players, events and decisions; secondly, critique of process: detailed critique of the process including the factors affecting creation, development and implementation and, finally, development of integrated supply chain innovation methodology: description of the actual process and then the critique of barriers and enablers to allow the development of a structured methodology of 'best practice' for innovations requiring an integrated supply chain approach. This paper reports selected findings from phases 2 and 3. Detailed reporting of the results can be found elsewhere (London and Siva, 2012).

3.1 Data collection

Through a series of interviews with key protagonists we uncovered stories which highlighted the organisational, communication and economic factors impacting on the process undertaken by the innovator group to deliver an innovation to the housing construction industry. This phase involved the conduct of eight semi-structured interviews with ten key players from seven organisations of the "innovator group" associated with the concrete footing innovation (refer to Table 1). The duration of the interviews was between 60-180 minutes. A key aim of the interviews was to enable participants to narrate stories which represented "critical moments" in their experiences of the innovation process. According to Chase (2005, p.661), while there are narrators who will tell stories whether or not researchers want to hear them, there are also others who might not take up the part of the

narrator unless they are specifically and carefully invited to do so. Chase (2005, p.661) suggests “framing the interview as a whole with a broad question about whatever story the narrator has to tell about the issue at hand” while at the same time remembering to extract specifics about the interviewees experiences. The interview questions for this study were designed to be broad and open-ended to provide participants the opportunity to express themselves in their own words without being influenced by suggestions from the researcher as well as to invite the narrators to tell their own stories (Foddy, 1993). However, whenever the response provided by the participant lacked clarity in terms of assisting the development of the proposed model and in answering the research questions, the researcher utilised extension or trigger questions to clarify and elaborate responses. The participants were asked questions relating to four key areas: their role in their organisation at the time and their specific role in relation to the waffle pod footing innovation, key events in the innovation process, barriers and enablers which hindered/drove the innovation and the key players in the process.

Table 1: Interview participants

Case study	Organisation type	Position in organisation	Role in relation to innovation	Location
C1	Large housing developer	State manager	Supply of experimental/ prototype sites Organisation of supply chain to create and implement system	Australia-wide
C2	Footing contractor	Managing director	Construction of footing system for experimental/ prototype sites	South Australia
C3	Building materials supplier	Sales representative	Promotion, distribution and selling of the system nationally	Australia-wide
C4	Plastic spacer manufacturer	Managing director	Manufacturing of key component of system ie plastic spacer	South Australia
C5	Engineering consultant firm	Managing director	Engineering design of the system Monitoring and testing of experimental/ prototype sites Obtained approval/ accreditation for system	South Australia Victoria
C6	Industry association	Regional manager	Promotion of the system in Queensland	Queensland
C7	Polystyrene supplier	Sales representative	Distribution of the system in Victoria Adaptation of the system in relation to waste management	Victoria

3.2 Data analysis

A data analysis technique referred to as the narrative inquiry approach was used in this study. The key actions and events which influenced decisions made were systematically identified to connect and map the consequences of those events over time against the creation, development and adaptation of the innovation (Riessman, 1993). The technique of story analysis was used for data analysis, which offered a way of connecting different stories

to understand the innovation process and in particular changes that took place over time (Bell, 1993). The unit of analysis was the cluster of organisations that were involved in the innovation and the collection of stories that described the various experiences of the participants. The interviews were recorded, transcribed and subjected to four stages of analysis including: Description of the stories from each participant in isolation in relation to their experiences during the creation of the innovation process; Collecting and connecting the stories and then matching to the five stages of the innovation process from all participants including agenda-setting, matching, redefining, clarification and routinising; Description of barriers and enablers to the innovation process and, Description of the pathway for the creation, development, adaptation and diffusion of this particular innovation.

3.2.1 Narrative analysis technique

The first part of analysis involved an identification of links between stories particular to each participant. Stories were identified and coded into the five stages of the innovation process including agenda-setting, matching, restructuring/redefining, clarifying and routinising. Three key steps were undertaken at this phase of analysis. Firstly, each interview was transcribed into “rough drafts” to develop narrative segments. A framework developed by Labov (1972) was used to identify the boundaries of narrative segments. According to Labov (1972) all well-formed stories are made from a common set of elements and each clause has a function, which includes: Abstract: what was this about?; Orientation: who, when, what, where?; Complicating action: then what happened?; Evaluation: so what?; and Result or resolution: what finally happened?. Secondly, the narrative segments were interpreted to identify the meaning of each story. In each story a particular feature was identified to demonstrate a certain element of a particular stage of the innovation process. Based on the participant’s decisions, activities or events described, each story was classified into categories according to the primary characteristics of the five stages of the innovation process. The third stage involved linking the stories into chronological order. The stories coded into the five stages of the innovation process were then “pasted together” to form a “metastory” to demonstrate the participant’s experiences related to the waffle pod footing innovation over time.

4. Results

Each case study organisation was analysed using narrative analysis and the stories from each participant organisation in isolation in relation to their experiences of the innovation process. The within-case analyses of each of the seven organisations were presented in terms of:

- “meta-story”: stories told by participants which have been “pasted together” chronologically. The meta-stories highlight the organisational, communication and economic factors impacting on the creation, development and adaptation of the innovation
- timeframe
- key players in the innovation process:
- inter functional supply chain relationships
- inter organizational supply chain relationships

- expertise: resources highlighted as significant to the innovation process in terms of specific knowledge domains, skills and experiences
- credibility: resources highlighted as significant to the innovation process to provide the innovation with reputation/credibility such as key milestones, events in the form of accreditations, publications, awards and credential backgrounds

Analysis and summary charts were developed for each case study. A total of fifty-seven stories were matched against the five stages of the innovation process with key themes identified in how participants experienced each stage of the innovation process. It is not the intention of this paper to discuss this part of the results, however, an example of stories coded into the first stage of the innovation process, ie "agenda-setting" is provided in the appendices (Table 2).

4.1 Transforming barriers to enablers: reflexivity and human capital

At each stage the firms experienced different problems resulting in the need for strategies to suit the changing requirements of the innovation process. Instead of simply identifying the barriers which occurred at each stage of the innovation process, a more useful approach we took was to identify common themes in how those barriers were overcome. The way that the innovator group overcame barriers can be mapped to how social, cultural or intellectual capital (or a combination of these) was used (Bourdieu, 1990). Thus the management of human capital is how barriers are transformed into enablers. To make sense of the way in which the players used social, cultural and intellectual capital we turned to a sociological theory known as Reflexivity theory (Giddens, 1991). In our interpretation a reflexive capability approach to the innovation process suggests that at any given time one would require a specific set of resources in terms of social, cultural, intellectual and financial capital. Successful innovators often seem to have awareness, whether conscious or not, of the specific capital required at various times and an understanding of where that capital resides. Furthermore it involves understanding the ways to access the various forms of capital in response to the creation, development, adaptation and diffusion of the innovation. A general theme running through the analysis is the fluid nature of the different forms of capital and their interconnectivity. The analysis has shown that the various forms of capital can be easily transformed into or leveraged into other forms of capital. A discussion of the inter-relationship between various forms of capital and how this influences the innovation process has been undertaken elsewhere (London and Siva, 2011).

In summary the individual stories from each participant was a useful starting point for identifying key barriers and enablers. The different experiences between participants were then cross-compared to identify any common themes. Table 3 (refer to appendices) provides a summary of the themes arising from the cross-coding of the participants' stories into the five stages of the innovation process. Further to this the inter-organisational process undertaken by the innovator group participants in the creation, development, adaptation and diffusion of the footing system was examined. Finally, linking the barriers to the enablers begins to bring some clarity to an innovation process pathway (Figure 1).

5. Innovation pathways methodology

As indicated by Figure 1 in the first instance the group needs to develop a clear market analysis and business proposition for the innovation. This early stage analysis will be iterative but such questions will include: Who are the competitors of the innovative system? What financial and IP stake does each player involved in the creation of the innovative have? Who will own the innovation? What type of ownership mechanisms will be developed? It also raises questions such as: Who will be most affected by introducing this new innovation? Ie Who are the competitors for this innovation and how will they try to influence the introduction of the innovation into the market place? This sort of analysis needs to be completed by each organisation involved in the creation of the innovation so that risks can be identified. Not only does the innovation group need to identify this at the organisational level but more widely across the sector as well. For example, if we introduce a new footing system who are all the stakeholders that will be impacted by the introduction of this new system? Who will lose market share? Who might gain market share?

5.1 Creation

In this phase the concept for the innovation was created and various players were identified as being significant contributors. After the creation phase where there was a reasonably clear understanding of the need for supply chain integration as the champion of the group saw that the most significant barrier in the development phase was the potential absence of particular key supply chain players. The strategy was to identify intellectual capital required to take the innovation forward and in so doing identify key knowledge domains. As the start up phase was considered to be reasonably high risk there was a careful consideration of the level of investment of resources. Therefore at this stage the group developed alliances to access the resources needed. This involved identifying typically like-minded people in the industry who were willing to take a risk and were excited about the proposition on the table. This is essentially identifying social capital that is needed in the group.

5.2 Development

After the original creation phase the group moved into the next phase of development. In this phase we saw modifications to the original design as pilot testing was completed. Importantly though another player came into the group who provided a greater capacity to distribute the system more widely to the market. This player clearly was invited into the group because of trust and mutual understanding matched with a clear business motivation.

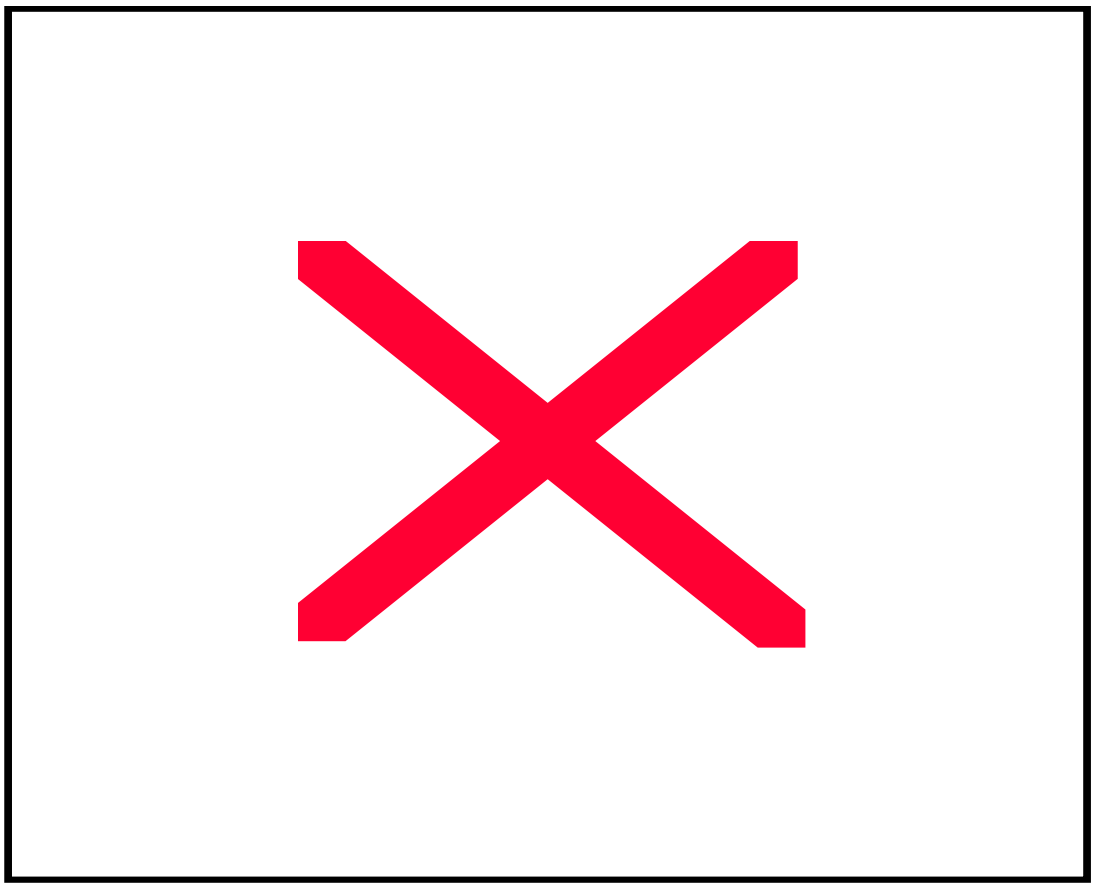

Figure 1: Innovation process pathways methodology (developed for this research)

5.3 Adaptation

The final innovation phase before the whole scale diffusion was another form of refinement of the innovation that is the some adaptations of design due to constructability requirements. In this phase we saw much more significant market penetration and competitors essentially began to sit up and take notice. Because the innovation became a much more plausible proposition and had now had testing, piloting, evaluation and approvals from regulatory authorities some significant barriers came into play. Five main barriers were identified as indicated in Figure 1. One such example was the difficulty of changing people's mindsets and perceptions that the innovation was a worthy system. The strategy in this instance was to seek various ways of demonstrating credibility through technical publications, alignment with various professional associations, awards and creating alliances with other leading players in the industry. The group took each particular barrier and developed a strategy to counter the challenges that they were facing and we have identified the particular form of capital that was used in each strategy.

6. Conclusion

We examined in a detailed manner the creation of an innovative system in the Australian housing construction industry. We can think of the innovation process as a chain of events. There is a series of steps that innovators need to go through to not only come up with a

great idea but also to then strategise to develop a cluster of actors to create, develop and drive the innovation through. There is perhaps a “creation myth” where we have come to believe that innovations revolve around the heroic acts of a single creative genius when in reality it is about pulling together resources from a chain of actors. At different times of the innovation process various relationships will be formed and reformed in response to situational needs. Once something is changed along the way there is a flow-on effect and everything downstream from that change is effected. The mapping of the location of the required human capital and then the strategizing to develop a cluster of actors whose collective contributions will achieve the design, construction and distribution of the innovation was an important finding of our research. This paper sought to develop an Innovation Pathways Methodology through a critique of the barriers and enablers experienced by the innovator group in relation to the concrete footing system. The identification of barriers and enablers achieved through this study is significant in that it allowed a critique of the unique characteristics relating to the pathway undertaken by the innovator group to create, develop, adapt and diffuse the waffle footing system innovation. This required appropriate management of functional relationships within organisations and also more importantly the inter-firm relationships in the supply chain. Barriers to the innovation process were generally considered as resulting from the lack of awareness of the resources and access to specific resources relevant to particular stages of the innovation process. Enablers were identified as the appropriate management and integration of the various resources in the form of social, cultural and intellectual capital which resided in the different firms within the supply chain at different phases of the innovation process.

The innovation process is dynamic. A critique of the barriers to innovation identified in this research highlighted that rather than dealing and coping with change in a reductionist manner the challenge of successfully delivering an innovation is to embrace its dynamic nature. The way that the innovator group overcame barriers related to the clear awareness of the inter-changeability of roles and relationships across the group of firms throughout the innovation process and the capacity to respond and adapt strategies to suit the changing requirements of the innovation process. The Innovation Pathways Methodology developed through the findings can be a useful tool for those thinking about implementing an innovation. It provides a starting point to identify where the weak links might be so that appropriate steps can be undertaken to transform barriers to enablers. The importance of this case study is that this was an innovation of national significance. The dissemination of this case study to the housing sector as part of its cultural heritage is important to demonstrate the challenges of innovation within a largely successful innovation implementation.

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APPENDICES

Table 2 Stories coded into the agenda-setting stage

Agenda-setting						
C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**
Opportunistic surveillance: *Story 3: "had a break when I realised one day sitting in the office…I'm paid to think about things"* *Story 5: "the other thing that hit me was in multi-storey car parks I'd seen where these waffle pods had been used…I just said, cant we do that same stuff here?"*	Opportunistic surveillance: *Story 1: "I was in Port Lincoln 30 years ago and they came up with a crusher bull waffle pod…So I sent a mob of my guys over there to try and pour a job"*	Opportunistic surveillance: *Story 1: "C3 is basically a building materials supplier…they were actually looking to diversify and try something else and have another product that they could promote Australia-wide"*		Opportunistic surveillance: *Story 1: "So what we did was set up some internal R&D projects…so we had different streams to what we were doing"* *Story 2: "because we were involved with footing designs and having problems with movement. As a structural engineer I had designed waffle slabs for first floors…So I figured we got nowhere for support in soils or footings in soil and maybe a waffle will be a good concept"*	Opportunistic surveillance: *Story 1: "and we were searching for footing systems that would work on very heavy clay in South Australia"*	Opportunistic surveillance: *Story 1: "I guess we saw a market opportunity"*
Performance gap: *Story 4: "the traditional [footing system] was a brick build-up…and what that meant was you had unknown rock excavation on the strip footings…when you hit rock, you called the customers up and said you're going to have to pay us some more money so straight away you're off-side"* *Story 6: "the margins in housing are quite low, they're terrible because of the inefficient way we did things"*				Performance gap: *Story 3: "the idea was to get a footing system that was as near as possible to a factory-produced…and above-ground…cause once you start digging you lose control of what you're building, you get over-runs, your trenches collapse"*		Performance gap: *Story 1: "we had an issue with our own recycle material – extruded etc to re-sell it…it wasn't very good return"*

Table 3 Cross case comparison: key themes in relation to five stages of innovation process

Stages of innovation process	Key themes	Case studies						
		C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**
Agenda-setting	Opportunistic surveillance	√	√	√	√	√	√	√
	Performance gap	√				√	√	√
Matching	Establishing fit between problem and innovation	√	√	√	√	√	√	√
Redefining	Changes to organisation/innovation	√	√	√	√	√		√
	Developing alliances to integrate resources	√	√	√	√	√	√	√
Clarifying	Convincing diffusion within organisation		√					
	Enablers to diffusion across organisations	√	√	√	√	√	√	√
Routinising	Barriers to diffusion across organisations		√	√	√	√	√	√
	Adaptations/re-inventions		√	√	√	√		√

People Capabilities for Promoting Sustainability in Facilities Management Practices

Norliana Sarpin, Jay Yang

Abstract Title

Sustainability needs to be embedded throughout the life-cycle of a construction project. From project conception, planning, design, construction stage, operation and maintenance to demolition, each phase of development should embrace principles of sustainability and the stakeholder involved should be empowered with the necessary skills. Past research explored the importance of ensuring sustainability measures during the occupancy phase based on considerations of Life-Cycle Cost Analysis and a project's long-term detrimental impact on the environment. Facility managers are in a unique position to promote sustainability over longer periods of project engagement and can apply a high level of influence on the built assets through management and upgrades. There is growing interest among facility managers in incorporating sustainability measures into day-to-day practice. More, however, needs to be done. Previous studies have identified barriers such as the lack of sustainability knowledge and skills, poor access to information, and unwillingness to change among facility management (FM) practitioners and stakeholders. This inhibits proper implementation of sustainable practices in the FM sector. A number of key factors, such as knowledge discrepancy, time constraints, diversity of FM functions and a lack of incentives, require urgent remedy. The capability of FM professionals and stakeholders will be a key enabler in managing the sustainability agenda, as it is central to the improvement of competency and innovation in an organization. Compared to the attempts at developing sustainability guidelines and performance measurement, research efforts relating to people capabilities and skills are still lagging behind. This paper discusses the progress to date of a research project aimed at formulating a people capabilities framework for sustainable FM practices based on expert opinions and industry feedback. Through literature review, the paper explores the challenges of incorporating sustainability principles into general FM practices before focusing specifically on FM personnel capabilities that may impact on the implementation of a holistic sustainability agenda in real life practice. The results of an industry survey are used to propose an action framework to identify, promote and utilise people capabilities in order to promote sustainability integration in FM practices. The paper provides a useful information source for FM personnel and organizations to bridge the gap between extensive tools on sustainable design and construction assessment at the front end and the need to maintain focus throughout the project life-cycle.

Keywords: facilities management, sustainability, capabilities, people, life-cycle.

1. Introduction

The construction industry is facing major environmental challenges worldwide due to its significant impact on the environment. To generate an effective built environment and

achieve sustainable construction along the project life-cycle, more attention should be paid to the occupancy phase. This effort can be carried out through the implementation of sustainable practice in building operations and maintenance activities. An emphasis on the sustainability issue during this phase is crucial based on its impact on the Life-Cycle Cost Analysis (LCCA) of a building, as well as its potentially detrimental impact on the environment (Hodges 2005; Prasad and Hall 2004; CIOB 2004).

Presently, there is an emergent interest among facilities managers and building owners to integrate sustainability measures into the management of built assets (Nielsen et al. 2009). This scenario is supported by the fact that FM personnel are in a unique position to view the entire process and influence the entire life-cycle of a facility. Facilities managers can also create long-lasting value for an organization by developing, implementing and maintaining sustainable FM practices since they are armed with the proper financial and strategic planning tools (Hodges 2005). Furthermore, past research suggests that the implementation of sustainability measures in FM activities can deliver benefits such as reducing energy consumption and waste, while increasing productivity, financial returns and standing in the community (Hodges 2005; Nielsen et al. 2009; Lai and Yik 2006).

However, despite the growing awareness of sustainability in the FM sector, very few managers and building owners positively embrace the ideas and implement them in their operations. This is due to the early stage of the sustainable development concept in FM practices, leading to a lack of the understanding and skills required to put it into action (Elmualim et al. 2008). Previous studies have identified various factors such as capabilities, knowledge and organizational issues as the barriers that inhibit sustainability implementation. Capabilities issues in achieving sustainability in FM including the lack of professional capability, capabilities discrepancies and skills and capabilities magnitude have been emphasized in several extant research studies as being crucial challenges that need to be addressed in an effort to promote sustainability (Hodges 2005; Shah 2007; Shafii et al. 2006). In addition, issues such as the lack of sustainability knowledge, knowledge chasm and challenges faced in the knowledge transfer process have been highlighted (Elmualim et al. 2009; Elmualim et al. 2010; Shah 2007; Jensen 2009). Moreover, the unwillingness of FM personnel and organizations to adopt new routines to implement sustainability in their business also contributes to current drawbacks.

In this context, there is a need for better understanding of the potential for enhancing the capabilities of FM personnel before the wider adoption of sustainability can be expected. Capabilities and skills are regarded as the key enablers in dealing with the sustainability endeavours of an organization. They are also vital to the fostering of competency in an organization so that it can innovate in a more sustainable way and vital to support the sustainability agenda in an organization (van Kleef and Roome 2007; Gloet 2006). Currently, research that focuses on soft issues such as people's capabilities and skills is still lagging behind the efforts of developing guidelines, technical manuals and knowledge portals. Therefore, it is beneficial to explore the capabilities issues in order to support the implementation of the sustainability agenda in facilities management (FM) practices.

The purpose of this paper is twofold. First, it aims to review the literature on the sustainability agenda in the FM sector as well as discussing capability issues in supporting a sustainability agenda in FM practices. Second, it discusses the components of people capabilities that have the potential to facilitate sustainability measures in FM practices. The progress to date of this on-going project is also discussed.

2. Facilities management and sustainability

Nowadays, there is an increasing demand for built assets in line with the needs of a rising number of communities. At the same time, there is a concern for a clean environment, the preservation of nature and the welfare of future generations. These conflicting requests have to be accommodated by construction industry policy-makers in order to balance the positive and negative impacts of development project. Therefore, the established concept of sustainable construction is now taking on more issues regarding natural resources required for human existence as well as the overall quality of life for both present and future generations. However, in this respect, sustainability considerations and applications in the construction sector are still at an early stage and much needs to be done to achieve sustainability goals (Wai et al. 2009; Myers 2005). Additionally, Shah (2007) suggests that specific sectors in the construction industry, such as the FM sector, are often neglected and require the immediate resurgence and adoption of the sustainability agenda.

The importance of addressing environmental issues at the operations and maintenance phase has been proved by examining the profound effect in terms of a building's Life-Cycle Cost Analysis (LCCA) and its impact on environmental damage. According to Fuller (2010) and Hodges (2005), the LCCA for a building over 30 years indicates that initial building costs (involving the design and construction costs) would account for approximately just 2 percent of the total cost, compared to the cost during the operations and maintenance phase accounting for around 6 percent. Focusing on the construction industry's detrimental impact on the environment, the Chartered Institute of Building (2004) asserts that the built environment especially the buildings themselves use 45% of generated energy for power and maintenance, meanwhile only 5% was used during construction. Sustainability considerations during the operations and maintenance phase is crucial in the whole life-cycle of a construction project, since it impacts more on the LCCA of a building and consumes more of the organization's costs. Considering the evidence, the role of facilities managers as the stakeholders who are responsible for the operations and maintenance of built assets is vital to reducing the construction industry's impact on the environment.

The integration of sustainability measures in FM practices can deliver substantial benefits such as reducing energy consumption and waste and at the same time increasing productivity, financial returns and standing in the community (Hodges 2005; Nielsen et al. 2009; Lai and Yik 2006). The need for sustainable practices focusing on the development of new ways of working in order to meet the sustainability criteria, as well as for skilled facilities managers to conduct tasks, is increasingly important. The role of the FM sector in a sustainability agenda can be applied to the entire life-cycle of a construction project, from design and construction to demolition, with particular focus on the operational phase (Elmualim et al. 2008). The involvement of facilities managers during the design process

should result in buildings that are: (a) better suited to meeting business needs, (b) more attractive to clients, (c) easier to commission and maintain, (d) easier to control and manage, (e) more cost effective to operate and (f) better able to respond to the needs of the occupants (Jaunzens et al. 2001). According to Elmualim et al. (2008), sustainability measures can be included during the operational phase in the maintenance and repair of the physical fabric of the site. This can be achieved by obtaining resources based on sustainability criteria, minimizing waste and disposing of it responsibly and reducing energy demands. Moreover, the role of the facilities manager has grown to encompass activities such as waste minimization, recycling initiatives, energy management and utility reduction to meet the sustainability expectations of customers and clients (Shah 2007).

Unfortunately, even though the FM profession has been presented with an opportunity to make real and measurable differences by driving the sustainability agenda forward, it does not at present have easy access to the specialist knowledge, tools and supporting case study material necessary to make it a reality (Elmualim et al. 2009). The demands require FM personnel to be able to understand and effectively respond to sustainable development challenges. However, research reveals that the capabilities, skills, knowledge and commitment of FM personnel regarding the sustainability agenda are deficient in a number of areas. As a result, their ability to effectively contribute to the sustainability agenda is compromised. Previous studies have identified numerous challenges in efforts to integrate the sustainability agenda in FM practices, including capabilities and skills, knowledge, organizational culture, personal attributes, management and authority issues as presented in Table 1.

Table 1: Challenges/issues in integrating sustainability in FM practices

No	Challenges/ Issues	Description
1	Capability challenges	• Lack of personal capabilities/skills • Lack of professional capabilities / skills • Lack of awareness on building whole life-value • Lack of competence in managing the people / institutions' attitude to changing process • Diversity of facilities management roles
2	Knowledge challenges	• Lack of knowledge on sustainability endeavours in the FM sector • Limited knowledge regarding key elements of sustainable development (environmental, social and economic) • Limited knowledge regarding legislation related to sustainability • Lack of effort in managing the sustainability knowledge
3	Organizational challenges	• Lack of senior management commitment to sustainability • Time constraints on implementing sustainability efforts • Lack of incentives to create a routine for tackling environment issues • Unwillingness to implement sustainability • Limited resources to implement sustainability • Increasing liability of FM organizations • Lack of financial support • Undervaluation of FM contribution to organization success • Limited data on local consumption of energy, water, etc • No sustainability performance indicators during operations phase

No	Challenges/ Issues	Description
		• Lack of guidance documents • No sustainability policy in the FM organization

The need for the implementation of sustainable practices in FM and for skilled facilities managers to conduct sustainability functions is increasing. This is because, facilities managers and building operators are the key actors in implementing sustainable measures in building operations (Hodges 2005). Hence, it is crucial for them to have appropriate capabilities, skills and knowledge to be able to respond and act on a sustainability agenda.

Therefore, in order to support sustainability implementation in the FM sector, it is important to investigate the issue of capabilities and skills. The capabilities of FM personnel and organizations have been identified among the key enabling factors to facilitate a sustainability agenda. Moreover, the need for strong capabilities in both people and organizations is increasingly important in dealing with the requirements of sustainability practice in FM. Additionally, through a literature review, it has been identified that up to now, compared to the research efforts on external aspects (i.e.; developing guidelines, technical manuals and knowledge portals), research focusing on soft areas or people-centred orientation (i.e.; capability of people, skills, personal motivation) is still lacking and lagging behind.

3. Capabilities to implement sustainability in facilities management

Previous researchers in sustainability have highlighted the importance of personnel and organizational capabilities in achieving sustainability goals. According to Gloet (2006), to support a sustainability agenda in an organization, there are four key areas of capabilities that need to be developed, namely, learning, roles, responsibilities and strategy. These capabilities are important to ensure that ideas related to ecology, sustainability and social justice form part of management's thinking and priorities. Likewise, van Kleef and Roome (2007) have identified specific areas of the capabilities needed to encourage business to implement more sustainable practices. These include: systemic thinking capabilities, capabilities for learning and developing, capabilities to integrate business, capabilities to solve environmental and social problems, capabilities in developing alternative business models and methods, networking capabilities and coalition and finally, collaborative building capabilities. These capabilities are vital for strengthening the competency of people and organizations (particularly in managing sustainability agenda issues and challenges) to operate in a more sustainable way and to support sustainability measures.

The role of the people or human domain in efforts to implement a sustainability agenda in an organization has been considered. Jeston and Nelis (2008) claim that the most important component in any business innovation is the management of organizational change associated with people/staff impacts and providing staff with the skills and capability to ensure they will be able to execute their job to a high standard. The people within the organization must have the knowledge and skills to be able to continuously improve the

business processes, as well as to measure and manage business in a way that leads to the betterment of the organization.

The contribution of the human resources domain in the successful integration of environmental management in an organization should be given more attention since it has a crucial role in stimulating the accomplishment of the organization's sustainability goals (Jabbour and Santos 2008; Boudreau and Ramstad 2005). According to Govindarajulu and Daily (2004), human resource dimensions play an important role in ensuring the effectiveness of an environmental management system together with the required technical aspect. Similarly, del Brío and Junquera (2003) agree that environmental management is human resource-intensive and depends much on the development of tacit skills through the employees' involvement. Therefore, environmental management and sustainability efforts in an organization are a complex process, which requires support from the area of human resources and people capabilities and skills in order to guarantee the success of its implementation.

In the FM industry, the issue of capabilities in achieving sustainability goals has been highlighted by Shah (2007), Shafii et al. (2006), Hodges (2005) and Yang et al. (2005) as being a challenge that requires remedying. The necessity for sustainable practice in FM and for capable facilities managers to facilitate this practice is becoming increasingly challenging. The involvement of the FM function is required in all aspects, with a focus on environmental and economic activities. Therefore, FM personnel and organizations need to improve their capabilities and skills in order to conduct this task efficiently in order to further the sustainability agenda in their operations. The focus of this research is on people capabilities within the organization or work-related context due to the promising opportunity that it brings to organizational growth and performance. It is also vital for transferring existing skills and knowledge to a new situation, such as the sustainability endeavours in an organization.

4. Potential people capability components to promote sustainability in facilities management practices

The authors have developed potential people capability components to facilitate a sustainability agenda in FM practices from an extensive review of past research as summarised in Figure 1. These components contribute to the environmental, social and economic objectives of sustainable development.

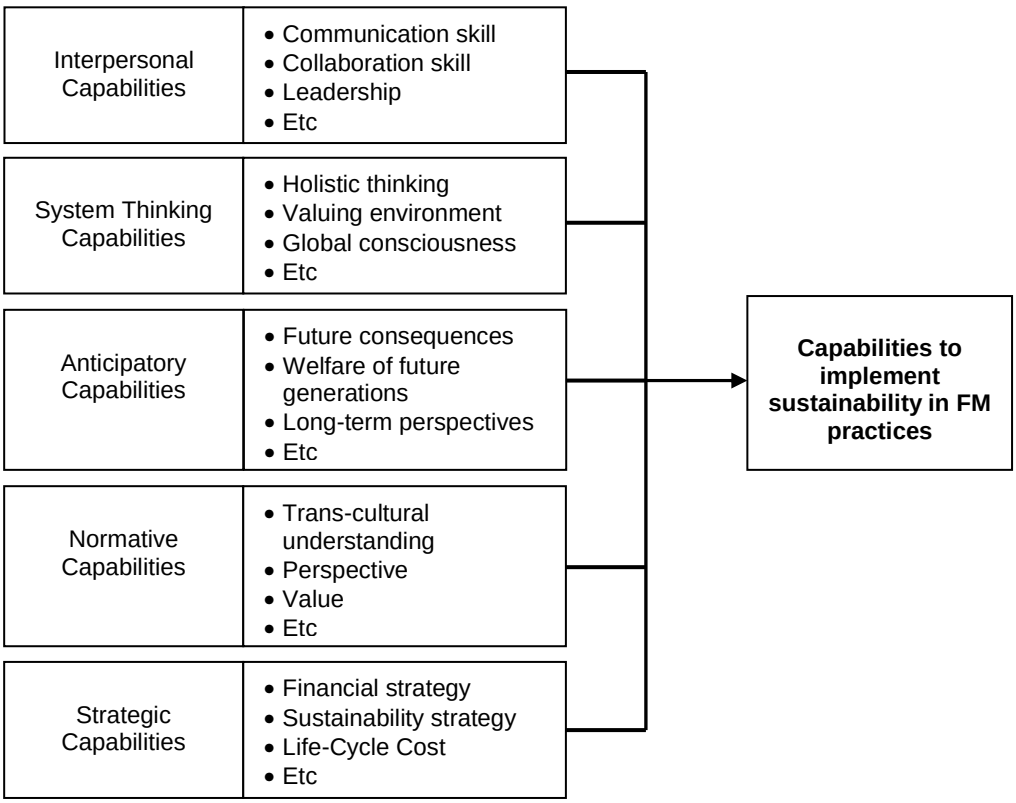

Figure 1: Components enhancing people capabilities in implementing sustainability in FM

Each component consists of attributes that can be designed and weighted differently depending on their importance in facilitating people capabilities. Five major components were identified as having the potential to enhance people capabilities to implement sustainability measures in the FM industry. The components are: 1) interpersonal capabilities; 2) system thinking capabilities; 3) anticipatory capabilities; 4) normative capabilities; and 5) strategic capabilities. These people capability components are based on the Wiek et al. (2011) classification for similar applications. Interpersonal capability refers to the ability to facilitate and enable FM personnel to solve the issues and challenges related to the sustainability application. System thinking capability is the ability to analyse complex systems across different pillars of sustainability (environment, society and economy) and over different scales. Anticipatory capability is the ability to analyse and evaluate related sustainability issues that may happen as a consequence of a present action. Normative thinking capability is the ability to map, apply and reconcile sustainability values, principles and goals that a person should know in terms of practices that should be discarded and those which must be maintained to sustain the balance of nature. Finally, strategic capability is the ability to design and implement specific strategies towards the implementation of sustainability in an organization.

A list of a attributes from these five major components were included in a questionnaire to assist the industry to identify the crucial people capabilities in facilitating sustainability implementation in FM. The people capabilities are identified through a wide range and variety of experiences for sustainability considerations and involve a significant number of researchers and practitioners. Therefore, there is a need to identify the most relevant and

critical aspects suitable for sustainability endeavours in the FM context through surveys of the local industry. The survey design is introduced in the following section.

5. Questionnaire survey and on-going research

In this research, a questionnaire survey was administered to ask the industry participants what capabilities they consider most important for facilitating the implementation of sustainability measures in FM practices. Single choice questions, multi-choice questions and five Likert scale questions with open-listed items were adopted in the questionnaire design. A structured questionnaire consisting of five (5) sections was designed according to the key elements of the people capabilities based on the findings from an extensive literature reviews. Table 2 shows the structure of the questionnaire.

Table 2: Structure of the questionnaire

	Category	Questions
1	Respondents general information	This section collects basic information in order to classify respondents. (e.g. professional roles in FM industry, length of professional experience, type of organizations)
2	Barriers for sustainability agenda in the FM sector	This section collects information to identify the impact of each barrier in the effort to integrate the sustainability agenda into FM practices. These barriers are categorized into three main challenges namely, capabilities, knowledge, and organization.
3	Attribute of people capabilities to promote sustainability in the FM sector	This section collects professional opinions to indicate the significance of people capability attributes in enhancing sustainability in FM practices. These people capabilities have been categorized into five components: • Interpersonal capabilities (25 attributes) e.g. development of communication skills, collaborative skills, ability to motivate, leadership skills. • System thinking capabilities (6 attributes) e.g. valuing environment, global consciousness, critical thinking. • Anticipatory capabilities (8 attributes) e.g. identifying short-term and long-term consequences. • Normative capabilities (5 attributes) e.g. trans-cultural understanding, cooperation. • Strategic capabilities (16 attributes) e.g. understanding organization's financial strategy, Life-Cycle Cost.
4	Further comments / issues relevant to people capabilities	This section invites respondents to provide further comments in regard to the research topic.
5	Further information	This section invites respondents to provide their contact information if they are willing to participate in the subsequent case study.

Respondents representing key stakeholders in the FM industry were carefully selected from various types of organizations involved in FM projects from both the private and public sectors across Australia. An appropriate sampling of FM personnel is necessary because it is rarely possible to examine an entire population of respondents due to the resource restrictions in most studies. According to Fellows and Liu (2008), the objective of selective

sampling is to provide a practical means of enabling the data collection and processing components of research to be carried out. For the purpose of this research, the survey sampling was drawn randomly from Australian FM stakeholders with different characteristics, particularly in terms of respondents' professional position, types of organization, level of education and years of experience. The respondents identified for this study included company directors, experienced facilities managers, business managers, building engineer and other professional personnel from diverse organizations such as clients, consulting firms, FM contractors, sub-contractors, government agencies and local authorities.

Around 120 questionnaires were sent out directly to the identified FM stakeholders through a web-based survey tool. To date, the authors have received over 30 valid questionnaires. A 30%+ response rate is expected. Information obtained from the survey will be used to identify key attributes of people capability components in order to facilitate sustainability measures in FM practices. A preliminary framework of people capabilities will then be developed based on the findings. Afterwards, selected case studies will be adopted to test and verify this preliminary framework and to generate the development of the contextual and visual representation of the final framework.

6. Conclusion

Compared to design and planning, the facilities management sector of the construction industry is facing a greater challenge to support the sustainability agenda. In addition to energy efficiency issues, facilities managers are now required to respond to all aspects of sustainability in this important part of the project life-cycle. Past research has revealed the lack of knowledge and skills among FM personnel and the need to enhance their capabilities in order to cope with new challenges.

In response to this, a study on people capabilities in FM is being carried out to explore current problems hindering knowledge and skill improvement and to identify possible solutions. Five major components affecting FM personnel have been identified as: 1) interpersonal capabilities; 2) system thinking capabilities; 3) anticipatory capabilities; 4) normative capabilities; and 5) strategic capabilities. A questionnaire survey is being conducted to explore the opinions of FM stakeholders on how they identify and interpret these key components and what practical solutions may exist to uplift the current standards. Critical attributes will be incorporated into a framework during the next phase of research, in an attempt to equip the FM team with a tool to collect the right knowledge, continue education and develop new mindsets to enhance the integration of sustainability measures with FM practices.

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Will BIM improve construction health and safety?

Alistair Gibb[1]

Abstract

All sorts of claims are being made about BIM (Building Information Modelling), including that it will revolutionise construction site health and safety. This paper presents the findings from a survey of ~300 construction designers and design advisers in the UK regarding BIM. The paper finds that the current status of knowledge and experience of BIM amongst UK design-related professionals is very poor. It argues that BIM is currently near the peak of over-inflated expectations on the Gartner Hype Cycle. Whilst there is considerable potential for BIM to bring benefits to construction, there is a danger that it will stifle occupational health and safety by focussing only on standard risks and hazards rather than on the need for careful review of design, means and methods to eliminate or reduce hazards before they create risks on the site.

Keywords: BIM, Building Information Modelling, health & safety, hype.

1. Introduction

Building Information Modelling (BIM) is currently being lauded across the world as the solution to all of construction's ills (e.g. Hardin, 2011; Suermann & Issa, 2009; Young et al, 2008, Shih et al, 2012) and the proclaimed benefits include improved health and safety of construction workers (e.g. Zhou et al, 2012). Whilst 3D CAD models have been around for many years, and the use of solid models for management functions such as sequence planning and clash detection surfaced in the engineering construction sector as long ago as the mid-1990s (e.g. Gibb, 1999, p141), the all-encompassing promise of BIM has only become *de rigeur* in recent years. In many ways, BIM has taken on the mantle of 'saviour of the world' from previous initiatives such as Lean and Modern Methods. These too have been previously hailed as generic construction sector redeemers – and, in some cases still are.

A full discussion on the history, development and current use of BIM is outside the scope of this paper and much has already been written on this (e.g. Shih et al, 2012). However, for the purposes of this paper BIM is defined as: "a model-based technology linked with a database of project information" (Lee et al, 2006) and "a receptacle for project information that is structured in such a way that the data can be shared" (BuildingSMART, 2010). BuildingSMART continues to explain that the core of BIM is an object-based 3D CAD model

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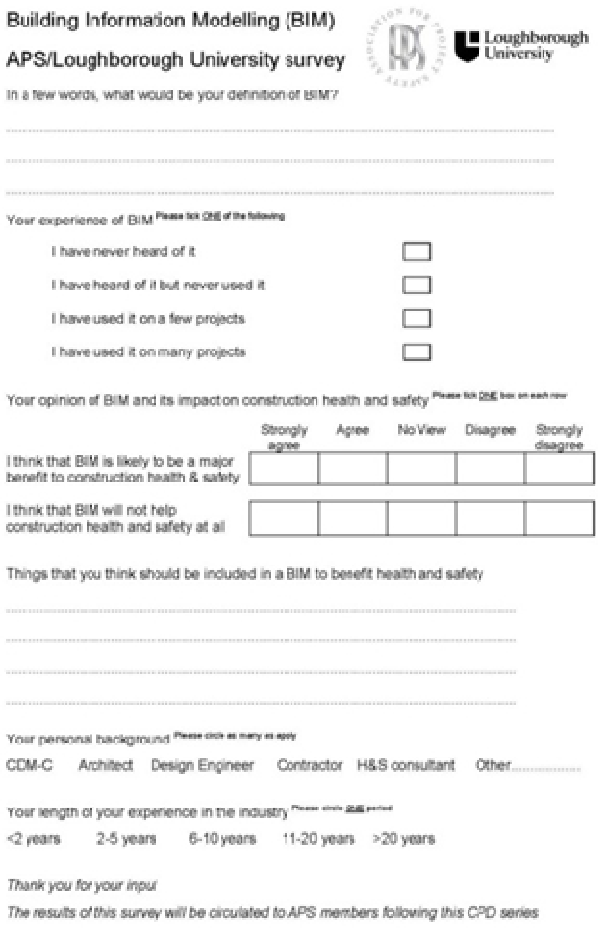
of the project, developed further to "4D (integrating time) or 5D (also integrating cost) and aspirationally, nD (covering a number of other factors)".

Current research work on BIM and occupational health and safety is very encouraging and clearly significant steps forward are being made (Zhang et al, 2012; Behzad & Hallowell, 2012; Sulankivi et al, 2012). However, the very fact that this work is still at the research stage, emphasises that in most cases it is not yet a reality in construction practice. Bold claims in the popular or construction press should be read with care and a degree of scepticism. This paper presents findings from a UK survey of design-related professionals on their knowledge and experience of BIM and its potential to improve construction health and safety.

2. Methods and Sample

Survey sheets as in Figure 1 were distributed before the start of each training event in a continuing professional development series for the Association for Project Safety (APS). The events covered implications for CDMCs[2] and designers from innovative construction technologies and BIM. 329 survey sheets were completed across 16 events, held regionally across the UK (Table 1) between Feb-Jun 2012.

The surveys were completed by attendees prior to any input regarding BIM so they test the prior knowledge and opinions of attendees. Attendees were asked about their professional background, where they could tick as many categories that applied. Not surprisingly, given that almost all were APS members, almost all identified themselves as CDMCs. Figure 2 shows the additional professions identified.



Building Information Modelling (BIM)

APS/Loughborough University survey

Loughborough University

In a few words, what would be your definition of BIM?

Your experience of BIM Please tick ONE of the following

- I have never heard of it ☐
- I have heard of it but never used it ☐
- I have used it on a few projects ☐
- I have used it on many projects ☐

Your opinion of BIM and its impact on construction health and safety Please tick ONE box on each row

	Strongly agree	Agree	No View	Disagree	Strongly disagree
I think that BIM is likely to be a major benefit to construction health & safety					
I think that BIM will not help construction health and safety at all					

Things that you think should be included in a BIM to benefit health and safety

Your personal background Please circle as many as apply

CDM-C Architect Design Engineer Contractor H&S consultant Other.....

Your length of your experience in the industry Please circle ONE period

<2 years 2-5 years 6-10 years 11-20 years >20 years

Thank you for your input

The results of this survey will be circulated to APS members following this CPD series

Figure 1 – Survey Instrument

[2] CDMC – the design-phase health and safety coordinator required under UK legislation (CDM 2007) – similar roles are required across the European Union.

Table 1 UK Regional training events where surveys were completed

APS Region	*Location*	*Surveys*
East Midlands	Kegworth	18
Northern Scotland	Aberdeen	9
Yorkshire	Leeds	28
East Anglia	Stansted	39
London	London	28
South West England	Southampton	18
South East England	Gatwick	24
South Central England	Milton Keynes	12
Scotland West	Glasgow	7
Scotland East	Edinburgh	19
Midlands	Birmingham	21
South West England	Bristol	27
Wales	Cardiff	26
North West England	Knutsford	35
Northern England	Newcastle	18
Northern Ireland	Belfast	6

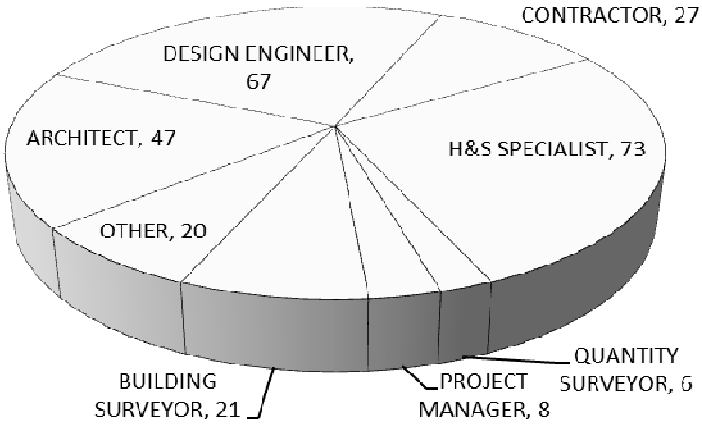


Figure 2 Professions in addition to CDMC

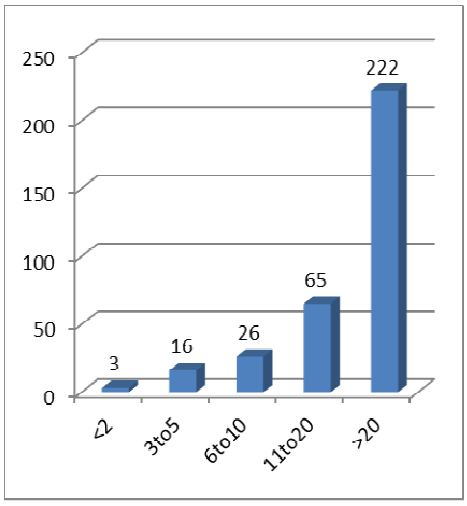


Figure 3 Years' experience

Attendees' length of experience in the industry revealed that 67% had over 20 years' experience and a further 20% had between 11 and 20 years (Figure 3). This was not necessarily in the CDMC role as this was not specified and the CDM Regulations only created the Planning Supervisor role in 1994 which was changed to CDMC in 2007. Therefore the experience was deemed to be in the other profession specified.

3. Results

3.1 Experience of BIM

Attendees were asked about their past experience of BIM (Figure 4). Almost a quarter of this experienced sample had never even heard of the term and almost three-quarters had heard of it but never used it.

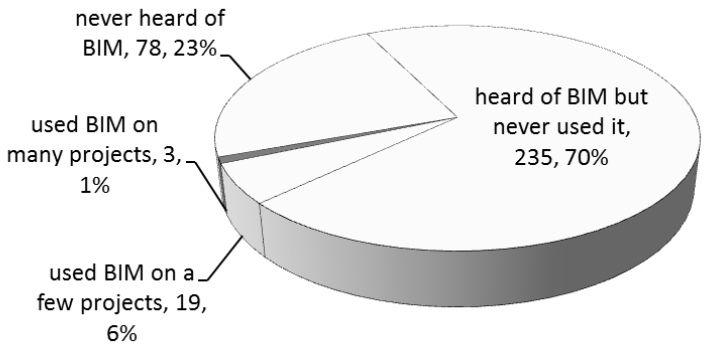


Figure 4 – Experience of BIM

Given the current publicity surrounding BIM and the amount of coverage in the technical press in the UK over the last year or so, the 23% who claimed to have never heard of the term was somewhat surprising, as was the very low number (n=22, 7%) of those who had used BIM on many projects. This illustrates that the hype attached to the subject may well be clouding the true extent and range of understanding.

3.2 BIM definitions

Before the start of the session, attendees were asked to provide a short definition of BIM to test their understanding of the subject alongside their statements regarding their own experience. 33% (n=111) did not complete this section or stated that they did not know, which was to be expected, particularly as a number admitted not having heard of BIM. 11% (n=36) merely restated the words Building Information Modelling. Only 16% (n=52) gave definitions that could be considered as fulsome or reasonably accurate when reviewed against the 'standard' definitions provided in the session. A simple thematic analysis (Table 2) identified the main themes as influencing more than just design (79), integration and coordination, including clash detection (59), 3D (53), sharing of information across project stakeholders (33) and a single or common model / store (15). Figure 5 is a Wordle representation of all 'correct' definitions (www.wordle.net) and Figure 6 a representation of the words used omitting the words Building, Information/Info and Model / Modelling.



Figure 5 Wordle of definitions



Figure 6 Wordle of definition omitting BIM

Table 2 BIM Definitions - Content Analysis (Rank Order)

(excluding zero entries, don't knows and incorrect entries i.e. scoring 1-5, n=183)

Term	*Number*	*Term*	*Number*
Design(er/ed)	93	Team	9
Info(rmation)….	88	Software	8
Model(ling)	80	Component	8
Building	77	Change(s)	7
3D	54	IT	6
Project	36	Standard(s)	6
Construct(ion/ed/or)	33	Collat(e/ed/ion/ing)	5
Coord(ination/inate/d	27	Communicat(ion/ed/e)	5
Computer	22	Cycle/Life cycle	5
Integrat(e/ed/ion)	21	Technique	4
Management	21	Better	4
System	19	More	4
Data	18	Architect(ural)	3
Process	13	Engineer(ing)	3
CAD	11	Collection	2
Element	11	Collab(oration)	1
Building information model	10	Object	1
Electronic	9	Improv(ed/ment)	1

In addition a few definitions offered (n=34) were significantly incorrect such as: *a theoretical approach to risk assessment & hazards; coordination of all services in risers and voids; an innovative construction planning technique; methods of managing project safety & risk information;* and *a database of key performance indicators*. Finally a small number used the opportunity to make particular points such as: *Gimmick! Fad! High cost disaster in the making; a new 'buzz word'; innovative but expensive; means of putting all liability for quantities onto the architect;* and *more of a student activity at college*. One respondent made the point that BIM was 'the future!' and exhorted: 'Get the training sorted now!'

3.3 Will BIM improve construction health and safety?

Respondents were asked to respond to two statements:

- I think that BIM is likely to be a major benefit to construction health & safety
- I think that BIM will not help construction health and safety at all

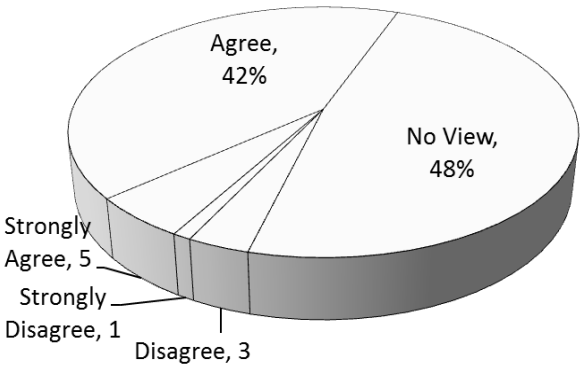


Figure 7 Responses to 'I think that BIM is likely to be a major benefit to Construction H&S

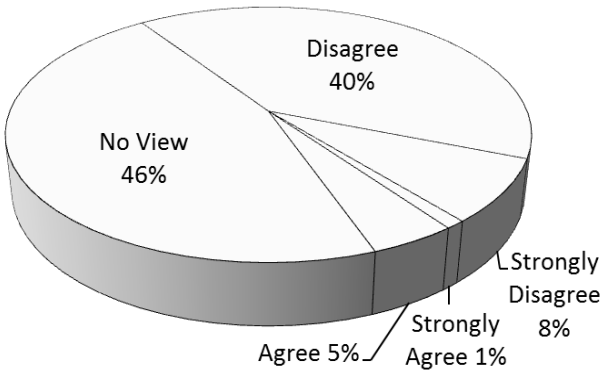


Figure 8 Responses to 'I think that BIM will not help construction H&S at all

Around half (48% and 46% respectively) of respondents either responded 'no view' or did not make an entry. This again is consistent with those who admitted that they had little or no appreciation of BIM. Other than this, there was generally strong agreement that BIM will bring benefits to construction health and safety. However, in further discussions during the training sessions, it was clear that this benefit was a future potential rather than a present reality since health and safety issues have not been incorporated within the BIMs.

4. Discussion

The precise nature and extent of a BIM is still not completely clear and the variety of definitions by the workshop attendees is mirrored across the construction sector. Some argue for a fairly narrow, technically-driven definition whilst others would agree with Tim Broyd, Halcrow Group director of technology and innovation who argues that BIM is "a set of software-enabled processes that allow project information to 'flow' through the lifetime of a project (building or infrastructure facility) such that individuals have access to the information they need, when they need it and in a manner that allows efficient and effective design, construction and operation."

One of the key challenges of BIM that was discussed at the workshops was the assumption that the stakeholders are all working collaboratively. Figure 9 is taken from the BuildingSMART guide to BIM and illustrates this point. If each stakeholder is to freely contribute to the BIM then they need a degree of confidence that their contribution is recognised and that their intellectual or commercial property is not abused.

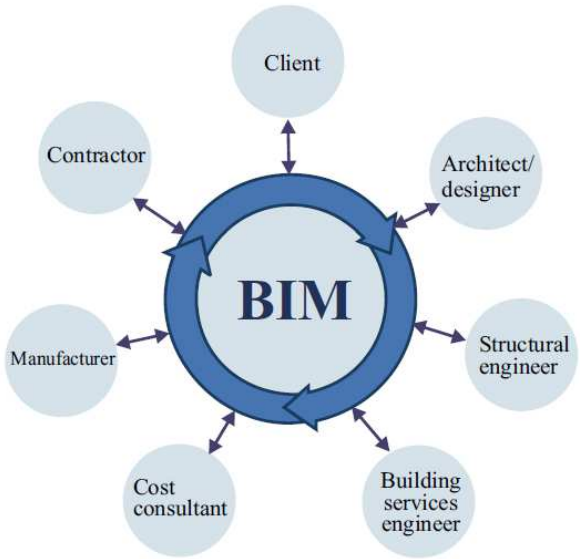


Figure 9 – BIM stakeholders (BuildingSMART, 2010)

The fact that the CDMC is not included in this representation was also not missed by this constituency. There was no clear view as to whether the CDMC constituency was in a position to act as the BIM coordinator, nor whether they would want to fulfil the role. The fear was expressed that the CDMC role could be bypassed completely by the onset of BIM.

In Europe, the Temporary and Mobile Construction Sites Directive has required designers and pre-construction planners to consider the health and safety of workers in the construction, maintenance and demolition phases of the building and facility. This has led to the Construction Design & Management Regulations in the UK and other national legislation across the European Union. This approach has also been extolled by a number of researchers and practitioners across the world, particularly through the Prevention through Design initiatives. The assumption of this approach is that design professionals are able to carefully consider their designs and make informed decisions having assessed the risks that would be involved during construction.

Figure 10, again from BuildingSMART, allocates (or relegates) health and safety to the rules and regulations category along with Building Regulations and Planning.

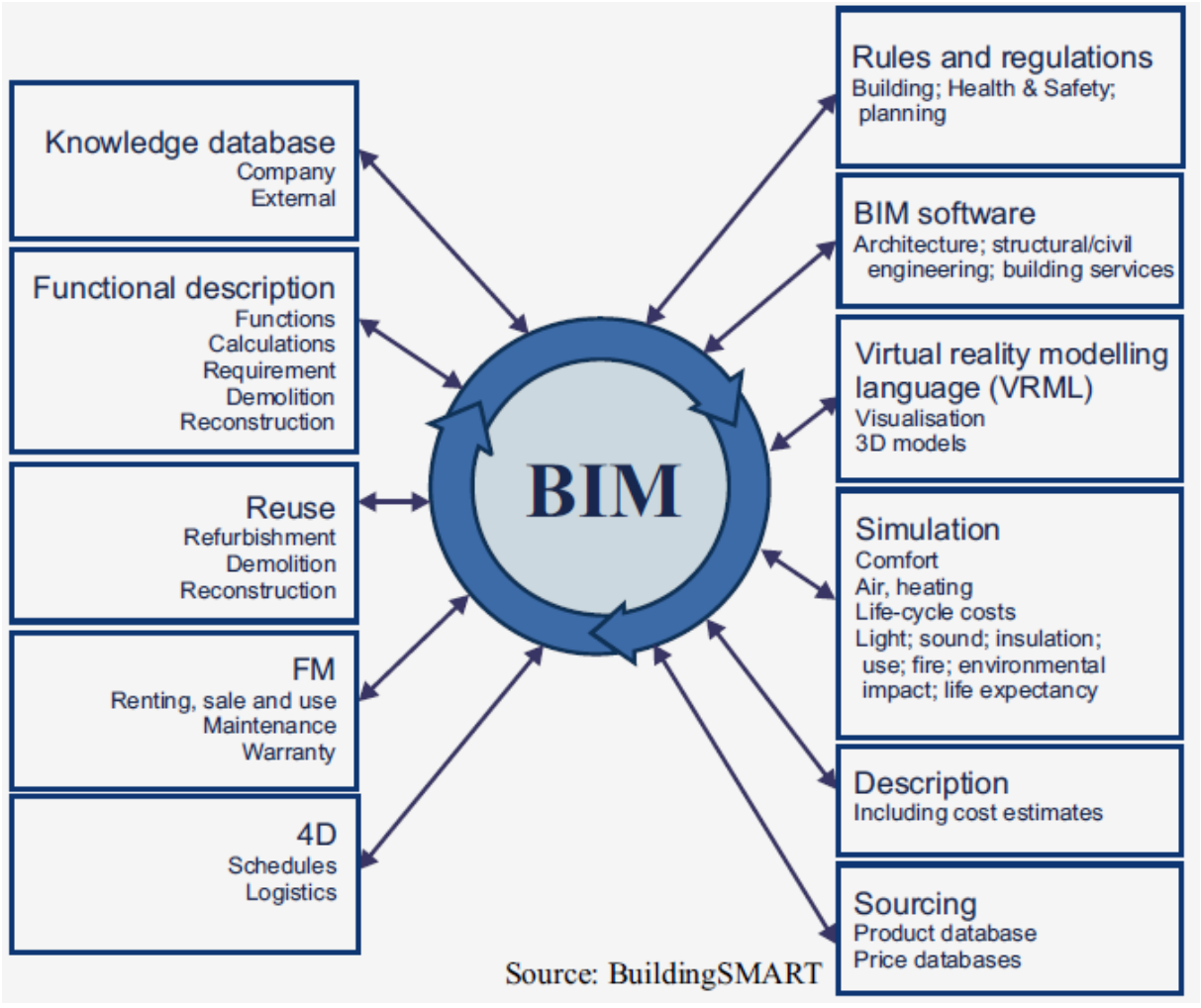


Figure 10 Categories in an ideal BIM (BuildingSMART, 2010)

The danger of this allocation is that occupational health and safety may just be treated as a matter of complying with legislative requirements rather than being seen as an integral part of project management. The workshop attendees agreed that this may result in effective health and safety being lost amongst a plethora of standardised data. Areas such as the control of substances hazardous to health (COSHH) tend to produce large volumes of information. Attendees warned that, as there was already a tendency to try to standardise risk assessments, this could be exacerbated by downloading copious amounts of health and safety data that could be included in a BIM. The danger is not that health and safety would be forgotten in a BIM but rather that it may be lost in a mass of information.

One of the dangers of all good ideas is assuming that they will solve all your problems. Figure 11 shows the Gartner Hype Cycle (Adapted from Fenn & Raskino, 2008). Workshop attendees agreed that BIM was currently near the top of the peak of inflated expectations. They argued for a more realistic set of expectations and an increased engagement with the further development of BIM, particularly with respect to health and safety.

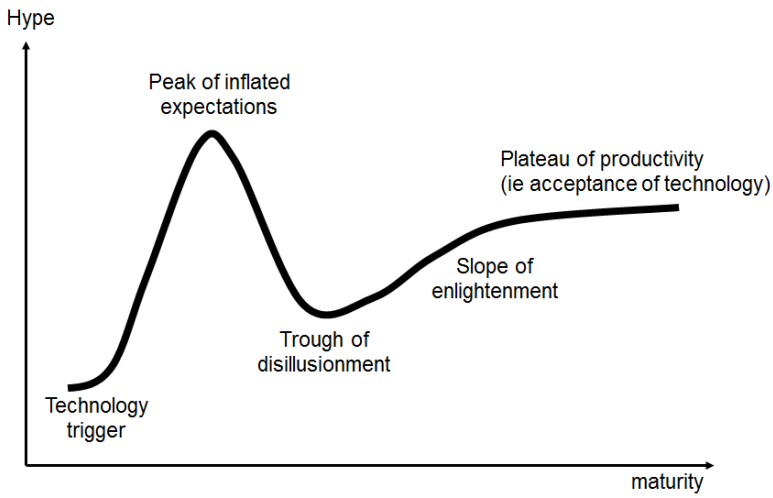


Figure 11 Gartner Hype Cycle (Adapted from Fenn & Raskino, 2008

5. Concluding thought

Notwithstanding the current limited deployment, and the distinct lack of knowledge about BIM, the UK Government is ploughing ahead with its requirements to implement BIM (level 2) on all Government-funded projects from 2015. So, as a community, we need to make sure that we engage with the development to ensure that construction health and safety maintains a vibrant and effective part of the BIM.

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The Process Of Implementing Project Management and BIM In The Colombian AEC Industry.

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Abstract

Since 2006 the Engineering and Construction Management research group at Universidad de los Andes has documented 20 case studies of Colombian companies using or implementing Project Management and BIM tools. Results showed that knowledge and understanding of Project Management and BIM principles, top management support, and organizational culture are the most influential factors when formulating an implementation strategy. It was also observed that some of the requirements for implementing BIM, such as transparency, process efficiency and new decision making procedures, made the process particularly challenging for some actors in the supply chain. The purpose of this paper is to present the results of a comparative review of these research projects. After analysing common failures described on the industry, it was found that most of BIM principles involve managerial improvements, therefore implementing contractual mechanisms to demand BIM in private and public biddings would surely improve industry's efficiency.

Keywords: Project Management, BIM, literature Review, Colombian AEC industry.

1. Introduction

Over the past decade, the Colombian Architecture, Engineering and Construction (AEC) industry has grown significantly. The AEC industry has been analysed in several MA dissertations in order to identify the failures and advantages of project execution. The most concurrent topics in such dissertations from Universidad de los Andes since 2006 will be analysed in order to identify the recurrent themes, main failures and propose future research subjects.

The approach proposed describes recurrent subjects found in the dissertations treating two main topics: Project Management and Building Integrated Modelling (BIM). These topics were selected based on the importance and advantages evident when leading construction

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industry; therefore, identification of the main barriers are relevant for improving Colombian productivity and success rates in Architecture Engineering and Construction (AEC) projects.

With respect to Project Management, two main categories arise as the most recurrent, Risk Management and Cost Management, each is described based on the main failures identified, and compared to international standards. Similarly, an identification of BIM's advantages and requirements for implementing this technology is analysed and compared to internationally defined maturity levels.

Nevertheless, the themes that will be treated on this paper are among a variety of project management strategies such as Lean and sustainable construction, that Universidad de los Andes has studied and published on different academic works.

2. Research methodology

The selection of dissertations for the elaboration of this paper was based on filter criteria according to the project's title and topic. The topic must be related to the main work areas established by the PMBOK which include Knowledge Management, Risk Management and Cost Management.

Several of the dissertations reviewed suggest the inclusion of an instrument for improving practices. Therefore, documents regarding Building Integrated Modelling (BIM) were included in the review and searched for, in the Uniandes database.

Examining the content of these papers, the common trends and propositions for future studies were analysed and compared with international trends. The most frequently cited academic papers were included in this research document. Table 1 lists all the documents and main topics reviewed. The methodology proposed is based, in the first place, on a local literature review that includes the most relevant documents presented since 2006 at Universidad de los Andes; and secondly, an international literature review based on the most frequently cited documents and new trends in such topics,. Finally, according to the literature reviews, a classification of the state of Risk Management and BIM development in Colombia was completed.

3. Project management

Project management has been defined as the standard to deal with and create changes within several management practices such as creation of new products, services or changes in organizational processes (Cleland & Gareis, 2006). Several changes have occurred over the past years whereby Project Management turned from being a rudimentary process—part of general management—to an independent, well-structured and defined process recognized by several associations such as PMI (Project Management Institute) and IPMA (International Project Management Association). These associations have documented and guided the best practices in order to undertake an accurate analysis based on cost, schedule and technical performance. According to the PMI, the main areas of focus for

successful project execution are: time, cost, quality, scope, risk, procurement, human resources and integration management.

Table 1: Documents revised for the elaboration of this document

		Author and year of publication	Main topics
Project Management	**General topics**	Liberatore, Pollac, & Smith (2001); Cleland & Gareis(2006); Caycedo(2007); Galán(2007); Imbeah & Guikema (2009); López (2010); Morales (2010); Zandin (2011); Morales (2011).	Tools for controlling cost, time and quality on projects; Project Management organizational schemes. Better practices; Methodology and software design; Management Model (APRAM) for managing schedule, cost, and quality risks in the construction industry; Project Management generalities and evolution; Evaluation of human resources on a project management group.
	Cost / financial management	Hegazy & Perzold (2003); Rivera (2007); Correa (2007); Lucero (2008); Cuello(2008); Lipke, Henderson, & Anbari (2009); Zapata(2010); Piedrahita(2010); Velasco (2012); Garvin & Ford (2012).	Cost optimization and dynamic project control; Scheduling, resource management and cash-flow-analysis; Financial modeling; Profitability on priority housing projects; Real projects best practices; Cost control structure; Budget control standards; Budget database actualization and completion; Earned Value Method (EVM) improvements; Free cash flow of a project based on risks and mitigation measures; Influence of inflation in the variation of prices of raw materials and services; Real Options on financial evaluation of projects.
	Risk Management	García (2007); Redondo (2007); Mendoza (2007); Salgado(2008); Guevara (2008); Puentes (2008); Acevedo (2010); Rodriguez (2010); Abdelgawad & Robinson (2010); Zou, Chen, & Chan-(2010); Beltrán (2011); Duque (2011); Alarcón, Ashley, Sucre, Molenaar & Ungo (2011).	Risk analysis; Methodology for implementing a "learned lessons" philosophy; Common risks presented during planning phase; Corrective actions that must be done to avoid risks; Risk identification, register and analysis during the operation and maintenance phase on construction projects; Case of study, identify, quantify, analyze and control risks present; Uncertainty management of activities' duration; Mode and Effect Analysis (FMEA) in the construction industry for mitigation of risks; Development and prove of a tool for evaluating state of risk management; Risk Analysis on public contracts; Comparison between the PMBOK and the NTC 5254 (Colombian regulation) on risk management procedures; Contingency model via Monte Carlo simulation for risk analysis and for providing contingency assessments.
BIM		Torres (2007); Isaza (2008); Succar (2009); Castañeda (2009); Iguarán (2010); Eastman, Teicholz, Sacks, & Liston (2011); Sánchez & Valencia (2011).	BIM influence on design, cost and scheduling on projects; BIM implementation plan for Colombian companies; Revision of BIM implementation on a Colombian AEC company; International guidelines and BIM Framework; BIM generalities and most relevant aspects for implementing BIM in Colombian industry; BIM literature review. Feasibility of BIM implementation; BIM generalities regarding definition, requirements, stakeholders and advantages of this implementing this technology; Case of study a Colombian AEC company and the methodology for implementing BIM in the organization.

3.1 Risk Management

Project Management Body of Knowledge (PMBOK) defines Risk Management as “the process concerned with identifying, analyzing and responding to project risk” (PMI Standards Committee, 1996). An effective risk management leads to the minimization of negative impacts on the objectives, cost time and quality of a project, through improved practices to deal with uncertain events.

3.1.1 Local Literature review

According to Colombian studies undertaken by MA students in Project Management for Construction, the importance of risk management is related to the nature of the Architecture, Engineering and Construction (AEC) industry; catalogued as one of the most dangerous (Sura, 2012) and recurrently affected by risks. Therefore, it is essential to qualify and identify the risks that companies involved within this sector and projects are exposed to.

The current state of project success in Colombian public biddings is alarmingly low, according to Beltrán, only 44% of the total projects planned by a public entity during the years 2006 and 2007 (311) were delivered based on the initial plan (Beltrán Real, 2011). Such statistics suggest that the initial phase of projects (planning phase) is not being appropriately developed; which naturally reflects the importance of this process where uncertainty is prevalent, risks are more probable and the basic decisions that define a project’s scope, requirements and success are made (Muñoz Redondo, 2007).

In relation to analyses undertaken over the past 6 years, the main causes involved with project failure on scope, quality, cost or schedule is initially related to the lack of a well-structured definition of projects, caused mainly by the inexistence of a serious planning methodology and unreliable control entities. All Colombian AEC projects must be validated by a local public entity, responsible for checking that normativity on urban, structural and architectural designs is in accordance with the regulations. Although, these entities do not have a standardized process for construction license approval, the criteria used is based on particular concepts and different interpretations of legal regulations, which consequently lead to major problems during and after construction (Mendoza Paternina, 2007).

On the whole, the importance of classifying risk is to find possible mitigation methodologies. Some of the strategies identified lean towards the implementation of new technologies and simulation tools (Puentes Hernandez, 2008) in order to improve planning, control and efficiency so that differences between executed and planned projects can be reduced (Salas Callejas, 2008).

Particularly in the case of the Colombian AEC industry, it has been shown that the construction of the basic unit model not only improves sales efficiency, but helps to identify and correct design errors before the construction phase begins (Salgado, 2008). However, the most recurrent and important method identified was the implementation of knowledge management, discussed next.

3.1.2 Knowledge Management

In Colombian practice, knowledge management has been one of the least developed practices involved with project management (Galán, 2007). The importance of this area is based on the supply of tools to positively influence the decision-making process during project execution (risk mitigation). The main input is a representative database resuming the history, projects executed and influential decisions made with their impact.

As mentioned previously, the Colombian sector does not understand the relevance and does not provide the personnel required to manage, store and analyse information regarding projects in the private and public sectors. Not even the most important company in the Colombian AEC industry, in charge of representing the public contractors, manages its information appropriately (Galán, 2007).

In order to evade the negative effects that risks could entail, several studies suggest that a complete database, that involves internal and external rules such as requirements on legal normativity (Caycedo, 2007), must be put together. To achieve success on any construction project, all the members of the company must be involved with the risk management process and contribute to the risk database at all the phases of the project. (García Villamizar, 2007). This database shall be used as the main input for the construction of a Risk Breakdown Structure that clearly characterizes and identifies risk and the respective mitigation, based on a learned-lessons philosophy (Duque Tejeiro, 2011).

3.1.3 International literature Review

After reviewing some studies developed globally and cited by several academic papers, it is evident that efforts are continuously increasing and even the most important projects such as the Panama Canal expansion, develop and invest in leading risk management techniques. In particular, the conventional concept of analysing cost and time effects separately has been replaced by an integrated view of these dimensions to obtain common risk factors and perform and adequate analysis of vulnerability during the different phases of the project. According to Alarcón et al (2011), a successful view of risk management is a 10 steps iterative-process where risks should be identified, analysed, prioritized, managed, triggered, measured, tracked, so a critical risk analysis and additional mitigation actions can be defined. Using this methodology, risks can be more accurately identified and the project managers can develop specially designed strategies to mitigate vulnerability and contingency levels.

3.2 Cost Management

Cost management is defined by the PMBOK guide as the processes that involve estimating, budgeting and controlling costs so that the project can be completed within the approved budget (PMI Standards Committee, 1996). Compared to risk management, cost management in Colombia is in a higher stage of development, possibly because the importance of budget control, the evident impact on project success and the nature of financing projects lead to better practices in this area.

3.2.1 Local Literature review

As defined by Rodriguez (2010), most private Colombian AEC projects are based on a capital structure that involves equity and debt, the latter in a much higher proportion. Therefore, the project must be clearly defined on cost and schedule in order to formulate a cash flow based on expenditures and obtain a construction loan via building societies (Correa, 2007).

Local research has uncovered the need for the implementation of a general economic Net Present Value model for each project. It must be designed to modify the most important variables regarding participation of the whole cost, to identify the critical elements and design a proper business structure (Zapata, 2010). The main variables that influence budget on typical Colombian construction projects are Workforce, Concrete and Steel prices (Cuello, 2008); hereafter research into project development must be based on sensibility analyses of these main variables.

3.2.2 International literature Review

Among international trends, Real Options have turned into a recurrent topic related to project evaluation regarding cost management. These options are strictly related to “real” projects based on the production of services or wells such as AEC projects, which are usually analyzed via Net Present Value. In terms of Real Options, an analysis is made according to the different decisions and scenarios that the environment and project execution can present with their respective probability of occurrence. After such analysis, the project manager has the flexibility to study the whole project and decide whether to continue, resize, freeze or abandon the project.

As already mentioned, AEC project environments are very variable and directly affect the development of any project, so a proper Real Option analysis can be very helpful in providing the necessary tools for making the right decisions that will lead to positive results (Garvin & Ford, 2012).

Although, international evidence emphasizes the importance of Probabilistic and Net Present Value project analyses, the Colombian AEC industry presents some limitations brought about by traditional risk management techniques still implemented by most project managers. Project managers are prone to making decisions that reduce uncertainty, therefore professionals in this industry usually do not select new ideas, they prefer to use conventional processes instead of investing time and resources on well-structured decision making methodologies (Garvin & Ford, 2012).

However another three main elements were identified as common deficiencies. Managers in this industry are loyal to the first budget made; they don’t refresh values, so budgets that could initially lead to successful projects, prove not to be profitable once execution begins (Piedrahita, 2010). Another critical element that must be considered for determining the prices and consequently the success of any housing project is sales speed as this implies loan costs from the early phases if the project is not sold rapidly (Velasco, 2012). Finally, the

lack of a defined methodology for time control and analysis of work planned vs. work performed leads to cost control failures when deciding which strategy should be implemented to finish with the initial budget (Lucero, 2008).

3.3 Maturity level

In addition to process definition, several attempts have been made to analyse the state and the culture of an organization's risk management capabilities. RM3 (Risk Management Maturity Model) was a tool created to develop a maturity assessment model, in which 5 main attributes were identified: Management, Risk Culture, Ability to identify risk, Ability to analyse risk and Application of standardized risk management system (Zou, Chen, & Chan, 2010)

In order to be in the highest level or maturity of risk management according to Zou et al. (2010) the company must: Continuously improve to maintain mature in risk management capabilities, ensure continued commitment by upper management and perform regular reviews of processes and techniques to guarantee the quality of risk management applications and practices. Other practices include investing in improving risk processes, identification techniques, risk analysis tools, employee skills and provide regular training to employees to maintain high levels of knowledge and skills.

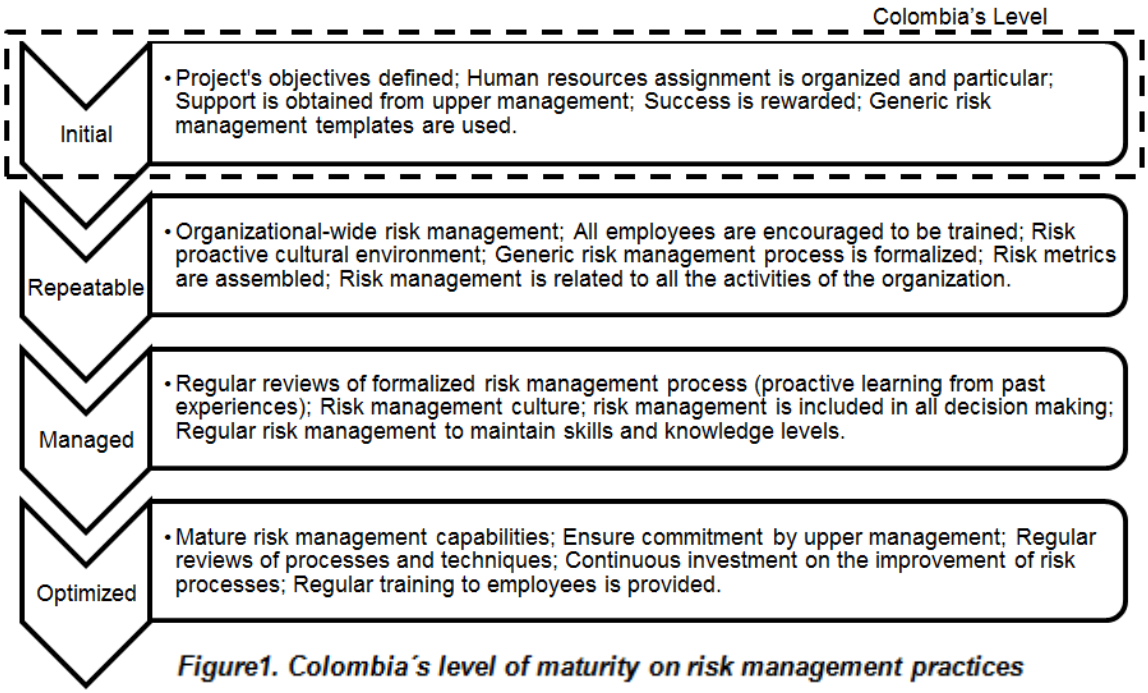

Figure1. Colombia´s level of maturity on risk management practices

According to these parameters, the Colombian AEC companies analysed are in the lowest phase of development, the main characteristics described in the case studies highlight the involvement of the upper management and their attempts to create a generic risk management process. Nevertheless, very low levels of training within the employees are identified and, as mentioned above, there is a huge failure in terms of documentation and even conceptual definition of the projects. Figure 1 summarizes the level of risk management in Colombia based on Zou et Al. (2010) levels.

4. BIM

BIM (Building Integrated Modeling) has been defined as one of the worldwide predominant trends to manage projects in the AEC industry. It is a representation of projects that changes the conventional 2D CAD model into an nD model that, instead of representing elements as lines, describes a series of objects with attributes (materials, team leaders, cost, etc.) that allows a better visualization and, therefore, avoids clashes between various systems (Eastman, Teicholz, Sacks, & Liston, 2011).

The main advantages of implementing this model are the reduction of industry fragmentation, improvement of efficiency, lowering of the high costs of inadequate interoperability, design support throughout the phases, project control throughout its life cycle, and regulation of the project team providing a well-defined mechanism to identify changes in roles and relationships (Succar, 2009).

Consequently the whole project is of better quality, lower costs and shorter durations, which can be understood as improvements in terms of knowledge and cost management, treated previously in this document.

4.1.1 Local Literature review

On Colombian companies, BIM is not a common trend, although among the studies included in the research methodology, two companies had already begun the process of implementing BIM as their modeling strategy for projects. According to Sánchez & Valencia (2011), the main barriers found in this process are the initial cost of acquiring the software, training personnel, technical support and the cultural change of modifying the standard process that has been used for a long time.

One of the companies analyzed had already begun this process, but the whole concept of implementing this technology was understood as the acquisition of the basic software and basic training. Only a few designers from different areas of expertise were instructed and, mounting the whole project in BIM has turned into the responsibility of those few, meaning that the work kept being fragmented (Iguarán, 2010). The second company that uses BIM technology began to do so because its main contractor demanded this technology as the standard for planning and developing their projects, therefore this process and the better practices were basically obligatory if they were going to stay in the business (Isaza, 2008). Although, the analysis proved that the technology was not being completely exploited and the main improvements that BIM assures were not being accomplished, a huge and recurrent mistake is that companies do not have the level of detail required to take advantage of the program and the model is only being used during the design phase. Therefore, the improvements in terms of the whole process and results are very limited (Castañeda, 2009).

4.2 Maturity level

Based on the maturity stages of BIM proposed by Succar (2009), it was found that the companies studied in the theses included in the literature review, are divided into two levels; Pre-BIM status and Object based modeling synopsis. The former is the basic stage in which project documentation is 2D, quantities and costs are not related to the model or documentation, work flow is linear and asynchronous and there is a low investment in technology and lack of interoperability. The object based modeling synopsis is characterized by single-disciplinary models, a lack of collaborative philosophy and disjointed communications. In order to get to the Integrated Project Delivery (IPD) level, which is the highest, coordination, communication, decision support, and other work processes enabled by integration of data in all directions must be implemented and standardized. Figure 2 locates the Colombian level of maturity regarding BIM based on Succar (2009) maturity

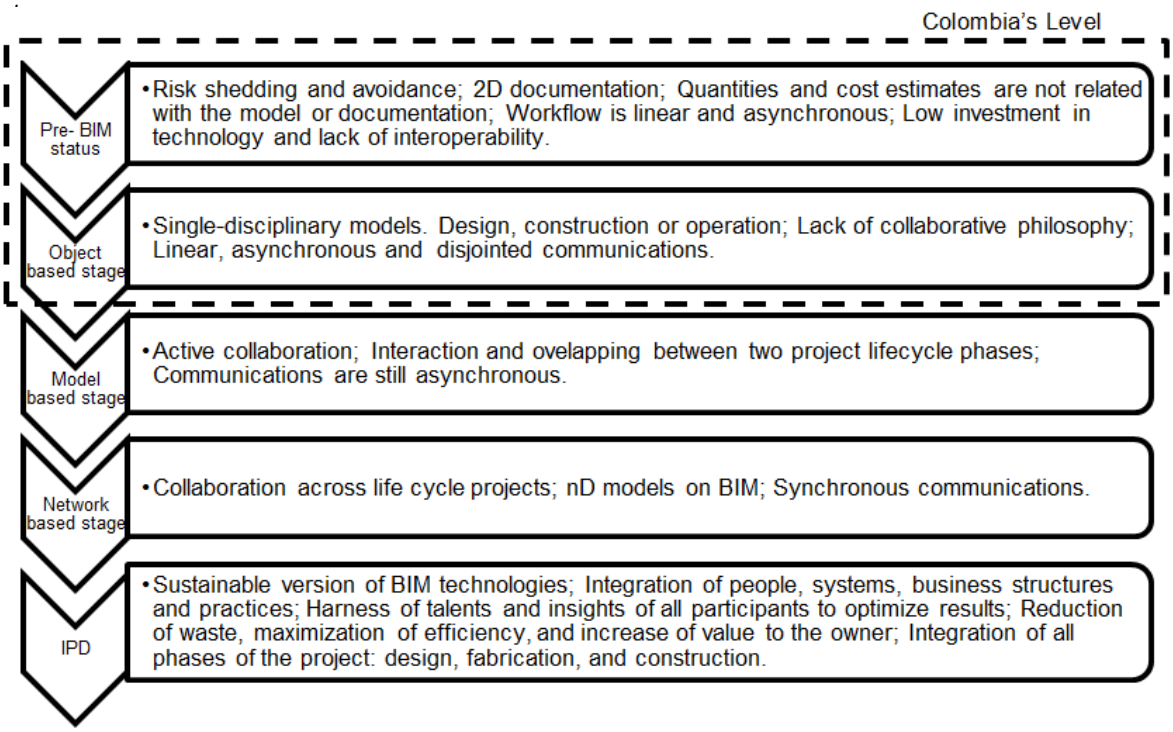

Figure2. Colombia´s level of maturity on BIM practices

5. Conclusions

Most of the documents reviewed in this paper, studied individual cases related to specific areas of project management regarding practices among small and mid-sized companies. Nevertheless, other studies have been made to define the process of implementing managerial techniques among most relevant companies in the industry; as detailed studies of practices implemented by leader companies on innovation, planning and management. It is worth to mention that an effort is being made to spread and implement better practices among agents involved in this industry, and big companies have proven to comprehend them.

As described above, it is evident that the mid and small sized Colombian AEC industry companies present very low grades of development according to the scales established

internationally with respect to risk management, knowledge management and BIM implementation. Therefore, a well-defined strategy must be employed to reduce the main deficiencies present, and improve the poor rates of success that are present on the execution of Colombian projects. Among the malpractices that should be highlighted, are the inner and outer fragmentations present within companies that hinder integration, knowledge management and the constant learning process that leads to the implementation of better practices.

According to the studies analysed, the most common risks present in the Colombian AEC industry are related mainly to planning and financial failures. In order to mitigate planning risks, a better-established process for approving construction licenses must be developed with the intention of reducing the adversities present during construction and encourage better planning phases for projects. The definition and standardization of the approval parameters is suggested as future work for the local planning authorities, which surely will ensure better success rates on public and private projects.

Insofar as financial failures, international trends such as real option evaluation and Net Present Value sensibility analysis of the most important materials that determine the viability of projects must be made.

The advantages of BIM were continuously cited as present failures of the AEC industry, consequently the implementation of this technology can be identified as one of the most feasible options to improve industry results. Although it was also observed that some of the requirements for implementing BIM, such as transparency, process efficiency and new decision making procedures, made the process particularly challenging for some actors in the supply chain.

The impacts and requirements of implementing a contractual methodology to overcome these difficulties and boost positive results via demanding the use of BIM for participating on public and private biddings are suggested as a future work.

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Non-residential building energy use today and tomorrow

Andrew Pollard[1], Michael Babylon[2]

Abstract

The six-year long Building Energy End-use Study (BEES) has collected detailed information on energy use for over 120 non-residential premises throughout New Zealand.

Major energy end-uses such as lighting and fixed wired appliances were measured by electrical energy measurements at the relevant circuit boards within the premise at one minute intervals. If present in the building, shared services such as lifts and HVAC systems were also monitored. Measurements were also made of selected individual plug-in electrical appliances by attaching specialised monitoring equipment to them. Additional information about the environment within the premise such as the temperature, humidity, luminance levels and CO_2 levels were also collected at a 10-minute interval. The monitoring period was typically over a two week period.

The energy use data from BEES provides a unique nationwide dataset. This paper discusses some of the characteristics of the observed energy use and possible pathways to improve the energy use in non-residential buildings. One important application for such a dataset is to provide realistic equipment usage patterns as inputs into computer-based building simulation models. These improved models will allow future building performance to be better predicted and will allow the impacts of changes to buildings and their operation to be better understood.

Keywords: Non-residential Energy Use, Energy End-Use, Building Energy Simulation, Computer Use, Appliance Use.

1. Non-residential buildings

The Building Energy End-use Study (BEES) is a study to better understand energy use in New Zealand's non-residential buildings. Defining what a non-residential building is itself a complicated question let along determining its energy use.

There is no database of New Zealand's non-residential buildings so a sample frame has to be constructed using a particular methodology. For BEES, a database of valuation records of legal titles was used (Camilleri and Isaacs, 2010). This database includes in addition to the rateable valuation information, a legal title and a usage category.

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The legal title identifies either; a land parcel, one or more buildings, parts of a building (for example, each floor of a multi-level building may have a separate title), or another non-occupied structure.

The activities within a building determine whether it is non-residential and the building category, e.g. commercial office or retail. Categorising the usage of a building can be involved. There can be a variety of activities undertaken within the building and multiple classifications may be required. This can include situations where there is a mixture of non-residential and residential uses such as apartments within the same building as retail businesses or offices. There are also more changes of tenancy within non-residential buildings than is the case for residential buildings. This can change the types of activities within in the building as well as result in varying proportions of floor area which is vacant.

Educational and health buildings have characteristics that typically make them distinct from other non-residential buildings. Commonly these types of buildings occur in clusters of buildings as part of a campus which may or may not have shared services between the buildings. For this and other reasons, educational and health buildings were excluded from the BEES sample frame (see Isaacs et al, 2009 and Isaacs et al, 2010).

2. Energy use in non-residential buildings

The varied tenancy in non-residential buildings can make collection of data on energy use complicated, as multiple energy accounts may be involved. BEES found that less than 9% of premises occupied all floors within their building (Saville-Smith and Fraser, 2012). In addition to the energy use of each of the tenanted areas within a building, there is also a base building energy use. Base building energy use is the energy used by non-tenanted activities and includes energy use for shared areas (lighting) and any HVAC plant, lifts or other services.

As a premise gets bigger, it would be expected that its premise energy use would also increase, as more areas may require more lighting, computers, office equipment, appliances and other energy services. In order to allow some comparison to be made between different premises, some scaling factor is required to correct for this effect. A common approach is to scale by the floor area of the premise. Scaling the energy use in this way produces a figure known as the Energy Use Intensity (EUI) for that premise. The energy use for the whole building (base building and premises) and the total floor area for the building could also be combined to calculate an Energy Use Intensity for the whole building (Peterson and Crowther, 2010).

3. Considering today's buildings

Until BEES the data on the energy performance of New Zealand's non-residential buildings was very limited. In the late 70's and early 80's there were a number of projects in the three main centres; Auckland (Beca Carter Hollings et al., 1979), Wellington (Baird, et al. 1983) and Christchurch (R. W. Morris & Associates, 1985), which examined the energy performance of commercial buildings in those specific areas. Making use of the results from

these studies today introduces some difficulties due to the changing building standards, insulation levels and HVAC performance. These earlier studies also were localised, selecting commercial buildings in a restricted area. This has the potential to bias the sample towards larger commercial buildings.

Around the same time Standards New Zealand (1982) developed guidelines for energy efficiency in non-residential buildings which included suggesting for buildings with particular activity types such as a target of an EUI of less than 100 kWh/m²•year for new office buildings. While these targets are still frequently used today, their origins are not commonly stated, perhaps not wishing to reveal the uncertainty in these targets.

In designing new non-residential buildings, a common means to assess how it will perform with regard to energy use is to use building energy simulation computer programs. Current building code requirements allow for building energy simulation programs to be used providing they meet certain requirements (Standards New Zealand, 1996; Judkoff and Neymark, 1995).

While building energy simulation programs can provide accurate estimates of a buildings energy use, this is dependent on having an extensive data set of building characteristics, weather information and accurate schedules of HVAC, occupancy and other equipment operation. These data sources are often not available and estimates are made reducing the accuracy of the building energy modelling. Indeed often schedules and inputs from overseas are used.

Lunneberg (1999) commented that equipment load calculations for use in building simulations are frequently over estimated and that this estimate can be out by as much as five times the measured load.

Detailed measuring of equipment load demands is expensive and can only be done once the building has been constructed and occupied. This has been done within the BEES project and the BEES energy monitoring provides an opportunity to explore how appliances are actually used in non-residential buildings. This provides a better understanding of the actual appliance loads within New Zealand's non-residential buildings and will allow better estimates to be made of aggregate appliance use for use in computer simulations of non-residential buildings.

4. Using BEES data to examine appliance loads in more detail

As part of the energy monitoring in BEES, at least three randomly selected appliances within each of the premises were measured over the two week monitoring period. These measurements were undertaken at a one-minute time interval to allow the characteristics of fast switching services to be examined in detail. For example, a refrigerator that cycles at say, a 14 minute period would always appear on if examined at the frequently used half-hourly interval.

This paper will consider computers as an example of a particular appliance load (part of the equipment load) for a non-residential building showing the pattern of typical use as well as how varied that use is.

Figure 1 is a standard exploratory data analysis (EDA) graph used within the BEES project. This type of data presentation and initial analyses supported by very high density monitoring provides an enormous amount of useful information where significant insight can be drawn from this type of data. Figure 1 shows a typical pattern of a desktop computer over twenty one days in a standard office environment. The measurement intervals are 1-minute which allows subtle patterns to be examined such as certain categories of loads (wattage), abnormalities (negative readings – either due to the inductive loads or instrument error – fluctuations, we can analyse how frequent and how significant these are), daily profiles, start and end of working hours, time and intensity of operation during each day, spikes and base loads. For example someone was working for a short period of time on Saturday 29 May and the computer was not used at all on 3 June, as it turns out this was a holiday weekend (Queen's Birthday) in New Zealand. A detailed description of these EDA graphs can be found in the BEES literature (Isaacs, et al 2010).

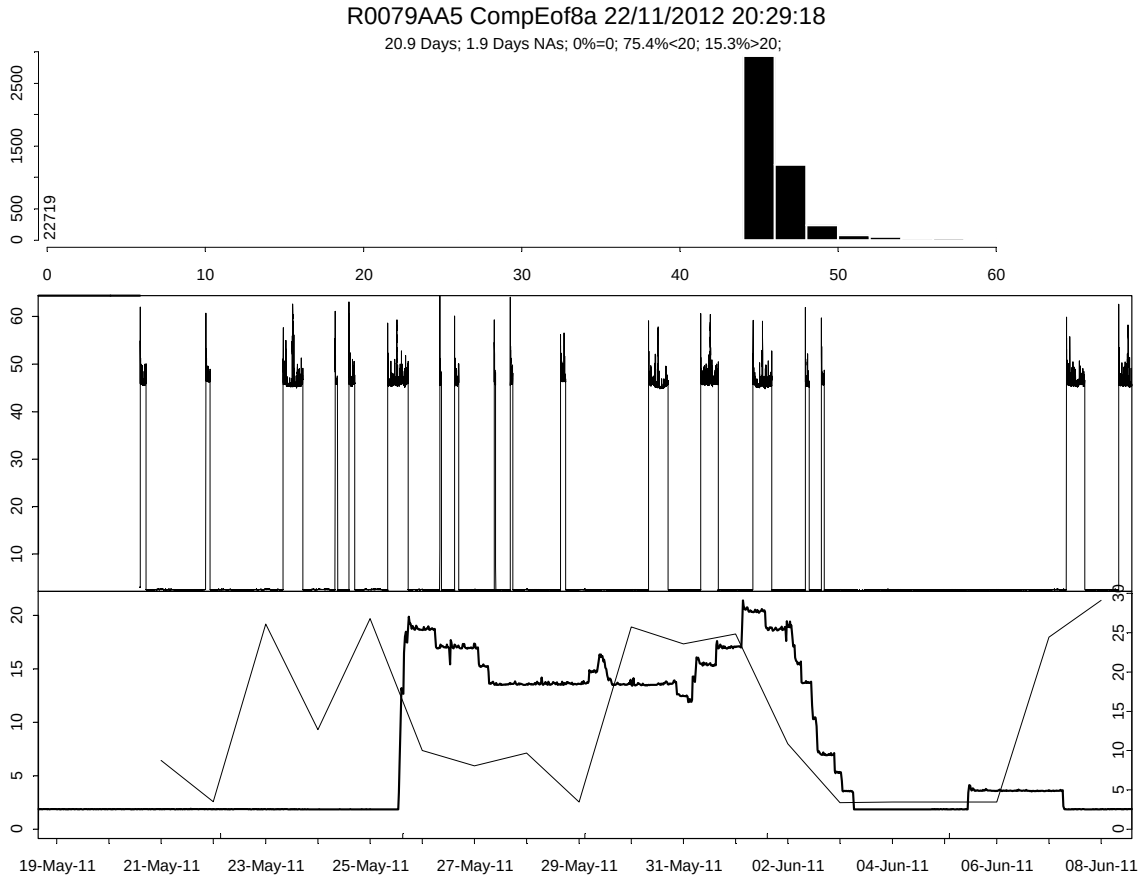

Figure 1 An exploratory data analysis (EDA) graph for a computer showing a histogram of the values in top graph, a time series graph in the middle graph and moving average (light line) and a time of day profile (dark line) in the bottom graph. These EDA graphs are routinely generated for each appliance monitored in BEES

Figure 2 gives the electricity use of one computer over one day at a one minute interval. This fine timescale allows for a detailed appreciation of “fine cycling” including clear distinctions when the processor and hard drive were performing harder. It was used in a standard office and it expected that only light processing such as word processing or basic spreadsheets were used rather than intensive processor tasks. There is a distinct but not particularly significant peak during the lunch time. Could this be lunchtime social activities which are more intensive in computer usage such as; playing games, checking social media or using the CD drive to listen to music?

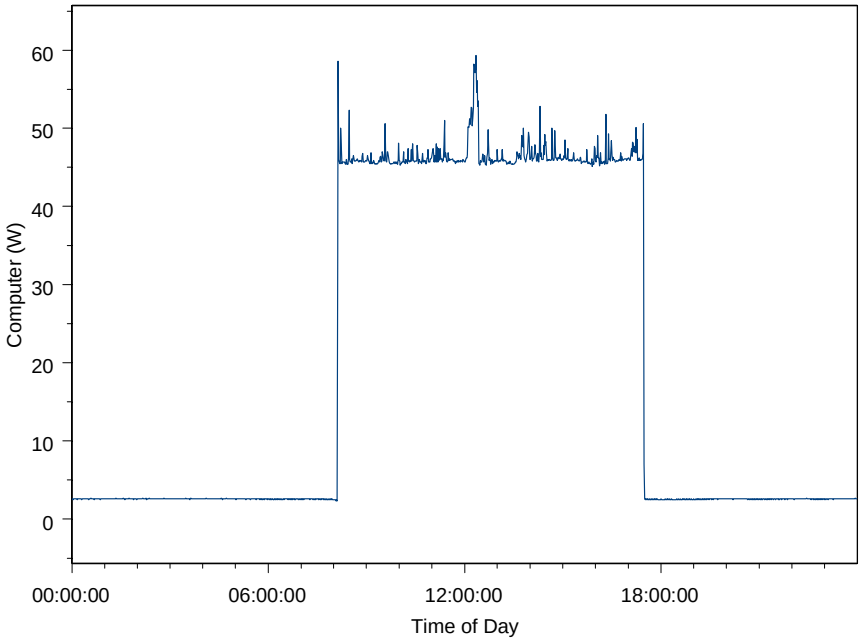

Figure 2 One day of use of one particular computer. The computer is in a low power standby mode until shortly after 8 o’clock when it leaps up to its operating level of around 45 W. After 17 o’clock the computer returns to its overnight lower power state. The interval between the data points is one-minute

The twenty-one individual days of use of the computer are presented in Figure 3 scaled to 10 minute intervals to better recognise repeated behaviours.

Figure 3 also shows in heavy black outline, the average time of day profile for the computer. This average profile is lower than the typical operating level due to the computer not always being on at that time of day. The level of the average profile will be reduced with the computer not being used on weekends and holidays as well as periods of the computer user being out of the office. The one day the computer being used in the evening results in a small blip ($^{1}/_{21}$ of the typical operating level) in the average profile for the evenings.

At least one feature is clearly identifiable; the computer is being used in a very consistent way and for particular regular tasks. When compared to other computers in the building, we observed similar profiles. Thus at least in this case it is quite simple to estimate the profile and the way the energy is used by computers in this business.

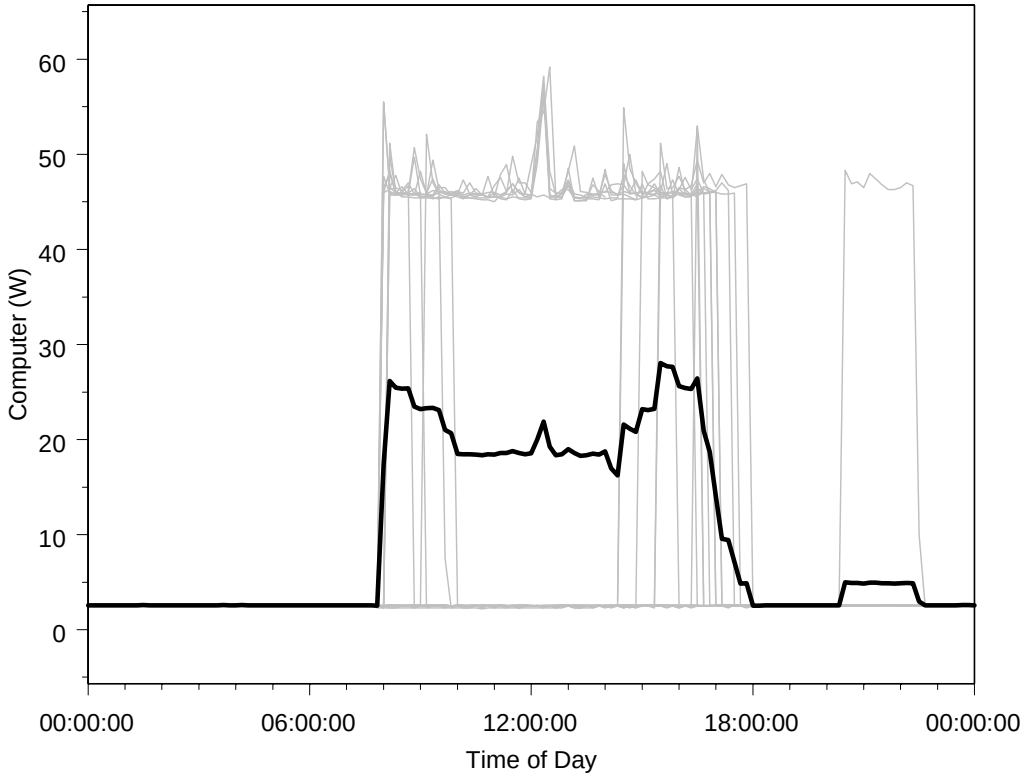

Figure 3 Twenty one days of the use of one computer shown superimposed (in grey) by time of day with the resulting time of day average profile shown in heavy black outline. The time interval has been changed to 10 minutes to emphases the underlying patterns.

For the purpose of this analysis we have selected fifteen computers in different premises available from the BEES database. Two thirds of these computers were in offices with the remaining third in retail premises.

Figure 4 gives the value of the estimated annual energy use (in kWh) of the fifteen computers examined in descending order. Computers present in offices are identified by the dark grey bars whereas computers in retail business are identified by the light grey bars. These computers were for individual use and did not include a display other than when this was an integrated feature of the computer (such as a laptop). The energy is collected when

the computer is used at the monitored premise. Laptops which are used away from the premise will only have the data from when the computer is present at the business recorded. The monitoring for the laptops is not of the operation of the laptop (as laptops can operate from batteries) but instead is when the computer is connected to an electrical outlet and using electricity.

The top three (20%) computers in the energy rankings were computers that were left on outside of the business hours. This 20% is similar to the proportion of computers in the United States of America that were identified as being 'on' outside of normal hours (Webber, 2005). These three computers use considerably more energy per computer than is the case for any of the other computers. The three laptop computers (ID's 10,12 and 15) were lower energy using computers. The highest energy using computer used more than forty times the energy than of the lowest energy using computer.

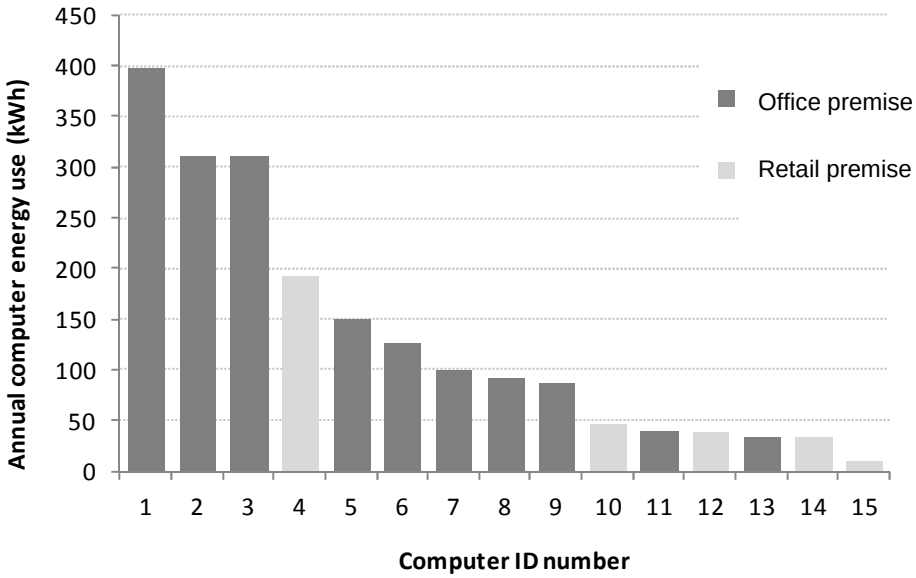

Figure 4 The estimated annual energy consumption of fifteen computers from non-residential buildings (excluding energy use for any separate screens).

Figure 5 gives the electricity time of day demand of fifteen different computers. Apart from the three computers that are left on outside of working hours, and the lowest energy using computer shown in the bottom right hand corner of Figure 4. All of the computers show an approximate square wave shape increasing energy use from around 8-9 o'clock in the morning and running until around 17-18 o'clock before dropping back to a standby load level outside of working hours. The differing factors for each of these computers are the power requirements during the operating houses as well as the varying standby power requirements outside of normal hours. The standby load varied from around 2 W to 10 W. One system appeared to have no power requirements outside of operating hours. It is likely this system was turned off at the end of the day rather than being set to standby.

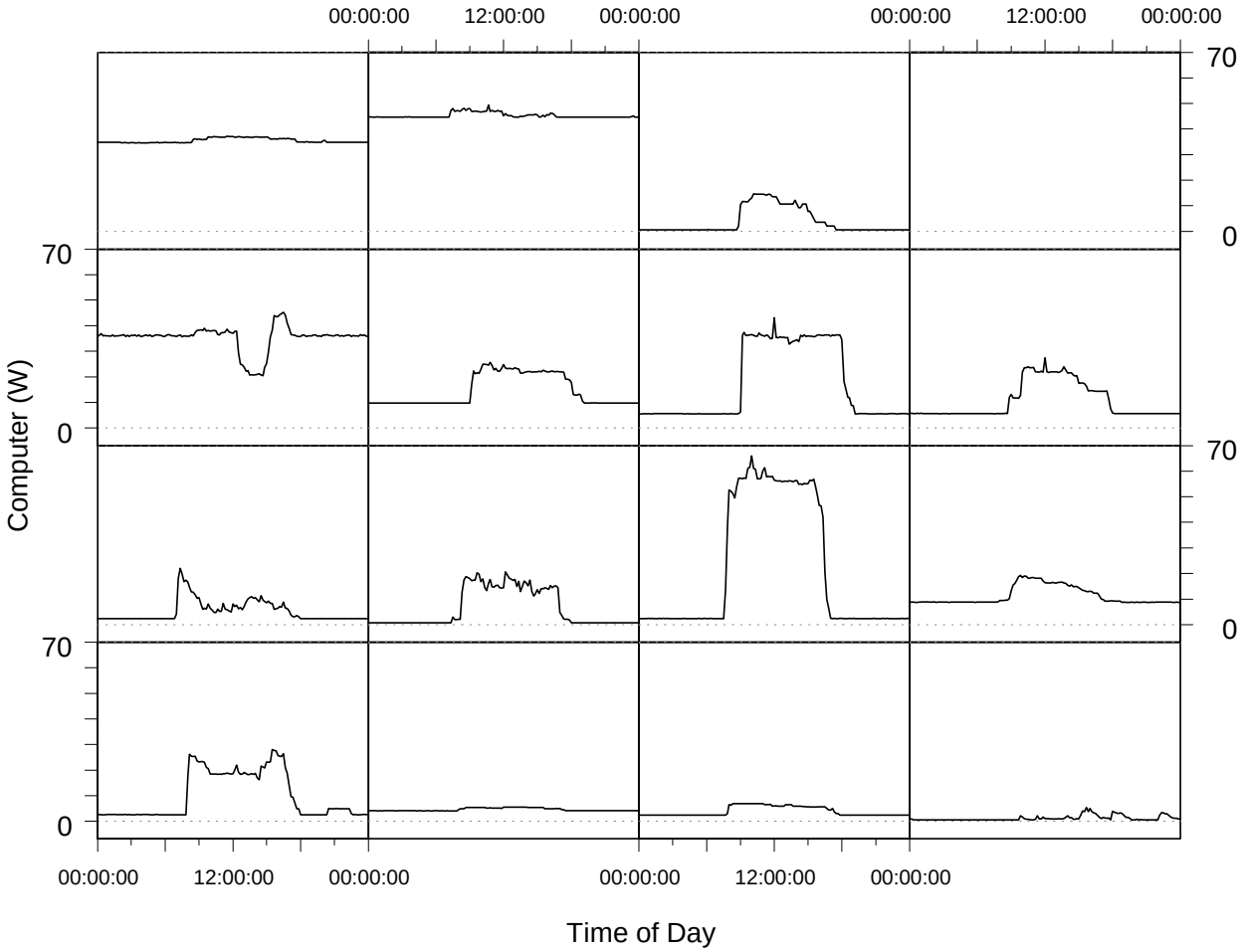

Figure 5 Computer power demand by time of day for fifteen separate computers (excluding any separate screens).

5. What this means for buildings for tomorrow

Building energy simulation is currently the primary means to examine the energy impacts of various building design options. While building energy simulation programs accurately determine the physical heat transfer processes going on within a building, they are dependent on having accurate information on the operational characteristics of the building such as the occupancy, HVAC and other equipment use.

The BEES data is revealing some of the variability present within equipment operation which will allow more realistic equipment schedules to be developed in the future.

The operational characteristics are ultimately dependent on the people using the building. While using more accurate equipment schedules will allow a more accurate calculation of the building energy to be made, there still may not be sufficient variation in the scheduling to

accurately summarise the collective behaviours of the building uses. A framework to better understand building energy will require drawing together physical building energy simulation models with behavioural models of what the users of the building are doing.

One emerging method to examine behaviours of a set of individuals is agent-based modelling (Macy and Willer, 2002). Agent-based modelling uses large scale computer based calculations of a set of basic rules on a number of agents within a target population. Agent-based modelling has had some application to energy use in buildings. Azar and Menassa (2012) is one such example, however this paper looked to examine the impacts of behavioural change, turning high energy consuming users into low energy uses, rather than in better understanding the overall operation of a building. Perhaps there is an opportunity for agent based modeling to be used to provide a range of operational schedules for input into building energy simulation models in an analogous way to have varying weather data is examined by considering a full year of data.

Building energy simulation provides a means to assess the energy impacts of a variety of design choices. Building energy simulation can be used to set targets for the energy use for a particular building by setting a level of maximum energy use that can only be achieved by incorporating good thermal design and a well performing HVAC system into the building. Care must be taken to ensure that a building's actual operating energy use is aligned with its design levels. Turner and Frankel (2008) highlight that this is not always the case with many 'high scoring' buildings actually requiring more energy that is set as a maximum for the code requirements (see figure ES-5 in Turner and Frankel, 2008).The overall energy use in the BEES buildings will provide some indication of variability of real building energy performance. This performance information will help to inform the setting of any performance thresholds for new buildings but would also assist the setting of targets for the retrofitting and upgrading of existing non-residential buildings.

The Energy Efficiency and Conservation Authority (EECA) and the New Zealand Green Building Council (NZGBC) have announced (EECA, 2012) that they will be developing a New Zealand version of the Australian NABERS (National Australian Built Environment Rating System) scheme which looks to assess buildings on their measured energy performance. BEES has provided energy use intensity information to the developers to assist with benchmarking against standard New Zealand buildings.

6. Acknowledgements

BEES is funded by BRANZ Ltd. through the Building Research Levy and the Ministry of Business, Innovation and Employment through its Building and Housing group and its Science and Innovation group. The Energy Efficiency and Conservation Authority (EECA) has also contributed to the funding for this project.

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Exploring BIM implementation: A case study in Hong Kong

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Abstract

Building Information Modelling (BIM) was introduced to the Hong Kong construction industry as a technology-oriented process innovation in the past few years. Improved functionalities and interoperability of software provide a collaborative platform for all stakeholders that will alleviate the fragmentation in the construction industry. However, the high expectations from BIM led to dissatisfaction by users, the nature of the fragmentation itself turns out to be one of the factors inhibiting further successful implementation of BIM.

In this paper, we present a case study that explores current BIM implementation performance in the Hong Kong construction industry. More specifically, we explore whether BIM implementation in Hong Kong is changing the old roles, relationships and working practice paradigms of stakeholders by providing a collaborative working environment on construction sites. Data were collected from ethnographic participant observation and one-on-one interviews within a social network perspective. The evidence shows that visualization tools are powerful facilitators of effective communication across project teams at the technical level. However, the communication techniques themselves in the construction process add little value to the improvement of co-ordination and cohesion in the building team, but the patterns of relationships and responsibilities within project teams have significant influence on the way communication takes place. Due to both team members' reluctance to change and power conflicts during collaboration, human agents mediate the positive influence of BIM on project collaboration to some extent.

Keywords: Building Information Modelling (BIM), inter-organizational relationships, collaborative working, social network analysis, human mediation

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1. Introduction

The construction industry has been widely criticized for its fragmentation (Shirazi et al., 1996, Baiden et al., 2006, Pohl, 1989, Ahmad et al., 1995). This is due to the rational human reflections embedded in the traditional culture of the construction industry over decades (Xue et al. 2010), where participants focus merely on self-protection and economic benefits rather than general performance of project delivery (Latham 1994, Egan 1998, Tang 2000). The increased complexity of construction projects (Gidado, 1996), lack of accurate building information and ineffective communication within project teams (Higgin et al., 1965) are all reasons for the poor collaborative working environment, which leads to unsatisfactory project performance.

Numerous academics and practitioners attempted to construct effective solutions leading to heightened communication and collaboration performance within project teams (e.g. NEC, lean construction, and IPD). In the 1960s, Tavistock Institute's (Higgin et al., 1965) pilot study on communication in the building industry provided a full picture of communication issues in construction projects. Two major problems emerged: lack of accurate building information and communication among stakeholders, which led to inefficient building operations. These primary communication difficulties stemmed from difficulties in clearly defining the roles of resource controllers and the complex interaction of technical, economic and social forces (Crichton, 1966). In their follow-up research in 1966, the concepts of interdependence and uncertainty were proposed as significant characteristics of construction (Crichton, 1966), which were later recognized as two categories of complexity of construction processes (Gidado, 1996).

In the past decades, BIM emerged as an important domain within current information and communication technology (ICT) research. It was promoted for various deliveries and potential advantages: single database, efficient design, effective visualization of clashes, etc. (Ashcraft, 2008, Azhar et al., 2008, Bernstein and Pittman, 2004, Howell and Batcheler, 2004, Hu et al., 2008, Singh et al., 2007). Among these expectations, provision of accurate building information from a single database and provision of service as a collaborative platform are especially attractive solutions to the fragmentation in the construction industry. However, two problems emerge.

First, although there have been numerous research studies on building information modelling, there is no rigid definition of BIM. BIM is considered as "an innovative approach to building design, construction and management" (Autodesk, 2003)**,** enabling the management of building information in different project phrases in the Architecture, Engineering, Construction and Operation (AECO) industry (Gu and London, 2010, Gu et al., 2008). It is a methodology generated from the interaction of policies, processes and technologies; managing the essential building design and project data in digital format through the entire building process (Succar, 2009, Succar, 2010). However, terms ranged from tangible products to intangible concepts such as 'Asset Lifecycle Information System', 'Integrated Model', 'Objective Oriented Building Model', 'Virtual Design and Construction & 4D Product Models' and even 'Integrated Project Delivery' etc. are all adopted to embody BIM. In practice, most BIM users prefer to regard BIM as an

advanced software rather than a new approach assissting them to accomplish their work (Holzer, 2011).

Secondly, although BIM was proposed as an innovative solution to the fragmentation of the construction industry, the nature of fragmentation itself turns out to be one of the factors inhibiting further successful implementation of BIM (Gu and London, 2010). The study conducted by Dossick and Neff (2008, 2010) proves that BIM's positive influence on project integration is limited to the technological level; the key to team cohesion is still based on human factors. Observation of current practice of BIM also indicates that a collaborative atmosphere with collective participation and contribution from all stakeholders in a building project will be of great significance (Gu et al., 2008), rather than the innovation itself. In fact, researchers had asserted that improved communication techniques themselves in the construction process will add little value to the improvement of co-ordination and cohesion in the building team, but the patterns of relationships and responsibilities within project teams have significant influence on the way team members communicate (Higgin et al., 1965).

In Hong Kong, proponents claim that BIM has the power to alter and reinforce the collaborative relationships between project stakeholders, rather than a simple technology innovation. However, the project team members broadly accept BIM as advanced CAD. Therefore, we conducted research to explore the reality of BIM implementation in the Hong Kong construction industry. In this paper, some preliminary findings from one case study will be presented and discussed.

2. Methodology

A social network is a social structure comprising components with meaningful social characteristics (Scott, 1991). It is generally defined as "a set of nodes and the set of ties representing some relationship, or lack of relationship, between the nodes (Brass et al., 2004)". The "points" or "nodes" represent individuals, groups or organizations, and the lines connecting these nodes refer to specific types of relationships or flows, such as friendship, kinship, common interest, financial exchange or knowledge flow (Scott, 1991). When represented in a graph, signs (+ or -) are used to indicate positive or negative relations, the directions of the relationships are denoted as arrows (Scott, 1991). In construction projects, formal and informal relationships of stakeholders can be depicted as social networks, the points or nodes represent the stakeholders and the lines indicate the relationships between them. By analysing characteristics of social networks, important information can be explored, such as "who is the key stakeholder to project's success", "How do main contractor and sub-contractors cooperate with each other", "What is the effectiveness of cooperation" and "How does each stakeholder perform?"

Social network analysis is a methodology in terms of social network theories (Kilduff and Tsai, 2003), taking social relationships as its research objective, analysing relational data collected in the social studies, providing both a visual and a mathematical analysis of human relationships

(Chinowsky et al., 2010, Scott, 1991). In the field of construction, research related to social network analysis is gradually increasing because of the wide range of participants that mutually interrelate and collaborate with each other in construction projects (Park et al., 2009). Loosemore had successfully explored SNA as a quantitative tool in the context of crisis management back in 1998; He also suggested that complementary qualitative research should be conducted to enhance understanding by producing reliable accounts of social reality (Loosemore, 1998). Pryke (2004) applied the method to analyse construction project coalitions in the context of partnering relationships. He developed an analytical framework as well as a social network theory of governance of construction coalitions. In this framework, construction projects are conceptualized as multi-layered interdependent networks, through which intra-coalition relationships can be delineated. The author also indicates that the correlations between different networks can provide a measure of the extent to which procurement methods are in transition, or what is often regarded as maturity. Later in his study (Pryke, 2005), this framework was applied to the analysis and formulation of a social network theory of governance, in which network density and centrality are chosen as measurement metrics to investigate the evolution of diverse networks during the adoption process of new procurement system.

In line with the characteristics of the proposed research, a case study approach was adopted. The proposed research is an exploratory study, aiming at investigating a “what” question (what are the impacts of BIM implementation on project teams in current Hong Kong construction industry). Although any of the five strategies: experiment, survey, archival analysis, history and case study can be used to conduct an exploratory study, case study would be the preferred strategy when focus of a study is on “contemporary phenomenon within some real-life context” and when the investigator has little control over events (Yin, 2003). In the proposed research, BIM implementation and its impact on project teams are all contemporary phenomena within current Hong Kong construction industry. Besides, due to limited BIM projects in Hong Kong, none of the other four strategies would be practical for lacking either historical evidence or control over events. In this sense, case study would be the most suitable approach to fulfill the research purpose. Various types of collaborative relationships were expected to be explored through both quantitative and qualitative methods. By delineating collaborative relationships between different stakeholders in the form of networks (e.g. communication network) and analysing the characteristics of these networks, the changes of roles and relationships across project teams were predicted to occur under BIM implementation.

Data were collected from over 4 months of ethnographic participant observation and 5 one-on-one interviews, along with documentation review from a social network perspective. The interviews were conducted with project team members who work with BIM on a daily basis. All the interviews were semi-structured with questionnaires as the fundamental guideline. Before we started interviews, the interviewees were requested to complete a questionnaire with two sections. In the first section, basic information (such as their experience of BIM, their roles in the project etc.) was collected. In the second section, relational data regarding social network analysis were collected.

However, due to the characteristics of the construction project, such as staff turnover, limited time to build trust among team members, problem-oriented collaboration, and contractual concerns over free exchange knowledge (Chinowsky et al., 2008), the implementation of the social network analysis showed a chaotic picture. Nevertheless, some preliminary findings from this case study have provoked discussion about current BIM implementation in Hong Kong.

3. Findings

In this case, BIM is adopted for mechanical, electrical, plumbing and fire safety system (referred to as MEP systems) coordination in the construction stage. The contract relationship exists between a professional BIM consultancy company and the main contractor. In addition to the modelling team in the consultant company's headquarters, a professional with BIM skills is assigned to manage the BIM system on the site with the title of 'BIM manager'. He and another three BIM-coordinators assigned from main contractor constitute the core BIM team in this project.

3.1 Role change

Nominal role change occurs during the BIM implementation process. New positions named "BIM coordinator, model coordinator or BIM manager" emerge from various professions. These coordinators are promoted from drafts man, modeller, CAD supervisor or MEP engineer in the MEP team. They do the same coordination work in the BIM project as they did in previous traditional projects; the role change is nominal with unchanged working content and procedures. In other words, no new patterns of collaborative relationships emerged under this BIM implementation.

On the other hand, the introduction of BIM indeed brought about role change at the project level. For instance, the central role of engineers in a project team is changing. In traditional projects, engineers are responsible for checking section views of drawings and updating all revised 2D drawings in their heads, which makes them the information flow centre and core decision maker. However, BIM models can provide the same information in a more precise way, weakening engineers' central position in the information flow networks. In this case, demand for MEP engineers reduces as the project proceeds. Four MEP engineers are assigned on site when the MEP coordination work starts. With BIM implementation, different professionals in the MEP team get used to relying on the BIM models when they need specific information , instead of searching for information from engineers in the tradition manner. At the end of project, there is only one MEP engineer left on site to supervise the MEP coordination. Nevertheless, it is unrealistic for team members to rely completely on BIM model because BIM can merely visualize the problems rather than solve them automatically. Engineers with rich project experience are still of great importance for the success of BIM projects.

3.2 Embedded norms

Norms indicate patterns of behaviour in a particular group, community or culture (in this paper, the particular group is the project team), accepted as normal and to which an individual is expected to conform. It relates to social norms that are 'customary rules of behaviour coordinating people's interaction with others' (Young, 2007). These are learned through social interactions (Kamau, 2009), arising in either a formal or an informal way; and they exist either in an explicit or an implicit manner (Burnett and Bonnici, 2003).

Before an innovation is completely accepted by a given group, the old working paradigms play the role of inhibitor. Evidence from the case study reveals that some norms embedded in project team members' working routines appeared to be great hindrances to successful BIM implementation. An interesting phenomenon in our third site visiting occurred: A designer from a sub-contractor delivered a copy of her updated drawing directly to one of the BIM coordinators, rather than uploading each revision of the drawings formally to the integrated BIM database for record. This may improve project team members' working efficiency by saving time to submit and download drawings from the database; however, if incidents relevant to the drawings occur later, disputes may arise because of lacking corresponding records in the BIM system as legal evidence. Nevertheless, this embedded working norm (in an implicit manner) is a good example of flexible use of technology. Although we failed to reach this team member for further interview, another interviewee mentioned it as normative behaviour, which happened frequently during team members' daily information exchange. This also reveals that BIM has not been accepted as powerful information storage and exchange system by the construction team.

In addition, professionals' perception and attitude toward collaboration is embedded in their working norms. Even though the clash detection under BIM implementation has reduced the workload of sub-contractors' design team, their staffs' attitude toward revision and submission of drawings is still passive. They believe it is cumbersome to check drawings by themselves, especially when they do not have BIM-related resource support from their own organizations. Hence, they would prefer to wait for the detailed revision list assigned by BIM coordinators and do what they have to do. However, BIM coordinators complain that the revision list is out of their working scope and has been extra workload for them. As one of the coordinators remarked 'Although only BIM coordinators have the permission to update drawings in the BIM software system, staff from sub-contractors can easily find updated drawings and download them from the database. If they can voluntarily repeat this job every day and accomplish possible revisions in advance, the amount of extra work left to us will be reduced considerably; we can focus on coordination and the efficiency of whole process will be improved significantly.' This problem, in his view point, could be solved either by providing the whole project team with a common server or by setting clear regulations to standardize team members' responsibilities and working procedures. He also proposed to set 'green lines' for sub-contractors as sub-deadlines for each revision, the BIM coordinators will then determine whether the updated version can be accepted or not.

3.3 Power of structures

By adopting a social network perspective, our research explored the formal and informal relationships among project teams and their impact on BIM implementation. The data indicate that both of them influence final project performance, but there is a lack of evidence that either one of them is of greater significance than the other.

The formal relationships embedded in contracts and organizational charts engender power conflicts and hierarchical behaviour among team members, but also create an effective mechanism facilitating collaboration. In this case, if any individual starts to exert negative influence on team collaboration, complaints will be sent to senior managers; by reassigning new members, intra-team and inter-team collaboration can be reinforced.

Compared with formal relationships of project team members, their informal network is less powerful during the decision-making process. However, it enables mutual trust building within project team members, and facilitates information exchange as well as knowledge sharing. With favourable social relationships with other team members, a specific individual can take full advantage of the social capital generated from his/her social networks (Oh et al., 2006). This is even more important in the context of construction projects, where rapid turnover of staff is very common.

3.4 BIM capacity

Currently in Hong Kong, most sub-contractors' own design team is neither professional nor efficient; some sub-contractors still need to hire external specialists to assist in the whole design process. The 3D drawing/modelling output is often behind schedule due to their limited capacity when using BIM software, which consequently delays the project schedule. More important, most of them are reluctant to adopt BIM because of its complexity and expensive cost.

In this case, although finalized drawings generated from zero-clash BIM models are distributed to the sub-contractors, installation errors still occurred on site during the construction process. The poor internal coordination of the sub-contractor affects the ultimate performance of BIM. This indicates that excellent organizational capacity of involved stakeholders (especially the contractors) is equally or even more important to the excellent technological capacity in a successful BIM project. Both of them should be listed as essential entry criteria for BIM project bidders. To employ contractors with qualified overall BIM capacity (including both technological aspects and organizational aspects) will then assist the success of BIM projects.. A scorecard method estimating one company's overall BIM capacity to be partner in a BIM project might be useful during the tender stage, for instance.

3.5 Maturity of BIM

Maturity is a core criterion of successful BIM implementation, requiring adoption of BIM through the whole project lifecycle. Common value among stakeholders for shaping the proactive market needs to be created. In this case, people from different parties deem BIM's functionality from various perspectives. Two of the respondents are from main contractors; they state that BIM is efficient and effective for clash detection, for reference, for visualization and for coordination. The other two respondents are from a consultant: one agreed with the former two respondents, believing BIM will provide further convenience to professionals during collaboration; but the other one assumed BIM to be a 3D tool for presentation.

This implies that current BIM implementation in Hong Kong is still in the primary stage of development. Taylor and Bernstein (2009) explored four paradigms of BIM implementation at the firm level: Visualization, Coordination, Analysis and Supply Chain Integration. They assert that different paradigms have different impacts on final project performance. They also suggest that with firm's increasing project experience, these paradigms will evolve along a trajectory from visualization, to coordination, to analysis, and finally to supply chain integration (Taylor and Bernstein, 2009). In this sense, current BIM implementation in Hong Kong is initiating from the preliminary visualization paradigm, and the further success of BIM implementation can be achieved when it evolves along the trajectory to the supply chain paradigm.

4. Conclusions

In this paper, we present a case study that explores current BIM implementation in the construction industry of Hong Kong. More specifically, we investigate if BIM implementation in Hong Kong is changing the old roles, relationships and working practice paradigms of stakeholders by providing a collaborative working environment on construction sites. Data were collected from ethnographic participant observation and one-on-one interviews from a social network perspective. Due to the typical characteristic of construction projects, such as staff turnover, difficulty of building trust within project teams, and contractual concerns etc., we failed to obtain the relational data for a social network analysis at the end. However, the non-relational data collected from this project has provided valuable information of current BIM implementation in the Hong Kong construction industry.

The evidence shows that current BIM implementation in Hong Kong is in the primary stage. In spite of various definitions of BIM in the literature, BIM is broadly accepted only as an advanced technology in the industry. The visualization functions of BIM are effective to facilitate communication across project teams at the technical level. However, the communication techniques themselves add little value to the improvement of co-ordination and cohesion within building teams, but the patterns of relationships and responsibilities within project teams have significant influence on the way communication takes place. Due to team members' reluctance to change and power conflicts during collaboration, human agents mediate the positive influence of BIM on project collaboration.

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Recent developments in the intelligent refurbishment of non-domestic buildings

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Abstract

This paper describes the state-of-the-art in the refurbishment of non-domestic buildings, and describes some of the innovative technologies that are in development and that could improve energy efficiency and reduce building emissions radically. By reducing heat and mass transfer through the envelope, the main energy consuming factors are tackled by reducing envelope air leakage, externally and internally insulating with vacuum and nano-structured technologies, reducing heat gains and losses with low U-value vacuum glazing and power generating windows, and coating external facades with self cleaning and pollution controlling, and energy scavenging materials. As heat gains and losses through the envelope are reduced, the use of energy within the building is tackled by refurbishing with low energy lighting systems. Innovative light fidelity lighting (LiFi) offers lower energy consumption, improved control of lighting, lower cost and quicker payback periods, and large area plasma lighting can both reduce lighting consumption and recover some heat generated in the lighting system for other services. Once heating, cooling and electrical loads are reduced, the plant requirement is reduced. Innovative low energy and renewable technologies can be used to minimise primary energy consumption and CO_2 emissions. Phase change materials (PCMs) store and release latent heat and can moderate internal temperatures in climates where there are medium to large temperature swings between day and night. Windcatchers can ventilate deep plate buildings using natural ventilation and be incorporated with low energy/renewable cooling and dehumidification systems. Biomass CHP systems offer a renewable source of heating and power. Heat pumps driven by low carbon and renewable sources can provide high performance and reliable heating and cooling systems.

Keywords: intelligent buildings, adaptive buildings, passive and active, low-carbon

1. Introduction

Buildings are responsible for about 45% of Europe's total primary energy consumption and carbon dioxide emissions, with non-domestic buildings accounting for about a third of the total (IEA, 2008). The EU is committed to reducing CO_2 emissions relative to the base year of 1990 by 20 per cent by 2020 and by 80% by 2050. As is pointed out in the EC (2001) and

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EC (2005), rational use of energy and integration of renewable energy technologies could substantially improve the energy performance of buildings, reducing the conventional energy demand in new and existing buildings by at least 20% and substantially contributing to reducing energy intensity. The European Directive on Energy Performance of Buildings (EC, 2003) aimed to improve the overall energy efficiency of new buildings and large existing buildings (>1,000m^2). The most recent update of the directive (EU, 2010) calls for cost-optimal solutions for both new buildings and for the renovation of existing buildings. This should be done by the implementation of advanced measures of technologies and materials in the building envelope, HVAC systems and on-site energy generation. A comprehensive overview has to be established, where different combinations of commonly used and innovative measures should be assessed.

Developments in sustainable energy technologies and building management systems have enabled new buildings to meet the European Directive on Energy Performance of Buildings. However, at current replacement rates of less than 1% mean that at least 75% of the current building stock will be in existence in 2050. Xing *et al* (2011) described some of the technologies currently in development. There is a clear need to develop new technologies and strategies in this area to address energy efficiency with appropriate procedures and building techniques, while taking account of the social acceptance by the buildings' users and the return on investment.

Mortimer *et al* (1998) produced carbon dioxide abatement curves that showed the cost effectiveness of various energy efficiency measures ranging from replacement of tungsten filament lamps with compact fluorescent lamps, replacement of gas boilers with condensing boilers, to the installation of loft and cavity wall insulation. It was shown that up to 2.5million tonnes of CO_2 per year could be saved cost effectively (the cost savings (£/tonne C) were greater than or equal the cost of implementation) at a discount rate of 8%. They concluded that for UK commercial sector using electricity supplied by gas fired power stations, the most cost effective measures were:

- Condensing natural gas boilers
- Compact fluorescent lamps
- Low energy computing equipment/accessories
- Thermostatically controlled valves
- Improved air conditioning systems
- Fuel switching

It was shown that replacement of single with double glazing was not cost effective, and that loft and cavity wall insulation had only a low cost effectiveness. However, it was pointed out that replacement glazing was commonly implemented for reasons in addition to cost effectiveness alone, such as the replacement glazing at end of life, the reduction in maintenance costs or the reduction in noise pollution. Loft insulation was found to be relatively ineffective because the majority of non-domestic buildings were flat roofed. Cavity wall insulation was ineffective because the majority of buildings were single wall masonry or concrete construction, or steel framed, glazed curtain walled construction. Measures such as

external and internal wall insulation or innovative roof retrofitting options were not considered.

Georgopoulou *at al* (2006) analysed greenhouse gas emission reduction potential for domestic and non-domestic buildings in Greece. In the non-domestic sector up to 70% of the potential reduction measures came from energy efficient electricity use, including low energy light bulbs, building management systems and ceiling fans. Investigating measures that were cost effective with economic support policies and subsidies, it was shown that win-win measures (measures in which abatement costs are less than or equal to the cost savings at a 6% discount rate) were around 4.5million tonnes of CO_2, representing 88% of the technically feasible carbon abatement measures. This did not include high cost measures such as external insulation, double glazing and solar thermal hot water systems. These additional measures represented about 8% of the technically feasible at a 6% discount rate.

We have divided the retrofit technologies into some general themes. The reduction in energy consumption as one of the major hurdles to cutting carbon dioxide emissions as well as reducing the running costs of buildings, reducing reliance on imported fossil fuels and increasing the security of our energy supply, and so tacking envelope losses is important in reaching a near Zero Energy Building. As heating and cooling loads are reduced, the energy used in operating the building increasingly dominates and so energy efficient and low carbon technologies that reduce energy consumption will be developed. With heating and cooling loads reduced, building services plant and machinery can be reduced and more efficient and low carbon and renewable technologies can be deployed.

2. Innovative and emerging technologies

2.1 Envelope

One of the main methods of improving thermal insulation both to reduce heat losses in cold climates and heat gains in hot climates is the installation of external or internal insulation. (Dylewski and Adamczyk, 2011, Anastaselos *et al*, 2009, Cabeza *et al*, 2011, Ballarini and Corrado, 2012). Many technologies are in development to improve thermal performance such as aerogel (Kamiuto et al 1999, Smith et al 1998), multi-layer insulation (Eames, 2009), gas-filled panels (Haller, 1999) and vacuum insulation (Fricke *et al*, 2008).

2.1.1 Biocrete Cladding: Biocrete sandwich panel cladding is a high strength highly insulated vacuum paneling system that can reduce heat transfer by up to 70% compared to standard insulation systems. It is produced using recycled paper components (hardboard skins with honeycomb cores with glass grit filling) with recycled glass fibre epoxy skins and multi-foil insulation, giving the equivalent thermal insulation from a 100mm thick panel as would be achieved from a 500mm Rockwool core panel. Aggregates and cementitous materials are highly energy intensive and contribute at least 5% to global carbon dioxide production. Society produces large quantities of waste, much of the waste is reusable, and its conversion has a minimal carbon footprint. The material content of Biocrete can vary depending on local raw material sources, but is mainly made up of waste paper/wood, grit/glass, aluminium and plastics.

2.1.2 Vacuum insulated panel (VIP): In many instances external insulation is unable to be used because of asthetic or practical reasons, therefore internal insulation can be effective in reducing heat gains and losses across envelopes. Vacuum insulated panels have been developed over a number of years, but have major drawbacks such as the loss of vaccum over time due to damage to the panels or leakage and therefore a loss of insulation performance. Innovative vacuum insulation panels that use nano-scale honeycomb structures to enable large volumes of air to be evaculated but provide machanical strength for the panel. The panels can have thermal conductance of 0.0036W/m.K, for a 25mm thickness VIP panel equivalent to a 165mm polyurethane insulation panel. The core material is a composition of silica and carbon, which produces a low-density, porous nano-structure. These cores are encapsulated under vacuum in a multi-layer metallised film, thus offering a rigid flat insulating panel.

2.1.3 Composite external panel: Composite panels inspired by the aerospace industry have potential for application in the commercial refurbishment sectors. Light-weight, strong and with low thermal transmission properties, composite panels can be embedded with active fibres to alter their performance dynamically, and integrate energy harvesting technologies into the envelopes of buildings.

2.1.4 External surface coating: Titanium dioxide has been used as a photocatalyst for self cleaning surfaces such as windows. It is however not ideal for use with conventional building materials such as brickwork and concrete walls because it can easily lose its photocatalytic capacity. A new photocatalytic coating that incorporates an oxidation catalyst (TiO_2) into an active oxide matrix to destroy organic matter and toxins, to inhibit the growth of algae and mould, inorganic nano-particles to minimise the adhesion of contaminants. The coating material can be used either as a self-cleaning coating on a surface of a building or can be used as a self-cleaning and pollution reducing coating for buildings in high pollution environments (Figure 1). The coating will be environmentally-friendly and long lasting and could be applied by spray, dipping or other simple coating methods at ambient conditions. Application of the coating will reduce the heat loss resulting from rainwater absorption by conventional wall materials. Coatings that selectively absorb and reflect solar irradiation help to reduce solar gain from roofs in the summer and reduce infra-red radiation losses in winter. High performance glazing often uses spectrally selective coatings that perform the same function.

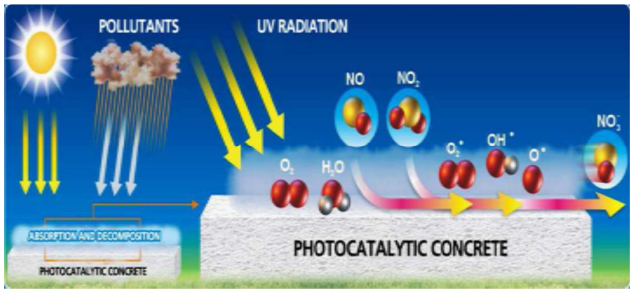

Figure 1. Illustration of photocatalytic concrete

2.1.5. Vacuum tube glazing: To improve the thermal performance of a glazing unit, a novel window technology using glass evacuated tubes and triple glazed evacuated panels has been developed. The vacuum tube glazing consists of two concentric glass tubes. The air is evacuated from the space between the glass tubes to form a vacuum, which eliminates conductive and convective heat loss. To improve the thermal performance of a glazing unit, a novel window technology using glass evacuated tubes has been developed, as shown in Figure 2. Each evacuated tube consists of two glass tubes. The outer tube is made of extremely strong transparent glass that is able to resist a large impact. The inner tube is also made of a glass tube. The air is evacuated from the space between the two glass tubes to form a vacuum, which eliminates conductive and convective heat loss. To maintain the vacuum between the two glass layers, a barium getter is used (the same as in television tubes). During manufacture, this getter is exposed to high temperatures which cause the bottom of the evacuated tube to be coated with a pure layer of barium. The vacuum tubes are enclosed within a frame. The tubes are covered with two sheets of glass with liner lenses to minimise vision distortion. The vacuum tubes can provide a much lower U-value (below 0.7 W/m^{2}K) than conventional glazing. The evacuated triple glazing units use the same technology to maintain a vacuum in flat panels.

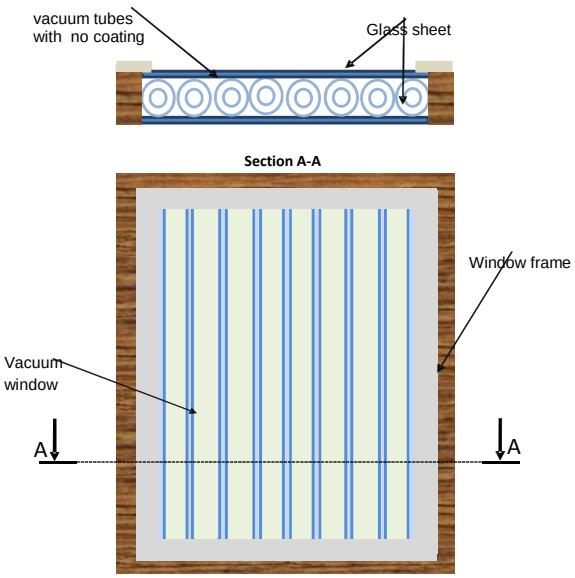

Figure 2. Vacuum tube window

It is expected that the vacuum glazed windows will reduce heat losses through glazing by 50% compared to the systems currently in place and 20% compared to high performance triple glazing.

2.1.6 Heat insulation solar glass (HISG): Windows are vital parts of a building in that they allow daylight into the building, reducing the need for artificial lighting and improving the occupant's health and wellbeing. However, windows are one of the major causes of energy consumption in buildings. Glazing that contains embedded structures are being developed so that light and heat can be selectively admitted to provide the required illumination and heat transfer. Heat will be transmitted and stored so that very little additional

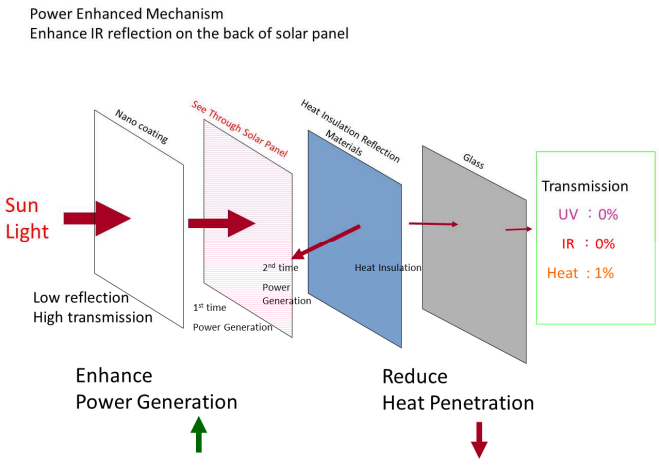

Figure 3. Heat insulation solar glass.

heating or cooling is required. Figure 3 shows a schematic diagram of the working principle behind the heat insulation solar glass. The glazing unit consists of four elements, a low reflection, high transmission glass sheet, a power generation sheet which consists of a transparent layer with embedded nano-crystals and semi-conductor materials which convert solar irradiation into electricity, a third heat insulation layer reflects infrared radiation back to the power generation sheet and increases the power output, but transmits visible light, and a fourth glass layer that interfaces with the interior of the building. The system is a power generator and a heat insulator and can convert up to 10% of the solar irradiation into electricity and reduce air conditioning energy consumption by up to 75%.

2.1.7 Energy scavenging: Standard photovoltaic (PV) systems convert solar irradiation directly into electricity and are now standard features of many public buildings. However, integrating PV systems into facades of existing buildings or old and historic buildings creates both a practical and aesthetic difficulties. Novel energy scavenging technologies are in development for small-scale harvesting in applications such as charging small power devices using movement (walking, running) and thermal gradients (body heat). Scale-up to applications in buildings is not feasible at the moment, but as buildings offer large surface areas exposed to the various climate conditions such as wind, solar and ambient temperature gradients, there are great opportunities for exploiting this vast resource and turn a building from fortresses built to fight against the environment into power generators and active, adaptable structures.

2.2 Energy efficient services

One of the most cost effective methods of reducing energy consumption and carbon emissions is by converting from incandescent lamps to compact fluorescent lamps (CFL) (Houri and Khoury, 2010, Trifunovic *et al* 2009a, Trifunovic *et al* 2009b).

2.2.1 LED/LiFi lighting: Electric lighting in most public buildings is the largest consumer of electricity after heating/cooling systems. Novel lighting systems that can change illumination levels, colour in time and space can create desirable places to live and work as well as cutting electricity use. Modern compact fluorescent lighting (CFL) reduced energy consumption by about 70% compared to a standard incandescent lamp. Modern CFLs, known as T5, can cut electricity consumption by about a half compared to standard CFLs (known as T8 lamps). Light fidelity lighting (LiFi) uses electromagnetic induction to operate and control lighting. The HiFi lamps have no physical connections to the power source and so are more reliable and last longer than CFLs. The system employs dynamic control of lamps using both external and internal light levels, and occupancy sensing to optimise energy usage.

2.2.2 Plasma lighting technology: The plasma lighting technology is complimentary to LED/LiFi systems for large area lighting. It is designed as a chain of modules going from the plug to the bulb. A power module outputs a direct voltage above 3 kV in order to supply a magnetron. This second component outputs microwaves at 2.45 GHz. The bulb, which is filled with a rare gas, is coupled to the magnetron so that a discharge appears at the electromagnetic resonance. Then the substance contained inside the bulb evaporates and

heats up by induction, and as a result, a flux of light is produced. After a short warm-up, the light becomes very similar to the sunlight, as showed by spectral measurements.

The plasma lighting system reduces the environment footprint of buildings in two respects, i) The high luminous efficiency reduces electricity consumption, ii) the design principle makes it suitable for intelligent heat management systems because most of the heat emission can be collected at its source.

This technology has a great potential in the illumination of large volumes or large areas. It is particularly well suited for shopping centres, stadiums, halls, atriums, exhibition halls, television studios and theatres.

2.3 HVAC

By reducing heat gains and losses the energy consumption of artificial heating and cooling systems can be reduced and low-zero carbon technologies can be employed. State of the art in low impact heating and cooling encompasses solar thermal heating for water and space heating in cold climates and solar thermal cooling in hot climates (Hirugnanasambandam et al, 2010, Casino *et al*, 2011), heat pumps for space heating and reversed heat pumps for cooling (Badescu, 2003) and Biomass boilers (Kalina, 2010). Combined heat and power (CHP) systems provide electricity from combustion fuel sources ranging from the small scale such as sterling engines and diesel engines to large scale systems such as gas turbine generators. The waste heat is utilised for space and water heating and/or cooling. (Mago and Smith, 2012, Thomas, 2008).

2.3.1 PCM in ventilated façade/solar collector: Phase change materials (PCMs) melt and freeze at a constant temperature and absorb or release latent heat in the process. Heat transfer processes across the building elements can be modified by storing and releasing the heat. PCMs can be used passively in a building element such as plasterboard or ceiling tiles, or actively as part of a ventilation system. PCMs are expensive materials and so passive installations have a limited use because they rely on natural convection and conduction to transfer the heat. The energy density of PCMs can be improved greatly by the use of forced convection as part of a ventilation system. However, natural ventilation systems do not use active ventilation. An alternative would be to create ventilated facades in which air flows either through natural means or by fans and blowers. PCMs integrated with ventilated facades could be much more effective than either passive or standard active systems. PCMs can have a single phase transition temperature, a range of temperatures or can have phase change induced chemically, electrically or acoustically. This could allow buildings to store and release heat in a controlled manner in response to outside conditions or internal requirements. Solar PV and solar thermal collectors could be integrated with the ventilated façade the extract electricity and heat.

3.3.2 PCM COOL-PHASE: The COOL-PHASE system uses the concept of a 'Thermal Battery' to capture and store heat. Thermal Batteries use materials that melt and freeze around room temperatures and are known as phase change materials (PCMs). In summer, air is passed through a heat exchanger solidifying the PCMs at night when the air is cool, storing energy. As temperatures rise through the day, warm air is passed through PCMs causing them to melt, absorbing heat from the air. Phase change materials (PCMs) melt and freeze at constant temperatures and absorb or release latent heat in the process. This concept is taken advantage of in the COOL-PHASE system to freeze (charge) the PCMs and transfer heat from the PCMs to the air at unoccupied periods when temperatures are low and then melt (discharge) the PCMs and transfer heat form the air to the PCMs and so reduce the swings in temperature in buildings. The only energy input is from fans that circulate the air. The COOL-PHASE system is illustrated in Figure 4.

2.3.3 Windcatchers/PV for natural ventilation: Where possible, passive systems are preferable for the provision of fresh air and thermal comfort. Novel passive solutions are being developed, including solar chimneys with photocatalytic coating for heating and self-cleaning incoming air during heating seasons or for natural ventilation and passive cooling in cooing seasons. A windcatcher integrated into a lightpipe to provide daylight and natural ventilation for buildings and a wind catcher integrated with indirect evaporative cooling. The indirect evaporative cooling system produces the cooling effect through the evaporation process while the wind catcher assists air flow in and out of the evaporative.

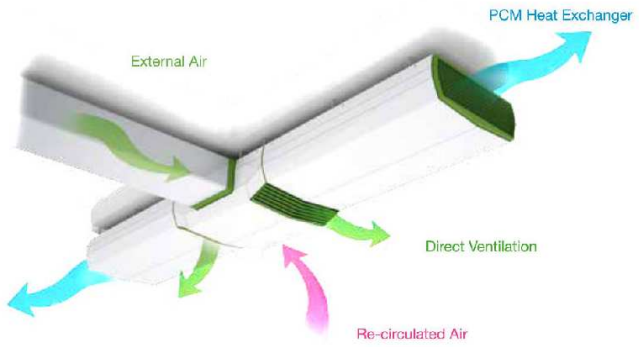

Figure 4. COOL-PHASE system

2.3.4 Inter-seasonal storage: By storing solar energy when it is most abundant but least needed and using it when it is needed, inter-seasonal storage could enable buildings that have large winter heating loads to store the required heat in summer and use it in winter. High energy density chemi-sorption technologies using novel large surface area nano-structured materials will be developed to store renewable heat efficiently and within building structures, such as foundations and highly insulated storage tanks.

2.3.5 Biomass CHP system: Biomass CHP systems using Organic Rankine Cycles (ORC) to provide heating to buildings and electricity from a novel expander based on a scroll compressor, developed for air conditioning in hybrid electric vehicles. The majority of micro-scale expanders employed recently in small-scale ORC applications suffer from problems including excessive working fluid leakage, thermal losses and low isentropic efficiency, The Sanden scroll compressor SHS-33B4150 developed for the Mercedes S400 electric hybrid cars employs DC brushless motors allowing low supply and exhaust pressure with no

clearance volume effect. It is enclosed in a semi-hermetic housing and so reduces the risks of refrigerant leakage.

2.3.6 Hybrid heat pump/solar thermal air conditioning

Electrically driven heat pumps are considered a renewable energy source if the coefficient of performance (COP) is above 3 (three times the heat output to the electricity input). They are becoming common for space heating in many domestic dwellings in places such as Sweden, France, Germany and Finland. High solar irradiation tends to be in syncronisation with cooling loads in hot and humid climates, so cooling may be achieved through solar powered refrigeration systems. However, because of low performance in comparison with standard refrigeration systems they require large solar collector arrays and space for the plant and machinery. A hybrid PV heat pump/solar thermal air conditioning system that utilises solar irradiation for operating the heat pump and the heat powered refrigeration system. It would be a totally renewable cooling system and could be used year round to provide water heating in summer and winter.

2.3.7 Salt tower system

The psychrometric energy tower is based on the interaction between water and air to provide water evaporating to make cold water. Fig 5 illustrates the salt tower system. This technology achieves a high cooling performance. The Psychrometric energy tower uses salty water, which interacts with air to condense water vapour held in the air into water. This produces warm water to improve heat pump heating performance. Moreover, this method prevents frost formation and so the heat pump can operate continuously even in the harsh winter season. The system provides a very efficient and compact regeneration process with a very little thermal energy or electricity input. The thermal COP is above 3 and the electric COP is above 10. The thermal energy could be powered by solar thermal heat, waste heat or rejected heat from the heat pump condenser.

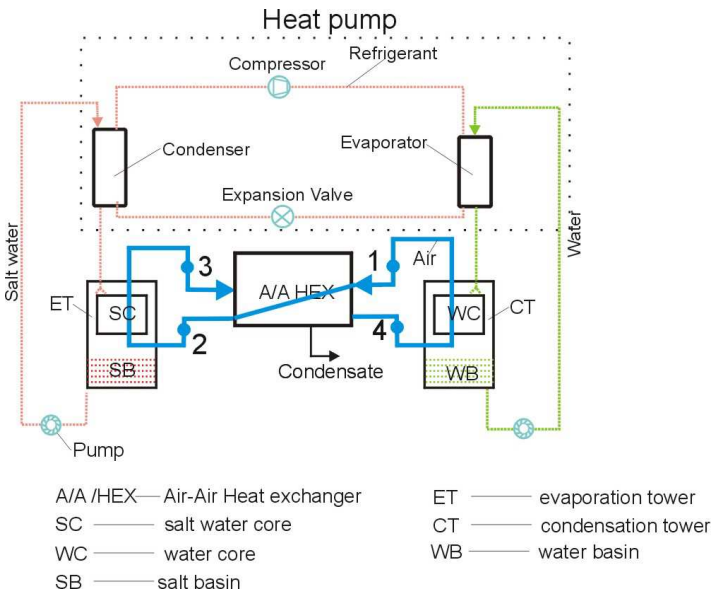

Figure 5. Salt tower heat pump system

2.3.8 Psychrometric energy core (PEC): a novel fibre membrane heat and mass exchanger is in development, in which sensible and latent heat in ventilation systems can be recovered. In one embodiment, a liquid desiccant (liquid that easily absorbs water) soaks a membrane and enhances moisture and heat transfer. In another embodiment water is used to provide indirect evaporative cooling. In hot and dry climates, the vast majority of energy

required is for cooling in summer. The PEC can act as a heat recovery exchanger, a cooler and a dehumidifier. The heart of the PEC is the impermeable fibre membrane heat exchanger. The membrane comprises a large number of cellulous fibres compressed into a thin layer (0.1-0.5mm) which allows heat to be conducted from hot to cold sides. The heat exchanger can be dry, in which case it acts as simple air to air heat exchanger but with the addition of moisture transfer from high to low concentrations. The heat exchanger can be wetted with water and can act as a direct or indirect evaporative cooler. The heat exchanger can also be wetted with liquid desiccant (liquid that readily absorbs water) and can act as a dehumidifier. The membrane allows moisture to transfer between the streams but prevents air and desiccant molecules from diffusing across the membrane. Cold and humid air flows in one direction and warm dry air flows in the opposite direction. Heat is transferred from the hot side to the cold side, reducing the temperature of the outlet air and increasing humidity while the inlet air temperature increases and humidity decreases. The moisture content difference between humid and dry streams causes water vapour on the humid side to condense. Moisture migrates to the dry side where it evaporates, increasing humidity.

3. Conclusions

By reducing heat and mass transfer through the envelope, the main energy consuming factors are tackled by reducing envelope air leakage, externally and internally insulating with vacuum and nano-structured technologies, reducing heat gains and losses with low U-value vacuum glazing and power generating windows, and coating external facades with self cleaning and pollution controlling, and energy scavenging materials. As heat gains and losses through the envelope are reduced, the use of energy within the building is tackled by refurbishing with low energy lighting systems. Innovative light fidelity lighting (LiFi) offers lower energy consumption, improved control of lighting, lower cost and quicker payback periods, and large area plasma lighting can both reduce lighting consumption and recover some heat generated in the lighting system for other services. Once heating, cooling and electrical loads are reduced, the plant requirement is reduced. Innovative low energy and renewable technologies can be used to minimise primary energy consumption and CO_2 emissions. Phase change materials (PCMs) store and release latent heat and can moderate internal temperatures in climates where there are medium to large temperature swings between day and night. Windcatchers can ventilate deep plate buildings using natural ventilation and be incorporated with low energy/renewable cooling and dehumidification systems. Biomass CHP systems offer a renewable source of heating and power. Heat pumps driven by low carbon and renewable sources can provide high performance and reliable heating and cooling systems. This hierarchical approach is targeted primarily at reducing the mass and energy flows in buildings that do not directly contribute to the business of the owners and occupants, whether that is administrative and management services in office buildings, teaching and learning in educational buildings or productive output in factories and industrial complexes. The cost of providing heating and cooling to overcome inadequacies in design and construction is wasted and could be invested in technologies described in this paper.

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Improving Subcontractor's Motivation By Construction Managers

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Abstract

The ability to motivate is one that is crucial for a manager in any professional field. The role of a project manager is no exception with the need to keep the subcontractors motivated and working efficiently in order to meet targets and deadlines. By improving the level of motivation you predictably increase the level of efficiency of employees and as a roll-on effect the achievement of project goals will be more assured. Motivation in the construction industry is often overlooked due to the short nature of many construction projects as well as the high turnover of employees and subcontractors from job to job. Nonetheless, if more emphasis were to be put on employee and subcontractor motivation, then project success would be easier to attain as the subcontractors would be working more efficiently and be more likely to achieve their targets and deadlines. With the benefits of improved motivation including increased project security and increased productivity, projects are more likely to meet targets and budgets. A research project has been taken with the aim to provide ways for management to improve subcontractor motivation and monitor its progress. This paper reports on the findings of the early stage of literature review. It has been found that not enough measures were being taken at the present time to positively influence subcontractor motivation and that there are many successful ways of motivating subcontractors in the construction industry, including things such as incentives, positive reinforcement, work facilitation and work participation. In particular, it was found that the main detail to take into consideration was that every worker is different and will respond differently to different motivation techniques. For this reason it is important to understand the workforce of subcontractors and motivate them accordingly.

Keywords: Motivation, subcontractor, project management, construction industry.

1. Introduction

Motivation may be defined as the characteristic of an individual willing to expend effort towards a particular set of behaviours (Tabassi and Bakar 2009). From a managers point of

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view, motivational practices ensure that their workforce performs at the highest possible standard and achieves the best results. To this end there is a significant amount of research that has been done on how to implement the most effective motivation as a management tool in organisations. Most of these studies are focused around general organisations and the motivation of the employees, there are few that take into account the unique nature of the construction industry, and even those that do look at applying the motivational theories to management and not to the subcontractor workforce.

The construction industry is a business that largely centres around the management of people. Being such a complex, dynamic and uncertain industry, it requires a precise and motivated workforce. And while it is generally accepted that construction workers can be motivated, it is an industry that predominantly focuses on motivation of the management teams and not subcontractors and construction workers. The issue of employee motivation is important as it establishes a substantial foundation for high performance levels with less unproductive work and wasted time on a construction site. The problem that this study addresses is the evident lack of understanding and awareness of the different motivational methods and the effectiveness of these methods in motivating construction personnel.

Despite the significant improvements being made by modern technology to equipment, materials and methods of design and construction, actual productivity in the construction industry is often seen as being below par when compared with that within other industries (Mansfield and Okeh 1991). All these advancements however do not change the fact that the construction industry continues to be a predominantly labour-intensive industry. This suggests that a proper emphasis should be given to such matters as communication, participation and motivation in order to improve productivity. These factors are going to play a crucial role in an industry with such an intensive labour requirement. Ultimately this means that for the success of the industry, workers have to be motivated using appropriate incentives and motivational techniques in order to improve productivity.

This study investigates whether the introduction of a motivational program for subcontractors, from a construction manager’s perspective, is profitable enough to offset the investment of time and money. This study is aimed to identify the most effective methods of motivation, and performance indicators that may be used to continuously monitor the progress of motivation techniques being used. With the analysis of the different motivation methods and techniques available, this study will address the lack of understanding about the techniques effectiveness, and determine the most effective ways to motivate construction workers, as well as uncovering any issues and difficulties which may present themselves.

One of the main reasons that employee motivation is not used widely in the construction industry is due to the short term nature of most projects. Employees and subcontractors are not involved with the client or employer for long enough to integrate with their organisation and develop a proper understanding of the job. Longer involvement would give management more time to integrate them into the motivational structures operating in the organisation, and in doing so increase productivity. This is a natural feature of the construction industry

and is unable to be changed; therefore it is management and their views and processes towards motivation that need to adapt to the industry.

This study will be identifying the main factors that promote positive motivational behaviour in the construction subcontractor crews. In doing this it will be determined what predominate factors and methods being used as motivation at the present time are, and whether they are the most effective ones to be using. To assess the effectiveness of motivation systems Key Performance Indicators (KPIs) will need to be researched and discussed in order to ensure that the benefits outweigh what is being spent in time and money on the systems. Both quantitative performance indicators and qualitative performance indicators will be represented. The expected outcomes of this study are the realisation that motivation of construction workers is not being used to its full potential on most projects and worksites and that with the proper motivation there can be favourable benefits to both the time and cost elements of a construction project.

The paper drew upon the research of previous studies and literature to form an objective view on the state of the construction industry in regard to the motivation of subcontractors. The research originated with the original theorists such as Maslow (1954), Hazeltine (1976) and Thomas (1990). Based on the study of original theories on motivation, it has been explored where the topic had progressed in the last 50 years especially in the regards to motivation of subcontractors in the construction industry. It soon became apparent that this was a niche in the industry which had been largely overlooked and as a result the amount of specialised research done on the topic was minimal. To compensate for this, the research topic chosen here was broken down into its different elements and looked at separately in order to determine how, as a whole they would be able to provide the data needed.

By looking at first motivation, then the characterises of the construction industry and then at the differing factors regarding the motivation at the construction worker level, a clearer picture was able to be put together for how these elements may be best used to answer the research problem. Then on top of that, performance indicators were studied to provide an idea of just how the implementation of some of these methods may be measured.

2. Motivational Theories

Motivational theories have been recognised and used for over 50 years now with Maslow (1954) being one of the first to propose the theory of human motivation. Maslow’s theory was based on the principal that everyone has base needs that they need to fulfil, and once these needs were fulfilled they could progress on towards self-actualisation. Maslow's hierarchy of needs is often portrayed in the shape of a pyramid, with the largest and most fundamental levels of needs at the bottom, and the need for self-actualization at the top. Then there had been more specific studies in the construction industry being conducted by the like of Schrader (1972), Hazeltine (1976) and Thomas (1990). Despite this, actual productivity in the construction industry is seen as being below par when compared with other industries (Mansfield & Odeh 1991).

These theories are based on the principal that needs generally must be fulfilled in sequence, and as individuals satisfy lower level needs, there is increased motivation for attaining the next higher level of needs (Cox et al, 2003). It is here where management have the opportunity to encourage greater productivity in employees by providing extra motivation. In construction, at the higher levels of needs, this could include things such as the possibility for advancement in your position or paid incentives. While there have been other studies done into motivation in the construction industry by the like of Schrader (1972), Hazeltine (1976) and Thomas (1990), the first real study to collaborate this work into a motivational model for the construction industry was Cox et al. (2006).

A study carried out by Mansfield and Odeh (1991) delved into the issues that affect motivation on construction projects and the differences which made motivation of construction workers unique when compared with other professional fields. Their study suggested that due to the predominantly labour intensive nature of the construction industry, more emphasis should be given to matters such as communication, participation and motivation.

3. Industry Characteristics

The construction industry exhibits problems and characteristics which, taken individually, are shared with some other industries but which, in combination, create unique conditions calling for a unique management approach. For motivation to be successful and effective in construction it is necessary to have an understanding of the unique characteristics of the construction industry. These unique aspects of the construction industry are also what make motivation of subcontractors more difficult. The factor which makes the workforce or labour in the construction industry differ from other industries is the fact that unlike an assembly line or manufacturing industry, whose workers remain at their jobs for relatively long periods of time, the construction industry is always dynamic. The reason for this is that the duration of most projects are between one to three years and the labour force fluctuates significantly during the project. This aspect of short-term employment, along with construction contracts, and availability of labour and management are the key points to be addressed in order to help reflect the psychological dimension of the nature of the industry, and its likely effect on motivation and performance (Mansfield and Odeh, 1991).

Short-term employment is a defining factor in the construction industry, due to the high turnover of construction workers on their different contracts; none of the workers are around long enough to establish any long term motivational systems. The very nature of construction projects is that they are short term, even the larger construction projects that can carry on for a couple of years, will not have contractors on for the whole time. This means, that unlike regular organisations, employees are not allowed to sufficient time to integrate with their organisation in order to develop a proper understanding of the job. As a result, the prospect of mutual ‘belonging’ between the organisation and the employees tends to suffer, and with it the performance of the workforce. (Mansfield, Odeh, 1991) Furthermore, the requirements of plant and equipment also fluctuate significantly from month to month during the life of a project, unlike in the manufacturing industry where workers get very

familiar with the plants and equipment, thus allowing them to avoid the stress of adapting to new machines, unlike their counterparts in the construction industry.

The Environment plays a very integral role in the construction industry. As the bulk of projects take place in the open, they are highly subject to the adverse effects of the environment. With exposure to the elements, on days when the weather is at its more extreme the performance of construction workers can be impaired resulting in: Errors of judgement; Carelessness; Complaints; General Lethargy; Irritability and poor mental attitude; Decrease in quality of work pace; and Unscheduled stoppages of work (Mansfield, Odeh, 1991). Factors such as these will all lead to decreased construction productivity which will result in failures to meet deadlines of budgets for a project.

Construction Contracts play a very important role in motivation as well, making the choice of contract that is entered into largely important to the success of the project. There are various types of contracts available ranging from the standard lump-sum contract to the more specialised cost-plus contract, and the choice of which by the client will play a role in the performance of management. By using a contract with some risk involved on the contractors behalf will motivate the managers to performing more efficiently, by reducing cost, controlling time, improving productivity and quality, and attending to the long-term goals of survival and growth. (Mansfield and Odeh, 1991). It therefore stands that a construction manager who is subcontracting out the different works required for a project will be able to keep these principals in mind and make sure that the subcontractors are assuming enough risk that they will be vigilant and more responsible for their work in order to minimise loss on their behalf.

The Availability of labour is an aspect that is mostly out of the control of construction managers, but one that will affect subcontractor motivation none the less. The availability of labour is an element of the industry that fluctuates with the economy, with other factors also playing influence as well, such as Population Density in the area of a contract; Local unemployment levels in the principal building trades; Current competition from other contractors in the area and the likely future competition; Local transport facilities; Availability of short-term housing within the area; The impact of local government training centres; The impact of legislation, e.g. Early retirement youth-opportunities programmes; and Subcontracting arrangements (Mansfield and Odeh, 1991).

When the labour supply is high, it can also be observed that there is a link to higher productivity in the labour. This can be attributed to job security, as when there is more labour going around than there is jobs, the workers will work improve their performance in order to keep their jobs. Conversely though, when the labour supply is low, labourers will not work as hard because they are not worried as much about losing their jobs.

4. Motivation Techniques

Almost all of the studies conducted in the area of motivation in the construction industry have focused on motivation programs at the general contractor or construction management level. Programs such as these at the management level have proven to be beneficial to a project by increasing productivity and by reducing a project's overall budget and/or duration. To

further these programs on down to the subcontractor and construction level it is necessary to determine what motivation techniques will be effective. Once subcontractors/workers are exposed to motivation programs on a regular basis, a company team image emerges instead of a visible division between the general contractor's management and the subcontracted workforce. The lines of communication begin to open allowing regular feedback and two way communications (Cox. et al, 2006). The current state of the construction industry dictates that bonus schemes are the main form of incentives in operation, but are these the most effective method of improving productivity, or are they just the least demanding option or are they just the most undemanding.

4.1 Motivation through incentives / rewards

The use of financial incentives and rewards in construction projects is seen as a key means of improving built environment outcomes (Rose and Manley 2011). Most commonly, financial incentives are used with the intention of reducing contract costs, minimising contract duration, and to achieve performance standards in areas such as quality, efficiency and productivity. Financial incentives are widely regarded as the most effective form of incentive in the construction industry due to the short term nature of it. Other incentives require the need to establish goals over time, and an understanding of the individual's motivational drive. According to Rose and Manley (2011), three types of financial incentives exist:

1. Share of savings incentives, where cost savings are shared between the client and the contractor based on an agreed formula

2. Schedule incentives, where a premium is offered to the contractor for the early completion of the project; and

3. Technical performance bonuses for meeting performance targets, other than cost and schedule. A performance bonus arrangement can be applied to a wide range of performance areas such as quality and functionality.

Implementation of financial incentive mechanisms in the contractual arrangement of a construction project can impact significantly on the motivation of contractors and hence project performance. Positive incentives, as a component of the project delivery strategy, aim to motivate contractors to align their goals with those of the client, via a financial reward. These incentive mechanisms take many forms in construction contracts including: profit sharing in cost plus incentive contracts, bonus performance provisions attached to various lump sum and cost reimbursable contracts, and multiple financial incentive mixes.

4.2 Motivation through goal setting

Motivation on the construction site through goal setting is an important form of motivation. An employee's motivation begins with their desire to satisfy their basic needs outlined in Maslow's theory. A great way to keep an employee motivated is to give them a reachable goal to strive for. Goal setting can be an effective motivational process when applied correctly because it creates a discrepancy between the current and the expected

performance. Researchers have shown that if goal setting is to be successful it must consider the following: Goal acceptance by the workers; the goals must be seen as a challenge; and the system must provide a mechanism for performance monitoring and feedback. (Cox. et al, 2006) It is important for management to keep in mind though, that while employees need clear and measurable objectives to strive for, the subcontractor or employee being motivated must feel that the goal is reachable, otherwise they may become frustrated or overwhelmed by the task.

4.3 Motivation through employee needs

Needs are the starting point of all motivational behaviour, and this was recognised over 50 years ago with Maslow's (1954) need hierarchy model. While it may be convenient to think that everyone's needs may be neatly summed up with his hierarchy, everyone is an individual and each will have varying needs.

Figure 1 is Schrader's (1972) adaptation of Maslow's (1954) hierarchy model for the construction industry. As the lower level needs are most often met already, they no longer serve as a motivating factor, and management should therefore facilitate the pursuit of the higher needs.

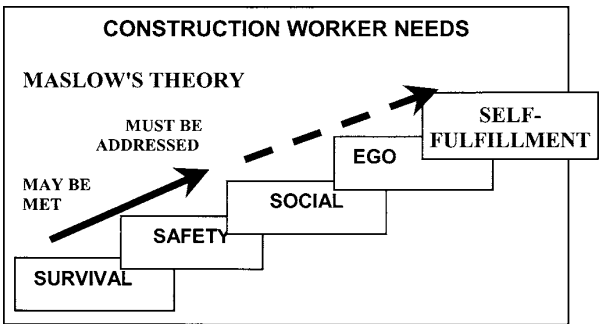

Figure 1: Construction worker's needs (Schrader 1972)

As a response to this model it draws the conclusion that the self-fulfilment of employees could be brought about with the investment in Human Resource Development. As stated by Armstrong (1990) "Human Resource development programmes aim to train new employees to the level of performance required in their jobs quickly and economically and to develop the abilities of existing staff, on that their performance in their present jobs is improved and they are prepared to take on increased responsibilities in the future." Training such as this then builds on this foundation by enhancing skills and knowledge as required to improve performance in the present job or to develop potential for the futures. By increasing a workers knowledge and expertise it will give them the tools to seek advancement in their career and strive for self-fulfilment.

5. Motivation and de-motivation of subcontractors

In order for a manager to motivate the construction workforce, they must have a solid understanding of the different motivation concepts and a willingness to adapt them to a

required situation and workforce. The challenge however is for a manager to apply these motivation techniques within the construction industry with his subcontractors.

Each of the three motivation techniques discussed above has its benefits and strengths. However, there is no particular technique that will fit every situation, especially in the construction industry. According to the study carried out by Cox, et al (2006), the majority of motivation programs can be grouped under five categories, namely Goal-setting, Incentives, Positive reinforcement, Work participation, and Work facilitation. The study then concluded that the contractors have the primary responsibility of the execution of the onsite work activities of crew members. Project owners on the other hand, have an interest in these matters because of the potential direct effect on the overall project.

Another factor that goes hand in hand with the motivation of subcontractor crews in the construction industry is de-motivation. De-motivation involves negative factors and influences that so often come into play on construction projects and bring down the productivity and moral of the subcontractors and employees. De-motivation occurrences that could be avoided from actions by the owner would be elements such as Design Changes, Poor Work Environments, and Delays on Financing

From a contractor's point of view, de-motivational factors would involve any negative occurrence or factor in the work environment which would bring about a lower morale. Steps a contractor could take to prevent factors such as these effecting the work environment would be Training first and second level supervisors; Providing open lines of communication; and Utilizing practices to eliminate de-motivational factors.

6. Subcontractor Motivational Model

As almost all studies in the area of motivation have focused on motivational programs at the general contractor or construction management level, it is the subcontractor level of motivation which has been overlooked. Motivation programs at the general contractor and management level have proven to be beneficial to the productivity of a project, as well as reducing the projects overall budget and/or duration, but it was not until Cox, Issa and Frey (2006) that this was looked at being applied to the subcontracted workforce and construction workers in larger projects.

Cox *et al*. (2006) identify the factors that promote positive motivation behaviour in construction subcontractor crews and using those attributes to create a subcontractor employee motivational model. The model shows that a supervisor should first create positive motivation based on confidence, which originates from worker competence and/or by the use of incentives. Next the supervisor should set goals in reference to quality of work and safety performance and also the needs of the worker. Finally, once goals are reached the worker should be rewarded with an incentive. Based on this analysis, money was suggested to be the incentive of choice. This proposed subcontractor-based employee motivational model is basically derived from the older research done into the topic of motivation; however it is more specifically and successfully aimed at the subcontractors of the construction industry.

7. Measuring Performance

Key performance indicators (KPI's) are compilations of data measures used to access the performance of a construction operation. They are the methods management uses to evaluate employee performance of a particular task. (Cox et al., 2003). KPIs have a range of applications and methods for which they may be used. As KPI's are generally used for monitoring the progress of construction projects, there are a lot of general models that exist for that purpose; however these fail to identify which indicators will accurately portray the changes in performance. In order to measure performance or calculate the effects of any given change on the construction process, one must first determine the appropriate Key Performance Indicators to focus on to measure its impact. Accurate analysis of construction performance can be attained only after the key indicators are determined and monitored. (Cox et al., 2003).

7.1.1 Productivity Performance

When assessing the impact of a given change in the construction process, one generally refers to the results as a change in in productivity for the task being measured. A classical definition of productivity is a comparison of the output of a production process to its corresponding input, i.e., the output to input ratio. The construction industry commonly tracks this change in progress in terms of work units completely attained during a given period of time and the associated costs in terms of man-hours or dollars (Thomas and Mathews 1996)

In order to accurately identify the KPI's associated with the construction process a baseline must first be determined. A historical baseline defines an average of past performance, knowing past performance gives a reference point to benchmark against and to measure future performance (Alfeld 1988). A baseline can be compilations of years of historical data collected on previous projects of a quick measurement of current production prior to initiating a change for improvement. Oftentimes, any variation from baseline (expected) performance level is an indication of a variance in performance. Variances can be either positive of negative and should bring about a cause for the further management interpretation to determine root causes. (Cox. et al, 2003)

7.1.2 Quantitative Performance

The most commonly accepted performance indicators are those that can be physically measured by dollars, units, or man-hours. Like any other form of business, construction companies look first to the areas which show a change in the amount of revenue generated. Quantitative units of measurement should remain simple, easy to gather, and easy to apply, while not placing a heavy burden on field personnel. The most effective and common units used as measurement are Units/MH, $/Unit, and Cost (Cox et al., 2003).

7.1.3 Qualitative Performance

Qualitative Performance indicators are not commonly accepted as reliable performance and productivity evaluation tools due to their perceived difficulty and/or inability to be measured. (Insert reference) Unlike quantitative performance indicators, qualitative indicators do not appear in the estimating/costing system utilised by the majority of construction firms.

Qualitative Performance indicators include indicators such as Safety, Turnover, Absenteeism, and Motivation.

8. Conclusion

It has been widely acknowledged that a good productive worker is an asset to any facet of an organisation. And once good workers have been made part of the teak it is important to keep them motivated. This will not only increase the happiness of the employee, but it will also increase productivity with benefits to the overall project including reduced costs and time restraints being met. This study was and its overall findings are supported by literature from previous works in the field, and as such no original data was obtained. This study found however that there is a largely untapped resource in the motivation of subcontractors in the construction industry. Despite all the numerous benefits foreseeable from the motivation of subcontractors, it is not effectively utilised by most construction managers.

Concluded from the study conducted so far, it is able to be said that while financial incentives are the most common incentives used currently in the construction industry, they are not necessarily the most effective for the bulk of employees. It was found that techniques such as positive reinforcement, work facilitation and work participation can all be just as effective depending on the type of employee. This was another factor that shone through in this study, that some workers are self-motivated while others are motivated by outside forces. Workers who are self-motivated set their own goals to reach, but it is important for those goals to have incentives attached to them. In the end though, it didn't matter if the employees are self-motivated, extrinsically motivated or both, in order for incentives to be most effective they must address the needs of the individual employee.

This research is significant in that it has the potential to finally bring the standard of productivity on a construction site up to the performance levels achieved in organisations with successful motivation techniques in place. With successful motivation in the construction industry, the productivity on a construction site will be increased as well as the standard of work. Clients will understand that they will be able to get better value out of their investments, and as a result will be more willing to make the investment, and as the construction industry is a cornerstone of most economies then the benefits will be far reaching.

The research conducted throughout this review has been limited in the regard that no original data was able to be collected. For this research to herald significant results then it would be necessary to select a large populous group from which to monitor and acquire data from. It would be suggested that multiple large organisations would be approached about allowing data collection from some of their large scale projects. Collecting data such as this would allow comparisons to be made with how productivity and other performance factors were at the present time and areas where improvement may be achieved. As this topic is a difficult one to research on a short term study, it will be expected that with a longer study of multiple complete construction projects, the results found in this study will be confirmed and solidified as the direction that management in construction field needs to peruse with motivation.

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Utilizing online learning for construction field supervisor training: Development, facilitation and assessment

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Abstract

Multiple jobsites and geographic regions in the United States and the world often make it difficult for industry to schedule training for employees. Another downfall is the expense of travel and time necessary to meet in one location. Virtual training via the internet has evolved and now provides real time collaboration between all participants no matter where they are located. This paper will describe the use of virtual training software to present synchronous distance learning program for construction field supervisors at a major university. Adobe Acrobat Connect Professional allows the faculty to use a hybrid synchronous, interactive delivery model for this certificate program. It allows the participant to be seen and to be heard, as well as to see and hear what is going on at the host site. The paper will outline the technology, curriculum, development, and evaluation of the first online Construction Site Supervisor Training Certificate program at Purdue University.

KEYWORDS: Online learning, field training, distance learning, virtual training

Introduction

Reacting to the input from the Building Construction Management (BCM) department advisory board at Purdue University, faculty members developed an online certificate program for field personnel. Past training for field supervisors had been done through training grants in which faculty would travel to the company to facilitate a training program. Due to the cost of travel, this would usually become a two day / sixteen hour training period where employees were paid and the faculty were paid travel, development, and facilitation costs. This could be cost between $15,000 and $20,000 for one company to train 15 field supervisors. As the state of the economy remains marginal, it seemed that a new model needed to be developed.

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Types of virtual training

The first full online learning course was complete in 1981 (Harasim, 2000). As the internet has allowed for access, research has shown that online-learning enhances student learning (Brewer, DeJonge, & Stout, 2001, & Hoffmann, 2002). Distance learning is expanding in all areas of higher education to create more opportunities for students (Allen & Seaman, 2007). The first computer technology has expanded from the correspondence courses of the 19th century to live television courses and now online web-based versions (Monolescu, Schifter, & Greenwood, 2004). It is now possible for anyone to acquire education from anywhere in the world. Research exists that shows minimal differences in the effectiveness of online learning as compared to the brick and mortar / face-to-face traditional methods of teaching. The major needs for online programs have been shown to be convenience, access, and flexibility (Devi, 2001; Ryan, 2001). In construction management, persons currently working in industry cannot be away from their jobs due to responsibilities onsite.

Research was conducted by reviewing some of the existing online programs. One of the challenges of online learning is retaining the student; research has also shown that the dropout rate remains high (Connolly, MacArthur, Stansfield, & McLellan, 2007; Levy, 2007). It was important for developers to build a program that would align with student success. There are four major categories considered for online courses (a) self-paced, independent study, (b) asynchronous learning, (c) synchronous learning, and (d) a combination of online and in-person learning (Bocchi, Eastman, & Swift, 2004). Table 1 outlines the relationship of each instructional method with time, location and interaction:

Table 1: Instruction Methods Comparison

Instructional Method	Location	Time	Interaction
Traditional Learning	Faculty and Student in same place	Meet at same time	One on one and group interaction
Self-paced, independent study	Faculty and Student not in same place	Meet only as necessary	One on one interaction with teacher as necessary
Asynchronous Learning	Faculty and Student not in same place	Interact at different times	One on one interaction with teacher as necessary
Synchronous Learning	Faculty and Student not in same place	Meet at same time	One on one and group interaction

The online training program must provide the ability to complete course requirements with minimal interference of work. In order to cut the costs related to travel and employee lost time on the jobsite, it was decided that the program needed to provide distance learning options.

The Adobe Connect Professional software tool, which was chosen for this training program, allows:

- Real Time interaction between faculty and class participants
- Interaction between all or part of the class participants
- No Travel to physical location of class
- Breakout Groups for small group discussions
- Polling ability to ask questions and display real time results
- Team Presentations where team members are at different locations
- Ability to record course discussions / lectures/ chat for review at later time or in case of missed class

Tools for teaching online

As early at 1916, curriculum theorists such as Dewey, believed that interaction was the defining moment of a student transforming knowledge into personal application and value (Dewey, 1916). The internet allows for this interaction to be accomplished in different methods. Figure 1 shows the relationship between interaction and the independence of time and distance.

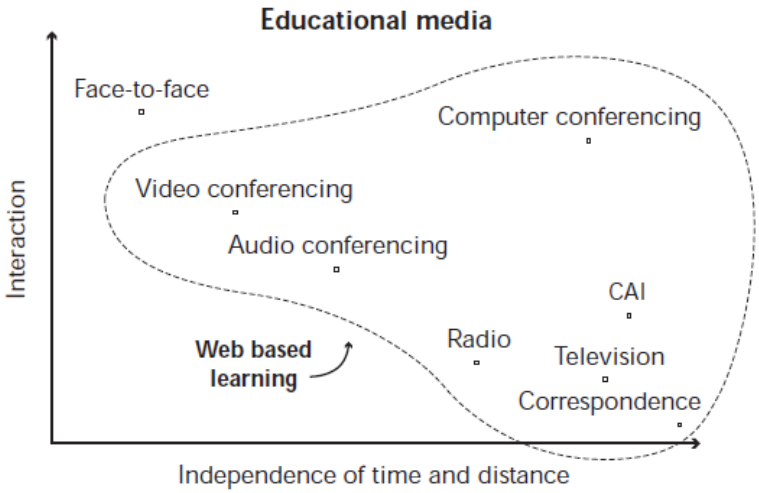

Figure 1: Relationship of Education Median with Interaction and Time and Distance (Anderson, 2004).

Adobe Connect Professional is used for real-time meetings and seminars enriched with interactive presentations and discussion capabilities. It combines existing learning content with real-time interactivity between presenters and students for engaging collaborative teaching and learning experiences. Microsoft PowerPoint slides can be used to give a professional outline in real time, live and recorded video, Flash animations, live screen-sharing, audio, and two-way text chat to deliver more effective presentations. Adobe Presenter (Presenter is a plug-in fully integrated with Microsoft PowerPoint that simplifies the creation and sharing of narrated, media-rich presentations. With Presenter dynamic presentations can be created to enhance training courses directly from within PowerPoint.

The Connect meeting room is a series of “pods” which can be moved and resized by the instructor. Pods include camera and voice, polls, chat, attendee list, whiteboard, notes, discussion notes, share, file share and web links. A single room can actually have multiple screens with multiple pod layouts. Figure 2 shows the Camera and voice pod, presentation pod, attendees pod, and chat pod. The classes use a room with three layouts: presentation, discussion and collaboration. Each screen has its purpose. Most of the class work is conducted on the presentation screen. The discussion screen is used to facilitate classroom discussions. The collaboration screen includes a large whiteboard which the instructor can use like a chalkboard for drawing illustrations during class.



Figure 2: Screen shot of Adobe Connect Professional Pod Layout Example

Managing the Connect classroom requires some multi-tasking by the instructor. In addition to presenting a lecture with Microsoft PowerPoint, the instructor must also monitor the chat pod for student questions. While potentially daunting at first, this technique is not unlike monitoring the traditional classroom audience for raised hands.

Not only can the students attend class at home or at work, but the student can also attend classes while traveling. One faculty member was able to participate in classes while traveling in Costa Rica. Another advantage of Adobe Connect Professional for distance learning is that it is desktop-based. This means that using Adobe Flash Technology, the desktop (or laptop) computers are connected directly to each other. The software allows students and faculty to broadcast and receive live video and audio using broadband internet access, a computer, an inexpensive webcam, and a hands-free headset/microphone. In addition to the classroom meeting room website (URL), each student has his or her own room adobe connect site (URL) in the Connect system. These rooms are used for breakout sessions during class and for student collaboration on projects and meetings outside of class. These rooms are available to the students 24 hours a day, seven days a week.

Case Study

The BCM program has a Construction Advisory Council (CAC) that meets twice a year to discuss different aspects of the construction industry and academic workshops. A part of this

meeting now includes breakout sessions to discuss industry needs and concerns. In 2009, a Field Training breakout group formed a task force made up of industry and BCM faculty representatives. Several proposed initiatives came from this group including:

- Further promote the role and career possibilities of the superintendent,
- training programs for existing site supervisors, and
- understanding demands of leadership on current field staff.

The feedback from this group helped outline the Construction Site Supervision Certificate (CSSC). The proposed courses were outlined and presented to the CAC in fall of 2010. It was received with an overwhelming response. The challenge then became how to deliver the 10 modules in an ever depreciating economy. Companies were limited in travel budgets and did not want to have the added burden of job site absences. The solution was to utilize a virtual classroom.

In 2006, the BCM department introduced a Distance Masters program utilizing Adobe Connect software. Implementing this program for the past four years had allowed the staff to become acquainted with the procedures and teaching styles required for virtual training. The CSSC program was developed with this delivery model and was established to allow workers to remain on site, at home, or at the office.

The program was developed into 10 modules. Module #1 was delivered live and in person on campus so participants could meet each other and establish relationships. The faculty also demonstrated the software and hardware requirements for the class. Classes 2-10 were all facilitated in Adobe Connect Professional on Monday evenings at 5pm (EST). The initial CSSC group of participants was predominately from Texas, Indiana, and Illinois. Some occasions required traveling participates to log in from as far as Costa Rica. The program was taught by three faculty members. Each course was assigned to a faculty member based on expertise and knowledge area. Adobe Connect allows for collaborative interaction as diagramed in Figure 3.

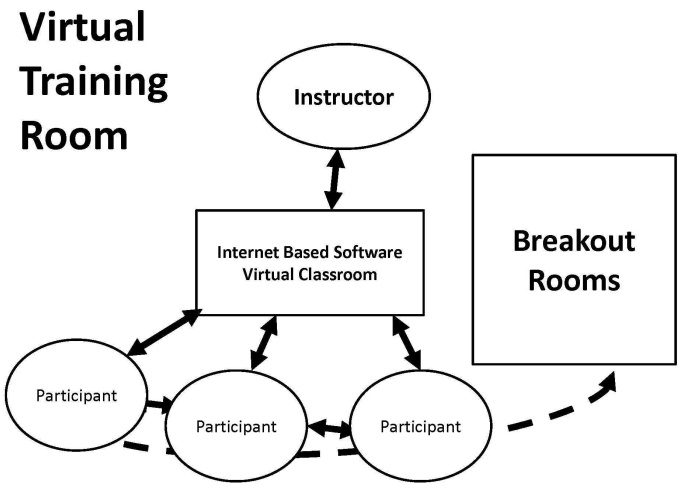

Figure 3: Virtual Training Room Schematic

There was initial skepticism by the participants as to the ability for a course to be taught in a Virtual Training Room. Many of the participants had less than 5 years of computer experience and were intimidated by the software. The initial on-site course put most concerns to rest when a simulation in the computer lab allowed them to see the ease and accessibility of the software. By the end of the second class participants were versed in using the system. Similar to in class training, students began to learn from one another. Each week participants were encouraged to share examples of job site situations that had happened and how they were handled. Participants became comfortable and active with sharing their ideas, photos, and examples via Adobe Connect during the class.

Upon completion of the modules, twenty of the twenty five students were able to attend the reception, dinner, and certificate ceremony. While the participants had only met in person once, they all greeted each other as old friends and peers. The ceremony allowed for verbal feedback and validation that the training was viewed as successful.

Virtual Training Post-Program Survey Results

A post-program evaluation was conducted on the initial group of CSSC students to provide feedback on issues related to the online course. Of the twenty-five participants, five responses (20 percent response rate) were returned. The following section presents the results from the post-program evaluation.

When asked if they would rather take the course online or travel to see the class in-person, all five respondents (100 percent) stated that they preferred taking the class via distance learning. Overall, they indicated that they would like to take online classes on Tuesdays (80 percent) and

Thursdays (20 percent) and that the 5-8 pm (60 percent) and 4-7pm (40 percent) time periods were preferred. Some of the students met with co-workers at the company's home office to participate in the class as a group. Some of these students shared computers in this group setting during class sessions, while others logged into the class on a separate computer. When asked if they thought the group setting was worth traveling to the main office versus taking to course from home/jobsite, two students (20 percent) strongly agreed it was worth the effort, two students (20 percent) indicated a neutral response, and one student didn't provide a response. Three students (60 percent) stated that the group setting was difficult to collaborate with other participants, while one student (20 percent) disagreed. When asked if they would prefer to have their own computer and headset, two students (40 percent) strongly agreed and two students (40 percent) agreed.

The results show that two students (40 percent) strongly agree and three students (60 percent) agree that taking the course with participants from other companies was valuable. Eighty percent (4 students) strongly agreed and twenty percent (one student) agreed that they enjoyed taking the course via distance learning. Eighty percent (4 students) strongly agreed and twenty percent (one student) agreed that they would recommend the CSSC program to others.

At the end of the course, each student received a framed certificate of completion during a closing reception. Eighty percent (4 students) strongly agreed and 20 percent (one student) agreed that the certificate meant a lot to them. One student (20 percent) strongly agreed and the remaining four students either agreed or remained neutral that the closing reception was worth attending.

Conclusions

This is a simple model for implementing an affordable field supervisor training program. It not only has flexibility to align with the needs of the construction industry, but also retains the rigor of academic standards with high level faculty. The Adobe Connect Professional technology is easy to learn for instructors and for participants. Although evaluations were small from the first cohort, improvements have been put into place to assist in the success of the next groups. This program should be taken into consideration for other programs needing to accommodate industry training at any level.

Future research has included formative evaluations throughout the training to allow the "students" to give input on their progress. More "homework" has been added to become learning outcomes that can become part of a summative evaluation for the company leaders that have sent employees to the training. Examples include weekly updates on what the field has used from training each week. This information can then be collected and submitted to the CAC board showing the outcomes and value for the training. Some companies now feel they have surplus funds to provide group training that may end in the development of the certificate in a face to face format.

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Critical engagement in informal settlements: lessons from the South African experience

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Abstract

This paper aims to present an approach to design thinking and teaching that takes the students and lecturers of design disciplines outside of the studio and university campus into contexts of deep complexity – informal settlements.

Conventional methods of architectural practice are deemed to be of limited use or value in informal contexts. These informally- and incrementally- developed contexts appear chaotic and of little architectural value at first glance but, when examined closer, intricate systems of decision-making and negotiation are revealed. The quality of spatial articulation that emerges could not have been achieved through formal planning and design processes. The informal process results in a distinctive spatial quality as well as complex and varied forms of ownership and habitation models.

The resultant fluidity and dynamism of these contexts offers critical lessons in design and the interaction between the different decision-makers/agents intervening at various levels of the built environment at any given time. As students and lectures engage with these contexts, employing tools such as structured mapping exercises, a better understanding can be achieved, as well as more appropriate design-decision making strategies for future interventions. By understanding the existing energies, activities and quality of routes, nodes and thresholds within these contexts, architects are better equipped to propose context-sensitive and sustainable solutions.

The intention is to better prepare students to engage in non-conventional professional practice – while the lecturers, and the institution to which they belong, are able to make meaningful contributions to a broader debate regarding the role of the profession and the professional in contexts of informality.

Through this process, it is also possible to provide much-needed services to identified vulnerable communities. However, the significance of the approach goes beyond that and involves the up-skilling of residents, the gathering of crucial data about the context, acquiring critical first-hand experience of the selected settlements; it also offers lessons on action research and knowledge on sustainable and socially-relevant technical solutions. The latter is achieved by identifying possible catalyst interventions, enabling the testing of development concepts through active build projects.

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Keywords: Design teaching, informality, non-conventional architectural practice, action research, and design/build

1. Introduction

The current state of housing and human settlements in South Africa is of serious concern – the inequitable spatial economy of South African cities is far from being transformed into more integrated, inclusive and sustainable communities. The role of built environment professionals and their institutions in contributing to the country's spatial transformation is being called into question; the relevance of conventional practice and professional approaches is a topic for consideration – which also raises questions with regards to the relevance of education in schools of the built environment and architectural departments. (Eicker et al 2012; 11)

Hollis (2009) explains that the treatise of architecture "is a discourse on perfection, a word which derives from the Latin for 'finished'…". However, this is far from the reality of how the built environment has been conceived and constructed or how buildings have been inhabited and used during their lifetime. This has rendered institutional architecture of very limited influence in terms of the impact it has made on the lives of the majority of populations – especially in developing contexts. Dewar and Louw (2012; 54) explain how South African human settlements are performing poorly in terms of various variables that have negative consequences socially, environmentally ans economically. They proceed to assess practice in the built environment disciplines and how the importance of spatial concerns, among others, and the lack of real inter-disciplinary investigation is hampering transformation (ibid; 55-57.

The role of architects, as traditionally understood, implies a service delivered based on a typical client/user relationship, which usually involves the design and delivery of a building through conventional methods, processes, financing and in line with current practice in the construction industry. However, these conventional approaches of architectural practice are being challenged, most critically in the context of South Africa's post-Apartheid re-development.

Current architectural practice has very limited reach, especially for people that inhabit informal settlements and large government subsidised residential projects. Due to the limitations of conventional education and modes of practice, as defined by the built environment's professional institutions, design professionals find themselves challenged when needing to engage in delivering a service to wider population groups outside of conventional and formal cities.

Currently 13.9% of South African households live in 'informal settlements' (SA Census, 2011). Architects often do not have the relevant understanding of contexts, technical know-how, the decision making strategies or the socio-cultural skills for engagement in informal areas. This observation is corroborated by Stephen Topham, National Upgrade Support Programme (NUSP), operating at national government level, who notes that current design professionals in South Africa have limited, to no experience in this field (Topham, 2009).

This reality demands that South African educational institutions develop teaching and learning strategies to equip design professionals with the skills needed to operate efficiently in contexts of informality. To facilitate such a shift in tertiary education, and ultimately to change professional practice, structured programmes need to be initiated early in under-graduate level and carried through into post-graduate programmes. These programmes should be formally recognised by local and national professional institutions and councils (Murray et al, 2007;44)

Alternative methods of architectural practice need not be limited to the informal sector. Alternative practice needs to be applied to all levels of human habitation; yet it is most needed in marginalised areas and communities.

2. The relationship between universities, proximate communities and professional bodies

Professional practice needs to be directed towards South Africa's most marginalised communities – contexts that pose great difficulties and challenges, yet also demonstrarte immense potential; the latent energy found in informal settlements could be re-directed towards transforming these contexts into viable and unique neighbourhoods (Simone, 2004; 409). The duality between disaster and opportunity presents itself in the potential to self-organise and self-govern, as well as in the social capital inherent in the majority of informal settlements.

Informally-developed contexts can offer lessons in the built environment that might have been overlooked. While appearing to have little architectural value, intricate systems of decision-making and negotiation are at play, resulting in distinctive spatial qualities and complex and varied forms of ownership and habitation – judging by the sterile environments created through formal mechanisms and processes, where there is little participation and involvement of users and stakeholders, these lessons from incrementally-developed contexts need acknowledgement and perhaps they need to guide new thinking, professional practice and delivery mechanisms in the built environment in general, and in residential contexts specifically. Informal settlements may offer critical lessons in adaptive re-use, mixed use, intricate thresholds between public and private space, shared communal areas and pedestrian-scale developments.

Currently South African architectural professionals have had limited involvement in these processes and debates, while professional institutes are far from embarking on a structured and studied process of preparing their membership in terms of training or, at the very least, by offering some form of acknowledgement, recognition and professional validation for architects that operate in contexts of informality. Architects will generally gravitate towards work opportunities and the National Upgrade Support Programme (NUSP) is overseeing a massive upgrading initiative which intends to improve the lives of 400 000 households by 2014 (Topham, 2009). This is part of the government's outcome-based approach to delivery. It is unusual that professional bodies would not see this as an opportunity for jobs, and an incredible opportunity to contribute to the spatial transformation of South African settlements. If this is to be achieved, then the complexities of working on informal settlement upgrade

projects and the impact this has on conventional architectural practice, professional fee scales and addressing ethical dilemmas need to be well articulated, resolved and explored in depth.

Universities could play a significant role in the above investigations; long-term collaboration between universities and proximate communities could allow the study of alternative development approaches in a process that could be mutually beneficial. Such a relationship would allow the architectural studio to move beyond the confines of the university campus as the university develops stronger connections with the city and communities within the city. The city thus becomes the training ground, the laboratory where partnerships and networks are built, and where technical solutions are tested. This process could contribute towards the development of more enlightened approaches to professionalism – challenging elitist, expert-driven approaches and acknowledging and respecting local ways of doing. Development practice could therefore be improved through the access to, and the application of, the wealth of knowledge being generated at universities (Osman, 2007).

Working in informal contexts requires a very different set of skills than what is currently offered at South African Universities, including both technical understanding as well as dealing with complex socio-political dynamics. Universities could become the lead agents in this process – facilitating communication between professional bodies, community leaders and agencies that operate in the field. They could also initiate the investigation of neglected ethics issues and help develop professional guidelines for architectural practice in contexts of informality.

3. Engaging with informality – an "open" way of thinking and practice

One complex issue is deciding where, how and when to intervene in contexts that sometimes have no clear "core", no clear spatial hierarchies or logic to the routes and access points. "While permanent and fixed components of the environment are crucial in achieving structure, robustness and identity, the adaptable, changeable and transitory is just as crucial in achieving more complex decision-making process and democratic environments. The balance/interface between the planned and unplanned needs a degree of disentanglement of physical and administrative systems at various levels of the environment, where change in one system does not disrupt the others." (Osman, 2007).

The application of this "open way" of intervening in the built environment – which makes reference to Habraken (1998) and Kendall (2003) and other documents by various authors – needs to be studied in terms of Informal Settlement Upgrading. Open Building thinking "… is believed to be very relevant to addressing accessibility and affordability issues in South Africa as well as ensuring more participation and acceptance from the various role players…" (Osman, 2007). This way of thinking might lead to very diverse interpretations of "upgrading" and might entail the upgrading of shack building industries rather than the upgrading of shack dwellings or settlements.

The need for viewing the built environment at different levels, requiring careful management of the relationships between the agents that operate at those levels, as well as the need to "disentangle" those levels to allow for a degree of permanence without restricting the necessity for constant transformation becomes apparent.

This approach allows for the integration of informal settlement upgrades and the provision of low cost housing within strategies that address the development of complete housing eco-systems rather than isolating housing for the poor. It also allows for the development of housing models that make "business sense" by allowing for the involvement of small-scale construction industries in the delivery of the "lower level" of the built environment (the infill or fit out levels) while the large and more experienced companies deliver the base buildings, that is the more permanent component of the built environment. The idea here is to allow for constant transformation and innovations at the lower level of the environment – with more players being involved in decision-making at those levels – while ensuring the delivery of high quality and efficient base buildings and neighbourhoods.

4. Principles of Participatory Action Research (PAR) and catalyst interventions

In engaging with contexts of informality, an adaptive strategy allows for a gradual decision-making process where the way forward is based on the latest available information while also allowing for a degree of flexibility as new partnerships are established and a more accurate understanding for the dynamics of the study area is being achieved: "Start where the system is. Have empathy with the system and the people in it, particularly as it will not like being 'diagnosed'." (Coghlan & Brannick, 2005)

Strict pre-planning is difficult – this adds to the complexity of the process and professional engagement as fluid processes need to be reconciled with, sometimes, ridged administrative settings and funding mechanisms – this applies to both university settings as well as the various agencies that a professional architect would need to deal with in an informal settlement upgrade project. There is a need to train architects in "… developing methods of architecture-as-research, leading towards non formulaic, non-western-centric hyper adaptable manifestations of 'cityness'**"** (Opper, 2012;16)

Participatory Action Research (PAR) is a widely used method. It attempts to render development assistance more responsive to the needs and opinions of local people, as alternative approach to development projects usually implemented through a technocratic process. The researcher is viewed as a change agent, who is required to be independent of macro-social organizations. In this process, research is transformed into interactive communal enterprise.

PAR is cyclical and reflective: the communication of results implies, not only communication to an academic audience, but also returning the knowledge to the participants. It is hoped that this approach will produce more socially meaningful research results and that it would democratize the research relationship (Babbie & Mouton, 1998).

When student groups are sent out into the study area, they are first required to undertake an observation and mapping exercise in order to intimately understand the context and the unique characteristics of the area. Potential partners are also identified through a sampling technique where leads, obtained during interactions with the community, are followed (Cohen, Manion & Morrison, 2000).

Participatory approaches in design can only be explored through real-life projects. This approach has, in the past, and may still, ultimately lead to questioning the very definition of architecture. Through explorative, action research it is hoped that the skills needed for operating in a changing professional environment can be achieved.

The idea of catalysts has been identified as being key in this process – the implemented projects are significant mostly in terms of process rather than simply a product or service to a particular community (Osman, 2007). The idea of catalysts was inspired by various writings – but mostly refers to concepts of "small change" in the book by the same name by Hamdi (2004). "… Teaching methods are enhanced and made more relevant, meaningful partnerships and networks are established and people are being educated and empowered through participation, skills-sharing and cultural and technological transfer. It needs to be recognised that this is a 2-way process and implies the creation of a mutual learning ground: from students/researchers/lecturers to local workers (skilled and unskilled), local entrepreneurs and the general community and vice versa." (Osman, 2007)

Identifying where interventions could take place, what kind of intervention and anticipating the kind of influence it would have on the surroundings is critical – the aim being to put in place an architectural/spatial intervention which will generate a catalytic response, thus allowing more agents to become involved in the formulation of their immediate built environment.

This approach is not unprecedented, having a long rooted tradition in design schools most notably seen in Samuel Mockbee's Rural Studio; "…of architecture that embraces not only practical architectural education and social welfare but also the use of salvaged, recycled, and curious materials and an aesthetics of place." (Openheimer Dean, 2012). These types of studios have become quite popular with other international examples include the Global Studio Projects, Oxford Brooke's Live Projects and Project H's Studio H 8. These groups exercise socially-motivated design principles through active projects that not only educate the students, but aim to give support the communities they are actively involved with (Delport Voulgarelis,2012).

South Africa has seen its own interpretation of this socio-technical design approach in the University of Pretoria's Housing and Urban Environments research field (HUE), which translates into learning modules at honours level, the University of Johannesburg and 26'10 South Architect's Informal Studio, the University of Cape Town's Hout Bay Washstands and the Cape Peninsula University of Technology's St Micheals's projects, to name a few. These are local universities engaging with communities through accredited studio projects and maintaining on-going engagement between stakeholders.

These initiatives sit in contrast to some Eurpoean-based studios operating in African contexts who, in some cases, have been criticized for not establishing sustainable relationships with their design/build projects and the communities involved – perhaps raising some questions about the approach and results. Some of these concerns could be resolved by establishing better partnerships between local institutions and/or local Non-Governmental Organisations (NGOs).

Despite these potential shortcomings, small design/build projects are however very significant as vehicles for collaboration, development and learning – process and partnerships for ensuring their success however still need intensive investigation. It is also important to note that not all catalyst interventions need to be spatial in character – however, the ultimate impact and potential spatial responses need to be carefully considered.

5. Proposed processes of engagement

A structured process of engagement is crucial in order to manage expectations of all stakeholders involved as well as to remain true to the nature of the design problem – expectation-management being the key aspect for ethical engagement in vulnerable communities. Stakeholders need to clearly capture and share the purpose and extent of the exercise during the initial process, as well as practising ethical due diligence throughout the project duration. Ideally the project team should aim to “give something back” to the community in question (refer to Figure 1); this is preferably not in the form of monetary donation, but could take the form of useful data gathered or documentation to assist in future development.

The ideal first step in this process would be to strategize the framework of engagement; this would be done by first establishing a working relationship with niche social development groups or NGOs already involved with the context and through carefully considered discussions with parties involved in an open and clear manner – this is crucial in avoiding the creation of false or misleading expectations.

Once this framework has been established, the nature of the outcomes should be clearly understood and considered when determining the types of exercises to employ during the investigation period. This could begin with simple site visits, using guided walks with local members of the community as a brief introduction to the context.

These initial visits should not be too prescriptive and should rather be used as a foundation towards achieving a working relationship between the research team and the other stakeholders. Once these relationships are defined, more complex workshop exercises could then be employed such as land-use mapping, spatial analysis and other objective data collection processes; these can also become useful tools in further establishing trust and articulating the expectations of all involved.

This process is time-consuming – there are no shortcuts. However, these seemingly mundane exercises are crucial to build a solid working relationship amongst stakeholders. The benefits of the process are rewarding in that the time an architectural department

invests in building these long-term partnerships with proximate communities allows them to have access to living laboratories to explore alternative ideas on professionalism and practice and offers the in the architectural departments contexts where they may intervene over a number of years.

Understanding the complex layers of the context allows students/professional to propose sensitive interventions – these may be architectural and spatial in character, but they may also involve solutions that demand investigations across other disciplines and lead to inter-disciplinary collabortions. This means that architectural departments would need to establish agreements and collaborations, not just with proximate disadvantaged communities, but also across faculties and departments within the university to ensure maximum efficiency and relevance in the training that they deliver to students as well as the service they offer partner communities.

The outcomes of these processes need not always be in the form of buildings or tangible products, but can also be produced as data which is presented as easily-accessible documents, web interfaces or other media devices which are of critical importance to stakeholder groups in terms of improving their negotiating power. An ideal process of engagement demands that possible interventions should be explained and work-shopped amongst stakeholder groups and ultimately shared with the broader local and professional community.

6. Participatory Action Research project examples

6.1 Slovo Park 2010/2012

The Slovo Park Project began as a small research initiative in the University of Pretoria's Housing and Urban Environments module of the architectural honours year. The process un-expectedly culminated in a joint built project with not only a physical product, but many other intangible outcomes that extended beyond simply another ‘community project’.

The student group of Bennett, Casson, Fillipe, Hattingh and Makgabutlane started the project by undertaking research to better understand the socio-economic context and day-to-day life in Slovo Park. From this engagement process, a larger urban framework was proposed that sought to link Slovo Park to its neighbouring community; the students intended to contribute to the development of the neighbourhood while maintaining the existing sense of community that was identified during the research phase.





Figure 2: Slovo building strategies (Bennett 2012)

After this phase, the students were required to present individual theoretical projects on how Slovo Park should develop; these projects were also presented to the community during their meeting with government officials on-site.

The responses from the students showed great variation with some designing a processional route from the settlement to the adjacent cemetery, incorporating the myriad of African cultures and their relationship to death and others focussing on housing by the provision of 'housing clinics'. The projects were an attempt to capture the humble manner in which the inhabitants of informal settlements exercise their power in build their own houses yet also allowing residents to benefit from much-needed technical know-how.

When the students were offered an opportunity to work with the community to design and build an actual building, the initial designs proposed were far too large and costly to build in the allocated 8 week duration of the project. The student group decided that they would combine the principles from each project into the design of a social facility within a civic space – the Slovo Hall. This hall and civic area would provide the people of Slovo Park with a place to meet and strategize with regards to the future plans for Slovo Park. An existing dilapidated structure that housed the 1994 election station was chosen as the site for intervention – it was believed that this was where the first change in the area began and it therefore had historial significance.

The Slovo Hall was specifically designed with a larger future vision in mind and phased into five early Construction Phases and five larger Future Development Phases. This scheme was then taken to the community for further design assistance and workshopped amongst residents of Slovo.

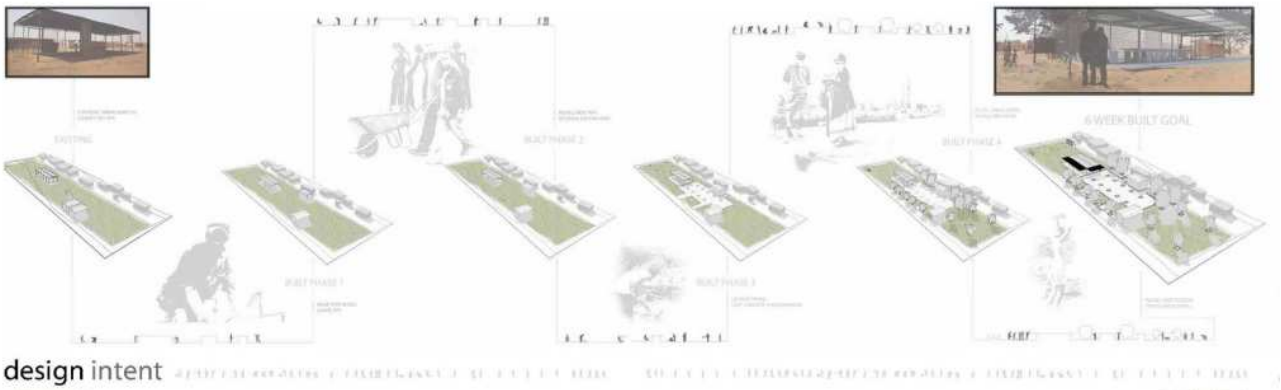

Figure 3: Slovo Building Strategy (Bennett 2012)

Building commenced in September 2010 with overwhelming support from the people of Slovo Park and local businesses. Each day varied from the previous – quick decisions had to be made as partnerships evolved, new patterns were identified and additional sponsors came on board. As more people joined the workforce and became involved in some or other way, the project dynamics were in constant transformation. The project was completed on

the 20th of November 2010 and opened with an exuberant day of celebration and deliberation when locals met and discussed the future of Slovo Park in their new hall.



Figure 4: Slovo Build Group 2010/2012; (Bennett 2011/2012)

The Slovo Park project introduced an alternative brief for architectural students, not only in the possible outcomes for the process, but also for the types of interventions that could be realistically implemented in short periods of time and with limited resources. The students involved were strongly influenced by the lessons learnt through this process. This became apparent in their dissertations in the following year, when several students challenged the current limited role played by the architecture profession.

This programme is still ongoing at the University of Pretoria where ex-students are directing new student groups in similar processes by building upon the relationships established from the initial process in 2010. This programme has laid the foundation for the establishment of a non-profit organisation, 1:1 – Agency of Engagement, which aims to facilitate processes which bring design professionals into the realm of informal settlements, partnering with communities and in developing viable intervention strategies.

6.2 Marlboro South 2012

The new master's programme at the architecture department at the Faculty of Arts, Design and Architecture (FADA), University of Johannesburg has been developed with an aim to achieve a reciprocal relationship of learning and exchange between the two domains of the design studio and the "field" (Opper, 2012). Over the last two years, the programme coordinators have collaborated with selected professionals and various agencies engaging in informal settlements to develop innovative student briefs that broaden the definitions of architecture and architectural engagement – the Informal Studio.

One of the agencies that were identified for collaboration was the South African Shack Dwellers International Alliance (SASDIA) which operates as a collective of Non-Governmental Organisations (NGOs) and Community Based Organisations (CBOs) that support marginalised, often informally-settled, communities. The agency supports the development needs of these community groups through a network of settlements known as the Informal Settlement Network (ISN) and a woman's based saving scheme known as the Federation of the Urban Poor (FEDUP).

One of these community groups within the ISN, known as the Marlboro Warehouse Crisis Committee, represents the occupants of abandoned warehouse structures in the industrial belt that straddles the former township of Alexandra, known as Marlboro South. These residents are mobilised around issues of evictions and limited services in the area and work together in lobbying for support from government.



Figure 5: Marlboro Warehouse Communities (Bennett 2012)

A studio exercise was established between the University of Johannesburg's Architecture Department and the Marlboro Warehouse Committee facilitated through the South African SDI Alliance. Here meetings between the NGO, the University and the CBO were held before the studio to determine an administrative structure of how to manage a sensitive process in order to yield usable and honest results for the community groups as well as for the students learning process.

The agreement was to divide the students and community members into small groups and asked them to determine not only site-specific design intervention/solutions at a framework level, but also small-scale interventions that would presented this back to the community for feedback.

The studio was arranged with weekly meetings in both the settlement site and the university campus, thus allowing everyone involved to experience the spatial realities of participating groups. The project addressed design problems from the large-scale land-use analysis, participative mapping and site-scale mapping all the way down to the level of the individual living spaces of residents of Marlboro South warehouses. This was done in mixed teams of students and Marlboro residents under the guidance of the SASDI Alliance.



Figure 6: UJ Informal Studio - Marlboro (Bennett 2012)

Unfortunately, an impromptu eviction of several community sites by the City of Johannesburg made the issues of capacity and focus very difficult, as well putting the students at potential risk. The studio was therefore altered and the majority of participatory work happened on the university campus.

From an academic point, the studio was highly successful in exposing students to the various forms of the tangible and intangible professional support that designers can offer. It also allowed the student body to experience contexts, cultures and people that they had not interacted with before. This studio process revealed how important it is for these processes to be managed by larger social groups, as universities do not have the capacity or scope to support such large social movements or deal with evictions and the associated repercussions. At first, the large team sizes were difficult to manage, but once properly organised and coordinated, large quanitities of data were very quickly sourced in a highly structured process. This proved invaluable in the ensuing lawsuit against the city, while creating a large volume of work which then informed the proposed design interventions made by the students.

7. Beyond the design studio

While the design studio exists as one of the most flexible and adaptable spaces to navigate the intricate and dynamic world of socio-technical design processes, it needs to be considered in terms of how professionals are required to operate in the 'real world'.

Identified 'living laboratories' allow universities to extend learning opportunities beyond the confines of the campus. If this process of engagement is to be successful, it needs to be well documented, agreements and intentions well articulated and communicated and the projects need to be set up in a manner that does not rely on individuals but addresses the wider interests of all parties involved.

The extension of the design studio into the city needs the support of both tertiary and professional bodies. The underlying ethos of these studios should not be one of entering an informal context and superimposing values of formality – but rather demonstrate a willingness to understand and 'un-learn' conventional professional practice in order to respond in ways that respect inherent energies and capacities of informal contexts. This approach ensures a key aspect that would ensure the sustainability of interventions made by a sense of ownership and authorship by the partner and recipient communities.

Acknowledgments

University of Pretoria & University of Johannesburg students and lectures, the
South African Shack Dwellers International, South African Alliance, the Slovo Park Community Development Forum & Marlboro Warehouse Crisis Committee.

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CIB 2013 World Congress

Using Serious Games and Virtual Simulations in Construction Technology Education

Perry Forsythe[1]

Abstract

In tertiary construction education programs, it is becoming increasingly difficult to take students to site to obtain first hand experience of construction technology. This is especially the case with large classes, sites that have limited safety capacity to take students, and the general logistical problems of getting students to and from site. The brevity of site visits provides novelty but restricts the depth of learning. Computer gaming simulation offers a potential alternative. Though not the real thing, the simulation environment provides targeted activities and problems; it also offers the potential to engage students for long periods of time and in an immersive environment. This paper looks at the use of virtual simulation games available in construction and then focuses on the implementation of a specific type of simulation suited to construction technology and construction processes. It involves the hands-on virtual usage of site equipment including excavators, cranes, forklifts and concrete placement equipment in the context of an active construction site. Students control and manipulate the machinery according to assigned tasks. The pros, cons and educational merits of such an approach are analysed including student evaluation of the simulation as a learning vehicle.

Keywords: serious games, virtual simulation, construction technology, education

1. Introduction

In the context of this paper, "serious games" are those that go beyond pure entertainment and have the purpose of motivating students to learn about specific aspects of their chosen profession or discipline. The concept has been around since the early 1970s with early texts by Abt's (1970) followed by the introduction of benchmark games such as Sim City (Electronic Arts, N.D.) which was released in 1989 and forced players into making complex decisions about the business of creating a productive and socially progressive built environment.

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Importantly, this paper looks at "serious games" in the context of andragogical usage which by definition deals with learning strategies for adults as distinct from pedagogy, which deals with learning for children. The distinction seems important because Knowles (1984) concept of andragogy puts forward the premise that adults need to know why they should learn something; need to learn experientially; generally approach learning as problem-solving; and learn best when the topic is of immediate value. Consequently, games must be designed accordingly to seek relevant learning outcomes.

Authors such as Zyda (2005) defines “Serious Games” as a mental contest, played with a computer in accordance with specific rules and uses entertainment to further educational and communication objectives. When this is coupled with the likes of Mihaly Csikszentmihalyi's concept of “Flow” (Csikszentmihalyi, 1990), serious games become an even stronger learning proposition. For instance Csikszentmihalyi's seminal psychological research about the daily activities of people, found that they felt best and most positive when completely engaged in an activity where time seems to fly by - “Flow” is his term for this feeling. He also identified that engagement is particularly strong when people are exposed to a challenge that is just beyond their current ability, but can realistically be reached via greater application (Csikszentmihalyi, 1990). It is clear that many video games make use of this very feature in engaging players to spend large amounts of time gaming, by creating tougher challenges in order to reach higher levels.

Within the gaming genre Aldrich (2009) draws the distinction between games, simulations and virtual worlds and this is useful in terms of better defining the specific type of “serious games” to be used in construction technology education reported in his paper. His categorisation includes:

- Games - are relatively simple and meant to encourage awareness of a certain thing,
- Simulations - are more associated with skill-building (such as the likes of flight simulator programs). These involve structured environments drawn from real life activities, with stated levels and goals.
- Virtual worlds - are 3-D environments where participants in remote locations can meet online and connect through detailed interactive models and undertake real-time collaboration, such as Second Life (Linden Lab, N.D.).

In applying this to construction technology, it is clearly important that students be immersed in the types of activities that they will encounter in professional practice. It is also important that a serious game provides a dynamic dimension that offers an alternative to the static learning typically associated with listening to a lecturer with hundreds of other people - a form of learning that tends to be common in university construction management programs (Forsythe et al 2011).

In trying to address this point, it is apparent that the video gaming industry has advanced in leaps and bounds and nowadays, most university age students have grown up playing such games. It is therefore not surprising that authors such as Prensky, (2001, p. 76) refer to this generation as “digital natives”. Research by Zyda (2007) serves to indicate the size of the video gaming industry by stating that it now generates more revenue than the movie industry

and it is now a preferred way for much of the population to spend time, ahead of watching television. Obviously, such a pretext augurs well for the prospect of utilising highly visual gaming technology for construction technology learning, and having students who will willingly use such games.

Bearing these points in mind, this study aims to focus on the aforementioned "simulation" level of applying serious games to learning. This is to be applied to undergraduate construction project management students and more specifically, the construction technology subjects their-in. These subjects are often difficult to teach in an applied way because of the practical difficulties involved in taking them onsite (Forsythe 2009). Here, Messner and Horman (2003) make the point that it is difficult but important to provide students with the opportunity to observe and experiment with the building construction process, and that virtual technology offers a pathway forward. Consequently, the high-end visual capabilities of modern games are thought to provide a degree of experiential learning that can be readily controlled and implemented by University educators, without the associated difficulties of going onsite.

2. Serious Games Applied to Learning in the Construction Context

Whilst there are not that many well known games and simulations within the construction project management discipline, those that do exist can be readily categorised. For instance, simulations that have been around for some time such as AROUSAL (Irwig and Lansley 1986) and MERIT (Meritgame), make little to no use of visually oriented gaming technology - both focus more on running a fictional organisation and making financial decisions pertaining to things like the allocation of resources, tendering on projects, making strategic decisions, team interaction and developing company management structures. Others, such as Virtual Construction Simulator (Lee 2011) have much higher visual capability but focus on scheduling the workflow of a building using time scheduling tools and assumptions about the time and resources required to construct each element in the building.

Whilst all of these scenarios have valid learning outcomes in their chosen areas of specialisation, none address the problem of helping students to understand hands-on construction processes and a detailed understanding of construction technology. As a result, it would seem that this is an area that could benefit from the serious game concept - especially in the form of video games simulation – hence directing the ongoing direction of research undertaken in this paper.

Applications in this specific area are still in the process of development including the likes of Newton and Lowe's (2011) use of Cry Engine 3 as means of creating a virtual environment for domestic construction. Here, are a variety of tools are used to analyse a range of domestic building representations. The game focuses on analytically investigating design and construction features, diagnosing design faults and building regulation breaches. Newton and Lowe (2011) acknowledge that the benefits of such an approach are still to be qualified, and consequently take a conservative position regarding the potential benefits until it can be fully evaluated.

On this issue, Horne and Thompson (2008) investigate the values and challenges of integrating visualisation technologies into built environment teaching – mainly from the tutors' perspective. Whilst the feedback they received was varied, the main underlying drivers concerned an extended learning process, increased student motivation and more diverse methods of teaching. Not withstanding this, there is still considerable work to be done in terms of executing such ideals. Killi (2010) makes the point that even though there has been increased interest in learning games, the development of appropriate game design methods has been inadequate – especially the lack of integration of education principles into games.

Further to the above, it is apparent that such technology is still ostensibly a surrogate for real life experience and so there is a need to consider the worthiness of such an approach compared to other "more real" types of learning. An obvious and traditional option here, involves site visits which can be used to supplement the principles learnt in class. A benefit of this approach is the ability to situate site visits within individual subjects but as alluded to previously, significant difficulties arise when large classes are involved. For instance, large classes typically need to be divided into smaller sub-groups and this can often fragment and disrupt the continuity of weekly classes. In other instances, the perceived safety risks of taking students onto site can often thwart such endeavours or at a minimum, create so much administration and paperwork that in real terms, site visits become very difficult to implement. Further, when site visits do occur, they are often for only short periods of time and may ultimately only consist of a talk in an onsite meeting room followed by a brief look at completed construction work – thus making it a novel experience but well short of gaining any hands-on experience of what the actual work activities involve. An alternative is workshop based learning especially where it can be used to regularly supplement lecture room activities. It is most effective where construction can effectively be scaled down to the limits of the space available without loosing the reality of the experiences involved. It has its merits but many construction degree programs now focus on management more than the technical aspects of construction and so unfortunately, the luxury of having ready access to such facilities – especially for fabrication and erection purposes – is now the exception rather than the norm. Still further, is the application of work-integrated-learning which has the advantage over both of the previous options by virtue of situating students in the work place, which potentially allows strong exposure to seeing (and perhaps even doing) what happens on onsite. In principle this is ideal but the main practical difficulty here, is the need for a program-wide approach that encourages concurrent work and study. Many programs are not able to support this degree of integration either internally or in externally coordinating with industry employers.

So from this discussion, it would seem that even though strong options exist for experiential learning about construction technology there are significant practical problems in implementing some of these approaches, at least some of the time. Though this paper in no way discourages the use of such approaches, alternative methods such as the use of serious games, should be considered as a supplementary approach where appropriate.

This raises a question of “when and where is appropriate?” Here it would seem that serious games provide a case for an alternative way of learning in construction technology where more ideal options (as discussed above) do not apply and particularly where:

- Students are in the early years of tertiary study and have little or no direct experience of construction because they have insufficient skills to obtain site based work.
- Students cannot predictably obtain the required experience of construction because the work they are involved in on-site, is not well synchronised with what they are learning in their degree program.
- Educators want to simulate on-site construction in a timely way that directly compliments and coordinates with class learning.
- Educators want a learning vehicle that can be readily deployed at a subject specific level and can compliment, but not be dependant on, program wide approaches to learning.
- Educators want to provide a type of experiential learning in large class settings that requires minimal resources in administering the learning vehicle.

The above factors have been taken into account in the logic applied to the current study and in the research method stated below.

3. Research Method

Due to the nature of the research aims and the previous discussion, one of the first tasks in undertaking the research was to target a first year construction technology course (low rise apartment building) and an area within the subject that would have generalisable appeal to students. The search for an appropriate pre-existing video simulation game was undertaken with the assistance of an international network of academic contacts and with the help of professional associations.

As consistent with previous discussion, attention was given to gaming technology that offered a fairly high degree of realism and visualisation. Within the chosen construction technology subject, attention was given to materials handling equipment (such as cranes, excavators, forklifts and concrete placement equipment). The game that was ultimately used allowed users to progress to upper levels after completing lower-level tasks. Each new task enabled use of a new piece of equipment on a larger building project. The scope of the game enabled students to operate equipment in a virtual onsite environment using the typical controls of real-time operation. As one example, students were able to drive and operate an excavator to excavate a site including the ability to present the machine to the workface, setup the out-riggers, then operate both the bucket and excavator arm hinging mechanisms, as well as pivoting the excavator around its central axis in order to dump dirt away from the excavation area. Students were required to excavate down to a certain depth and stockpile the soil. In another instance, students were required to operate a forklift including lifting pallets of bricks and moving them to different locations and then stacking pallets on top of each other - with a view to showing them the difficulties in manipulating the controls and also the dangers that occur when stacked pallets for fall over.

An initial tutorial was held to show students how to use the game and then they were required to undertake the simulation individually, in their own time.

The above was undertaken by 100 students and of those, 56 students (56%) undertook a questionnaire based evaluation of the simulation. Informal feedback from students and related email correspondence was also recorded.

Five of the questions used a 9 point Likert scale (Likert 1932) to canvass opinion on the extent to which students liked or disliked the simulation. This included questions asking if it helped them understand the site operations better than previously; if they better understood the constraints under which the targeted equipment worked on site; and the extent to which they thought it would assist them make more informed site management decisions.

Another bracket of questions inquired about the individual student's level of onsite experience and open questions about the best and worst features of the simulation and how its usage for learning could be improved.

4. Findings

The Likert scale questions provide the most targeted detail concerning opinion on specific learning related issues. Here, the 9 point scale was calibrated such that a score of "1" indicated that the student "strongly disagreed" with a given statement in the questions, and at the opposite end of the scale, a score of "9" indicated a student "strongly agreed". A score of "5" represented a neutral score at the changeover point between positive and negative opinion.

With this in mind, Table 1 shows the mean score for a number of the Likert scale questions. Here, it can be seen that even though there were positive responses to the simulation, most were close to a neutral score. Here, the strongest score was 5.8 and concerned the ability of the game to help students understand the operating issues of materials handling equipment onsite. In another instance, there was only very mild support (almost neutral, at 5.05) when questioned about whether or not the simulation provided a better understanding of the practicalities of managing such equipment on-site.

Table 1: Quantification of Likert Scale Questions

Questions	Mean score
1. The simulation helped me to understand the operating issues of materials handling equipment on site	5.8
2. The simulation provided a better understanding of the practicalities managing equipment on-site	5.05
3. The simulation provided an acceptable compromise to site-based learning	5.01
4. A game-driven approach has much potential for learning outcomes and should be used more often.	5.31

Similarly, opinion about whether the simulation was an acceptable compromise to site experience or not, indicated a mean response that was very close to neutral at 5.01. Here, it is difficult to say from the responses whether students actually accept compromise on such issues or not. Or, whether or not they have an understanding of the constraints that occur in trying to provide an appropriate learning environment. As one example of this, a student suggested in the open question responses, that it would be better if the University organised forklift and excavator training and students could then drive such equipment around onsite- hence indicating a somewhat idealised view of what is realistically possible.

In addition to the above, students were asked a more general question concerning whether or not they thought that a game-driven approach had much potential for assisting learning outcomes and should be used more often. The mean score for this question was 5.31 - which is nestled in between the previously discussed scores - and so it can be said that the general attitude about simulation games and the specific game under evaluation in this paper, were ultimately quite similar. Adding to this, the ambivalent attitude towards simulation games indicated above is somewhat surprising given the "digital native" tag discussed earlier in the paper. For instance, it was expected that students would be eager to use such games but this now seems to be a more contentious issue (irrespective of the success or failure of the specific game under evaluation).

This and the generally low positive scores reported earlier prompted the need to investigate the data further in order to obtain a better understanding of the spread of responses. For instance, there was a need to know if significant numbers of students either strongly agreed or strongly disagreed with the statements in Table 1. For instance, such a scoring pattern would indicate that two opposing extremes of opinion would serve to cancel each other out – thus causing a relatively neutral score – but as distinct from many scores occurring in mid range. To test this, Table 2 collapses the Likert scale scores into a lesser number of categories reflecting only low, medium and high categories (for the same questions reported in Table 1).

Table 2: Collapsed Likert Scale Scores into Low, Mid and High Categories

Questions	% of low Likert scale scores (i.e. scores from 1-3)	% of mid range Likert scale scores (i.e. scores from 4-6)	% of high Likert scale scores (i.e. score sfrom 7-9)
1. The simulation helped me to understand the operating issues of materials handling equipment on site	24	27	49
2. The simulation provided a better understanding of the practicalities managing equipment on-site	24	49	27
3. The simulation provided an acceptable compromise to site-based learning	23	48	29
4. A game-driven approach has much potential for learning outcomes and should be used more often.	20	44	36

As can be seen in Table 2, the most significant difference in opinion occurs under statement 1 where 49% of students provided "high" scores for this aspect of the simulation game, but this was to some extent offset by 24% of markedly "low" scores. Whilst this issue is discussed further in the following paragraph, it is also noteworthy that with regard to the other statements analysed in Table 2, the difference between high and low scoring was less pronounced as evidence by the strong proportion of mid range scores for these questions.

Given the above, it would seem that the best use for the simulation – in its current form - is primarily for the purpose of helping students understand how equipment operates at an experiential and immersive level. From the data, there is a near majority of students who strongly support this position. Even so and of equal interest, is the need to find out why others are so strongly opposed to it. Responses to the open questions were found to provide a degree of insight into both this and related issues. Here, responses relating to the main "pros and cons" of the game were categorised using thematic analysis where the coding method was developed under the guidelines recommended by Boyatsis (1998). Only on popular themes are reported as distinct from rarely mentioned content. With this in mind, the main themes (based on frequency of response) are presented in Table 3.

Table 3: Main themes relating to "Pros" and "Cons of the Simulation Game

Pros	Cons
• Experience machine usage and process onsite • Convenient/flexible/simple to use • Novel/fun/engaging • Realistic format and interactive	• Slow/time consuming/not fun • Relies on gaming skill over real understanding of the site • Poor controls, technical glitches and poor user instructions • Already have real experience/doesn't reflect reality

In considering the main "pros" presented in Table 3, it can be seen that most reflect the experiential, immersive and flow concepts discussed earlier in the paper. It is however clear, and ultimately not surprisingly, that not all students like this kind of game and therefore the "cons" provide some indication of the issues that may have influenced the Likert scale scores. This is thought to be especially the case where students believe educational outcomes should be less reliant on gaming skills, thus suggesting that there is a threshold point beyond which students become intolerant to the gaming approach. It is suspected that such a perspective is further fuelled where technical problems in using the game and where slowness in reaching new levels of game resulted in frustration. Last but by no means least, it is apparent that those who already have real world experience of the simulated equipment found the process to be of little use to them – hence suggesting the future need to qualify the experience of those who may already have real world experience – so as not to impose redundant learning upon them.

In the open questions, students were also asked for ways of improving the game. Few distinct themes emerged. Even so, one interesting and relevant insight suggested the option of using the virtual environment provided by the game as a means of not only experiencing the intended operation of materials handling equipment but in addition, allowing teachers to

create more analytical management questions by simply using the virtual environment as a backdrop for context. For instance, students could be asked to study the situational variables of the site and then undertake research on about finding appropriate real-world machines that would be most appropriate for undertaking the type of excavation involved and with the work rate required. Another option is to situate regulatory questions in the context of the virtual site (such as hoarding requirements and safety procedures). This approach would provide an extended and more management oriented use of the game which from the previously discussed Likert scale scores, may help address the apparent lack of appeal in this area of learning.

5. Conclusions

In testing the use of a virtual simulation game (i.e. concerning materials handling equipment in construction technology subjects) there was positive support for the game in the context of helping students immersively experience operational usage of such equipment. Though a near majority provided strong support for this, it was also apparent that an alternative point of view existed in the student cohort for a smaller but still significant group of students. Consequently, there is a need to improve the design and execution of such games or provide alternative arrangements in order to provide appropriate engagement for students who for various reasons are not engaged by this form of learning. More specific conclusions include:

- The success of construction simulation games as a means of experiential and immersive learning for students is dependent on students not having first-hand experience of the work processes being simulated by the game i.e. there is no motivation in playing learning games about things you already know
- Given the previous point, it is best to use such games in the early years of University study when students are unlikely to have much site experience. If some students in the group already have the relevant site experience then they should possibly be diverted to an alternative learning activity.
- The usage of construction simulation games can be fun, engaging, instructive and experiential in terms of finding out about the operating parameters of commonly used equipment on-site.
- Students who are not naturally drawn to virtual simulation games are likely to be critical of the skill and dexterity required by the game versus the underlying learning outcomes that the game is trying to assist. Further, the experience can be quickly eroded for many by the frustration brought about by the likes of poor gaming controls, instructions and other functional aspects of the simulation. For this reason, it is considered best that simulations (of the kind tested in this study) are best used in relatively short bursts that support lecture content about core principles rather than dominate learning activities.
- In extending learning outcomes, the game needs to go beyond purely providing experiential usage of the machines and must create situated problems that have an analytical context about the usage of the machines and the impact on site management. One way of doing this is for educators to leverage the virtual environment by create their own problems which can be developed separately to the game, yet can use the game environment in a parallel and supportive way.

Obviously, another option is to design such features into the game, but a problem with this approach is mainly the fact that once it becomes hard wired into the game, it becomes difficult to change, thus reducing the ability to respond to changing needs and to refine learning objectives.

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Modelling Time Buffers in Repetitive Building Projects: a Case Study

Francisco Orozco[1], Vicente González[2], Eduardo Maravilla[3]

Abstract

Variability management in construction using buffering-driven production strategies is an emerging issue among researchers and practitioners alike. In the last two decades, construction researchers and practitioners have provided a number of buffering approaches for managing variability in construction projects. However, there is a lack of practical approaches, preventing a widespread adoption of buffering-driven production strategies in the construction industry. To overcome these limitations, this research proposes a practical approach to mitigate the impacts from the variability produced in the activities duration of repetitive building projects. A repetitive project of 50 houses was analysed as a case study over a 9 months-period, collecting production data from ten construction activities. By simulating the case study, a different schedule approach other than the traditional one was proposed, isolating the beginning of each activity in order to protect the downstream activities from the upstream activities variability. This research shows that a practical approach for allocating Time Buffers was effectively developed. Further research should consolidate the buffering framework.

Keywords: lean construction, risk management, scheduling, time buffers, variability.

1. Introduction

Construction Projects seldom happen as ideally as planned. Nature's uncertainty induces variability to spoil plans and becomes a major factor affecting project performance and productivity. Variability leads to ineffective production, increased cycle times, increased cost, and derailed plans. In fact, variability is a “common-place” in production systems (Hopp and Spearman, 2000). In construction projects, variability comes up as the fluctuating behaviour of factors such as production rate, labour productivity, and construction schedules. The use of buffers is one of the ways to protect the performance of construction projects against the negative impacts of variability (González et al, 2009). Buffers can prevent the loss of throughput, wasted capacity, inflated cycle times, larger inventory levels, long lead times, and poor customer service by shielding a production system against variability (Hopp and Spearman, 2000). Several types of buffers exist: inventory buffers (e.g., materials, work-in-process, and finished goods), capacity buffers (e.g., in-excess labour and equipment capacity), and time buffers (e.g., time contingencies and floats) (González et al., 2011).

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In construction, there are certain links between different buffers that allow them to be easily managed. For instance, the correspondence of work-in-progress (WIP) buffers and time buffers can be found between consecutive and dependent activities in repetitive projects (Figure 1). This correspondence allows these buffers to be explicitly considered in the construction schedule of these projects (González et al., 2010).

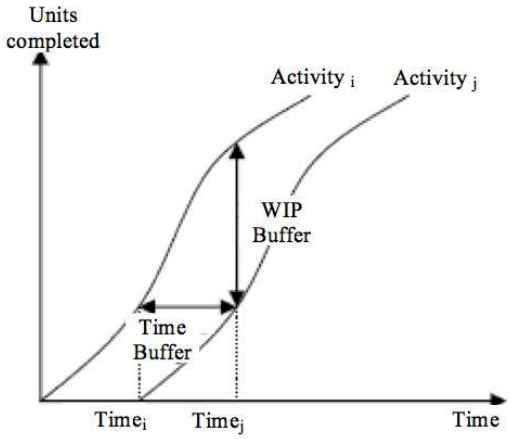

Figure 1. Types of buffers and their relationship (Adapted from González and Alarcón, 2003).

In the last two decades, construction researchers and practitioners have provided a number of buffering approaches for managing variability in construction projects, improving our understanding of the role of buffers as a production strategy in construction (Alarcón and Ashley, 1999; Goldratt, 1997; González et al. 2009, 2011 and 2012; Horman, 2000; Park and Peña-Mora, 2004; Tommelein et al. 1998; Walsh et al. 2007). These authors claim that a planned and deliberate use of buffers in construction has a positive impact on project performance. Buffering-driven production strategies can minimise the impacts of variability, thereby achieving significant reductions in lead times, waste and costs associated with projects. Horman (2000) suggests that when a buffer is used correctly, it not only provides a cushion or protection, but it also increases the ability to respond efficiently to changing conditions, and thus may be used to maintain or even increase system performance.

The use of contingencies or time buffers is a key issue when scheduling construction projects. Normally the scheduling techniques along with the management heuristics used to plan projects under or overestimate the size of the time buffers. For instance, the most typical scheduling technique is the Critical Path Method (CPM), which is deterministic in nature and neglects the variable nature of the construction activity durations. Otherwise, there are scheduling techniques that try to introduce uncertainty in the duration estimates such as the Program Evaluation and Review Technique (PERT), which represents a variation of the CPM networks. However, PERT is - to a certain extent – a “deterministic” technique because the same distribution of durations will be produced every time given the same input project data, so it is difficult to generate different production scenarios (Lu, 2002; Lu and AbouRizk, 2000; Barraza et al, 2000). As a result, it is hard to accurately estimate the

size of time buffers using deterministic approaches, when the production scenarios that are analysed are variable or “stochastic” in nature.

In the other hand, the traditional management heuristics in construction to manage buffers have been based mainly on intuition and experience of the decision-makers. This follows the typical management pattern in the construction industry, in which there is not record of successfully applying decision-making support methods (McGray, 2002). Therefore, construction practitioners still work with optimistic projections and use poor buffer mechanisms to protect construction processes from the negative impacts of variability (Gonzalez, 2009). In addition, there is a lack of practical methods to determine the size of buffers in construction, which prevents the application of buffering strategies in projects, negatively impacting project performance (Gonzalez et al, 2011; Park and Peña-Mora, 2004).

To overcome these limitations, this research proposes a practical approach to mitigate the impacts from the variability produced in the activities duration of repetitive building projects. This paper analyses, as a case study, a real repetitive project of 50 houses over a 9 months-period in Guadalajara-Mexico, collecting production data from ten construction activities. By simulating the case study, a different schedule approach other than the traditional one was proposed, isolating the beginning of each activity in order to protect the downstream activities from the upstream activities variability. This research shows that a practical approach for allocating Time Buffers can be effectively developed.

2. Research Methodology

Current studies shows that the construction industry is still affected by delays and cost overruns due to the difficulty of controlling variability in the processes. Although there have been efforts to control variability in construction, this has not been reduced enough in order to make projects more predictable (González and Alarcón, 2010). Reducing variability in construction activities is a complex task that can take a considerable time.

Commonly it is assumed that each activity begins when the previous one ends up. The typical approach is focused on reducing the variability at the end of the activities where variability is noticeable. However, this paper addresses a different perspective: to control the beginning of the activities instead of the end of them. If the beginnings of the activities are controlled, which is seemingly feasible, the variability of activities duration, which is visible at the end of the activities, will become much more manageable and estimates will be more reliable. It does not imply that the variability at the end of the activities will not be controlled, but this approach can produce a smoother and reliable progress of the activities.

The proposed approach in this paper is based on practical experience and observation of horizontal housing projects, and implies to control the start dates of the activities, which can be established by the general contractor, in order to manage the impact from variability. A time buffer between consecutive and interdependent activities (similar to that shown in Figure 1) has to be estimated in order to isolate them. Thus, the probability that a delay in an activity can affect the start of the next one is reduced.

A number of steps were followed to undertake this research:

1) The behaviour of each activity needs to be represented with a probability distribution. It is assumed that companies are able to fit the probability distributions for their own activities with their historic data.

2) The required time buffer between activities to provide a certain confidence level (e.g., 95%) that the activity “n” is not going to affect the activity “n+1” needs to be determined.

3) Repetitive projects can be easily scheduled using the “line-of-balance” method. However, this chart shows the progress of the activities assuming that the “units” (e.g. houses) are performed sequentially. The proposed approach suggests that the beginnings of the activities have to continue even if a previous unit has not been finished. Thus, two lines for each activity have to be plotted; one for the pace of its beginnings (completely straight with the speed determined by the management) and another for its finishes.

4) The amount of resources that would be demanded by this approach is going to be variable. So the proposed approach assumes to have all the necessary crews at any time over the execution of the project. Its effects will be explained in detail in the case study.

5) Finally, the amount of human resources demanded by the system is calculated in order to check the feasibility of the proposed approach.

3. Case Study

The proposed approach was tested with real data from a housing project composed by 50 houses, executed in the metropolitan area of Guadalajara, Mexico. Ten activities were chosen to be analysed. Their actual cumulative progress was measured and plotted on the line-of-balance chart shown in Figure 2, which presents in the horizontal axis the dates in which the different activities started and in the vertical axis the cumulative progress represented for the number of completed houses by each activity.

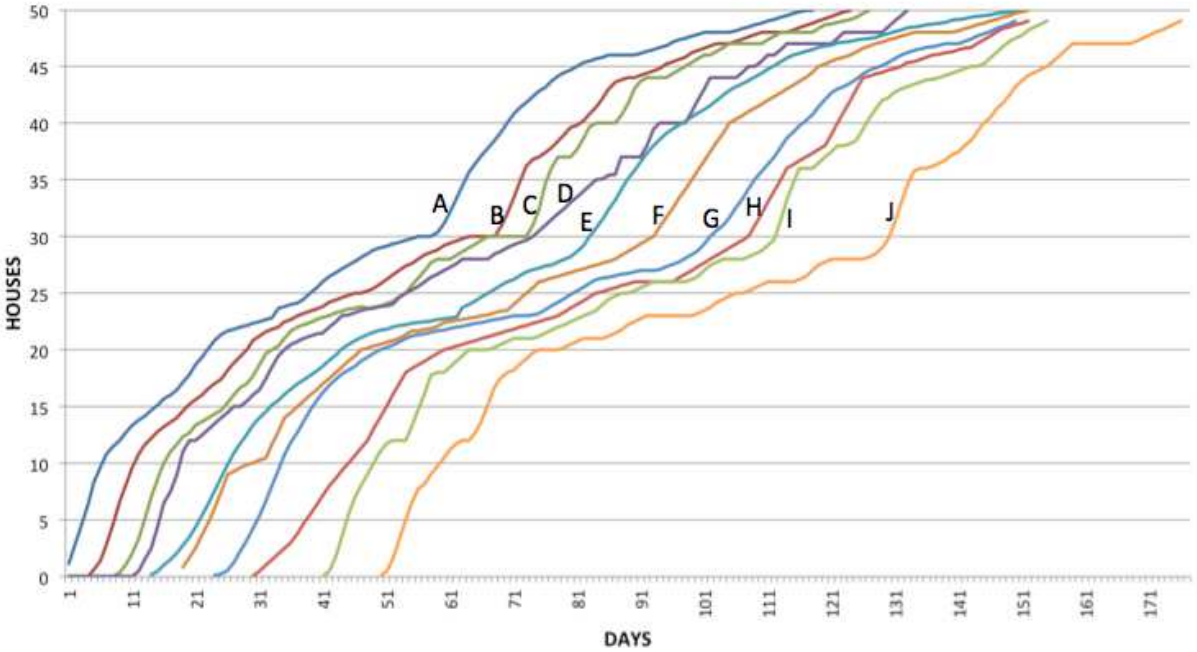

Figure 2. Line-of-balance chart shows the actual cumulative progress for ten activities.

The activities measured were (Figure 2):

A. Excavation and foundation
B. Levelling, strap footing beams and reinforced columns
C. Drainage system
D. Backfilling and compaction
E. First floor brick walls
F. First level roof pouring
G. Second floor brick walls
H. Second level roof pouring
I. Roof parapets
J. Roof waterproofing

Based on an unrealistic construction schedule with zero variability, it was plotted a line-of-balance chart that met the goals of the project developers, producing a progress pace of two houses a week for each activity (see Figure 3). As a result, an expectable term of 215 days was produced for the ten activities analysed. This “ideal” construction schedule provides a point of comparison in relation to the data collected and the further analysis to find out an “optimum” time buffer size. In practice, it is impossible to deliver a project with no variability. Thus, the ideal construction schedule also helps to understand how much the project analysed was disrupted because of the influence of the variability in the activities duration.

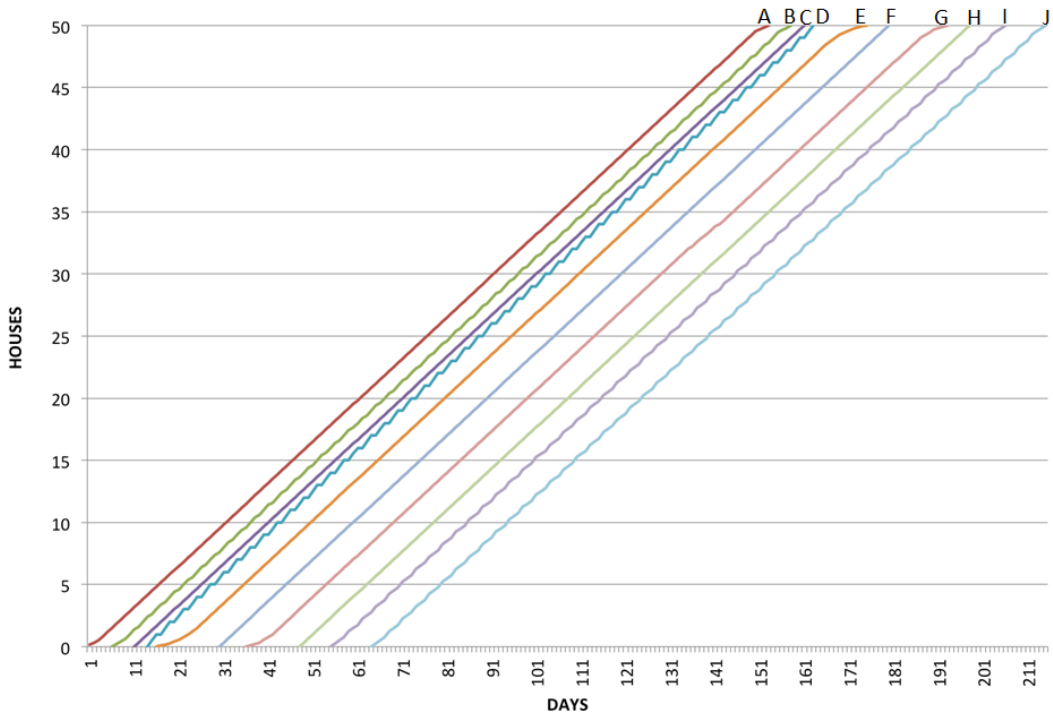

Figure 3. The unrealistic cumulative progress for ten activities in a line-of-balance chart.

Note that the separation observed between each activity depends on the duration of the activity itself and the required time buffer to assure that a minimum space is available for the next activity (i.e. to avoid congestion between the crews).

There were analysed only ten activities that were under the control of the managers and subcontractors performed the rest of activities. Those ten activities were performed by the same type of labour, which means that the crews were interchangeable.

Probabilistic distributions for the activities duration were fitted. First, the standard deviation for each activity was determined. Then, normal distributions for durations were tested using goodness-of-fit tests (chi-square test). In general, poor results assuming normal distributions were obtained. Beta distributions were also tested obtaining much better results for a couple of activities. However, the time buffer for both normal and beta distribution were nearly the same in this case study. For example, assuming beta distribution the activity will last a maximum of nine days, and with normal distribution the result is 9.50 days.

Even though the beta distribution provided better results for goodness-of-fit, the normal distribution was used as this distribution can be fitted in simpler fashion than the Beta distribution (Gonzalez and Alarcon, 2010), and accordingly, the assessment of the Normal properties is much simpler than Beta distributions. This study pays attention in the maximum values that the activities duration can reach, which are very similar, in order to determine the size of the time buffers.

The time buffer required between activities is determined bearing in mind the degree of risk that the manager is willing to accept. To calculate the size of the time buffer, a certain

number of standard deviations or sigmas is added to the mean of the activity duration according to the desired confidence interval. For instance, to calculate the time buffer between the activities A and B, considering a one-sided confidence interval of 97.5%, it is necessary to add 1.96 standard deviations to the mean of the activity A duration. The calculation is shown as follows:

$$Time\ Buffer_{A\text{-}B} = Mean\ of\ activity\ A\ duration\ (6.34\ days) + 1.96\ standard\ deviations\ (s.d.=1.45) = 9.18\ days\ to\ start\ the\ activity\ B$$

The same procedure was repeated for all the activities obtaining the results shown in table 1:

Table 1. Calculation of the time buffer $_{i\text{-}j}$ for the activities in Figure 2.

ACTIVITY	Mean of duration	Std. dev.	Time Buffer	Next higher whole number	Start date
A. Excavation and foundation	6.34	1.45	9.18	10	1
B. Levelling, strap footing beams and reinforced columns	4.58	1.33	7.19	8	11
C. Drainage system	3.16	0.84	4.81	5	19
D. Backfilling and compaction	2.00	1.47	4.88	5	24
E. First floor brick walls	11.94	2.24	16.33	17	29
F. First level roof pouring	5.82	0.75	7.29	8	46
G. Second floor brick walls	8.94	2.70	14.23	15	54
H. Second level roof pouring	5.86	0.50	6.84	7	69
I. Roof parapets	4.20	0.93	6.02	7	76
J. Roof waterproofing	4.08	0.73	5.51	6	83

According to the time buffers calculated in Table 1 a manual simulation in Microsoft Excel was performed to create a different scenario and show how the project would perform under the proposed conditions: controlling the beginnings of the activities, applying the time buffers calculated, and leaving the durations unrestricted. The result for the ten analysed activities is shown in the Figure 4.

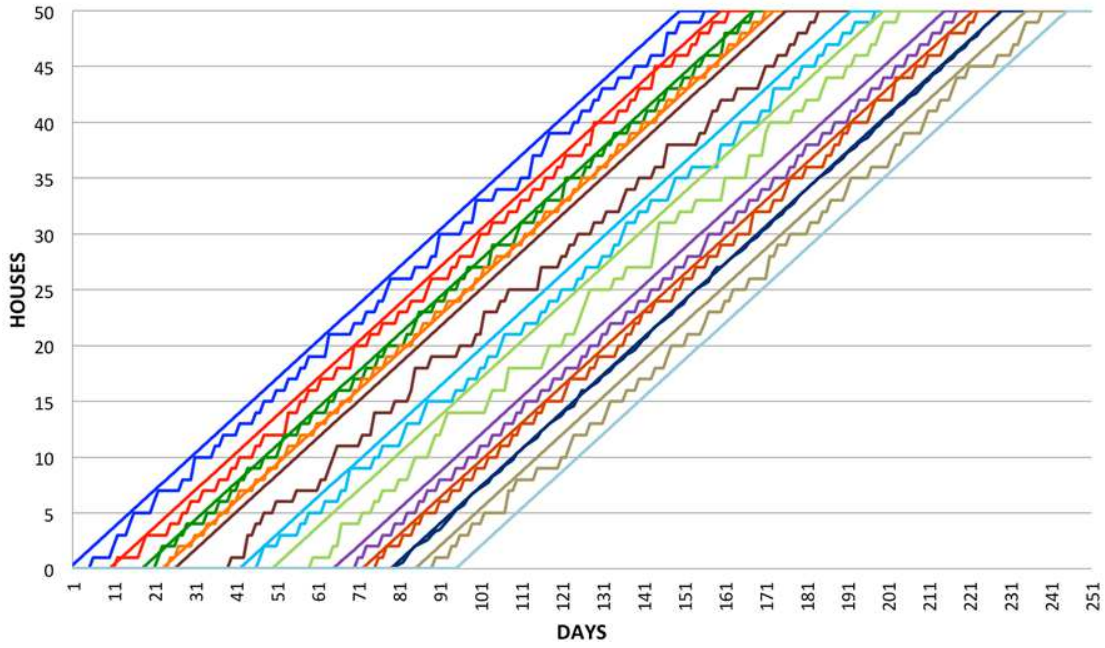

Figure 4. Line-of-balance chart for the ten analysed activities considering the proposed approach.

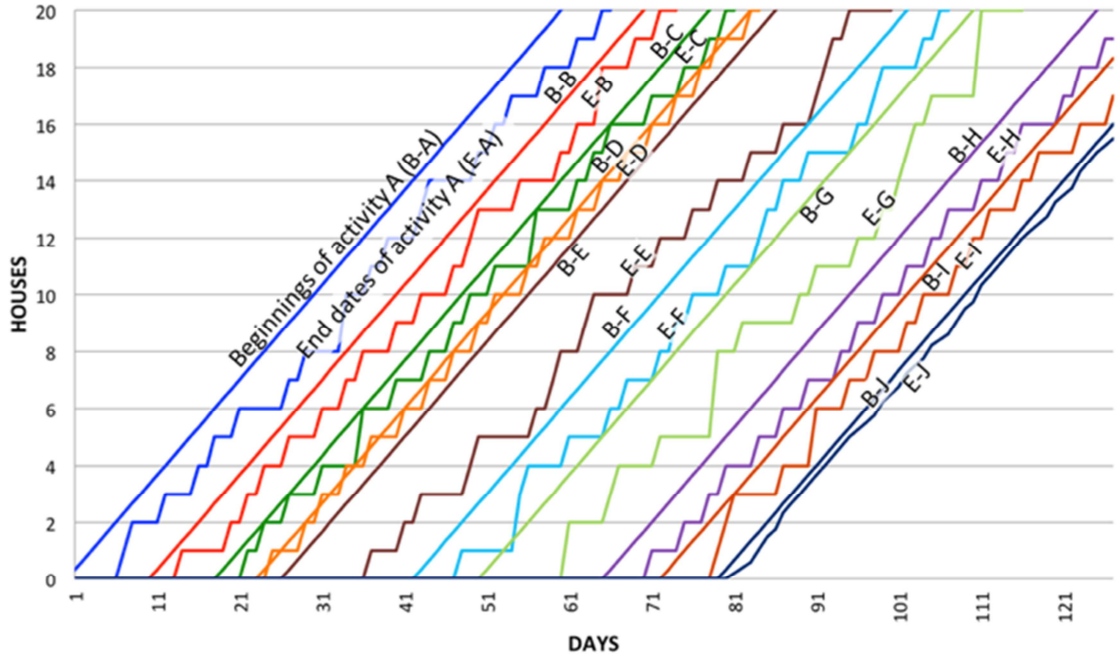

Figure 5. Line-of-balance chart for the first twenty houses considering the proposed approach.

The figure 5 shows a zoom on the first twenty houses and how the proposed approach isolates each activity, showing very satisfactory results. The straight lines represent the planned beginning of the different activities (e.g., the first line from left to right are the planned beginnings of activity A, B-A) and the broken lines are the end dates of activities (e.g. the second line from left to right are the end dates for activity A, E-A), which are unstable due to their own variability. Time buffers prevent – to a certain extent - that the

broken lines touch the following straight lines, which would imply that an activity is delaying the start of the following one.

Figure 5 shows how virtually in any point an activity disrupt the following one. Note that for each house all the activities have some float. This means that in case an activity causes a delay in another activity there is some room to recover the delay.

The conceptualization of this approach implies that the number of crews varies along the project. The proposed approach implies that it must start the next house even if there is no crew available, so a new crew has to be hired. On the other hand, if a crew finishes its work and there is no new activity to start, this crew had to be laid off. Figure 6 shows the number of crews that should be working simultaneously in the project every day.

In order to apply this approach in a real project, the daily required crews should have a minimum degree of variability. A contractor can't hire crews one day and lay them off the next. A simulation was performed to validate how many crews would be required each day under this approach (see Figure 6). It can be seen that the shape of the daily demand for crews is similar to a real project. However more in-depth analyses are required to even the demand of crews.

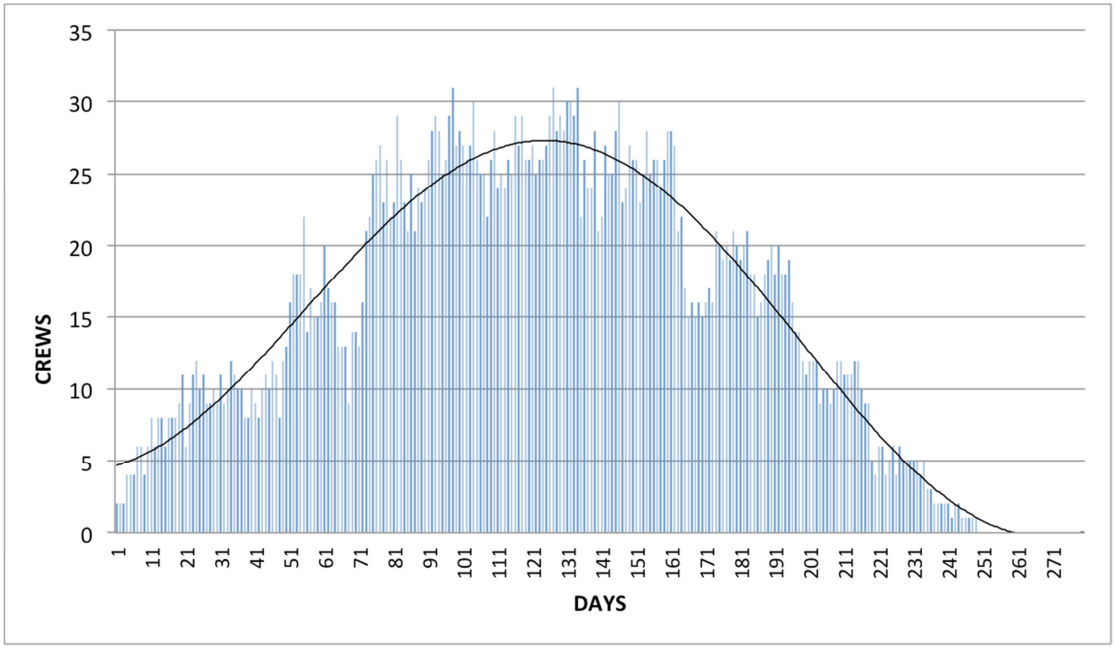

Figure 6. Amount of crews required each day along the project.

4. Conclusions and further work

Based on the results obtained when simulating a real project controlling the beginnings of the activities it can be concluded that this approach seems to be practical and feasible. The total time taken to complete the ten activities would be about 245 days. The utopic project without variability had an expectable term of 215 days. The difference between those terms

is caused by the additional days required between activities to minimize the risk of interference.

In the other hand, when analysing the amount of crews required every day in the project when applying this approach it can be observed that it could be considered feasible. The curve of personnel required (shown in figure 6) is a good approximation of a logical process of hiring crews along a regular construction project.

Further work is needed to find out how crews' variability can be handled and their impact on the proposed rhythm of activities.

Besides, it can be assumed that there will be a learning curve and it implies that the project will have less variability in activity durations as the project progresses. This effect should be analysed to find out if it could bring important benefits to consider when estimating the total duration of the project. It would also be interesting to quantify benefits in costs by implementing this approach.

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Use of roof space ventilation to address summertime overheating in New Zealand houses

Kathryn Davies[1], Roger Birchmore[2], Robert Tait[3]

Abstract

Previous research in New Zealand houses has indicated that recent increases in insulation and double glazing requirements may have led to increased problems with summertime overheating. Monitoring of a typical New Zealand house (standard three-bedroom, lightweight timber frame construction) in the Auckland region has shown that the roof space achieves extremely high temperatures in summertime and even mid-season. The roof space therefore is a heat source that has the potential to impact significantly on overall internal temperatures.

Although the principle of ventilating the roof space to outside is well established in the northern hemisphere, traditional best practice in house design in the New Zealand climate does not recommend it. However, this advice is based on older construction standards, which included single glazing and lower levels of insulation than are currently required. This paper reports on the results of a project to test the impact of passive ventilation of the roof space in a New Zealand house built to current standards, with the intention of improving comfort levels within the living spaces. The ventilation system tested consists of air vents inset into the soffits on both the north and south sides of the house, with a ridge vent along the length of the house.

The house has been monitored across summer, autumn and winter conditions, recording internal air temperature and relative humidity throughout the living spaces and roof space of the house. Results indicate that the passive ventilation is an effective measure to reduce summertime temperatures in the roof space, with subsequent impact on the temperatures experienced in the living spaces of the house. Wintertime temperatures appear to be relatively unchanged. The project demonstrates that there is a case to be made for the adoption of passive ventilation of roof spaces to improve the thermal performance of homes in New Zealand.

Keywords: ventilation, temperature, over heating, cooling, energy

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1. Introduction

There has been substantial research demonstrating that New Zealand houses are not well heated, and many spend significant periods of time below the minimum range of indoor air temperature of 16°C recommended by the World Health Organisation. This has been shown to contribute to poor health outcomes (Howden-Chapman, 2005), and has prompted a greater emphasis on higher standards of insulation in new homes, including an extensive programme of retrofit improvements in existing homes (McChesney, Cox-Smith & Amitrano. 2008). Other measures designed to improve comfort levels and reduce energy costs have also been investigated, including glazing types (Tait, Birchmore & Davies, 2011) and various retrofit options (Page, 2009; Smith, Isaacs, Burgess & Cox-Smith, 2012). Several of these studies have identified that while these measures have been effective in raising the very low minimum temperatures, maximum temperatures have also increased beyond the WHO recommended upper limit of 24 ^{o}C, creating summertime overheating in many homes.

At the same time, there has been a drive to improve the heating options in New Zealand homes, to move away from traditional wood and gas fuelled heaters that contribute to air pollution and greenhouse gas emissions. Instead, homeowners have been encouraged to install electric heat pumps, with Government subsidies provided from 2009-2012 to reduce the purchase and installation costs to homeowners. There has been rapid uptake of the technology, with heat pumps installed in approximately 21% of New Zealand houses in 2009, compared with only 4% in 2005 (Burrough, 2010). This technology has introduced the possibility of cooling into homes where previously such an option did not exist. French et al. (2009) found that in the Auckland region, heat pumps were used for cooling in 81% of homes where heat pumps were installed. An increased number of heat pumps will clearly lead to peaks in summertime energy loads which were not present in the past. Given that this coincides with the time of year where the hydro lakes in New Zealand are at their lowest levels (Knight, 2009), there is an increased likelihood that electricity to support this cooling will be supplied from gas or coal fired sources.

2. Ventilated roof space scenario

As previously documented (Tait et al, 2011; Birchmore, Davies & Tait, 2012), Unitec Institute of Technology makes use of houses built by carpentry and plumbing and gasfitting students on the Unitec campus to test the performance of building materials and techniques in a full scale situation. In this project, one of the standard houses was used to explore the impacts of a low cost and low-tech modification to this common house type, specifically to address the problem of summertime overheating. The changes to the building were intended to be uncomplicated and suitable for retrofit to existing homes as well as incorporation into new-build homes.

Previous findings indicated that extremely high temperatures were reached in the roof space of the house, as shown in Figure 1. The temperatures in the living spaces were also high, but there was a time lag between the roof space peak temperatures and the internal peak temperatures. It was hypothesised that the high roof space temperatures are acting as a radiant heat source for the living spaces, and thus impact significantly on the overall internal space temperature. If this is the case then reduction of these temperature extremes in the roof space would reduce the instances of uncomfortably high internal temperatures in the living spaces.

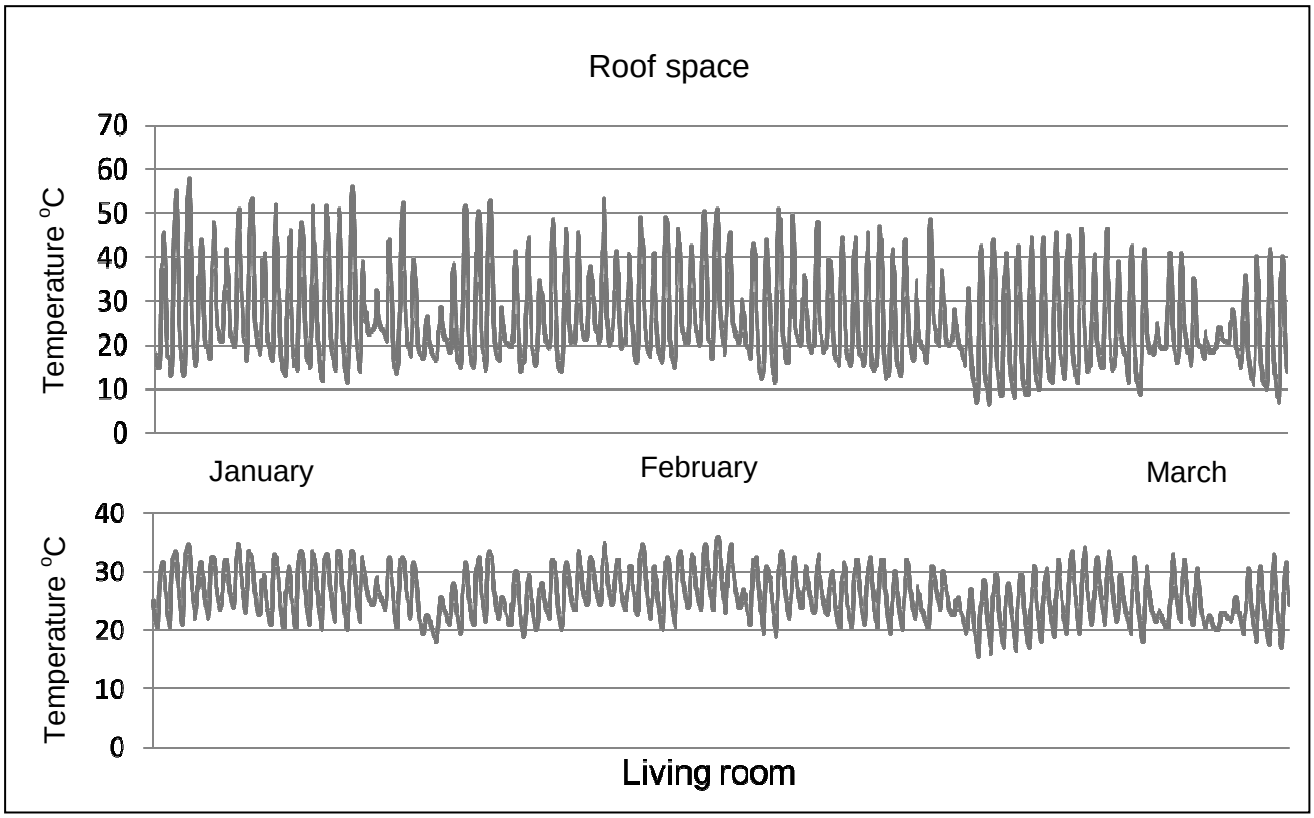

Figure 1 Comparison of roof space and living room temperatures in unventilated case

Using the buoyancy principle, the house was modified to allow passive ventilation to the roof space, with no modification of the rest of the house as previously monitored. Holes of 40mm diameter were drilled at intervals along the soffits on both sides of the building, resulting in 108 holes in total. The standard roof ridge was replaced with a proprietary ridge ventilation system. Figure 2 shows the modifications made to the house. The intention of the modification was to allow buoyant hot air to exit the roof space at the ridge, drawing in cool air at the soffits, creating a continuous air flow that increases as the temperature increases. As is evident from the photographs, the system used is low impact both visually and technologically.

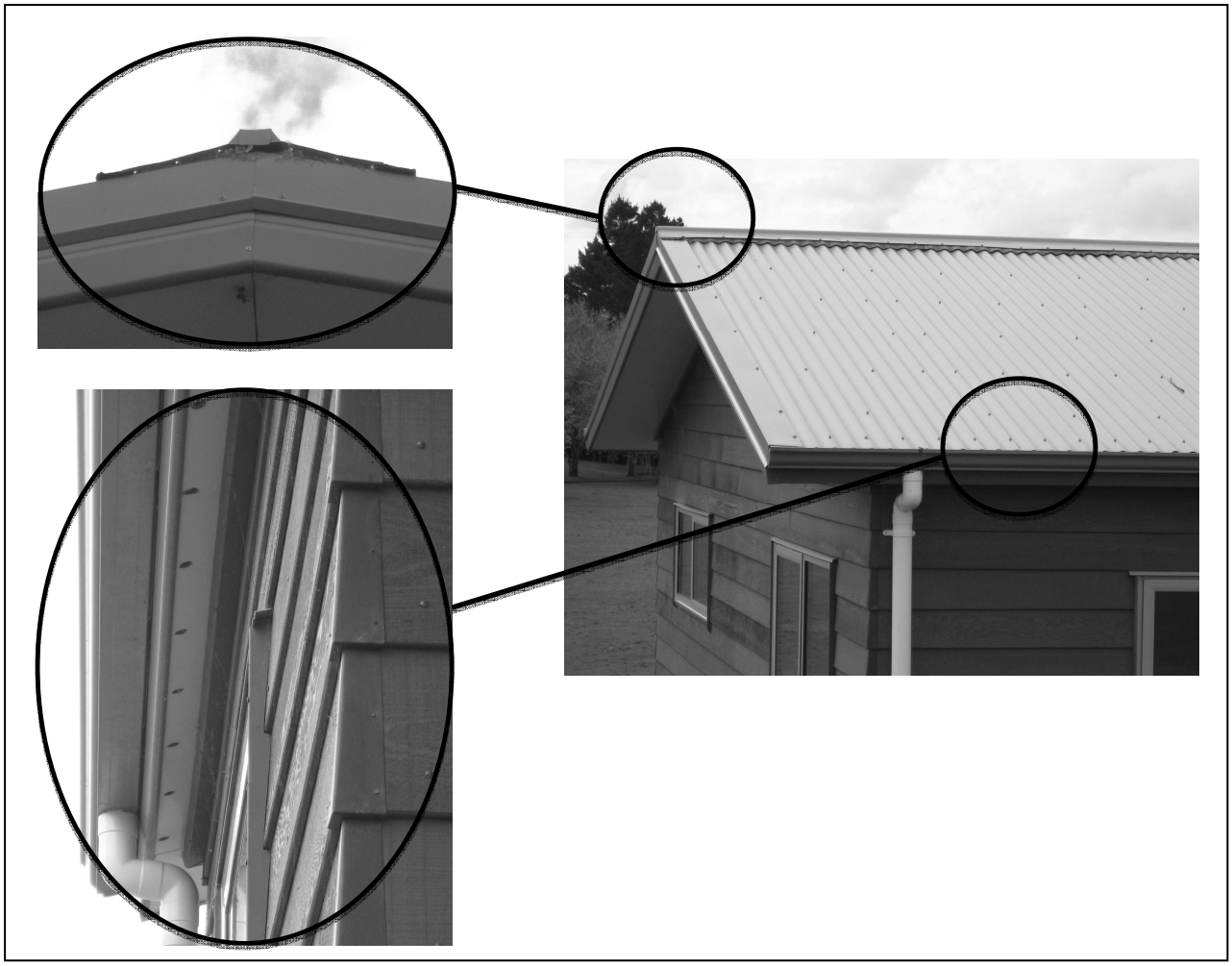

Figure 2 Modifications to house for passive ventilation

3. Methodology

Sensors were set up in various locations inside the house to sample the internal air temperature and relative humidity at hourly intervals. Sensors used are Lascar EL-USB-2 Humidity & Temperature USB data loggers. These measure and store relative humidity and temperature readings over 0%RH to 100%RH and -35°C to +80°C measurement ranges. Sensors were suspended in the living space at a height of 1500m above ground level, and

located to avoid direct solar radiation. A sensor was also centrally located in the roof space. Weather data is collected on site.

The unmodified house was monitored between December 2010 and August 2011. The roof modifications were then made and the monitoring continued from December 2011 until September 2012. While not constituting a full year of data in either case, this period covered the full summer and winter seasons and was considered sufficient to meet the aims of the study.

4. Findings

In order to analyse the impact of the ventilated roof, the weather data was examined to identify days in both periods that were as similar as possible in three measures: external air temperature, global solar radiation and wind speed. The temperatures inside the roof space and living space in each case were compared. In addition, mean temperatures across selected days and periods were examined, as were peak temperature data.

The data analysis focuses on the peak summer period of February – March to demonstrate the effect of the modification on maximum summertime temperatures, and the peak winter period of July – August to identify that the modification does not negatively impact winter temperatures.

4.1 Summer time measurements

The data were first examined by comparing the performance of the house on days when weather conditions were similar in 2011 and 2012. While there were of course no identical matches, a number of days were reviewed which could be considered close. Figure 3 shows the weather data for one of these comparisons, representing February 28, 2011 and February 11, 2012. Solar radiation and air temperature reach slightly higher peaks in the 2011 case. Wind speeds are also slightly higher, and overall this could be expected to result in similar internal temperatures between the two cases. Figure 4 then presents the comparison of the external, roof space and living room temperatures in the 2011 (no roof ventilation) and 2012 (ventilated roof) scenarios.

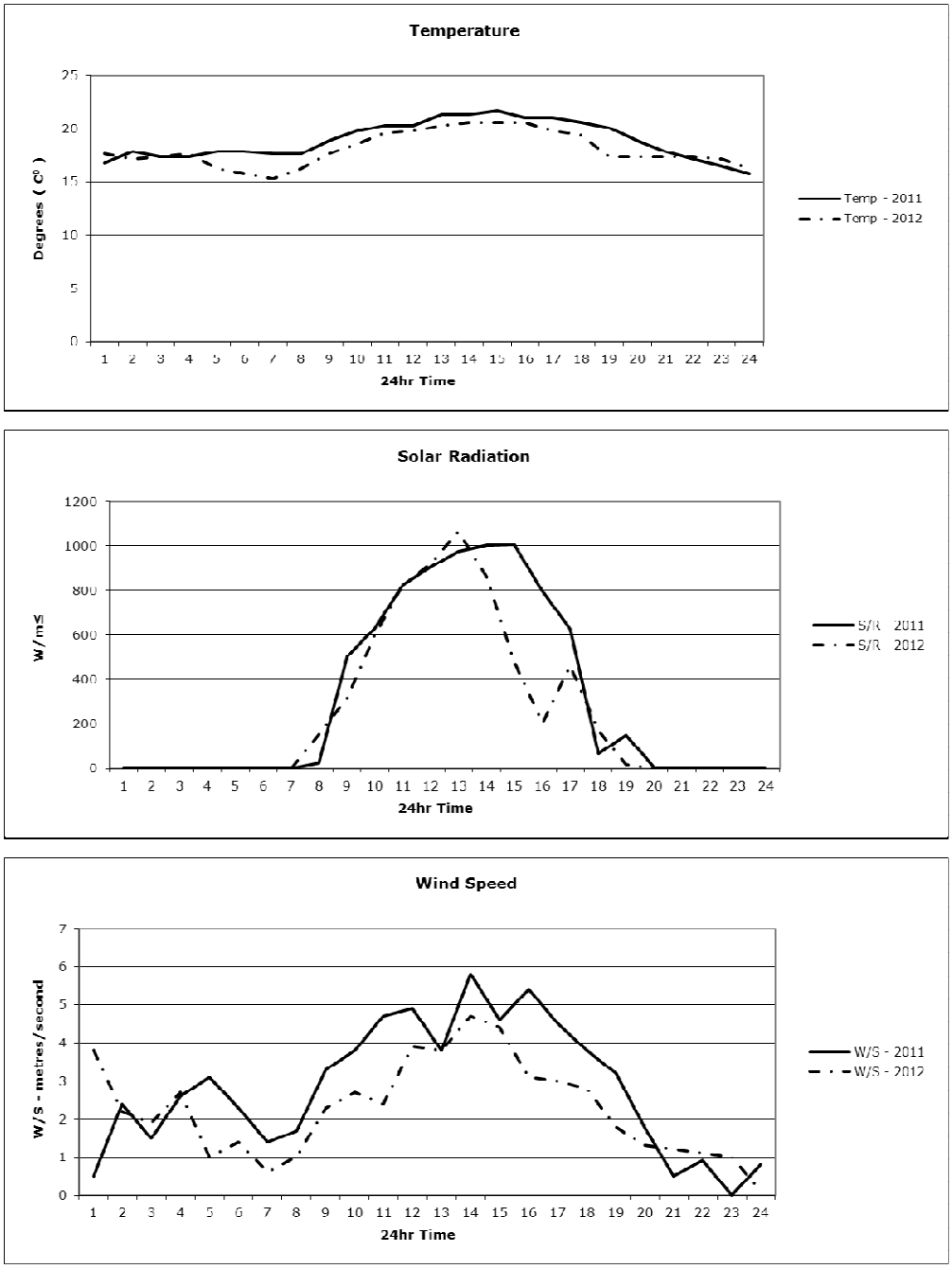

Figure 3 Weather data comparison example – summertime

As is evident in Figure 4, the variation in temperature for the internal sensors, although slightly greater than that seen in the comparison of external temperatures, is still very small. However, this small difference persists across the summer season, and the ventilated roof case can be seen to reduce temperatures overall by 1-2 degrees.

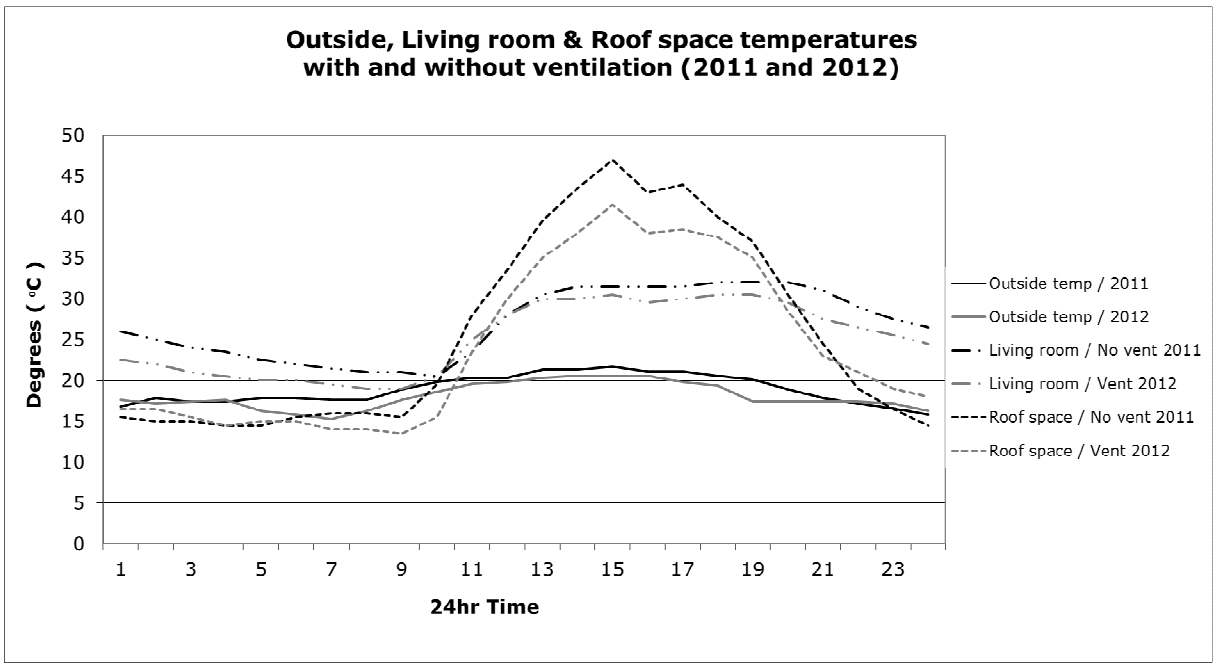

Figure 4 Temperature comparison for example summer day

The temperature difference becomes more distinct when averages over the period are viewed, as shown in Figure 5. The average external temperature in February 2012 was 1.4 degrees less than over the same month in 2012. The average internal temperature following the ventilation modifications was 2.4 degrees less. Similarly in March, the external average was 0.6 degrees lower in 2012, whereas the internal average was 1.6 degrees lower.

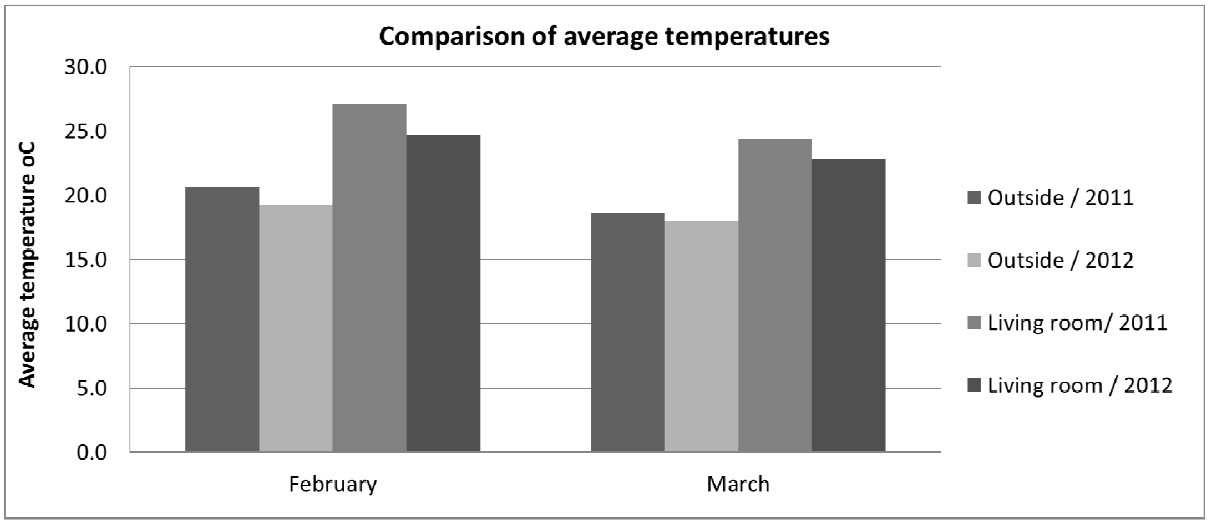

Figure 5 Average temperatures for summer months

Although the overall average temperatures appear reduced by the roof ventilation, a more substantial difference is visible when peak temperatures are examined, see Figure 6. The average daily maximum outside temperature in February 2012 was 22.5^{o}C, 1.4 degrees higher than in 2011. The maximum interior temperature however was 2.9 degrees lower in 2012. In March the temperatures overall were not as high and the difference in maximum external temperatures went from 1.5 degrees difference externally to a 2.1 degree difference in maximum internal temperature with the roof ventilation in place.

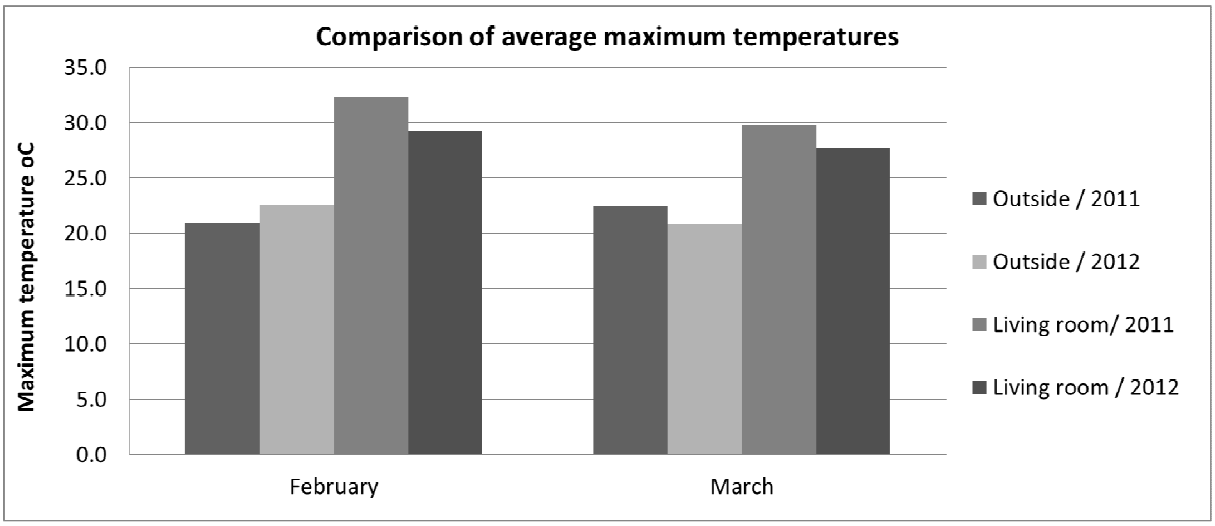

Figure 6 Average daily maximum temperatures for summer months

These results show that a small but consistent reduction in the summertime temperatures has been achieved through installation of the roof ventilation system. The improvement to maximum temperatures to a greater extent than to temperatures overall is consistent with the buoyancy-driven system, as higher temperatures will create greater air movement.

4.2 Winter time measurements

A key objective in addressing overheating concerns was that any reduction in high temperatures was not to be achieved at the expense of winter time cooling. To check whether this was the case, similar analysis was conducted on the average temperatures in the roof space and living room during the coldest winter months of July and August.

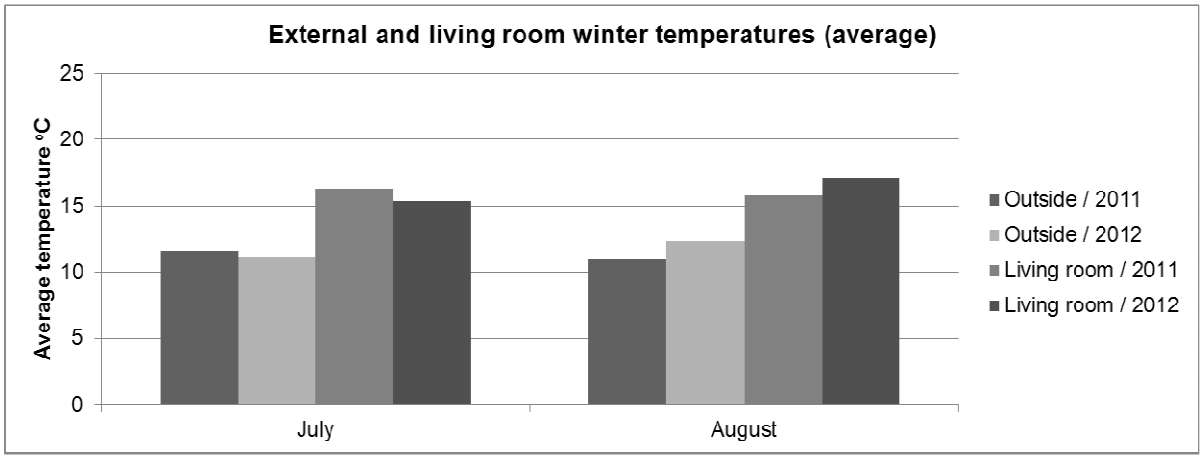

Figure 7 Average temperatures for winter months

Figure 7 shows the comparison of external average temperatures with temperatures in the living room, for each of the winter months. The relationship between internal and external temperatures is uniform across the winter measurements. The temperature difference in outside temperatures between July 2011 and July 2012 was 0.4 degrees. This was matched with a difference in internal temperatures of 0.5 degrees. A similar comparison is evident for August temperatures, where the outside temperature difference between years was 1.4 degrees, while for internal temperatures the difference was 1.3 degrees.

Again this result is consistent with expectations for the buoyancy-driven system. When temperatures are low, air movement is much reduced, and therefore there is no additional heat loss within the roof space.

5. Conclusions

A passive ventilation system such as the one reported here is a low-cost addition to a new-build house or a simple retrofit to an existing house. It is visually unobtrusive and technologically low impact. The results presented here demonstrate that this minor alteration can reduce the peak overheating in the living spaces of a house, without adding to the cooling of the space on cooler days. While the reduction of temperatures by 1-2 degrees may appear to be a trivial change when maximum temperatures are reaching above 30 degrees, the reduction in energy use for cooling across the housing stock will have a significant impact on peak loads. Even when viewed within a single house, the payback period for such a modest outlay will be relatively quick. The system has no impact on the need for heating of the house, as the most significant effect is on peak temperatures and there is less or no effect on temperatures within or below the WHO recommended range of 16-24°C.

In the case studied, the inlet openings in the soffits were of a minimum size to allow air movement. Future work will include experimentation with the size of inlet openings to see if they increase ventilation rates and improve temperatures further, and to investigate the effect of ventilating via the gable ends instead or as well as the ridge vent.

Acknowledgements

This project forms part of a “Whole of House” research centre that is currently being established at Unitec Institute of Technology in Auckland, New Zealand, and has been supported by the Unitec Internal Research Fund. Materials for the project were contributed by Viking Roofspec, Auckland, New Zealand.

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Empirical Analysis of the Impacts of Safety Motivation and Safety Climate on Safety Behaviour

Saeed Al-Haadir[1], Kriengsak Panuwatwanich[2] and Rodney A. Stewart[3]

Abstract

Safety is a major concern for construction companies, as it is a source of substantial direct and indirect costs. In some countries, the rate of total workplace injuries from construction activities can be as high as at least 50%. This is undoubtedly a serious matter warranting urgent attention. In the past decade, interest in the nature of 'safety climate' and its role in predicting occupational accidents and injuries has increased. However, research findings regarding the relationships between safety climate and other key outcomes constructs such as safety behaviours and safety outcomes are to some extent inconsistent. Recent safety climate literature suggests that examining the role of safety motivation may help provide a better explanation on such relationships. In view of this, the authors of this paper have developed a conceptual model depicting the relationships between three main constructs: Safety Motivation, Safety Climate, and Safety Behaviour. In particular, the model hypothesises that Safety Climate has a mediating role on the relationship between Safety Motivation and Safety Behaviour. The aim of the research study presented in this paper was to empirically assess the proposed conceptual model within the context of Saudi Construction Industry. To achieve this, a questionnaire was developed through a critical review of literature and was pilot tested with a number of safety management experts. A survey was then administered in Saudi Arabia targeting project managers, site managers, site engineers and supervisors at construction workplaces. In total, 430 sets of questionnaire were distributed and 265 valid responses returned. Based on this dataset, a series of statistical analyses were performed including basic descriptive analysis, Exploratory and Confirmatory Factor Analyses as well as Structural Equation Modelling (SEM). The results from the analysis support that Safety Climate fully mediated the relationship between Safety Motivation and Safety Behaviour, within the context of Saudi Construction Industry.

Keyword: Safety Climate, Safety Behaviour, Safety Motivation, Construction, Saudi Arabia

1. Introduction

The National Safety Council (NSC) estimates that the construction industry employs about 6% of the industry workforce; however, on average, it is responsible for approximately 21%

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of all industrial deaths (Rechenthin 2004). In fact, it is documented that the construction industry has the highest rate of accidents of all industries as well as the highest rate of disabling injuries and fatalities (Hinze 1997). As reported by Bomel (2001), up to 40% of accidents occur in the construction industry in Japan, 50% in Ireland and 25% in the United Kingdom. In some developing countries such as Saudi Arabia, around 51% of total workplace injuries occurred in the construction sector (General Organization for Social Insurance 2010). Safety has thus become one of the primary concerns among construction organisations as well as construction researchers.

Traditionally, safety research has focused on identifying individual attributes, such as personality traits or attitudes which are associated with accident-proneness (Sutherland and Cooper 1991). However, major disasters, such as Piper Alpha and Chernobyl, have illustrated the importance of work climates and management practices as contributors to system failure (Reason 1990). Consequently, increasing attention has been paid to the role of the work environment and management practices as determinants of safety in the workplace (Barling et al, 2003). Much of this research has focused on the concept of safety climate (Neal and Griffin 2006). Although the safety climate literature has examined the link between safety climate and safety behaviour, and with accidents; there remains a number of conceptual and practical difficulties associated with the relationship between both constructs (Neal and Griffin 2006). Some researchers have suggested that examining the role of safety motivation may help provide a better explanation on the link between safety climate and safety behaviour as well as other associated outcomes (Clarke, 2006).

The primary aim of this paper is to develop and empirically test a conceptual model that integrates safety motivation, safety climate and individual safety behaviour to produce an improved integrative model of construction workplace safety, as well as to provide an appropriate measure for safety motivation in the workplace. In particular, the model proposes that workers' safety climate is a key mechanism through which safety motivation leverages individual safety behaviour.

2. Conceptual model development

In safety literature, essential background knowledge is generally provided in relation to how safety climate is associated with safety outcomes. One shortcoming apparent in the literature is the lack of comprehensible and consistent construct definitions and conceptualisations, in both the predictor and criterion sides (Clarke and Robertson 2005). The existing inconsistencies between studies and empirical findings are not in line with theoretical predictions. Even though there have been efforts to overcome this problem in particular domains, no study to date has comprehensively addressed the deficiencies (Christian et al. 2009). Moreover, the literature regarding safety climate and safety behaviour reveals that safety motivation (SM) plays a part in these relationships (Clarke 2010). These observations led to the development of a theoretical framework addressing three constructs: safety motivation (SM), safety climate (SC), and safety behaviour (SB) (see Figure 1).

In particular, the framework hypothesises that SM has a primary influence on SC and SB. Moreover SC impacts safety behaviour directly and it should be noted that the mediating

effect of safety climate between safety motivation and safety behaviour has never been tested within the construction context. The following sections provide details of each of the model's constructs.

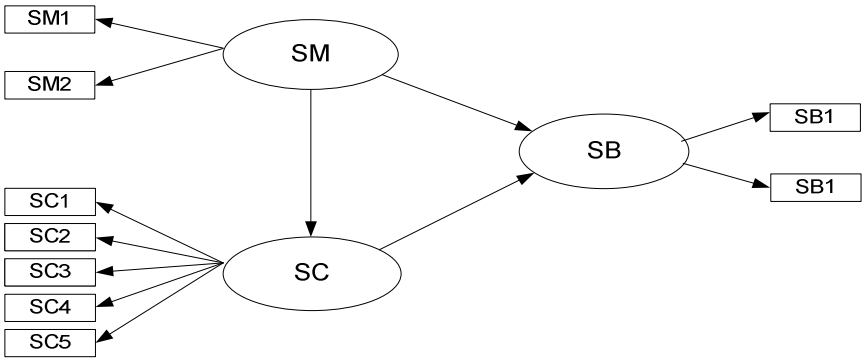


Figure 1: The conceptual model

2.1 Safety motivation (SM) construct

The study of motivation is the study of action (Eccles and Wigfield 2002). Motivation has been defined as "the set of psychological processes that cause the initiation, direction, intensity, and persistence of behaviour" (Fey 2005). Another definition refers to inner factors that drive action and to outside factors that can act as inducements to action (Locke and Latham 2004; Moynihan and Pandey 2007). Motivation, in general, is intention to do something, and can be intrinsic or extrinsic (Locke and Latham 2004). A careful literature review of safety motivation reveals a number of theories focusing on the differences between intrinsic and extrinsic motivation. When individuals are intrinsically motivated, they engage in an activity since they are interested in and enjoy the activity. When extrinsically motivated, individuals connect with activities for instrumental or other reasons, such as receiving a reward. The theories presented in the following paragraphs focus on the question of why (Eccles and Wigfield 2002).

Intrinsic motivation theory argues that extrinsic incentives and pressures can weaken motivation to perform even inherently interesting activities. However, Deci et al. (1999) expanded the extrinsic-intrinsic motivation dichotomy in their argument of internalisation the process of transferring the regulation of behaviour from outside to inside the individual. When individuals are self-determined, their motives for engaging in behaviour are completely internalized. Deci and colleagues defined several levels in the process of moving from external to internalised regulation. These are: "external", "introjected", "identified" and "integrated". External level refers to the regulation coming from outside the individual; introjected level represents internal regulation, based on feelings that one has to do the behaviour; identified level indicates internal regulation based on the utility of that behaviour, and integrated level refers to regulation based on what the individual thinks is valuable and significant to themselves (Deci et al., 1999).

Based on the Operant Conditioning Theory, Weiss (1990) developed four tools that managers can apply to motivate high performance and prevent workers from engaging in other behaviours detracting from organisational effectiveness. These tools are: positive reinforcement, negative reinforcement, extinction, and punishment. These tools were tested by Teo et al. (2005) and the findings showed that only three tools can help workers who "do not care" about working safely to be more safety-aware. The first tool is positive reinforcement, which gives workers outcomes (positive reinforcers) they desire when they perform organisationally functional behaviours. Secondly, negative reinforcement eliminates or removes undesired outcomes (negative reinforcers) once the functional behaviour is performed. Hence, to motivate workers to perform their jobs in a safe manner, managers may criticise or threaten workers. Once the workers work in a safe manner, they stop receiving the undesired outcomes. Whenever possible, positive reinforcements should be used, as negative reinforcements make the workplace unpleasant and may cause subordinates to resent managers and try to get back at them (Jones and George 2003). The third tool is punishment, which involves administering an undesired or negative consequence when dysfunctional behaviour occurs. In regards to job safety, punishments can include pay cuts, temporary suspensions, demotions, and firings. Punishments and negative reinforcements are different. Negative reinforcement is used to encourage workers to work in a safe manner, while punishment is used to stop unsafe work behaviour. When the workers work in a safe manner, the negative reinforcement is removed. In the case of punishment, it is administered when unsafe work behaviour is performed. The above theories can be summarised in relation to the two major sources of motivation: intrinsic and extrinsic. Intrinsic motivation refers to behaviours that happen in the absence of external control, whereas extrinsic motivators are external motivation sources, when individuals believe that the behaviours they engage in will lead to certain outcomes such as pay and praise (Nirmala 2005). Intrinsic motivation does not mean, however, that a person will not seek rewards. Thus, safety motivation scales should measure both intrinsic and extrinsic motivation. The aim for understanding the nature of motivation is to measure safety motivation appropriately, and to discover the impact of motivation on the relationship on safety climate and worker safety behaviour, in order to predict and control human behaviour in workplace. Table 1 describes the dimensions of safety motivation along with description and associated references.

In the current study, it is proposed that workers' safety motivation is a key variable having a direct impact on both workplace safety climate and individual behaviour. A desired safe behaviour in workplace is usually uncomfortable and inconvenient (Geller 2010). Without safety climate and individual motivation, shortcuts may unavoidably be taken. The motivation has to be linked to required actions for the outcome to be achieved (Gershwin 1994) which is safety climate in the current study. The motivation alone does not produce the positive change unless there is an appropriate safety climate to maintain safe manner and no reversion to unsafe behaviour especially in the developing countries. This goes along with person-organization fit concept which is one of the most popular areas of research in the general management and organizational field. This domain captures the congruence between the characteristics of individuals and the characteristics of organizations (Bright 2007). Thus as the congruence between individuals who have the value and motivation toward safety and the construction safety

climate, will drive workers behaviour to become more safe and committed. Individuals are only expected to allocate discretionary effort when they believe that their individual interests are aligned with those of the company will make a reciprocal investment in their well-being Therefore, workers safety motivation will work when there is a constructive safety climate (Vroom 1964).

Table 1: Operational details of the 'Safety Motivation' construct

Dimensions	Description	References
Intrinsic Motivation (SM1)	Intrinsic motivation refers to desired behaviors that happen in the absence of external control.	Moynihan and Pandey, 2007; Neal and Griffin, 2006; Vinodkumar and Bhasi, 2010.
Extrinsic Motivation (SM2)	Extrinsic motivators are external motivation sources; individuals believe that the behaviors they engage in will lead to certain desired outcomes.	Teo et al., 2005; Vinodkumar and Bhasi, 2010.

2.2 Safety climate (SC) construct

During the last two decades, safety climate has been researched in three principal ways: (1) designing psychometric measurement tools and determining their underlying factor structures; (2) developing and examining theoretical models of safety climate to find out determinants of safety behaviour; and (3) examining the relationship between safety climate perceptions and actual safety outcomes (Cooper and Phillips 2004). One of the objectives of this study is to measure safety climate perceptions and develop and test theoretical models of safety climate to ascertain determinants of safety behaviour and accidents.

Many researchers have studied the factors which contribute to project safety success within various industries. The majority of these researches were conducted in high hazard industrial sectors, including transport, power generation, offshore oil and gas production, manufacturing, and construction. The results are presented thematically, under the headings managerial factors, supervisory factors, workforce factors, and other system factors (e.g. Yule 2003). These research studies concentrated on identifying factors associated with successful safety performance in organisations. In fact, the inconsistencies in identified safety climate factors could be due to the diversity of questionnaires, samples and methodologies used by different researchers. On the other hand, even when the same questionnaire was used, different factors were still found (Glendon and Litherland 2001). Therefore, it can be concluded that dimensions of safety climate differ from industry to industry, and from county to county (Fang et al. 2006), hence no universal set of safety climate factors. However, a number of similarities can be found between different safety climate research studies. Based on the literature synthesis particularly from the three recent investigations by Fang et al. (2006) and Choudhry et al. (2009), the present paper conceptualises safety climate as consisting of the following dimensions: worker perceptions of management's commitment and communication; worker appreciation of risk; worker

competence; work pressure; and worker perception of safety rules and procedures (see Table 2).

Neal et al. (2000) pointed out that several research studies emphasising the relationship between safety climate and safety behaviour reported a positive effect. One of the key assumptions of the present study is that the link between safety climate and safety behaviour is a direct relationship. Mohamed's (2002) research findings make certain that safe work behaviours are influenced by existing safety climates on construction sites. These results suggest that safety climate and safety behaviour are directly and positively associated.

Table 2: Operational details of the 'Safety Climate' construct

Dimension	Description	References
Management Commitment and Communication (SC1)	The frequency and quality of communication and how keen the management is to improve safety performance.	Mohamed, 2002; Fang et al., 2006; Neal and Griffin, 2006; Vinodkumar and Bhasi, 2010
Competence (SC2)	The effectiveness of safety training, skills and qualifications of relevance to safety issues.	Mohamed, 2002; Fang et al., 2006; Vinodkumar and Bhasi, 2010.
Personal Appreciation of Risk (SC3)	An individual's subjective assessment of acceptable risk in the workplace.	Mohamed, 2002; Fang et al., 2006.
Work Pressure (SC4)	The level to which workers feel under pressure to complete work, and the amount of time to plan and perform work safely.	Glendon et al., 1994; Flin et al., 2000; Mohamed, 2002; Fang et al., 2006.
Safety Rules and Procedures (SC5)	The availability of safety equipment and facilities to carry out the job safely and the effectiveness of safety inspections and emergency procedures.	Flin et al., 2000; Mohamed, 2002; Fang et al., 2006.

2.3 Safety Behaviour (SB) construct

Safety Behaviour (SB) has two components describing the actual performance of individuals at work. Borman and Motowidlo (1993) proposed two main components of performance: task performance and contextual performance. These two parts of performance can be used to differentiate SB in the workplace. First, based on definitions of task performance, this current study uses the term safety compliance to describe the core safety activities which need to be carried out by individuals to maintain workplace safety, such as wearing personal protective equipment. Second, based on definitions of contextual performance, safety participation is used to describe behaviours such as participating in voluntary safety activities or attending safety meetings. Safety participation behaviours may not directly contribute to workplace safety, but they do help to develop an environment that supports safety (Griffin and Neal

2000). The Borman and Motowidlo's (1993) concept was used by Griffin and Neal (2000) to examine the relationship between safety climate and safety behaviour. Table 3 summarises the two dimensions of the safety behaviour construct, along with their descriptions, and associated references.

Table 3: Operational details of the 'Safety Behaviour' construct

Dimensions	Description	References
Safety compliance (SB1)	Self-measure of performance of safety related behaviors.	Neal and Griffin, 2006; Vinodkumar and Bhasi, 2010.
Safety participation (SB2)	Self-measure of involvement in safety support activities.	Neal and Griffin, 2006; Vinodkumar and Bhasi, 2010.

3. Research design

A quantitative research method was selected to examine the proposed conceptual model. A questionnaire survey was used in order to assist the collection of data from individuals at construction sites. All model constructs were measured using a five-point Likert-type response format. Items, relating to each of the constructs, were used in the form of statements to measure individual constructs under investigation. The different statements used in developing the questionnaire were drawn upon scales that had been previously used by researchers (Choudhry et al. 2009; Mohamed 2002; Vinodkumar and Bhasi 2010). Participants were asked to rate the statements using a five point Likert-type scale (from 1= "strongly disagree'' to 5="strongly agree'').

The scales were further developed by including complimentary additions of new items and some items were reworded and rephrased to suit local working practices and culture. The contents of this draft questionnaire were discussed with senior safety professionals from Saudi construction industries and senior professors in engineering management studies to ensure face validity. After considering each item in detail, required changes were made by simplifying, rewording, removing and replacing some of them.

Descriptive statistics and reliability of the studied variables were firstly analysed. Confirmatory factor analysis (CFA) was then employed to verify the validity of the five safety management practices (management commitment and communication, competence, personal appreciation of risk, work pressure, safety rules and procedures), two components of safety behaviour (safety compliance and safety participation) and two components of safety motivation (intrinsic motivation and extrinsic motivation). The Structural Equation Modelling (SEM) technique was used to conduct the path analyses to test the relationship between the model constructs and the goodness of fit of the model. SPSS 20 with AMOS 19 software was used for all the basic descriptive analyses, CFA and path analysis. The study employed the following model fit indices: normed chi-square (x^2/df); goodness-of-fit index (GFI); comparative fit index (CFI); incremental fit index (IFI); and root mean square error of approximation (RMSEA). To be considered as having an adequate fit with the data, all the

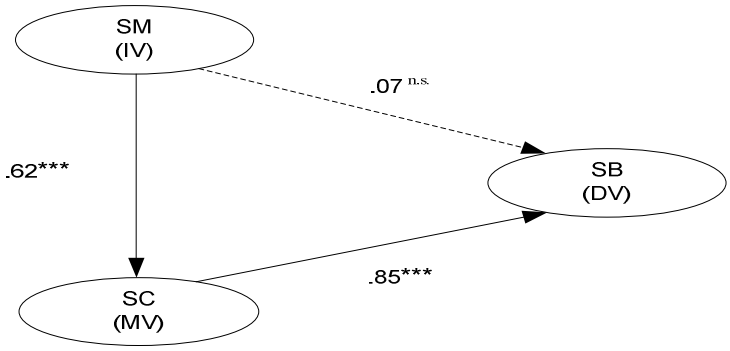
indices of the model should meet the following criteria: $x^2/df < 3.0$; GFI, CFI, and IFI > 0.90; and RMSEA < 0.08 (Hair et al., 2006).

4. Analysis results and discussion

The survey was conducted with Saudi Construction Industry (SCI) during Feb and May 2012. The study sample targeted only individuals in the construction workplaces (supervisors, engineers from main contractors as well as subcontractors). In total, 430 survey packages containing a questionnaire, an introductory letter, and an incentive were sent out via email. Of the 430 surveys sent, 295 usable questionnaires were returned thus achieving a response rate of 68.6%. The majority of the respondents were site engineers (44.4%) and project managers (29.8%) aged between 31- 40 (35.9%) and 31-40 (30.2%) with a bachelor's degree (76.3%) and Master's degree (22%). Most of them were employed in engineering firms, 29% were in civil and infrastructure projects, 20.5% in residential building and 18.7% in urban development with a size ranging from small-to-medium (100-2000 employees, 49.8%) to large (>2000 employees, 50.2%). Overall, the respondents were considered a good representation of the survey population.

The measurement model (a CFA model) depicts a series of relationships that suggest how measured variables represent a construct that is not measured directly (Hair et al., 2006). In this study, the measurement model was developed by integrating the individual CFA models of all the constructs into a single model. The CFA results of constructs are adequate, the factor loadings, ranging from 0.48 to 0.86, and were all significant at $p < 0.001$ level, suggesting convergent validity. All the correlation coefficients among constructs, ranging from 0.67 to 0.83, were less than 0.850, thus supporting the discriminant validity of the constructs. Finally, since the model fit indices proved to be good, unidimensionality was established.

Following the CFA, SEM was performed to preliminary evaluate the fit of the conceptual model as well as the hypothesised relationships between the constructs. The fit indices of the conceptual model were considered to ensure the model explains the data well. Figure 2 shows the results for the model with standardised path coefficients. Overall, the fit indices of the model proved to be satisfactory: $x^2 = 63.42$; $df = 21$; $x^2/df = 2.48$; GFI = 0.96; CFI = 0.96; IFI = 0.96; and RMSEA = 0.08.



$x^2 = 63.425$; $df = 21$; $x^2/df = 2.48$; GFI = 0.96; IFI = 0.96; TLI = 0.93; CFI = 0.96; and RMSEA = 0.08

*** $p < 0.001$; n.s. Not significant at $p < 0.05$ level.

Figure 2: Final model with standardised path coefficients

According to the path coefficients, safety motivation appears to have a good and positive influence on safety climate in Saudi construction workplace (0.62, p < 0.001). Safety climate for construction workplace at Saudi context (0.85, p < 0.001) is shown to have a strong positive influence on safety behaviour. However, the safety motivation construct does not appear to have a direct influence on the safety behaviour with the presence of safety climate. According to Baron and Kenny (1986) and Bennett (2000), a mediator is a variable that indicates how the association occurs between independent and dependent variables. A mediator effect is only tested when there is a significant direct effect between the independent variable and the dependent variable, but there is an opportunity that a mediator variable theoretically occurs ``between'' the two variables. A mediator effect exists if the following conditions are met: (1) variations in the independent variable (in this case, SM) predict variations in the mediator variable (SC), (2) variations in the mediator variable (SC) predict variations in the dependent variable (SB), and (3) When the relations between IV and both MV and DV are controlled for in the model, the direct relationship between the IV and the DV becomes non-significant. Having met these conditions, it can be established that SC fully mediates the relationship between SM and SB within the context of this study.

The above analysis results indicate that the developed conceptual model is fully supported by the data, which confirmed the direct link between the safety climate at Saudi construction workplace and individual safety behaviours. Moreover, the results supported that safety climate mediates the influence of individual safety motivation on safety behaviour in construction workplace. Bright (2007) suggested that individuals are attracted to workplace settings that are most compatible with their characteristics. Using this line of reasoning, it can be argued that individuals at construction workplace with safety motivation interest would not work appropriately in a safe manner unless these workplaces contain safe working conditions that support their safety motives. This is consistent with Neal et al.'s (2000) findings that safety motivation had a weak effect on safety behaviour, and safety climate exerted a direct effect on behaviour which was unexpected in their study. Furthermore, Neal and Griffin (2006), contrary to their hypotheses, found that safety motivation was not associated with subsequent changes in safety compliance, which is a part of safety

behaviour in their study. The results suggest that interventions specifically aimed at improving safety behaviour using a range of safety motivation techniques (both intrinsic and extrinsic) will be more effective when they are carried out within the context of a positive safety climate.

5. Conclusion

This paper presents a study attempting to examine a conceptual model proposing that the Safety Climate (SC) will mediate the relationship between Safety Motivation (SM) and the Safety Behaviour (SB) of individuals in Saudi construction workplace. The study was carried out using a quantitative method design integrating questionnaire survey. The model derived from the SEM analysis of the survey data indicates that safety climate appears to play a key role to safety behaviour by mediating the relationships between both safety motivation and behaviour. The study demonstrates that general safety motivation can influence perceptions of safety climate, and that these perceptions of safety climate in turn influence safety behaviour. The motivation alone does not produce the change unless there is an appropriate safety climate to maintain safe manner and no reversion to unsafe behaviour. These findings provide valuable guidance for researchers and practitioners trying to identify the mechanisms by which they can improve safety in the workplace. In particular, a construction workplace in the Saudi context should place an emphasis on creating safety climate as it is the main player that leverages the use of safety motivation to achieve desired safety behaviour.

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Application of Q-methodology in studying construction stakeholders' perceptions of OSH risks – An introduction to the preliminary stage

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Abstract

There is increasing recognition that many construction occupational health and safety (OSH) hazards arise as a result of activities in the planning and design stage. Improvement of construction OSH performance can be influenced by various stakeholder groups, not just the appointed construction contractor. It is important for stakeholder groups to take each other's perspective when considering OSH risks. However, different stakeholder groups may have different perceptions of OSH risk, leading to difficulty in establishing a common strategy to eliminate hazards and/or and reduce risk. This study aims to map the similarity/difference between stakeholder groups' OSH risk perceptions. An innovative Q-methodology is adopted for data collection. Q-methodology involves a number of procedures by which respondents sort a set of sample objects (known as a Q-set) into certain order, according to their subjective judgements. Photographs will be used as stimuli for the Q-sort in this study. This paper introduces the rationale of Q-methodology, and describes the process of developing and validating the Q-sort instrument for this construction application.

Key words: **Occupational health and safety, Construction industry, Design, Stakeholders, Q-methodology**

1. Introduction

The construction industry in Australia performs poorly in occupational health and safety (OSH) compared to other industries. Table 1 shows the incidence of worker fatalities in the Australian construction industry from 2003-04 to 2009-10. For each year, the number of deaths in

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construction accounted for more than 10% of the total number for all industries, and the percentage was as high as 18.1% in the year of 2009-10. The fatality rate (i.e. deaths per 100 000 workers) for the construction industry was significantly higher than that for all industries (yet approximately 50% of the U.S. rate).

Table 1: Worker fatalities in construction industry, Australia, 2003-04 to 2009-10; Source: Safe Work Australia, (2012)

	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10
Number of deaths while working							
Construction	38	28	42	50	40	44	39
All industries	272	253	287	301	292	289	216
Percentage	14.0%	11.1%	14.6%	16.6%	13.7%	15.2%	18.1%
Fatality rate (deaths per 100 000 workers)							
Construction	4.9	3.4	4.8	5.3	4.1	4.5	3.9
All industries	2.8	2.6	2.8	2.9	2.7	2.7	1.9

It has been traditionally assumed that contractors play the main role in construction safety (Toole, 2002). Existing regulations and policies have put obligations on contractors (as employers of workers) to identify, assess and control OSH risks in their planning activities (Hare *et al.*, 2006). Efforts to improve construction OSH performance have mainly targeted construction contracting companies. For example, Aksorn and Hadikusumo (2008) identified a range of safety programs adopted by contractors, including comprehensive safety polices, safety training, site inspections, safety incentive schemes, personal protection programs, safety auditing, safety record keeping, job hazard analysis, etc. Though some recent OSH improvements have been noticed, safety performance remains poor in construction and further improvement is needed (Atkinson, 2010).

There is an increasing awareness that a holistic approach is needed to manage construction OSH (Hare *et al.*, 2006) and there are many preventative opportunities upstream. Many technical and professional contributors make decisions that can potentially impact on OSH. For example, recent studies have demonstrated that on-site accidents are often rooted in design decisions (Behm, 2005; Gambatese *et al.*, 2008). The design of a facility can influence how a project or its components will be assembled and what construction tasks will be undertaken (Gambatese and Hinze, 1999; Toole, 2002). The concept of Construction Hazard Prevention through Design (CHPtD), which is '*a process in which engineers and architects explicitly consider the safety of construction workers during the design process*' (Toole and Gambatese, 2008, p. 225), has gained momentum in recent years. Toole and Gambatese (2008) suggest that one trajectory along which CHPtD could progress is for designers to choose materials and systems that are inherently safer than alternatives. In fact, the selection of a particular building system or construction method is implied by decisions made in the project planning and design stages. Consequently, it is important for professional and technical contributors to 'upstream'

decisions to understand the OSH risks implicit in different building systems or construction methodologies, the choice of which may logically flow from their decisions.

However, professional groups in the construction process may have different perceptions of OSH risks associated with alternative design systems/methodologies. Researchers have identified a number of barriers which prevent designers from considering safety issues, e.g. lack of construction process knowledge, lack formal education of construction safety and limited involvement in overseeing site safety (Gambatese and Hinze, 1999; Toole, 2002). The construction industry is characterized by a high level of fragmentation and the interests of different stakeholder groups can lead them to think about OSH risks differently. Lingard *et al.* (2012) revealed how poor interest alignment among project stakeholders in the planning and design stages of a project contributed to increased OSH risk during construction. Differences in stakeholder groups' perceptions of OSH risks may result in difficulty in establishing a common strategy to identify hazards and take appropriate risk control actions early in the project life cycle. Surry's (1979) decision model of accident occurrence illustrates that people need to perceive a risk in order to respond to it appropriately. Risk perceptions provide sensory cues to individuals, who then cognitively process the sensory cues, and decide the response to the cues by applying decision making rules. If a decision-maker cannot recognise a hazard or perceive a risk accurately then 'safe' decisions are unlikely to eventuate. Therefore, it is worthwhile to investigate the OSH risk perceptions of decision-makers in construction projects and perhaps ultimately, to develop a shared understanding.

Existing studies have adopted different approaches to assess construction professionals' risk perceptions, including asking respondents to rate a list of hazards according to their degree of riskiness (e.g. Holmes *et al.* (1997)), quantifying the level of risk perceived by professionals with an objective algorithm method (e.g. Hallowell (2010) and Jannadi and Almishari (2003)), using self-report questionnaires to compare different groups' risk attitudes and perceptions (e.g. Findley *et al.* (2007)), and requesting participants to rank risk qualities such as the prevalence, level of exposure and control over risk (e.g. Leiter *et al.* (2009)). These approaches identified groupings of people with similar perceptions about specific hazards presented to them by researchers. In reality, however, people need identify situational hazards for themselves and decide how to respond to them. In the context of a construction project, decision-makers are expected to identify hazards implicit in the design of a facility or in a planned construction sequence, and evaluate the level of risk against certain attributes/criteria.

This study employs Q-methodology with an innovative photographic data collection method to explore construction industry stakeholder groups' OSH risk perceptions. Q-methodology requires participants to put a sample of objects (known as a Q-set) into a rank order according to a condition of instruction. When the objects are arrayed into categories, the resulting pattern is called a Q-sort (Brown, 1980). The Q-set can take different forms, such as statements of opinions, photos, or other articles. In this study, photos representing the construction processes implicit in different building systems will be used as stimuli. Using photos allows participants to

identify hazards and subjectively judge the level of OSH risk in the depicted scenarios. This paper reports the process of developing and validating the photographic Q-set instrument.

2. Q-methodology

Q-methodology was developed in as early as the 1930s, with its main proponents being Stephenson (1953) and Brown (1980). It emphasizes the concept of 'operant subjectivity' (Brown, 1980). So, the rationale is to explore participants' subjective views about a phenomenon. A Q-sort is a picture of an individual's conception of the way things stand, and it is self-referent (Brown, 1980). There is no right or wrong way to do a Q-sort. Studies using Q-methodology seek to understand and interpret human experience and individual differences rather than generalize results to a population.

Though Q-methodology has gained wide application in research areas, such as psychology, human personality, politics and attitude study and, more recently, in landscape design, it has not been used extensively in the construction management or OSH areas. However, recently Q-methodology was used to explore construction workers' experiences of work-family fit in one Australian study (Turner and Lingard, 2011). The current research is, to our knowledge, the first attempt to use Q-methodology in studying construction stakeholders' perceptions of OSH risk.

3. Q-set development procedures

3.1 Research question

The research question determines the nature and structure of the Q-set to be generated (Stenner *et al.*, 2008), and affects the 'condition of instruction', which is used to guide participants to perform the sorting task (Watts and Stenner, 2005). The aim of the present research is to compare construction industry stakeholders' OSH risk perceptions. In particular, we are interested in finding out: (i) whether different stakeholder groups (e.g. architects, engineers, constructors and OSH professionals) share similar (within-group) understandings of OSH risks in construction work, and (ii) whether there are between-group differences among these stakeholder groups. Understanding points of similarity and/or difference will help encouraging stakeholders to consider the OSH implications of their professional practice for others 'downstream' of decision-making processes (e.g. construction workers). It could also lead to interventions such as training to improve risk identification and mitigation.

3.2 Generation of the Q-set

Q-methodology requires researchers to generate a Q-set which is broadly representative of the issues under investigation (Stenner *et al.*, 2008; Watts and Stenner, 2005). Typically, a structured approach is used to generate a Q-sort, i.e. identifying the key dimensions of the study topic first and then selecting stimuli to represent all the dimensions (Brown, 1993; Fairweather *et al.*, 1998). Stimuli should enable participants to easily grasp the central issue they reflect

(Stenner *et al.*, 2008). In the present research, photographs are used as stimuli as they are effective and straightforward in representing a construction scenario, yet can maintain the richness of information needed to assess OSH risks. Photographs have previously been used as experimental stimuli successfully in such areas industrial quality assurance (Kleiner, 2001) and construction hazard identification (Kleiner and Hallowell, 2012).

Participants' risk perceptions will be explored by showing them photographs of the use of different construction methodologies or building systems. This method is meaningful because each building system or construction methodology has particular OSH risk attributes, and the use of a particular system or methodology is determined by decision making in the project planning and design stages. Compared to for example, providing photographs of actual hazards this approach requires decision making in addition to search cognitive processes. Participants will be asked to provide their assessment of the likelihood of an accidental injury arising when a depicted construction methodology or building system is used. They will then make an assessment of the severity of consequential injury should an accident occur. The separate assessment of likelihood and consequence was preferred because this will enable participants to distinguish between construction scenarios with the potential for high impact/low probability and low impact/high probability events.

To develop the Q-set, four main building elements were selected as follows: (i) façades; (ii) roofs; (iii) building structures; and (iv) building services. Each of these elements has a range of different systems or methods by which it can be constructed. These systems/methods are implicit in decisions made about the design of a building/structure. For example, whether a building uses steel or a concrete structural frame is a design decision which ultimately influences the methods/processes used during construction, and arguably also the prospective hazards to which construction workers are exposed.

Various sources were used to identify photos to represent the different building methods/systems for the four building elements. These included web construction databases, researchers' and colleagues' collections and Flicker (with photo use permission sought). Following review and evaluation, a set of 40 photographs was compiled, comprising ten photographs for each building element. Usually, a Q-set size of 40 to 80 is considered to be satisfactory (Stainton Rogers, 1995; Watts & Stenner, 2005).

3.3 Development of the Condition of Instruction

The 'Condition of Instruction' establishes the rules by which participants are asked to perform the sorting task. It specifies the criteria for participants to rate the sample of objects in the Q-set. The condition of instruction can force a particular distribution of responses (e.g. quasi-normal distribution in a forced Q-sort) or it can allow participants to rate each object freely. In this research, researchers decided to use a free sorting method after the instrument was tested with several industry participants. One participant commented that a forced distribution presented a problem for some categories of photograph. For example, the primary risk for the "roof" building

element category was falling. A fall from a roof would most likely result in a serious injury or death and thus the participant could not rate any of the “roof” photographs as being of insignificant or minor consequence.

Block (1956) states that forced sorting requires participants to make the same number of discriminations between objects, which makes comparisons between the ordering of different participants straightforward. However, other researchers criticize that as conditional probabilities are involved, the probability of each alternative (i.e. *p* of placing card k in pile x) is reduced in a forced Q-sort (Cronbach and Gleser (1954), Gaito (1962)). Gaito (1962) also argues from psychological perspective that the use of forced distribution destroys spontaneity and affects participants’ motivation. Some researchers have statistically compared the results obtained from using different sorting methods and observed that there is not much difference between the results of forced and unforced Q-sorts (Brown, 1971; Brown, 1980; Hess and Hink, 1959; Block, 1956). Thus, Brown (1980) concludes that ‘*distribution effects are virtually nil, the existence of factors being affected almost entirely by the pattern of item placement*’ (Brown, 1980, p. 289).

The researchers also decided to ask participants to sort photographs depicting each of the building elements separately. This is because one of the test participants commented that sorting all of the cards simultaneously was difficult due to the number of cards and difficulties in comparing the OSH risks inherent in one building system with those inherent in other building systems (e.g. roofing systems were not comparable with building service systems).

The condition of instruction requests participants to perform two rounds of sorting for photographs of each building element. Participants are firstly instructed to sort the photos onto a grid according to their subjective judgements of likelihood of an accidental injury occurring during the construction process depicted. The grid contains five columns with rating scale ranging from ‘-2 Rare’ to ‘+2 Almost certain’. Then participants will be asked to sort the photos into another grid based on their judgements of the severity of consequence if an accidental injury occurred. The grid is designed with a rating scale ranging from ‘-2 Insignificant’ to ‘+2 Catastrophic’. After each round of sorting, respondents will be asked with a number of open questions to explicate the reasons underlying the sorting patterns.

3.4 Testing the instrument

To ensure that the photographs were representative and the condition of instruction was clear and effective, instrument testing was conducted to test the Q-sort method with industry professionals. The purpose of the testing was to evaluate whether: 1) the photographs provided sufficient detail and information for professionals to make meaningful judgements about OSH risks; 2) the photographs were representative of different construction methodologies/building systems for each building element; 3) the condition of instruction was clear and enabled participants to undertake the Q-sort appropriately; and 4) the time required to undertake the Q-sort was not excessive and would be acceptable to participants.

The photographs were individually printed and, brief descriptions were added to each photograph. These descriptions were succinct, value-neutral statements about the construction methodology/building system depicted. None of the statements contained any reference to OSH hazard or risk. Each photograph was also given a unique identification code. Table 2 shows the photograph codes and corresponding descriptions, and Figure 1 show two sample photographs.

Table 2: Photograph codes and descriptions

Photo codes	Descriptions
S01	In-situ reinforcement concrete column construction
S02	Steel framed structural system
S03	Precast reinforced concrete tilt-up system
S04	Precast reinforced concrete columns, beams and slab panels
S05	Reinforced concrete structural frame with post-tensioned slabs
S06	Steel structural frame with precast concrete decking
S07	Steel structural frame with steel decking to receive concrete cover
S08	In-situ reinforced concrete core wall under construction
S09	Reinforcement fixing for in-situ concrete slab and columns
S10	Precast concrete columns erected with brackets to receive further elements
F01	Precast concrete panel system for housing
F02	Precast concrete panel system for car park
F03	Concrete and window panel façade system
F04	Full storey prefabricated façade system
F05	Glazed panel façade system
F06	Mixed glass and concrete panel façade system. Note: concrete sections covered by glass panels
F07	Prefabricated glass panel with aluminium shading façade system
F08	Trespa Meteon panels installed to a back drained rainscreen façade
F09	In-situ RC walling
F10	Concrete block wall façade system
R01	Metal roof canopies
R02	Flat in-situ reinforced concrete roof with bitumen membrane water proofing
R03	Steel roof sheeting system to a frame building
R04	Timber rafter system for curved roof panels
R05	Tiled roof on timber rafters
R06	Plywood sheathings installed to roof trusses
R07	Stone roof panel installation
R08	Roof-top plant room construction
R09	Pre-assembled timber roof canopy system
R10	Prefabricated roof systems for offsite built classrooms
B01	Services suspended from steel roof structure
B02	Services suspended from concrete structure
B03	Services suspended from concrete structure
B04	Services suspended from steel structure with spray-on fire retardant
B05	Services for ceiling void
B06	Services installation
B07	Services suspended from concrete structure
B08	Services suspended from steel panel
B09	Modular wiring systems
B10	Pre-assembled building service modular installed offsite

Note: S – Structure; F – Façade; R – Roof; B – Building services

F01



Description: Precast concrete panel system for housing
Source: By courtesy of Mark Vines of RMIT University

R10



Description:Prefabricated roof systems for offsite built classrooms
Source: CRC for Construction Innovation

Figure 1: Sample photographs

Three industry professionals participated in the testing. They were a general manager (civil engineering) of a large construction contractor (participant 1), a safety manager from a medium sized construction company (participant 2), and a building surveyor with considerable industry experience of risk management (participant 3). After one sorting interview with one professional, the photograph set and condition of instruction were modified according to the professional's feedback, and then used for the next sorting interview and subjected to further modification.

Apart from the two comments given by participant 1 mentioned above (i.e. free sorting the photographs in a set by set way), participant 1 and participant 2 also commented that some photos were similar in content (especially for the category of building services), while some photos lack sufficient detail for them to make meaningful OSH risk judgements. Table 3 lists the codes of photos that considered deficient by the participants and the reasons they gave.

Table 3: Deficient photographs identified by participants

Category	**Participant 1**	**Participant 2**
Façade	F07 lack details	
Structure	S10 insufficient information	S08 insufficient information
Roof		R08 more related to building service
Building service systems	B04 and B05 are similar B07, B02 and B03 are similar	B04 B05 are similar B06 B07 are similar

A total of eight photos were removed for the third sorting interview. The ID codes of the removed photos are F07, F08, S10, S08, R07, R08, B05, and B06. The photos of F08 and R07 were removed because the permissions to use the photos were still pending. Participant 3 commented that the condition of instruction was clear, and the photos were representative and provided sufficient information for her to make judgements. She was also comfortable about the time duration for performing the Q-sorting task.

Table 4-6 show the sorting results of the three "test" participants. It is observed that the participants share very similar OSH judgements for some photos (for example, F01, F09, R01, R05, B10, S06, etc.), yet have substantially different OSH judgements for some other photos

(for example, F02, F05, R03, S01, S07, etc.) The results indicate that the Q-sort instrument discriminates between participants' perceptions of high and low risk situations and will be able to collect data to compare the similarity/difference between stakeholders' OSH risk perceptions.

Table 4: Sorting result given by participant 1

Likelihood of accidental injury					**Severity of consequence of accidental injury**				
Rare	Unlikely	Moderate	Likely	Almost certain	Insignificant	Minor	Moderate	Major	Catastrophic
Façade					Façade				
F05	F06	F07	F01	F08		F10	F03	F01	F08
		F10	F03	F02			F04	F02	
		F04	F09				F05	F06	
							F07	F09	
Roof					Roof				
R10	R02	R07	R01	R03	R02	R10	R07	R01	R03
		R09	R04	R05			R08	R04	
			R06				R09	R06	
			R08					R05	
Building Services					Building Services				
B10	B06	B01	B05			B09		B01	B05
	B09	B08				B06		B08	
						B10			
Structure					Structure				
	S01	S02	S05	S08		S09	S02	S01	S03
		S03	S06					S04	S05
		S04	S07					S06	S07
		S09						S08	

* Participant 1 didn't sort the deficient photos in the building service category and structure category

Table 5: Sorting result given by participant 2

Likelihood of accidental injury					**Severity of consequence of accidental injury**				
Rare	Unlikely	Moderate	Likely	Almost certain	Insignificant	Minor	Moderate	Major	Catastrophic
Façade					**Façade**				
	F02	F05	F10	F08	F02	F03	F06	F09	F08
	F03	F07	F06	F09	F05	F04	F10	F01	
		F01					F07		
		F04							
Roof					**Roof**				
R02	R03	R04	R01	R08	R02	R03	R04	R01	R08
R10	R07		R05	R06	R10	R07		R05	R06
	R09					R09			
Building Service					**Building Service**				
B10	B08	B05	B07		B10	B08	B02	B07	B03
B09		B01	B03		B09	B05		B06	B04
		B02	B06			B01			
			B04						
Structure					**Structure**				
S02	S08	S09	S06	S05	S01	S08	S09	S03	S05
S01		S10		S07	S04	S02	S06	S10	S07
S04				S03					

Table 6: Sorting result given by participant 3

Likelihood of accidental injury					**Severity of consequence of accidental injury**				
Rare	Unlikely	Moderate	Likely	Almost certain	Insignificant	Minor	Moderate	Major	Catastrophic
Façade					**Façade**				
	F04	F02	F01	F09		F04	F03	F01	F02
		F03	F05			F10	F05	F09	
		F10	F06				F06		
Roof					**Roof**				
	R02	R09	R01	R06	R02	R03	R09	R01	R06
		R10	R03				R10	R04	
			R04					R05	
			R05						
Building service					**Building service**				
	B01	B02	B03			B01	B02		
	B09	B08	B04			B08	B03		
	B10		B07			B09	B04		
						B10	B07		
Structure					**Structure**				
	S04	S03	S02	S01		S07	S02	S01	
	S07	S05	S06			S09	S04	S03	
		S09						S05	
								S06	

* Eight photos have been removed

Summary

This paper depicted the process of developing and validating a Q-set for exploring construction stakeholders' judgements of OSH risks. An innovative Q-sort method will be used in large scale testing using photographs as stimuli. Photographs ensure that richness and accuracy of information can be conveyed in describing a scenario. Through a pilot study, the instruction of condition has been modified, and the sets of photos have been refined. The validated Q-set together with the condition of instruction will be used for collecting data from different construction stakeholders to compare the similarity/difference between stakeholders' perceptions of OSH risk. The researchers hope this paper provides guidance for future researchers to conduct research in the construction management or OSH areas using Q-methodology.

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Effective TMO Project Workgroups: An Investigation of Antecedent Conditions

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Abstract

In seeking to explain the antecedents of cross-functional TMO workgroup cooperation, Anvuur and Kumaraswamy (2007) [*Journal of Construction Engineering and Management*, 133(3), 225-34] proposed a conceptual framework which emphasizes the formative role of four factors: common goals; equal status; integrative interactions; and authority support. This study tests this framework empirically, based on responses from a Hong Kong survey of built environment professional managers and using structural equation modelling. The findings support the role of the four factors, showing that a superordinate construct—teamwork climate for cooperation—formed from the four factors significantly and positively influences workgroup members' in-role, extra-role, compliance, and deference behaviour. Therefore, project managers may usefully strive to create the generative project environments for the four optimal conditions for teamwork.

Keywords: Alignment, Cooperation, Cross-Functional Workgroup, Teamwork Climate, Temporary Multi-Organisation (TMO).

1. Introduction

Construction projects are complex adaptive systems involving many self-organising, differentiated yet complementary functional specialisms, which tend to be *across*—rather than within—firms and have high interdependencies in inputs, processes and outcomes (Hobday, 1998). The managerial imperative for joint-production in such temporary multi-organizations (TMOs) as coalitions (a nexus of contracts) becomes essentially one of cross-functional integration (Lawrence and Lorsch, 1967). This implies a shift in focus away from (management of) task execution (*taskwork*) and towards issues of coordination and cooperation (*teamwork*). Teamwork has been defined conceptually as "a set of interrelated cognitions, attitudes, and behaviours contributing to the dynamic processes of performance" (Salas *et al.*, 2008:541). Performance refers to the actual activity engaged in (the behaviour) which advances the goals of the social collective – *not* an appraisal of the outcomes of that activity, which is effectiveness (Dulaimi and Langford, 1999; Salas *et al.*, 2008). The question of how to foster effective teamwork in joint-production environments has attracted—and continues to attract—a lot of attention from researchers. One of the key discoveries of previous research in this area is that favourable (shared) cognitions about the work environment and its expected behaviour can promote teamwork and cooperation (DeChurch and Mesmer-Magnus, 2010; Mohammed *et al.*, 2010). Previous research also highlights the crucial role of training, coaching and facilitation (i.e. teambuilding activities) in creating and sustaining these favourable cognitions (Salas *et al.*, 2008). In the context of construction

projects, efforts at team-building take the form of interventions for socialization, focus on the creation of a conducive work environment and are broadly represented by the partnering ethos (Anvuur and Kumaraswamy, 2007).

Based on an extensive analysis and synthesis of the extant literature, Anvuur and Kumaraswamy (2007) developed a conceptual model of partnering and alliancing which emphasizes the formative role of four factors (properties of the work environment) in promoting effective teamwork and cooperation in TMO workgroups: common goals, equal status, integrative interactions, and authority support. The four factors are properties of the TMO workgroup environment and are distinct yet highly interrelated and mutually reinforcing concepts, thereby representing a superordinate latent construct (Law *et al.*, 1998), referred to this study as *teamwork climate for cooperation* (hereafter, teamwork climate). While the project (workgroup/team) environment has been identified in numerous conceptual and factor analytic studies of critical success factors for project effectiveness, and while other studies have also reported significant effects for one or another of the teamwork climate dimensions (Thamhain, 2004; Brookes *et al.*, 2006; Tuuli and Rowlinson, 2009), there has been to date no systematic empirical test of the effects of all four teamwork climate dimensions in a construction TMO workgroup setting—and this is despite the framework itself being welcomed by some. The purpose of this paper is to redress this by empirically investigating the proposition that teamwork climate significantly and positively influences TMO workgroup members' cooperative behaviours.

The framework proposed in Anvuur and Kumaraswamy (2007) is shown in Figure 1, except that "cooperative interactions" has been replaced with "integrative interactions for clarity and consistency in terminology. In this framework, the dominant construction industry conditions which were the original drivers for the partnering motif are depicted in the left-hand column. The four teamwork climate dimensions in column 3 are the *process benefits* from the implementation of the components of partnering in column 2 and lead, in turn, to the *content benefits* (e.g. cooperation, project effectiveness, innovation) in the right-hand column. Note that the content benefits are also mediated by many other cognitive and affective processes (e.g. interpersonal trust, positive affect, group identification). The focus of the present paper is to link, empirically, the four teamwork climate dimensions to individuals' cooperation with their TMO workgroups. The first dimension of teamwork climate, common goals, underscores the presence and salience of a normative goal frame, which motivates workgroup members to enact such behaviours as are necessary to advance the goals of the workgroup. The second dimension, equal status, underscores the presence of a workgroup environment characterised by mutual professional respect and equal opportunities for participation ('voice'). The third dimension, integrative interactions, emphasizes the presence of a workgroup environment characterised by participative safety and frequent interactions among workgroup members in joint decision-making and problem-solving. The final dimension, authority support, underscores the presence and abundance of senior management support—both articulated and enacted—for collaborative working. The four dimensions are interrelated and reinforcing. For example, when present, authority support helps to stabilize the normative goal frame in workgroup members through "goal contagion" effects and when absent, can create subversive undercurrents to any shared cognitions developed by workgroup members (Lindenberg and Foss, 2011).

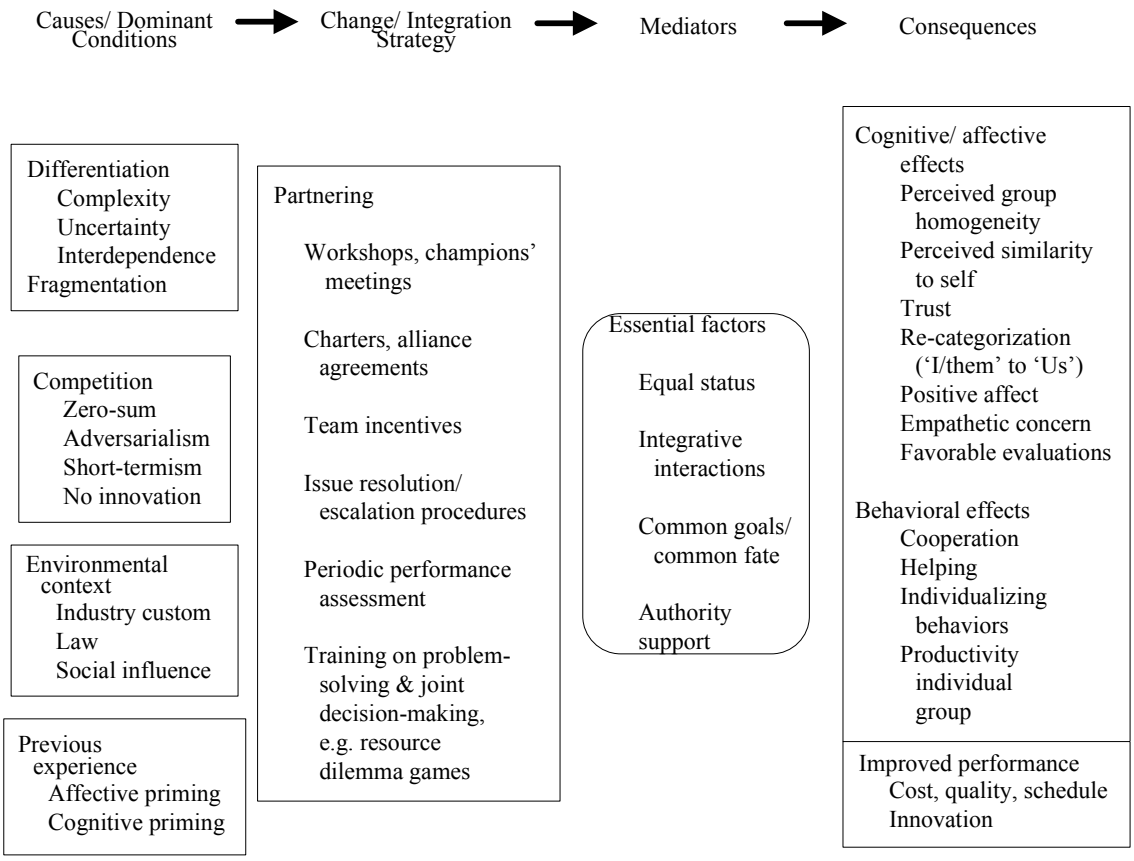

Figure 1: Conceptual model of partnering and its effects (Source: Anvuur and Kumaraswamy, 2007)

In this paper, hypotheses linking the superordinate teamwork climate construct to TMO workgroup members' cooperative behaviours are tested for corroboration using a Hong Kong sample. The individual level of analysis is adopted. Cooperation is conceptualized as individuals' performance behaviours which advance the goals of their proximal workgroups, and has four dimensions in terms of whether and to what extent role-incumbents creditably perform their work roles (*in-role*), go the extra mile and undertake extra task activities or help colleagues with their work-related problems (*extra-role*), adhere comprehensively to work-related rules and procedures (*compliance*), and defer to relevant authorities or 'best practice' standards of appropriate conduct where rules or norms are non-existent or vague (*deference*). The four performance behaviours are context-specific and constitute distinct, yet interrelated manifestations of the cooperation of individuals' with their workgroups. The construct validity and substantive utility of this four-dimensional cooperation model have been established in previous studies (e.g. Anvuur and Kumaraswamy, 2012; Anvuur *et al.*, 2012). The main proposition examined in this study can therefore be represented by the following four testable hypotheses:

Teamwork climate will significantly and positively influence TMO workgroup members' in-role behaviour (H_1)*, extra-role behaviour* (H_2)*, compliance behaviour* (H_3)*, and deference behaviour* (H_4).

In the sections that follow we describe our data collection method. We then describe our data analysis procedures, present the results of those analyses and discuss the implications of our findings for research and practice.

2. Method

2.1 Sample and procedure

The sample size was N = 140 and comprised built environment professional managers in Hong Kong. Average age of participants was 44 years. Average total experience of the participants in construction was 20 years and in current position, seven years. All but three participants had at least a bachelor's degree. The sample comprised 101 Chinese, 37 Caucasians and two participants of other ethnicities. The proportion of women managers in the sample (about 4%, n = 5) compares reasonably well with the total proportion of women employed in the Hong Kong construction sector (about 9%, see Hong Kong Census and Statistics Department, 2011).

Items for the present study were drawn from a larger Hong Kong questionnaire survey, data collection for which commenced in November 2006 and ended in March 2007. The questionnaire was sent out to 1100 potential respondents randomly drawn from a sampling frame for a study population defined using a purposive sampling procedure. Out of this number 153 valid responses were received, representing a response rate of 18% or the higher rate of 20% when adjusted for the 'non-eligibles' in the sampling frame. The questionnaire design, data collection and examination procedures for the survey are described in detail elsewhere (see Anvuur and Kumaraswamy, 2012; Anvuur *et al.*, 2012).

2.2 Measures

The variables of interest in this paper were measured with 33 scale items phrased as questionnaire items with Likert scale response formats. Instructions preceding the questionnaire items (save the demographic and social preference items) orientated respondents to focus on their role *and* proximal cross-functional workgroup within *one* and *the same* construction project that they were recently involved in within 5 years of survey date. Items measuring the four dimensions of individuals' cooperation with their workgroups (in-role, extra-role, compliance, and deference) are based on Anvuur and Kumaraswamy (2012) and were scored on a 5-point response format (1 = *never* to 5 = *very often*). *In-role* behaviour was measured using four items. A sample item reads 'I fulfil the responsibilities specified in my job description'. *Extra-role* behaviour was assessed with four items, for example, 'I volunteer to do things that are not required in order to help my workgroup'. *Compliance* behaviour was measured with three items. A sample item reads 'I comply with

work related rules and regulations'). *Deference* behaviour was assessed with three items, for example, 'I willingly follow my project organization's policies'.

The teamwork climate dimensions (integrative interactions, authority support, common goals, and equal status) were measured with 19 items each scored on a 5-point response format (1 = *strongly disagree* to 5 = *strongly agree*). *Integrative interactions* implies frequent interactions among workgroup members in joint decision-making and problem-solving, and was measured using four items adapted from the 'interaction frequency' subscale (α = 0.84) of Anderson and West's (1998) Team Climate Inventory (TCI). A sample item reads 'We meet frequently to talk both formally and informally'. *Common goals* was measured with six items adapted from the 11-item 'vision' subscale (α = 0.94) of Anderson and West's (1998) TCI. The TCI vision subscale reflects the extent of clarity, sharedness, attainability and importance of workgroup objectives, and is consistent with the conceptualization of common goals in the present study (e.g. 'I very much agree with my workgroup's objectives'). *Authority support* reflects the extent of support of the authorities, procedures and norms for joint decision-making and problem-solving in the workgroup. This was measured with six items adapted from Siegel and Kaemmerer's (1978) 'support for creativity' scale (split-half reliability = 0.94). A sample item reads ' Our ability to function cooperatively is respected by the leadership'. *Equal status* implies mutual recognition, appreciation of and opportunities for individuals' contributions to the workgroup effort. This facet was measured with four items adapted from Tyler and Blader's (2001) 8-item 'respect for work' scale (e.g. 'Colleagues in my proximal workgroup value what I contribute at work').

We also included controls for the effects of ethnicity, age, gender, and educational attainment in order to account for these possible alternative explanations for the cooperation of individuals with their TMO workgroups. The control variables were dummy-coded to test the effect of being Caucasian (i.e. other ethnicity = 0), older (i.e. ≤50 years = 0), female (i.e. male = 0), and holding a postgraduate qualification (i.e. bachelor's and below = 0) on in-role, extra-role, compliance, and deference behaviour.

3. Results

The two-step approach to structural equation modelling (SEM) (Anderson and Gerbing, 1992) was implemented using AMOS (Arbuckle, 2011). First, we performed a confirmatory factor analysis (CFA) to assess the fit to the data of our measurement model, which included the four dummy-coded control variables (ethnicity, age, gender, and education), the four cooperation dimensions (in-role, extra-role, compliance, and deference), and the four first-order constructs, integrative interactions, authority support, common goals, and equal status, loaded onto a the second-order super-ordinate latent construct called teamwork climate. Once a good-fitting CFA model was obtained, we then proceeded to specify and test a structural model containing the hypothesised relations between teamwork climate and the cooperation dimensions.

3.1 CFA

Maximum likelihood estimation was used to estimate the CFA model in AMOS, with each dummy-coded control variable fixed by assigning it an error variance of zero. Table 1 shows the construct reliabilities (CRs; the conceptual equivalent to Cronbach's alpha), interconstruct correlations and average variance extracted (AVE) estimates for the variables in the CFA model. Evidence of reasonable fit to the data of a CFA model of this complexity would include a significant χ^2 value, a normed χ^2 (i.e. χ^2/df) value below 5, comparative fit index (CFI) and incremental fit index (IFI) of 0.90 or higher, and root mean square error of approximation (RMSEA) and standardized root mean residual (SRMR) of 0.08 or below (cf. Hair *et al.*, 2010).

The results of the analysis confirmed a good overall fit of the CFA model to the data: $\chi^2(df = 629) = 928.27$, $p = .000$; $\chi^2/df = 1.47$; SRMR = 0.065; RMSEA = 0.059; IFI = 0.91; CFI = 0.91. Good convergent validity is generally indicated by (Hair *et al.*, 2010): statistically significant factor loadings of 0.50 or higher; AVE estimates of 0.50 or higher; and CR estimates of 0.70 or higher. All standardized factor loadings ranged from 0.61 to 0.97, and all freely estimated loadings were statistically significant, $p = .000$. The factor loadings for the second-order teamwork climate construct were substantially high (integrative interactions, $\lambda = 0.76$; authority support, $\lambda = 0.88$; common goals, $\lambda = 0.75$; equal status, $\lambda = 0.75$). The CR estimates for all latent constructs were substantially higher than the threshold value of 0.70, thus suggesting adequate reliability. Except for extra-role, with an AVE estimate of 0.47, all AVE estimates in Table 1 exceeded the threshold value of 0.50. The below-threshold AVE estimate for extra-role is despite its substantially high CR estimate of 0.86. However, it is not uncommon for acceptably reliable latent constructs to have below-threshold AVE estimates (Hair *et al.*, 2010). Overall, however, the evidence supports the convergent validity of the CFA model.

Discriminant validity is demonstrated if the AVE for each construct is greater than its shared variance (i.e. squared correlation) with any other construct (Hair *et al.*, 2010). The discriminant validity of the CFA model is demonstrated in Table 1 where it is clear to see that each AVE estimate is greater than the squared interconstruct correlations in the row and column in which it is found. The pattern of statistically significant, positive correlations among latent constructs in Table 1 ($r \geq 0.22$, $p < .05$), consistent with theoretical expectations, provides evidence of nomological validity on a zero-order basis. Of the four control variables, ethnicity was significantly associated with extra-role behaviour ($r = 0.19$, $p < .05$) and compliance ($r = 0.20$, $p < .05$), age was significantly related to gender ($r = –0.19$, $p < .05$), and education was significantly associated with compliance ($r = 0.19$, $p < .05$).

3.2 SEM

Having established satisfactory fit of the CFA model to the data, we proceeded to test the structural model for corroboration (or otherwise) of hypotheses H_1 through to H_4. The SEM model also included paths from each of the four control variables (ethnicity, age, gender, and education) to in-role, extra-role, compliance, and deference behaviour. The results suggested a good fit of the SEM model to the data: $\chi^2(df = 634) = 970.42$, $p = .000$; $\chi^2/df = 1.53$; IFI = 0.90; CFI = 0.90; SRMR = 0.08; RMSEA = 0.06 with a 90% CI of (0.05, 0.07), $p = .008$. The structural model is shown in Figure 2. To avoid visual clutter, error terms for factor

loadings, disturbance terms for latent constructs, as well as all the objects, names and parameters associated with the four control variables are not displayed in Figure 2. Scale items for first-order constructs in are represented in Figure 2 by numbers (1–34). All coefficients for the variables of interest in Figure 2, including path coefficients and freely estimated factor loadings were statistically significant at $p < .05$. The stability of parameter estimates between the CFA and SEM models (allowing for the expected insignificant factor loading fluctuations of ≤ |0.05|) provides further evidence of discriminant validity.

Table 1: Construct reliabilities, interconstruct correlations, and variance extracted estimates

Construct	CR	1	2	3	4	5	6	7	8	9
1. Compliance	0.95	0.72								
2. In-role	0.95	0.40[c]	0.67							
3. Extra-role	0.86	0.32[b]	0.61[c]	0.47						
4. Deference	0.89	0.67[c]	0.30[b]	0.33[b]	0.61					
5. Teamwork climate	0.94	0.22[a]	0.35[c]	0.52[c]	0.22[a]	0.62				
6. Ethnicity	1.00	0.20[a]	0.00	–0.06	0.19[a]	0.16	1.00			
7. Age	1.00	0.01	0.00	0.04	–0.05	0.09	–0.10	1.00		
8. Gender	1.00	0.05	–0.04	–0.07	0.04	0.02	0.03	–0.19[a]	1.00	
9. Education	1.00	0.19[a]	0.01	–0.01	0.15	0.07	0.01	0.04	0.02	1.00

Note. $N = 140$. CR, Construct Reliability. Entries below the diagonal are correlations among constructs. Diagonal entries are average variance extracted (AVE) estimates. Ethnicity. Age, gender and education were dummy-coded to test the effects of being Chinese (Other ethnicity = 0), older (≤ 40 years = 0), female (male = 0), and holder of a postbachelor's qualification (bachelor's degree or below = 0).
[a]$p < 0.05$
[b]$p < 0.01$
[c]$p \leq 0.001$

Except the effect of education on compliance behaviour (not shown in Figure 2) which was statistically significant and positive ($\beta = 0.17$, $p = .037$), no significant effects were found for the other control variables. We found support for our substantive hypotheses. Hypothesis H_1 predicted that teamwork climate will significantly and positively influence in-role behaviour. This was supported, as the structural path from teamwork climate to in-role behaviour (see Figure 2) was statistically significant and positive ($\beta = 0.45$, $p = .000$). The results in Figure 2 also show that: teamwork climate is significantly and positively related to extra-role ($\beta = 0.62$, $p = .000$), compliance ($\beta = 0.23$, $p = .015$), and deference behaviour ($\beta = 0.24$, $p = .019$). Therefore, hypotheses H_2, H_3 and H_4 were also supported.

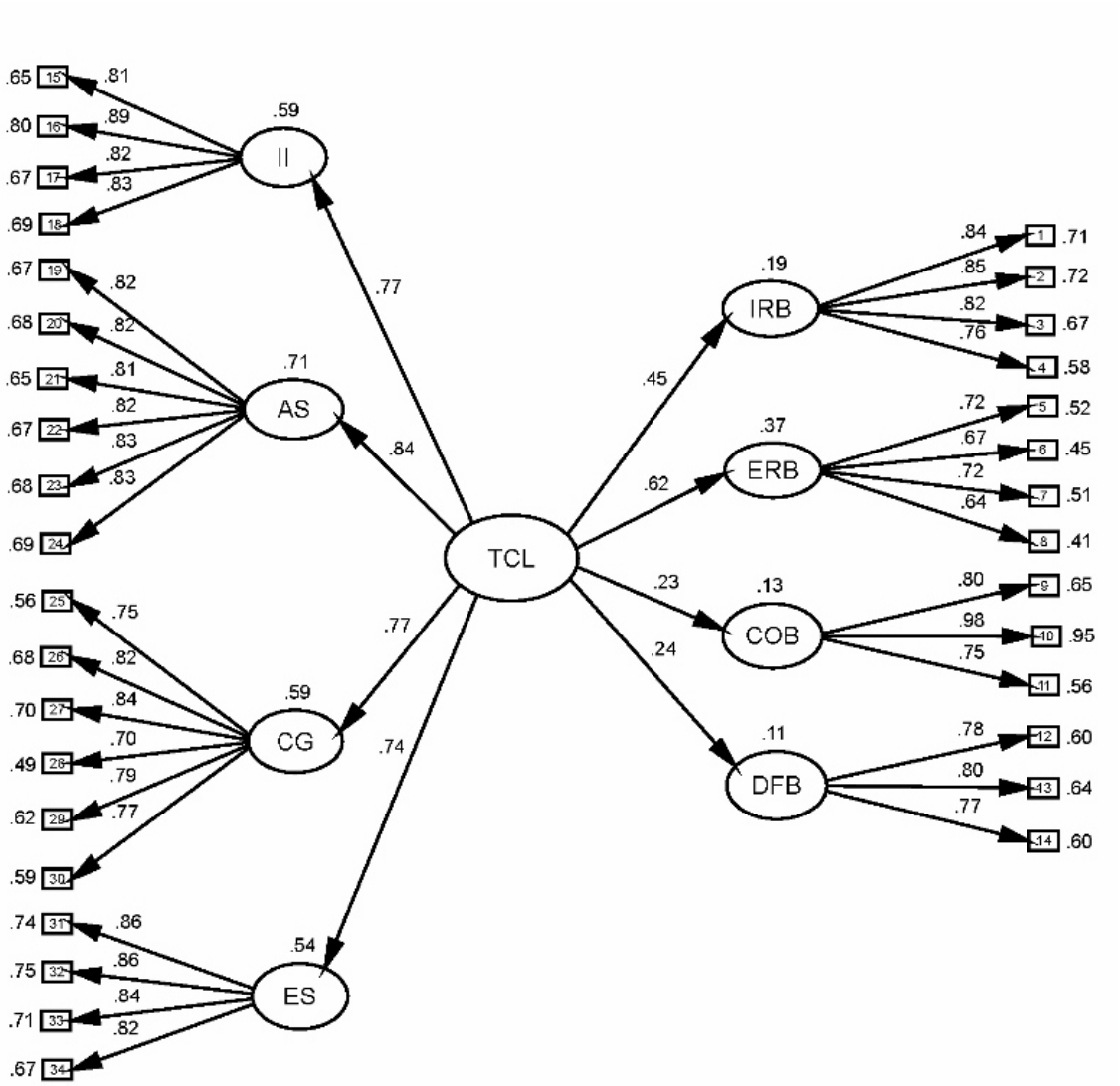

Figure 2: Structural equation modelling results

N = 381. e = error term; d = disturbance term. χ^2(*df* = 634) = 970.42 and χ^2/*df* = 1.53, *p* = .000; IFI = .90; CFI = .90; SRMR = .08; RMSEA = .06. All standardized coefficients are statistically significant at *p* < .001, and are from analyses that included dummy-coded controls for the effects of ethnicity (Non-Chinese = 0), age (≤ 40 years = 0), gender (male = 0) and educational attainment (bachelor's and below = 0) on in-role, compliance, extra-role, and deference behaviour. Education had a significant effect on compliance behaviour (*β* = 0.17, *p* = .037). No significant effects were found for the other control variables. II, Integrative Interactions; AS, Authority Support; CG, Common Goals; ES, Equal Status; IRB, In-role Behaviour; ERB, Extra-role Behaviour; COB, Compliance Behaviour; DFB, Deference Behaviour.

4. Discussion and conclusion

The results show that teamwork climate significantly and positively influences all four dimensions of role-incumbents' cooperation with their TMO workgroups. Thus, if TMO workgroup members perceive a shared sense of purpose, mutual professional respect, integrative interactions, and senior management support for collaborative working—a teamwork climate—they are likely to be spurred on to engage in more in-role, extra-role, compliance, and deference behaviour. These findings provide sound empirical support for the conceptual model proposed in Anvuur and Kumaraswamy (2007). The findings are also consistent with those of previous research that investigated the performance consequences of aspects of the workgroup environment in projects. For example, Thamhain (2004) found that the project team environment—operationalized as including factors such as professional recognition, respect, and senior management support—positively influenced the performance of the 76 IT project teams he surveyed. Tuuli and Rowlinson (2009) found that empowerment climate positively influenced the in-role and extra-role behaviours of members of the 115 construction project teams they surveyed. Their conceptualization of empowerment climate—as consisting of access to opportunity, information, resources, support, informal power and formal power—is consistent with the conceptualization of authority support in this study. In their study about the social network basis of knowledge management in project contexts, Brookes *et al*. (2006) found that professional respect was significantly correlated with the effective sharing of information and knowledge among workgroup members (i.e. relationship "conductivity"), which is required for effective joint-production in new product development projects.

The findings of this study provide support for modelling the four properties of the TMO workgroup environment (common goals, equal status, integrative interactions, and authority support) as dimensions of a superordinate construct, here teamwork climate. There is also support for this in the extant literature. For example, based on an extensive meta-analysis of previous studies, Pettigrew and Tropp (2006) concluded that the four teamwork climate dimensions—originally proposed by Allport (1954) as the optimal conditions for reducing racial and ethnic prejudice in intergroup encounters—were applicable to other groups, and were best conceptualized as an "interrelated bundle". Consistent with this view and proceeding from different conceptual antecedents, Carson *et al*. (2007) modelled the internal team environment as a superordinate construct consisting of shared purpose, social support, and voice, and investigated its effects on shared leadership in the MBA consulting teams they studied. Their definition of shared leadership—as distributed leadership influence among team members in areas related to direction, motivation and support (Carson *et al.*, 2007:1218-9)—is consistent with the conceptualization of extra-role behaviour as including helping workgroup colleagues with their work-related problems. Carson *et al*. (2007) found that the internal team environment positively influenced shared leadership. The significance of being able to model teamwork climate as a second-order factor reflected by common goals, equal status, integrative interactions, and authority support is that this provides theoretical parsimony and bandwidth (Law *et al.*, 1998; Edwards, 2001). However, as support for a multidimensional construct should be by exception rather than the norm (Edwards, 2001), future research could usefully investigate the utility of modelling the multidimensional teamwork climate construct as a superordinate construct—rather than by its set of dimensions—in other TMO workgroup contexts.

The usual limitations of a study of this kind, deriving principally from the self-report nature of the data, sample demographics and location specificity (Hong Kong) are best left to future research to address, and were mitigated in part in this study through statistical controls. These limitations notwithstanding, the findings of this study should be instructive to project managers trying to create and sustain high-performance project teams. If, as our results suggest, creating a TMO workgroup environment in which project actors perceive a shared sense of purpose, recognition for their professional contributions, experience joint-decision making and problem-solving, and the support of the authorities, workgroup and TMO norms is sufficient to tap into the full spectrum of individuals' cooperative behaviours, then project managers need to be heedful of these four teamwork climate dimensions.

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Wall Panelisation – Offsite Manufacture and Construction of Houses

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Abstract

Off-site manufacture offers the means to achieve more efficient construction and improved building performance. Current building practices have predominately evolved from traditional trades and practices, without a re-engineering process to take advantage of current materials, equipment and engineering. Off-site manufacture presents an opportunity to improve many aspects of construction, whilst satisfying aesthetic, design and long-term quality requirements.

A key technology is the factory manufacture of wall panels comprising framing, external cladding and finishes, windows and doors and a straight forward means of site assembly and fit-out.

Monarch Building Systems commenced a major R&D Project in 2002 to develop a new, more efficient method of building houses to lock-up stage. It set out to avoid bricklaying, rendering and on-site installation of windows and insulation. Simplification of on-site tasks and safety issues were also targeted. R&D activities covered the development of an advanced cladding product and a large scale manufacturing plant for the cladding material and wall panels utilising advanced automation and robotics.

To further increase manufacturing efficiency, detailed design solutions have been developed utilising the Autodesk Revit Building Information Modelling (BIM) environment, and custom engineering to take full advantage of the systems. This fully flexible system directly outputs custom data files for each stage of the automated manufacturing process along with construction and quality assurance documentation.

The technology and systems for design, manufacture, logistics and site construction, including complimentary products and systems for floor slabs, internal walls and roof and eave framing, have been proven with hundreds of conventional houses constructed achieving aesthetically pleasing finishes, economical construction costs and improved building performance.

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The panelised wall systems have now proven to be commercially viable in residential construction and Monarch Building Systems are ready for the technology, manufacturing plant and systems to be taken up by other building organisations both in Australia and elsewhere.

Keywords: panelisation, prefabrication, house construction, efficiency, light weight cladding.

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1. Introduction

House building in Australia for the last 50 years has consisted predominantly of brick veneer construction, with a concrete slab floor, timber framing to walls and roof, and a plasterboard internal lining. With consumer preferences shifting to rendered external wall finishes combined with industry pursuit of cost reduction and improved sustainability, house construction is ready for a change in technology associated with the external building fabric.

Various themes have emerged as possible directions for the future of house building, each having the common element of performing more processes in a factory environment instead of trade work on a building site. We have categorised the majority of the innovative proposals into 3 themes:

- Supplying house construction with a standardised kit of parts where the assembly logic is derived from another industry e.g. Toyota Housing Corporation where the thinking comes from the Japanese car industry and the IKEA Flat-Pack house where the thinking comes from the Swedish furniture business.

- Panelised wall construction where large sections of external walls are pre-assembled with external cladding in a factory and craned into position on the construction site e.g. American builders are adding plywood sheathing and installed windows to timber wall frames to speed up and simplify on-site construction.

- Modular construction with all finishing components for joining together on-site with minimal trade work. This approach has appeal for remote area construction where trades labour is not available or expensive.

Pantex Pty Ltd, a privately owned Queensland based builder and its manufacturing arm, Monarch Building Systems Pty Ltd (Monarch) embarked on a project in 2002 to develop and refine a new panelisation system suited to warm and temperate climates, which addressed the issues of labour cost minimisation and the need for improved sustainability performance. The Monarch Panelisation System is now a proven viable approach to house and other low rise construction. It has been used extensively in building designs embodying contemporary architecture.

2. The Monarch Panelisation System – Wall Panels

Panels for residential construction are typically 2500mm or 2800mm high to suit 2400mm and 2700mm ceiling heights respectively. Panel width is 105mm. The panel length often suits the length and articulation of the house external walls, with a maximum of 6500mm. A full component specification is listed in Annexure 1. The main components of the wall panel are:

- A steel frame comprising elements of high tensile (450-550 MPa) steel with a zinc aluminium coating. The steel studs have a flange design suited to the screws and joints holding the cladding material. Various aspects of the steel frame are unique to Monarch to accommodate roof frame point loads, bracing requirements, and a flush internal surface as a base for quality plasterboard finish. Pre-punching for services holes and bolt attachments is an important feature. Monarch has created a certified manual for standardised engineering performance covering a significant range of house architecture and size.

- A light weight concrete sheet product as exterior cladding. Calsonite®[4] is a composite of light weight concrete, a dense surface layer, internal reinforcement and reflective foil bonded to the back face. Calsonite is 27mm thick and is produced in sheet sizes of 1200mm x 2358mmm and 1200mm x 2700mm. Full properties of Calsonite are listed in Annexure 2.

- Panels are created by screw fixing Calsonite to the steel wall frame. The jointing system between sheets of Calsonite incorporates an imbedded micro-expansion joint to accommodate minor building movements. A full masonry expansion joint is set between panels to comply with building codes (typically at 4.5 to 6.0m centres). Panels have Calsonite horizontally protruding or retracted at their ends to suit building external and internal corners. Calsonite also vertically overhangs the frame bottom-plate to provide weathering in a standard slab recess.

- Window and door frames have extended fins for factory sealing onto the Calsonite face except for the frame head which weathers behind the Calsonite. The window and door frames are screw fixed to the steel frame. Trimming the aluminium frame on the interior is an aluminium extrusion which snaps into a recess and holds against the internal plasterboard, creating an aluminium reveal and architrave. This extrusion is normally installed after painting of the plasterboard.

- Panel finishing occurs after the panels have been stood vertical and level in accordance with the architectural layout, secured in position and the roof framing and cladding have been installed. The panel surface is smooth and has a basic sealer to prevent moisture uptake. Panel corners and main expansion joints are set using unique jointing methods. The joint between the Calsonite and the concrete slab is filled with a polymer sealant which cures to form an elastomer. Walls are then ready for the application of a coloured acrylic based render as the finished surface. The render finish provides the first stage of water proofing.

3. Facilities

Monarch have completed a manufacturing plant with 10,000m² of floor area at Narangba (northern suburb of Brisbane) for the manufacture of 500 house lots per annum on a single

[4] Calsonite® is a registered trademark of Monarch Building Systems Pty Ltd

shift basis. The plant comprises a Calsonite manufacturing line including curing ovens, a panel production line, and plant for the fabrication of steel framing to complete the whole house. The plant is highly automated. It is serviced by a digital network, many roll formers, press tooling, wall and truss assembly and overhead crane transfer of incoming goods and product despatch.

Embracing the manufacturing, transport and erection of houses is the detailed design function. Detailed design takes place in the Autodesk Revit Building Information Modelling environment principally direct from architectural drawings. Subsequently the manufacturing data is transferred directly to relevant work stations. The manufacturing data is complemented by automatically generated quality assurance checklists and diagrams for on-site assembly of panels and other structural components. The fully flexible manufacturing environment has been designed and equipped for high labour productivity despite the norm where each house is an individual product, with little repetition between successive houses.

Factory facilities are complemented by delivery trailers, a long-reach crane equipped prime mover, scissor-lifts for on-site assembly and racking for safe handling.

4. Issues in House Construction impacted by Panelisation

For panelisation to be effective as a means of speeding up house construction and reducing cost there are a number of adjoining components and tradespeople which are impacted compared with traditional brick veneer.

- Slab – Bonus useable floor area is typically 5% compared with brickwork due to reduced external wall thickness

- Incoming power – must go up through framing or be external to wall (with a cover plate)

- Frame should be earthed during construction

- Electrical and plumbing – grommets are fitted in service holes to isolate the services from the house frame

- Steel roof framing of a style similar to framing used in commercial construction has been developed by Monarch. Features of the roof framing system are:
    - Trusses at 2400mm maximum centres
    - Purlins for roofing attachment instead of battens
    - Ceiling joists support the plasterboard ceiling and create a ceiling diaphragm
    - Bolted connections throughout the roof framing to facilitate efficient on-site assembly

- A unique solution has been developed for eaves involving a purpose designed pre-painted steel fascia

- Plasterboard sheeting, carpentry, electrical and plumbing fix-outs are entirely conventional except for the type of fasteners

- Various trade activity is eliminated altogether from site work:
    - Window install and sealing
    - Damp course install
    - Bulk insulation install
    - Cladding install
    - Building wrap
    - Frame straightening and bracing
    - Roof frame tie-down rods

5. So How Much Faster is Panelised Construction?

Our experience is that a competent carpentry gang comprising 2 tradespeople and 1 apprentice would require:

- 170 man hours to erect and anchor wall panels, frame non-load bearing internal walls from stud and plate, erect roof and ceiling framing, assemble and underline eaves

- 94 man hours to install safety wire, perimeter safety rail, insulation blanket, roofing sheet (pre-cut Monarch System) and gutters

- 4 man hours to install front and side swing doors and double panel lift door

These times apply to a 200m² floor area, 4 bedroom house on a concrete slab with a 25° pitch hip roof and 600mm eaves. Reflecting much of coastal Queensland, the times allow for a house built to withstand a tropical cyclone in a non-exposed location.

In other words, for 3 men it takes 10 x 9 hour days (30 man days) to achieve full lock-up with full internal framing. The comparable labour times for an equivalent brick-veneer and roof sheet house are estimated at 52.5 man days.

6. Implications of Panelisation on the Cost of a House

The cost of building a house obviously depends on a multitude of factors, with the more obvious related to house design, specification, location and labour costs. Our analysis is based on regional Queensland with characteristics of long-distance supply chains and extremely high labour costs on an international comparison. Our economic terms of reference are based on recent experience in project home construction which has seen a cost structure of frame and lock-up as a proportion of total house costs as shown in Figure 1.

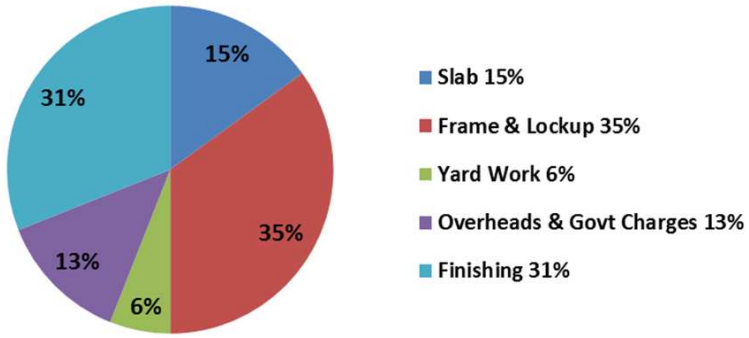

Figure 1: Breakdown of project home construction costs in Regional Queensland

Realistically the frame and lock-up component of the total cost of a project home is only approximately one third. While worthwhile savings can be achieved by a builder using the Monarch Panelisation System, we do acknowledge that the impact on total house costs will only be incremental. For example, a 10% reduction in material and labour costs in frame and lock-up translates into ~3.5% of overall house cost which may become ~2% of a House & Land package.

The cost of the panelised product is also subject to on-going improvements, particularly in relation to the costs of the very mature technology of the timber frame and brick veneer alternative. For panelisation to be competitive, the technology of its manufacture must be advanced and this has been substantially achieved. The on-going potential for further cost structure improvement is mostly related to increased scale of manufacture. Monarch's facilities have the capability of manufacturing at a nominal rate of 1000 homes per annum with little change to existing equipment or configuration (dual shift). The change in cost of manufacture as a function of production volume is forecast in Figure 2.

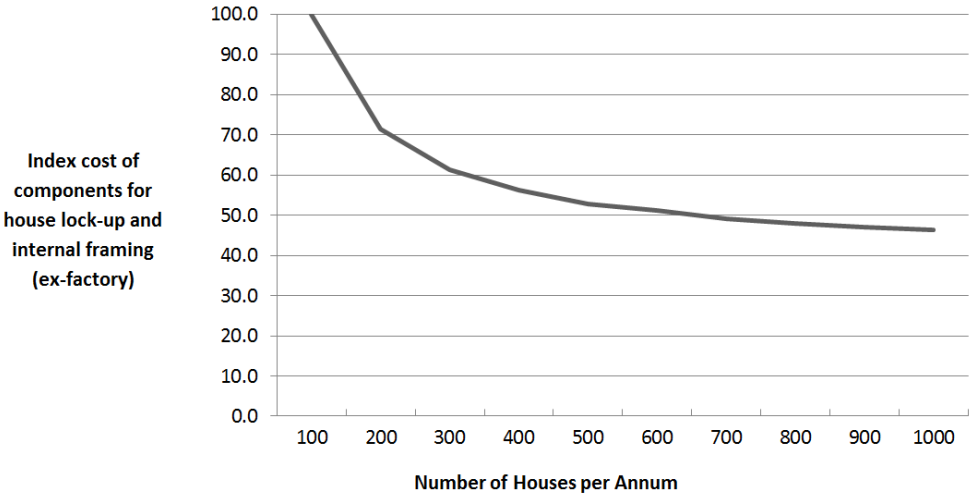

Figure 2: Effect of Manufacturing Volume on Panelisation Supply Costs

This graph shows that the panelisation product and manufacturing methods have significant potential savings as the extent of adoption grows.

7. Sustainability

The Monarch Panelisation System's sustainability advantages are as follows:

a) The most obvious is the very high standard of durability – this is not temporary housing!

- Complete waterproofing afforded by 2 stages of moisture resistance
  - Render finish layer
  - Aluminium foil layer - this double waterproofing avoids rotting in the frame and internal finishes and the formation of mould

- Complete termite resistance

- No timber reveals, door sill or jambs which deteriorate under the influence of sun and rain

b) Lower energy consumed in the building products (embodied energy). Table 1 shows a detailed calculation of embodied energy in the Monarch wall panels compared with an equivalent house with brick veneer construction and render finish.

Table 1: Embodied Energy (MJ) in External Walls and Windows (60 linear metres of wall)

Material / Component	Timber Frame and Brick	Steel Frame and Calsonite
Frame and bracing Ply	9,754	34,800
Hold-downs, Brick Ties, Nails, Straps	9,267	950
Insulation & Sarking	2,880	0
Brick & Mortar/Calsonite	57,678	44,640
Finishes & Jointing	30,796	13,609
Windows, reveals, architraves	8,260	11,168
Total	**118,635 MJ**	**105,167 MJ**

Data for embodied energy in various construction materials has been sourced from:

Hammond G and Jones C (2011) Inventory of Carbon and Energy V2.0 University of Bath, UK

Alcorn A (2003) Embodied Energy and CO_2 Coefficients for NZ Building Materials Victoria University, NZ

Manufacturer data has been used for unique constituents incorporated in Calsonite and materials for jointing and applied finishes.

8. Conclusions

The house building industry is under pressure to build in a more sustainable manner and to use modern technologies to build more efficiently (cheaper). In most of Australia, timber framing and brick veneer cladding is still the norm but with a relative lack of quality timber resources in Australia, there is a gradual change to steel framing. A further shift from brick veneer is likely to be driven by an unwillingness of younger generations to follow the bricklaying trade.

These basic factors provide background to the need for a change to greater use of technology for external wall construction. Monarch has embraced the challenge to develop a replacement technology. This has resulted in a new cladding product, an innovative means of volume manufacture whilst satisfying customised design requirements, and handling and on-site installation.

Comparisons have been made relative to traditional housing construction of timber frame and brick veneer, together with the modern trend of a smooth rendered finish. Panelisation can simultaneously deliver advances in durability and in embodied energy. The use of steel house framing and the Monarch aluminium framing system for windows and doors avoids ongoing maintenance but at the expense of initial embodied energy. Nevertheless the sample analysis of embodied energy present here demonstrates that worthwhile reduction in embodied energy can be obtained even with metal frame systems.

Panelisation will also lead to cost reduction in house construction and these benefits will increase as Panelisation is adopted on a larger scale.

The benefits of panelisation are particularly significant in regional locations where the systematic approach to construction adds to labour cost efficiencies. Experience in the housing market indicates that early adopters of the panelisation system include multi-residential project developers, project builders and franchise builder groups.

Monarch has developed manufacturing equipment and systems which provide building efficiencies from the use of panelisation compared with traditional material supply and construction methods. Continuing research and development will ensure that even greater sustainability and efficiencies will be achieved in future.

The photograph gallery shows examples of recent Queensland housing under construction and completed with panelisation.



















Annexure 1: Component Specification of Wall Panels

Steel Frame

- up to 3200mm high, 6500mm long panels
- nominal 78mm width incorporating
- studs from G500 & G550 steel ZnAI coating
- pre-punching for electrical, data, water services
- heads for point loads from roof structure
- bracing required in excess of that generated by attached cladding
- trimmings for window and door openings and noggings for attachment loads
- holes for floor and roof connections
- self-piercing rivets as primary connection within the frame supplemented by tab and slot and welding
- pre-engineering of frames based on extensive manual of design reference verified by comprehensive testing
- maximum weight of panels ~ 400kg

Calsonite® - Light Weight Concrete Cladding

- nominal 27mm thickness
- reflective foil bonded to back sealed for waterproofing
- screw fixed to steel frame at centres dependent on wind and bracing loads
- micro expansion at 1.2m max horizontal centres (not transmitted to the render face)
- installed with full expansion at centres nominated in the masonry code
- performance established for impact resistance, sound transmission, fire rating, water proofing, structural strength
- subject to rigorous QA in manufacture

Aluminium Framed Windows and Doors

- customised frame integrating reveal and internal architrave
- fully tested and accredited sash and screen systems for sliding glass windows and doors, fixed glazing, double hung windows. Casement and louvre windows are also available
- customised frame and sill for panel doors
- frames sealed against the face of panel in panel assembly
- screw fixing of aluminium frame onto steel frame

The window and door frames have been developed by Monarch and are used in conjunction with sashes designed and manufactured by G. James Glass & Alum (Qld) Pty Ltd.

Wall Finishing Render System

- wall panel surface is factory finished both smooth and flat
- the cladding is offset at corners to accommodate jointing and continuity of smooth surface
- a polymer sealant seals the joint between wall cladding and the concrete base (or steel & plywood flooring system)
- a 1 coat acrylic based render system is applied on-site to give a final coloured trowelled texture finish
- stipple can be incorporated in the finish by appropriate trowelling techniques

Annexure 2: Properties of Calsonite

Property	**Performance**
Construction	Lightweight concrete composite
Outside Face	Cementitious Render
Inside Face	Reflective Foil
Thickness	27mm
Density	600kg/m³
Bend Strength (3 point bend, 300mm length, 1200mm width) - Average load at break - Average deflection at break	 3324N 10mm
Impact Resistance (70mm x 1.4kg steel ball from 3.3m) - Maximum indent depth	 4mm
Moisture Transfer	Waterproof, Zero transfer
Termite Resistance	Termite Proof
Flatness (maximum deviation of surface from a plane in any 2m length)	< 2mm
System Thermal Performance*	1.06m² K/W (R value)
System Fire Resistance* (structural/integrity/insulation)	- / 60 / 60
System Acoustic Performance* (predicted by computer modelling)	Frequency (Hz) R(dB) 100 19 125 19 160 25 200 31 250 36 315 41 400 45 500 48 630 50 800 52 1000 53 1250 54 1600 56 2000 55 2500 50 3150 50 4000 53 5000 56
System Bracing Value (2490mm wall height)*	8kN / horizontal metre of panel

* when installed to manufacturers recommendations

Integration of Saudi Arabia's Conservative Islamic Culture in Sustainable Housing Design

Mohammed Al Surf[1], Connie Susilawati[2], Bambang Trigunarsayah[3]

Abstract

The cities of Saudi Arabia have perhaps the largest growth rates of cities in the Middle East, such that it has become a cause in shortage of housing for mid and low-income families, as is the case in other developing countries. Even when housing is found, it is not sustainable nor is it providing the cultural needs of those families. The aim of this paper is to integrate the unique conservative Islamic Saudi culture into the design of sustainable housing. This paper is part of a preliminary study of an on-going PhD thesis, which utilises a semi-structured interview of a panel of nine experts in collecting the data. The interviews consisted of ten questions ranging from general questions such as stating their expertise and work position to more specific question such as listing the critical success factors and/or barriers for applying sustainability to housing in Saudi Arabia. Since the participants were selected according to their experience, the answers to the interview questions were satisfactory where the generation of the survey questions for the second stage in the PhD thesis took place after analysing the participant's answers to the interview questions. This paper recommends design requirements for accommodating the conservative Islamic Saudi Culture in low cost sustainable houses. Such requirements include achieving privacy through the use of various types of traditional Saudi architectural elements, such as the method of decorative screening of windows, called Mashrabiya, and having an inner courtyard where the house looks inward rather than outward. Other requirements include educating firms on how to design sustainable housing, educating the public on the advantages of sustainable housing and implementing new laws that enforce the utilisation of sustainable methods to housing construction. This paper contributes towards the body of knowledge by proposing initial findings on how to integrate the conservative Islamic culture of Saudi Arabia into the design of a sustainable house specifically for mid and low-income families. This contribution can be implemented on developing countries in the region that are faced with housing shortage for mid and low-income families.

Key Words: Islamic culture of Saudi Arabia, housing for Mid and Low-income Families, Sustainable Housing, Semi-Structured Interview, Saudi architectural elements.

1. Introduction

Since the development of the concept of sustainability, nations worldwide have adopted the concept of sustainability and evolved it dramatically since it's conception in 1987 by the U.N. World Commission on Environment and Development (UNWCED). It's well known that the

[12]main factor behind the development of sustainability is to make sure that natural resources are not jeopardized for future generations. There are three basic factors that define sustainability: environmental factors, economical factors and social factors; these three factors formulate the sustainability triangle.

Saudi Arabia is a harsh dry climate country where water is a scarce natural resource. Environmental in addition to social factors of Saudi Arabia make the application of sustainability a challenging task that requires the collaboration of all key stakeholders in the country. Several reasons validate the need of applying the concept of sustainability in Saudi Arabia that include, limited natural resources, rapid urbanization rate, growing social awareness, environmental impacts and economical impacts (EL-Batran, 2008, Gamboa, 2008, Garba, 2004, Henderson, 2002, Karam, 2010, Stensgaard, 2008, Swain, 1998)

Saudi Arabia is experiencing a huge housing crisis (Abdulaal (2011). In Jeddah, for example, the draft of the Jeddah Strategic Plan indicates the severe shortage of adequate housing for low and mid-income residents. Abdulaal (2011) goes on to declare that, although there are no sound or scientific statistics to back up this claim, continued growth of unplanned settlements is evidence enough of this increasing shortage of adequate housing for this sector of the public, with nearly one million residents currently living in unplanned areas of Jeddah. “It was estimated that the supply of housing units in Jeddah included 697,000 units in 2007, and there is currently a shortfall of 283,000 homes in Jeddah, including 80,000 in the low income sector. The Jeddah Strategic Plan calls for 151,600 new units to be built to accommodate those people currently living in unplanned settlements, with a further 47,500 units to be built annually to meet the demands of population growth. With regard to future requirements, the strategic plan foresees the need for 953,000 units, and an investment of US$640 billion, over the next 20 years.”(Abdulaal, 2011)

This tremendous growth caused strain in various sectors of the Saudi Arabian economy (Mubarak, 1999). Housing is one of the affected sectors, especially among low and mid-income earners (Gamboa, 2008). According to Gamboa (2008), even when one managed to secure housing, it was neither sustainable, nor efficient in the provision of cultural needs of the occupants. And according to Hamed (2003) designing sustainably is no longer a luxury addition to a building, it is now vital to the survival of the present generation and those yet to come.

Compounding the growing housing crisis in Saudi Arabia is the lack of regulations from the government sector concerning the application of sustainable methods. Karam (2010) enforces the lack of regulations by saying that there are no enforceable building codes, nor are there any regulations to follow that integrate the principles of sustainable architecture in the country. He goes on in recognizing the fact that several researchers have debated that

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one of the most significant and cost-effective ways to foster the prevalent use of sustainable practices is setting a comprehensible set of these codes and standards, specifically with regard to diminishing household energy and water consumption (Karam, 2010). These regulations will need to follow the laws of Islam and incorporate the conservative Islamic culture of Saudi residents.

Saudi Arabia is a conservative Muslim country that follows the laws that are transcribed in the Holy Quran and the Sunnah (sayings and living conducts of the prophet Mohammed). In addition, to understand the economic system of Saudi Arabia, one must comprehend that the economic system is based on the Quran and Sunnah, the accumulated knowledge of Islamic jurisprudence generated by consensus (ijma), analogy (qiyas) and independent interpretation (ijtihad) (Astrom, 2011).

As a preliminary study, which was carried out as part of an ongoing PhD research, this paper's focus is how to achieve sustainable housing in Saudi Arabia, with special emphasis or interest on the conservative mosque community. It is based upon this groundwork that this study concentrates in particular on the multifamily detached housing units. It begins with a discussion of challenges that were faced in developing sustainable housing in Saudi Arabia – such as climate, economic and social. It then moves on with the description and discussion of the results from the semi-structured interview, and then finally culminates with some concluding remarks.

2. Challenges Facing Sustainable Housing in Saudi Arabia

High cost of living has discouraged people to implement new 'expensive' sustainable housing. The public perception about this 'new concept' is expensive, and some of the public are still unaware of this 'New Concept'. Although the financial benefits are remarkable in the long term, concerns are sometimes voiced about the initial cost of green projects (Cityscape 2010). Munton in Eden (2000) argues that what will determine the success or failure of this international call to arms, will be the local responses that will make it a practical programme (Eden, 2000). Eden goes on and states that local governance in addition to the planning process and the involvement of citizens are critical to the success of the sustainability programme. But to incorporate the local public, they must first of all be educated on sustainability and they should be persuaded on why they should want to participate (Eden, 2000). With the large estimated population in Saudi Arabia, it is no easy task to apply a new concept to a country that has developed from living in tents as recently as the 1930's. The challenge is not in applying a sustainability scheme to the housing sector, magnanimous as this is, but rather in initially educating the public and government sectors about sustainability, and convincing them that this is the right way to go for the sake of the future as well as strengthening the present.

2.1 Climate Challenges

Harsh dry climate of Saudi Arabia in addition to pollution and global warming raised environmental challenges facing the housing construction industry in the country. The climate in Saudi Arabia is generally harsh, dry desert conditions with extreme temperature

differences ranging from -11°C to 51.1^{o}C (Piccolo, 2010). Another environmental challenge that faces Saudi Arabia and other Arab countries is the scarcity of water. In order to react to the increasing demand of water, several Arab countries relied on non-renewable groundwater provisions to amplify their scarce water supply (Swain, 1998). In addition, due to the extremely limited conventional water resources such as fresh surface water and renewable groundwater, alternative sources such as wastewater reclamation and desalination have been adopted since the 1960's (Stensgaard, 2008). In addition to climate challenges and water scarcity, the ecological footprint in Saudi Arabia is approximately 4.5, hectares/capita - almost two times the global average. Compounding this is the fact that Saudi Arabia is among the top 20 countries that are most environmentally challenged (Al Fadl, 2010).

2.2 Economic Challenges

Saudi Arabia has the largest oil reserve in the world, which has been the main catalyst of the economic growth of Saudi Arabia since the 1930's. This is confirmed by the U.S. Department of State when it states that prosperity from the oil industry has made rapid economic development achievable in the country. (U.S. Department of State, 2011). The near-to-non-existence of mortgage financing is the main factor for the current disequilibrium in the Saudi residential property market. Although there is a substantial pent-up demand for mid or low-end residential real estate, the actual demand – in other words potential investors able to purchase this type of housing without assistance of a mortgage – is quite limited. Therefore, Saudi property developers are reluctant to even build such projects, hence a further increase in the housing deficit as compared to the needs of the community. Independent economist Saud Jleadan reports that with an annual increase of 150,000 units, the country has a current deficit of two million housing units. Experts of the housing industry such as REFCO (Saudi-based mortgage lender "Real Estate Financing Co.") and Clayton Holdings (U.S. consultancy) have estimated that Saudi homeowners are only 30% of the population – a decrease of more than half of the percentage of the Saudi population, which were homeowners only 20 years ago.

For the world's largest oil exporter, these are striking numbers signifying an alarmingly uneven distribution of wealth and benefits. (Karam, 2010). And what makes matters worse is that there are no regulations or a set of standards that that would safeguard the safety, health and security of tenants (Colvin, 2006, 23). The tendency of Saudi residents to rent over owning originates from the fact that they simply cannot afford to buy a house in the current real-estate market. Houses are being provided by developers at more than SR1 Million ($270,000), but demand is strongest within the SR500,000 – SR750,000 range – evidence resulting from the fact that the average income of Saudi households ranges most generally from 5,200 to 6,000 Saudi Riyals monthly (Savard et al., 2010).

2.3 Social Challenges

The Saudi culture is defined by the teachings of Islam and is governed by what the Qur'an and the Hadith of the prophet Mohammed (PBUH) state. The culture of Saudi residents is a family oriented culture where all family members are close and the elderly are respected and

are considered the wise members of the family. It is not uncommon to find extended families reaching to three or four generations may living in the same house (North and Tripp, 2009). With this multigenerational household in mind, it is evident that the Saudi house would be larger in scale as opposed to those where a single family live in a two bedroom unit or similar.

One of the major social challenges facing sustainable housing in Saudi Arabia is achieving privacy. Privacy is crucial in the design of a Saudi house, and the concept of privacy is perceived from three different areas as stated by Daneshpour (2011), between the neighbours dwelling as well as the street, between the sexes and privacy between individual family members (Daneshpour, 2011). Abu-Gazzeh (1996) states, “The concept of privacy has become a subject of growing concern for people, architects, urban designers, landscape architects and social scientists involved in development projects in Saudi Arabia.” Al Surf and Susilawati (Al-Surf and Susilawati, 2011) further discuss that unplanned distribution of the residential areas has been the instigating factor resulting in a potentially dangerous mixture of foreign single labour forces living in or nearby previously designated family residential areas. This has led to many serious security issues across the city of Riyadh in addition to the rest of the Kingdom.

The house design should separate private and public life, maintaining their independence. Alhazmi and Nyland (2010) point out the importance of gender segregation where it is fundamental to most people’s educational, social and political activities. To incorporate this fundamental requirement in housing design, the housing designer should divide the house into three distinct areas: private areas for the inner family members such as the father and the mother, semi-private areas for the whole family, such as the living room. And finally, public guest zones for men and guests. According to El-Shorbagy (2010) the traditional Islamic-Arab house layout segregated the house between what is public, semi-public and private areas of the house. He also adds that the design of the house is an inward looking design where the outside walls are generally featureless, which discourage strangers from looking inside.

3. Semi-structured Interview

This research pursues to investigate and interpret the theoretical and practical knowledge of challenges facing sustainable housing in Saudi Arabia. Above and beyond that, this research aims to construct meaning through an interpretation and understanding of the participant’s theories, experiences and knowledge. The participant’s views are critical to forming the findings of this research and stipulate a specific and locally constructed reality. This paper utilizes a semi-structured interview with experienced professionals as the main research method for its primary data. Careful selection of the panel is necessary to the success of the semi-structured interview. The following criteria were used to correctly identify eligible participants for the interviews:

- Established practitioners/stakeholders considered knowledgeable by the housing construction industry and have extensive working experience in housing construction for Low and Middle-income households in Saudi Arabia.

- Experts directly involved in housing projects (either currently or recently) with a sustainability focus, and
- Experts who are in decision-making roles in organizations or companies associated with sustainable housing projects.
- Knowledge of the local capabilities; and
- Objectivity with respect to sustainable housing policy options and criteria.

3.1 Semi-Structured Interview Background

A total of nine professionals agreed to participate in the semi-structured interview. There were a total of ten questions ranging from broad themes to more specific issues, the first of which was of very general nature, asking of the participant's work experience and relation to the construction industry. Only five questions are discussed in this paper, including one about culture and privacy, due to its significance to the outcomes of this paperThere were a total of ten questions that started from very broad themes, as in discussing the participant's work experience, to very specific issues related to the research. The following were the questions that all nine participants answered to where only the first five questions are discussed in this paper including a question about privacy due to its cultural significance to the findings and outcomes of this paper:

1. What is your interpretation of Sustainable Development, specifically in the housing industry (sustainability definition)?
2. What parameters/factors of sustainability do you account for when dealing with a housing project (the triple bottom line of sustainability)?
3. What are the critical success factors and/or barriers for applying sustainability to housing in Saudi Arabia and how can barriers be managed?
4. In your opinion, does the Saudi Building code discuss or relate to the cultural needs of the Saudi population and their unique cultural characteristics?
5. One of the crucial elements in the design of a Saudi house is it must provide a private environment and out of the sight-range of passing pedestrians. In your opinion how can privacy be achieved in a sustainable way in a Saudi house?

The participants were approached by email invitations that were sent a few times to get their approval to participate, the duration of which took more than one month. The participants ranged from academics to architects to government workers to private contractors, as can be seen in the following table.

Table 1 Participant Profiles

ID	M/F	Age	Current Position	Education	Job Sector	Years of experience	Worked with sustainable projects	Have Knowledge about the subject	Knows the Saudi Building Code
A-1	M	30-40	Director of Research and Assessment	Master	Private	8	Yes	Yes	Yes
A-2	M	30-40	Architect	Bachelor	Public	12	No	Yes	No
A-3	M	40-	Architect	Master	Public	12	Yes	Yes	Yes

ID	M/F	Age	Current Position	Education	Job Sector	Years of experience	Worked with sustainable projects	Have Knowledge about the subject	Knows the Saudi Building Code
		50							
A-4	M	30-40	Architect (Academia)	PhD	Public	10	No	Yes	No
A-5	F	30-40	Architect	Bachelor	Private	3	No	Yes	Yes
A-6	M	30-40	Architect (Academia)	Master	Public	6	No	Yes	No
A-7	M	30-40	Consultant (Academia)	PhD	Public	12	Yes	Yes	Yes
A-8	M	50-60	Contractor	Bachelor	Private	32	No	Yes	No
A-9	F	50-60	Consultant/Advisor	Bachelor	Private	15	No	Yes	No

3.2 Results and Discussion

Due to the constraints of this paper, not all the results are revealed. Only the important results that were controversial or had a great impact on the researcher's expectations are presented and discussed.

For the first question, the participants had the chance to tell the researcher about their work experience and if they had any contact with sustainable housing projects. The outcome of the question was that three of the nine participants had been in contact with sustainable construction projects, and they were A-1, A-3, and A-7 as illustrated in table 1, while the remaining six have not been in any contact with any sustainable project.

All the participants had a great deal of knowledge when it came to answering the second question, which was about how would they define sustainable development. Al Surf and Susilawati (Al-Surf and Susilawati, 2011) discussed such awareness by stating although "the sheer new-ness" of the concept is the main barrier, still there is a marked rise in awareness among the public as well as professionals, as we see from the following responses:

- Sustainable housing is any housing, which proves to be environmentally friendly, has low-cost long-term maintenance and is affordable to the consumer.
- A sustainable housing development is a development that is built from local material, which is suitable for the local environment and culture while employing (absorbing) the local weather for its advantage in energy efficiency.
- Sustainable development is mainly the conservation of resources for future generations. It is concerned with the conservation of energy resources for the longest possible period of time.

For the third question, the participants agreed on most of the sustainable design factors, which demonstrated that the participants are aware of the factors that should be incorporated into the design of a Saudi house. The following table illustrates the response rate in relation to the sustainability factor descending from the highest selected factor to the lowest:

Table 2 Sustainability factors in housing projects

Category/ Theme	Total
Water Management	8
Resources (Materials)	7
Day Light	6
Energy	5
Cost	5
Natural Ventilation	5
Quality	4
Recycling	3

Responses to the fourth question highlighted barriers in applying sustainable methods to housing construction in Saudi Arabia, as revealed in table 3:

- Lack of public awareness of the positives of sustainable housing.
- Lack of stakeholder interest in applying sustainable housing.
- Shortage in sustainable construction material.
- High cost of sustainable housing and long period of return of investment.
- Low levels of investment in sustainable housing.
- Lack of alternative designs of housing and focusing only on the villa typology.
- Lack of awareness from designing firms of how to design sustainable housing.

Table 3 Barriers to applying sustainability on housing

Critical Success Factors	Worked in Sustainable Projects			Never Worked in Sustainable Projects						Total
	A-1	A-3	A-7	A-2	A-4	A-5	A-6	A-8	A-9	
Lack of stakeholder interest		X	X			X	X	X	X	6
High cost	X	X	X	X	X					5
Lack of public awareness		X		X	X				X	4
Shortage in sustainable construction material			X				X			2
Low levels of investment		X				X				2
Lack of alternative designs	X									1
Designing firms lack of awareness	X									1
Total Barriers selected	3	4	3	2	2	2	2	1	2	

The results deducted from Table 3 makes it clear that those having direct contact or real experience with sustainable projects are more inclined to understand the barriers, as these participants are the ones which selected 3 or more of these selections. It is therefore imperative that such persons should be consulted for formulation of a sustainable rating system unique for Saudi Arabia.

On the other hand, the following statements were considered to be critical success factors (CSFs) to applying sustainable methods to housing construction in Saudi Arabia, which can also be found in detail in table 4:

- All designing firms should be educated on the Saudi building code

- Take advantage of local media to create public awareness of Saudi building code.
- New housing projects must use the Saudi building code
- Renovate Old housing projects to reach the minimum level of the Saudi building code
- The Saudi building code should address and solve local environmental problems

Table 4 Comparison between participants regarding CSFs

Critical Success Factors	Worked in Sustainable Projects			Never Worked in Sustainable Projects						Total
	A-1	A-3	A-7	A-2	A-4	A-5	A-6	A-8	A-9	
Implementing new laws	X	X	X	X	X	X		X	X	8
Educating firms	X	X	X		X	X		X	X	7
Educating the public	X	X	X		X	X		X	X	7
Environmental comfort	X	X	X	X	X	X	X			7
Grey water treatment			X				X			2
Using solar energy		X					X			2
Rainwater collection	X	X					X			3
Total CSF's Selected	5	6	5	2	4	4	4	3	3	

From table 4 it is evident that participants who worked with sustainable projects have selected five or more critical success factors (CSF's) while the other participants who did not have any interaction with sustainable projects have selected less CSF's, illustrating the fact that exposure to sustainable projects greatly impact their judgement of CSF's and how they apply to sustainability on Saudi housing. One of the noticeable results from this table is that the utilisation of solar energy is one of the least selected CFS's. This can be due to the high cost of installing solar panels as well as the high maintenance cost of such a system.

In relation to the fifth question, which was asking the participants to discuss the Saudi building code (SBC), it was shocking to see that six of the nine participants did not know that there was even such a building code. But it is not surprising to find out that the three participants who have had some interaction with sustainable projects have knowledge of the SBC as it is illustrated in the table 1.

In response to this reaction, the first thing is that the Saudi building code was not introduced until 2007, which means that is relatively new in the construction industry. The second reason is that the Saudi Building Code National Committee (SBCNC) did not introduce itself to the construction industry well enough so that all the construction industry was informed of the Saudi Building Code. The following outcomes from the participant's responses should be considered as a guideline for the SBCNC:

- All designing firms should be educated on the Saudi building code
- Take advantage of local media to create public awareness of Saudi building code.
- New housing projects must use the Saudi building code
- Renovate Old housing projects to reach the minimum level of the Saudi building code

- The Saudi building code should address and solve local environmental problems

The question regarding the adaptation of privacy in current and future sustainable Saudi housing design had an agreement across the board, which indicates that all the participants agree on the importance of this aspect, both culturally and religiously. Several methods of achieving privacy have been outlined by some of the panel members, which include:

- Refrain from the design constrictions of fenced villas.
- Employment of Mashrabiya concept
- Provision of clearstory fencing along the room walls instead of typical windows
- Designing a house with an introverted concept (looking inside a court).
- Introduce camouflage and pattern in the house, in addition to the idea of a courtyard.

Overall, the concept of privacy can be achieved in the design process of a sustainable Saudi house, which can serve both the cultural and religious needs of its occupants. Designers should incorporate a minimum level of privacy that can fulfil the occupant's needs and any additions or alterations can be done according to the extent and willing of the homeowner.

4. Concluding Remarks

High cost of living has discouraged people to implement sustainable housing concept. The public perception about this 'concept' is expensive, and some of the public are still not aware about this 'concept'. With the large estimated population in Saudi Arabia, it is no easy task to apply a sustainable housing concept to a country that has developed from living in tents in the 1930's to having a sustainable scheme applied to the housing sector and convince them that this the right way. The findings from the interview suggest accommodating the conservative Saudi Culture in design requirements for sustainable houses. The following points are also derived from the interview:

- Enlightening architectural and construction firms on sustainable designs
- To implement regulations resulting in enforcement of application of sustainable methods in housing construction.
- Encourage Saudi government to erect affordable sustainable housing units.
- Promotion of green energy to become the main energy source for housing.
- The importance of rainwater collection.
- The value of grey water treatment systems

This discussion of the applicability of sustainable methods on the housing construction industry in Saudi Arabia can be utilised for other developing countries in the region that are faced with similar housing shortage especially for mid and low-income families.

Further research is on-going as part of the researcher's PhD, and results from the first and second Delphi rounds, which are additional research methods used in the PhD thesis, will be available as they arise along the timeframe of the PhD thesis that will discuss further agreement between participants on the research topic.

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Impact of High Voltage Overhead Transmission Lines on Property Value

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Abstract Title

This paper examines the impact of high voltage overhead transmission lines (HVOTLs) on the prices of detached houses in Eight Mile Plains in Brisbane using hedonic price modelling. Controlled the housing attribution effects the study found that there are significant difference in house prices over the distances from HVOTLs. In particular the houses within 50 meters buffer zone are 15% lower than the median house price in Eight Mile Plains. However, the distance effect diminished over the 200 meter buffer zone. However, the result of hedonic regression model shows that the proximity to HVOTL has little impact on dynamic changes in house prices over time.

Keywords: HVOTL, Externalities, Hedonic Model, Risk Perception, Property Value

Introduction

This paper presents some of the findings of recent research undertaken in Queensland about the impact of High Voltage Overhead Power Lines (HVOTL) on adjacent property value. HVOTL infrastructure can create externalities and perceived threats to the immediate environment and adjoining residents. Their intensity will vary according to individual and community attitudes and expectations. Intertwined with these reactions is the fear of the homeowner's wealth and financial security being impacted with possible reductions in the value of their real estate.

HVOTLs are a familiar and readily-identifiable hazard for homeowners. Previous research (Elliott and Wadley, 2012; Cotton and Devine Wright, 2011) suggests that they presented a symbolically negative image of the industrialised world. Elliott and Wadley (2012), through a series of focus groups undertaken in Queensland, identified that health implications of Electric Magnetic Fields (EMFs) as the most likely HVOTL risk attribute to attract concern and the consequential risk of a possible reduction in property value often became evident in discussions about EMF and, in fact, most other transmission effects. All effects bear directly on the homeowner but EMF risk in particular has the potential to amplify indirectly (i.e. 'ripple') among the community and in the property market in a process known as 'consumption depreciation.' Residential real estate is both a consumption good and

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investment asset and is sensitive to social settings and planning regimes and practices. When HVOTLs are involved, purchase decisions factor in not only a resident's perceived loss of utility in foregone views and compatibility of adjacent land uses, but also in a reduction of investment value if prospective purchasers perceive a place as stigmatised. The environmental stigma arising from HVOTL is the perception of potential buyers and sellers of real estate in proximity to HVOTL who consider that the real estate is compromised in its utility by risk attributes and consequently diminished in value. Numerous factors affect market perceptions of utility.

A criticism of market perception studies in terms of measuring aspects of market behaviour is that they reflect hypothetical rather than actual behaviour of market participants. In many cases it is suggested that they exaggerate the real impacts of HVOTL risk (Kroll and Priestley, 1991). As such, attitudinal research is often considered fraught with potential difficulties with respect to quantifying likely market behaviour by potential buyers.

For this reason, more quantitative studies such as regression analysis are favoured when it comes to measuring diminution of property value. This research contributes to the existing literature in two important ways. First, there is no published literature involving case studies of HVOTL impact on property value in Australia and the findings of this research adds in important ways to those of overseas studies. Recent research findings of international studies on HVOTL have shown that proximity to and the visual encumbrance of HVOTL has a varying negative impact on property values (Rosiers 2002; Sims and Dent, 2005) and it is particularly important to incorporate a visual assessment and measure of impact which HVOTL towers and lines have on homes within their individual surroundings as a variable within the hedonic price model. Actual views of HVOTL from each house are different and they could minimise or maximise its impact on the property value. Google street view is used to assess the visual presence of HVOTLs for all the houses within a 250m zone[3].

Second, there is no published research in Australia into the impact of HVOTL on dynamic changes of house price in terms of capital growth over time. This project investigates the proposition that the presence of HVOTL impacts on the long term capital growth potential of adjacent housing prices.

2. Literature Review

Although HVOTLs have existed for over 100 years, many people, and homeowners in particular, are still wary of them. Research into public reactions to the provision of lines has reinforced the finding of negative perceptions, albeit with substantial variation in intensity caused by measurement differences across studies, as well as disparities in socio-economic status and the choice of environmental variables (Priestly and Evans, 1996). Public perceptions of risk initially focused on aesthetic and engineering qualities. The year 1979 was a turning point, suggesting the first relation of EMF exposure to possible human health effects (Werthiemer and Leeper, 1979). Whilst such a link remains unproven, fears of transmission facilities have since been repeated (WHO, 2007). Issues of safety and

[3] This is a threshold distance to visually identity HVOTL

environmental damage, as well as interference with property rights, abet the negativity (Furby at al., 1988). Proposals of new lines can foster apprehension about local residents' wealth and financial security, due to resumption procedures and associated compensation rights which could appear complex and threatening. The few recorded papers appear amongst studies of 'difficult' industrial landuses (Cameron and Milburn, 1992; Haddad, 1993; and Sullivan, 1998) and other forms of infrastructure (e.g. railways) (Bertolini, 1998) and airports (Freestone, 2009). Some interest has been shown within the real estate journals, where Rosiers (2002) employed a micro-spatial approach to analyse the value of property in the vicinity of HVOTL facilities. Around Glasgow, Scotland, Sims and Dent (2005) revealed that most valuers and realtors perceived negative impacts on HVOTL-affected properties of 3 to 10% of total value. Proximity causes a significant diminution in value, whereas a right of way, created near the rear of the house, can significantly increase value despite the view of the line itself.

The literature relating to this more quantitative approach can be broadly classified into case studies based on statistical techniques such as regression or appraisal or valuation based case studies utilizing relatively small samples of properties. The literature is now relayed in more detail and the links between stigma of place and the processes shaping property price are examined in more detail. An outline of major case studies published in the last 30 years utilising regression analysis is outlined in Table 1.

Table 1: Hedonic valuation studies reported in refereed journals

Study	Decrease in price	Effects observed	Period/Date of study	Date of publication	Powerline capacity	Location and sub market
1. Colwell and Foley	8.8% 3.6%	15m 65m	1963-1978	1979	138KV on steel	Illinois, USA residential
2. Colwell	6.6% 2.0%	15m 65m	1968-1978	1980	138KV on steel	Illinois, USA residential
3. Ignelzi andThomas	1.0-9.0%	100m	1976-1989	1991		USA
4. Kinnard et al	3.0%	65m	1956-1965	1967		Hartford United States
5. Kinnard et al	2.0%	65m	1973-1984	1984		United States
6. Kinnard et al	0.3%	65m	1990-1995	1996		United States
7. Kinnard et al	0.2-4%	65m	1990-1996	1997		United States
8.Hamilton and Carruthers	5.0%	120m	1985-1991	1993		
9.Hamilton and	6.3%	100m	1985-1991	1995	230kv and 500kv on	4 residential suburbs in

Schwann	1.1%	200m			steel	Vancouver, Canada
10.Callanan/ Hargreaves	27.3% 9.1% 2.7%	10m 30m 100m	1983-1993	1995	110kv	Inner city residential Wellington, New Zealand
11.Des Rosiers	5-20%		1991-1996	2002	315kv on steel	Montreal, Canada
12.Dent and Sims	11.5% av	100m	2001-2002	2005		Scotland

Source: Based on Gallimore and Jayne (1999)

From Table 1 it will be noted that negative impacts on property values from HVOTLs more or less range from one to nine per cent, depending on proximity. However, care must be taken in interpretation. Most studies focussed on residential precincts. For example, distances at which the effects are observed vary from study to study with respect to central points or origin. Central points of measurement include the centre of transmission line, the edge of right of way, the centre line of the right of way and the centre point of the right of way. Also, factors such as the topography and nature of landscape will differ. In addition, It is reported that only half these studies produced results which were statistically significant (Gallimore and Jayne, 1999).

Since 1979 a number of other studies have been conducted. Colwell published a further paper in 1990 based on the previous study area and data set. One particular criticism of work was that no account was taken of a possible enhancement in value arising from lots which are contiguous to the easement and therefore have ‘use’ of the greenbelt as in an open view, gardens, swing sets etc. Colwell (1990) accordingly hypothesized that:

- residential selling prices are related both to proximity to the lines and to the towers. It was argued that lines and towers have a large negative impact in close proximity but that it declines at a decreasing rate as distance increases. Additional distance beyond a few hundred metres might make very little difference.

- any impact of the power line and towers might be lessened through time.

In summary, the second study again established that the negative impact of tower lines is large in close proximity, but declines as distance increases. Furthermore, the impact of the lines diminishes with time (Colwell, 1990). Additionally, there can be an additional negative value impact of proximity to towers but it showed no significant signs of diminishing through time.

3. Data and Methods

3.1 Data

The paper uses real estate data (RP Data) which provides detailed property information on property ownership, features and attributes, land size and sales transaction history.. All the sales transactions within Eight Miles Plain for the period between 1st January 2001 and 20th November 2010 were collected, which includes over 5,000 property sales transactions. Some properties have multiple sales within the window timeframe while many of them have no sales history. The analysis of price change as the dependant variable uses only those properties which have recorded repeat sales transactions within the window timeframe in order to calculate the individual price growth rate. Over 460 sold houses have at minimum double repeat sales transactions, 87 of which have triple transactions, 17 with four repeat transactions and 2 houses with 5 repeat transactions within the frame time period of 2001-2010. HVOTL has been constructed within the case study area since the early 1970s and a second double circuit 275Kv tower line was commissioned and constructed in 2003. Community engagement for the second 275kV line occurred during period 1999 to end of 2001

The independent variables used are measured at both the level of the individual house and the HVOTL. The existing literature suggests that a range of housing characteristics may account for differences in the determinant of house price. Previous studies (Priestley and Ignelzi 1989; Colwell, 1990; Callanan and Hargreaves 1995; Bond and Hopkins 2000; Rosiers, 2002; Sims and Dent 2005)) have all considered the impact of HVOTL on property value, including proximity to transmission line, nature of neighbourhood, size of property and date of sale. In this paper we account for these factors using a range of numerical indicators (Table 2). As the focus of this paper is on house price it controls for the effects of individual houses by including variables accounting for the current housing attributes (number of beds, number of bathrooms, number of garage, land size and building age). Finally, in order to account for HVOTL, we include two measures for visual presence and proximity to HVOTL. Table 2 shows some samples of the visual presences of HVOTLs by distance. The visibility of HVOTLs varies over the distance to HVOTL but also affected by topography and landscape. The house of H1 is located within 50m and H2 sits over 100m from HVOTL. However, their visual presences are different by the landscape. Interestingly, in spite of the long proximity (over 100m), HVOTLs from the upper-hill house (H2) is clearly visible. The topography of property location plays an important role in this case.

Table 2: Selected property sample for visual assessment

	Visibility	Actual Image of View
H1 Within 50m	Invisible	
H2 Over 100m	Highly visible	

3.2 Methods

3.2.1 Buffering Analysis

This study examines the impact of high voltage powerlines on residential property prices using a combination of spatial modelling techniques and geographic information system (GIS). We first accessed the RP data base to gain the information on the house prices for individual dwellings over the period 2001-2010. A case study of Eight Mile Plains in Brisbane is selected as a major powerlines coverage area (see Figure 1). The houses with actual sales prices are geocoded by longitude and altitude coordination and present on the satellite image map (refer to Map1). Proximity to HVOTL is measured by Euclidean distance from the powerlines. The dots with different colour scheme represent the five distance buffers: (1) less than 50m; (2) 50 to 100m; (3) 100 to 200m; (4) 200 to 300m and (5) over 300m.

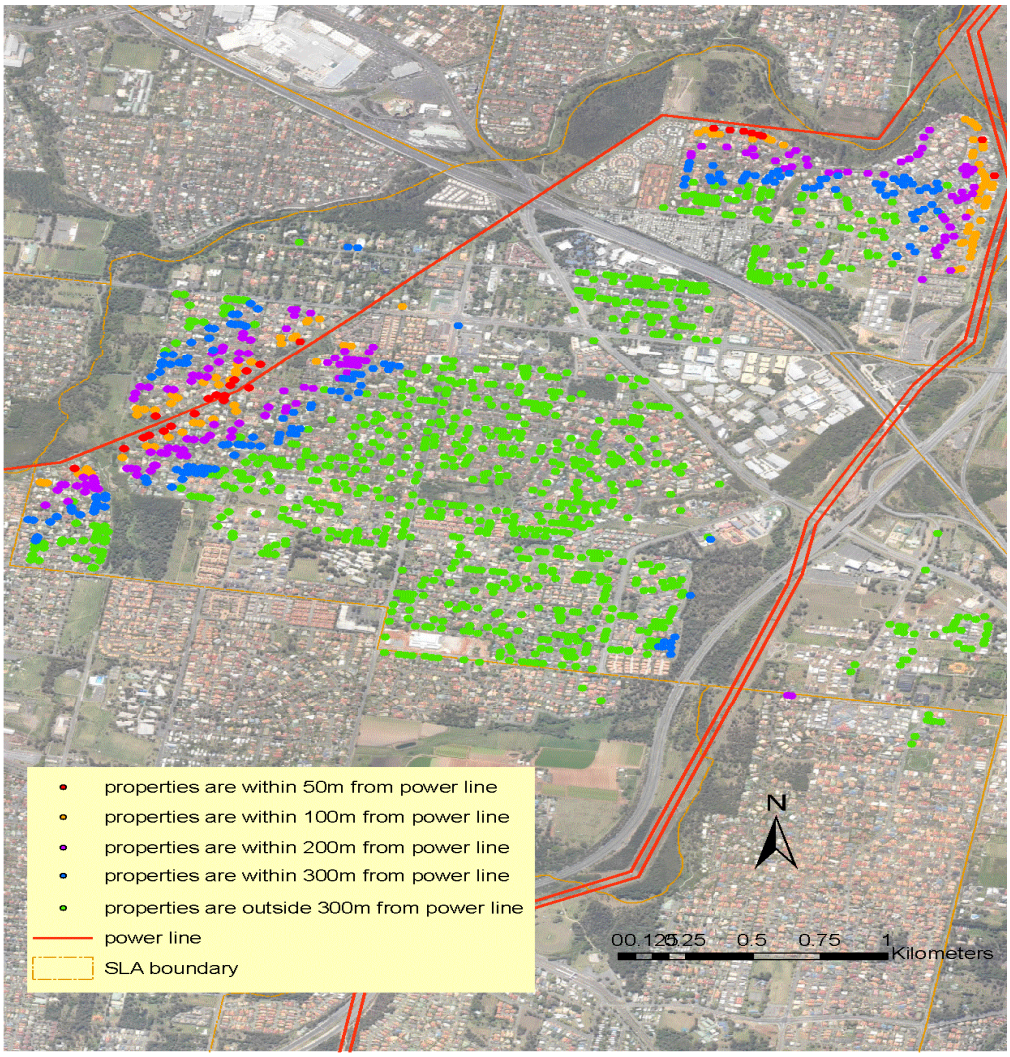

Figure 1: Sold houses in Eight Mile Plains by distance buffers 2001 to 2010

3.2.2 Hedonic Price Model

The hedonic price function (HPF) here refers to market clearing function produced by the interaction of bid functions of households and offer functions of vendors or suppliers as to a market equilibrium. Assuming each individual dwelling is heterogeneous differentiated by a bundle of housing attributes such as the number of beds, toilets and garages, land size, and built year and so on. The hedonic model will determine the value contributions to property with the negative externalities of HVOTL such as visual, safety and health factors. These externalities are measured by two continuous variables of visual impact and actual distance.

P(H) = f (housing characteristics, h1, h2…,hk, HVOTL externalities e1, e2…ek, other factors r1, r2…rk).

This hedonic price equation estimates the change in housing value P(H) that would result from a marginal increase in HVOTL externality E. However, this model does not explain how the externalities negatively or positively contribute to the changes in property price growth or

decline. For instance, if we know that the house price is strongly correlated with the proximity to HVOTL (closer is relatively cheaper) then we would want to know, 'Is the growth rate of house prices nearby HVOTL also lower than that of house far from HVOTL?' The possible externalities of HVOTL on the price change over time can be estimated by:

Price Changes Per Annum ΔP(H)[4] *= f (housing characteristics,* h_1*,* h_2*…,*h_k*, HVOTL externalities* e_1*,* e_2*…*e_k*, other factors* r_1*,* r_2*…*r_k*).*

4. Results

4.1 Descriptive Analysis

A simple descriptive analysis based on median house price has been conducted. Figure 2 shows the median house prices in Eight Mile Plains by four distance buffers. It shows a strong correlation between the proximity to HVOTL and median house price.

There are some basic findings from the buffering analysis which includes:

- The property sale prices within 50m distance from the HVPL (Red marked) show 20% less than the mean house price within Eight Mile Plains.
- The distance between 50 and 100m shows approximately 15% lower than the mean price.
- The mean property price between 100 and 200m is $370,000, around 7% lower than the mean sale price.
- However, it seems that there is little impact on the property prices if distances over 200m

However, this descriptive analysis does not explain the magnitude of this effect on property prices as it does not take account of housing attributes. The following section will estimate the marginal externality of HVOTL with a treatment of housing attributes in the determination of property value.

[4] ΔP(H) is calculated by (first sale price – last sale price)/spell years

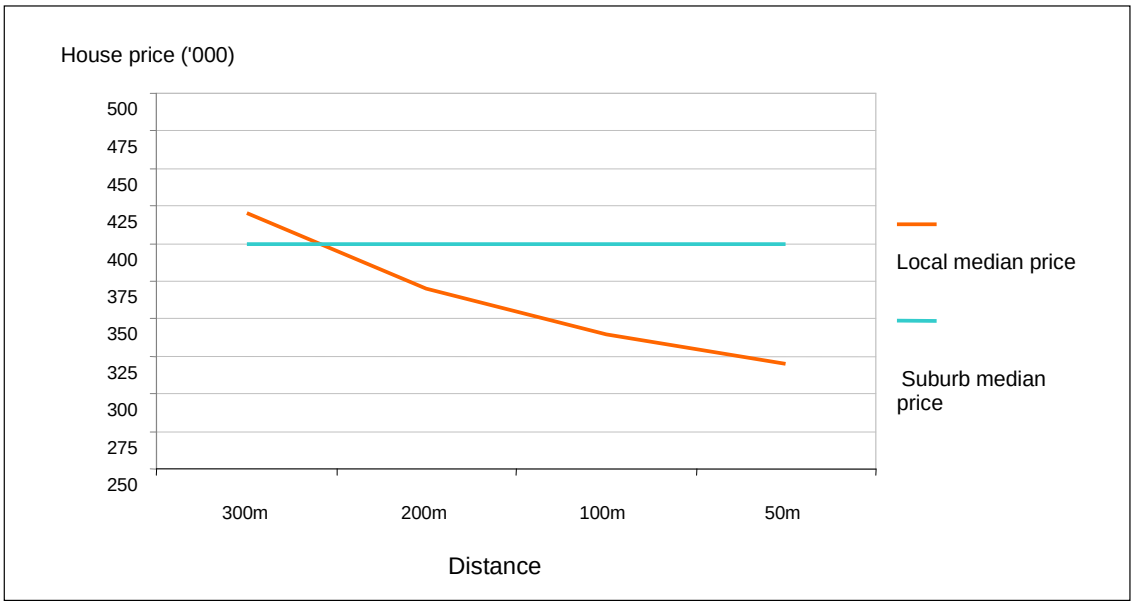

Figure 2: Median house prices by proximity to HVOTL

4.2 Hedonic Price Modelling

The analysis in this paper proceeds from a consideration of externalities of HVOTL focusing only on proximity variable before moving to consider the visual presence of HVOTL. The results of the analysis are presented in Tables 3–4. These tables present the outcomes from the hedonic regressions with the beta coefficients (β) and the robust t-scores. The βs are interpreted in the usual way and illustrate the magnitude of house price determinant in Eight Mile Plains given a particular outcome on the independent variable of house sales price.

The result reveals that all the selected housing attributes contribute to house values and they are statistically significant. The results of the coefficient estimates show that the most important determinant of house prices are the number of bedrooms, land size, sales frequency, number of bathrooms, number of garage and distance to HVOTL in order. It is interesting that the distance to HVOTL still contributes to the property value even if controlled all the housing attributes. When we substitute the proximity to HVOTL to the degree of visual presence the model prediction (r^2) is improved (see Table 4). This finding confirms that the visibility of HVOTL is a more important price determinant than the proximity to HVOTL.

Table 3: Hedonic Regression to House Price with Proximity to HVOTL

	Unstandardized Coefficients		Std. Coefficients	t	Sig.	95.0% Confidence Interval for B	
	B	Std. Error	Beta			Lower Bound	Upper Bound
(Constant)	-4773525.741	1729792.565		-2.760	.007	-8193418.565	-1353632.916
Beds	28699.736	13687.155	.178	2.097	.038	1639.495	55759.978
Bathrooms	41104.890	15476.251	.227	2.656	.009	10507.510	71702.269

Garages	11923.289	16919.741	.054	.705	.482	-21527.948	45374.525
Area	110.250	50.858	.165	2.168	.032	9.700	210.800
Year_Built	2458.674	873.902	.211	2.813	.006	730.924	4186.424
Dist_PL	69.425	30.019	.166	2.313	.022	10.075	128.774

r^2=.323

Table 4: Hedonic Regression to House Price with Visual Presence of HVOTL

	Unstandardized Coefficients		Std. Coefficients	t	Sig.	95.0% Confidence Interval for B	
	B	Std. Error	Beta			Lower Bound	Upper Bound
(Constant)	-4425020.097	1712483.660		-2.584	.011	-7810692.288	-1039347.906
Beds	25834.697	13495.240	.160	1.914	.058	-846.118	52515.511
Bathrooms	42256.341	15067.078	.234	2.805	.006	12467.918	72044.764
Garages	12543.437	16692.318	.057	.751	.454	-20458.172	45545.047
Area	125.137	50.739	.187	2.466	.015	24.825	225.450
Year_Built	2252.657	866.397	.193	2.600	.010	539.742	3965.571
Visual_Ass	34770.677	11447.474	.217	3.037	.003	12138.406	57402.948

r^2=.341

The results from the repeat sales models are presented in Tables 5 and 6 and utilise annual sales appreciation rates of properties as the dependent variable. These models incorporate distance from and view of HVOTL respectively as independent variables and both models perform poorly with respect to r^2. The variables of distance from and view of HVOTL are not significant and do not contribute to changes in price growth, building age being the only significant variable. These results suggest that after the initial impact on property prices of visual encumbrance and distance from HVOTL, possible long term effects of stigma that might arise from HVOTL provision are not present with respect to the future investment value of homes.

Table 5: Hedonic Regression to Price Growth with Visual Presence of HVOTL

	Unstandardized Coefficients		Std. Coefficients	t	Sig.	95.0% Confidence Interval for B	
	B	Std. Error	Beta			Lower Bound	Upper Bound
(Constant)	9192044.179	4389834.563		2.094	.038	513105.427	17870982.931
Beds	-41422.121	34735.002	-.120	-1.193	.235	-110095.086	27250.843
Bathrooms	29733.495	39275.334	.077	.757	.450	-47915.951	107382.941
Garages	12346.417	42938.596	.026	.288	.774	-72545.493	97238.327
Area	56.681	129.067	.040	.439	.661	-198.492	311.854
Year_Built	-4570.578	2217.771	-.183	-2.061	.041	-8955.230	-185.926
Dist_PL	44.159	76.182	.049	.580	.563	-106.457	194.775

r^2=.05

Table 6: Hedonic Regression to Price Growth with Visual Presence of HVOTL

	Unstandardized Coefficients		Std. Coefficients	t	Sig.	95.0% Confidence Interval for B	
	B	Std. Error	Beta			Lower Bound	Upper Bound
(Constant)	9576714.342	4385709.611		2.184	.031	905930.842	18247497.842
Beds	-43710.490	34561.617	-.127	-1.265	.208	-112040.663	24619.683
Bathrooms	27887.311	38587.130	.072	.723	.471	-48401.518	104176.140
Garages	14130.807	42749.406	.030	.331	.741	-70387.066	98648.679
Area	77.464	129.942	.054	.596	.552	-179.439	334.367
Year_Built	-4802.483	2218.864	-.192	-2.164	.032	-9189.295	-415.670
Visual_Ass	35622.744	29317.241	.104	1.215	.226	-22339.017	93584.505

$r^2=.058$

5. Conclusion

This paper sets out to demonstrate the effect on residential property value of HVOTL at various distances and locations utilising GIS analysis and a case study based on sales transaction data within the suburb Eight Miles Plain, Brisbane Queensland. Findings of the research suggest that proximity and the visual encumbrance of HVOTL are significant variables in determining house price but do not impact detrimentally on the capital appreciation of the property within the various distances and locations set within the case study area. These results suggest that after the initial impact on property prices of visual encumbrance and distance from HVOTL, possible long term effects of stigma that might arise from HVOTL provision are not present with respect to the future investment value of homes.

Using descriptive statistics to determine the impact of HVOTL hazard on selling price at various distances from the line, the results indicate a gradual increase in mean selling price with increasing distance from the HVOTL until a distance of 200 metres or more when there is little or no impact on property price. More specifically, sale prices within 50m distance from the HVOTL (marked by a single red line in Figure 1) show a 20% reduction price when compared to the mean house price within Eight Mile Plains. Prices within the 50 to 100m band show approximately 15% lower than the mean price and approximately 7% within the 100 and 200m distances. These findings reflect those of the most recent overseas studies using hedonic regression techniques. More particularly Sims and Dent (2005) in their UK based case study demonstrated the value of property within 100 metres of the HVOTL is reduced by 6–17 per cent (an average of 11.5 per cent). The presence of a pylon was found to have a more significant impact on value than the HVOTL and could reduce value by up to 20.7 per cent compared with similar property sited 250 metres away. Rosiers (2002) found that overall the price reduction was approximately 10% of mean house value of the global sample and 15%-20% for upper price properties

Limitations of the study include that the RPDATA transaction data used to assess the impact of HVOTL, which were limited to the post HVOTL provision (after 2001). Further research is needed which would compare the growth in property prices of sales transactions both before

and after the period of HVOTL provision. In addition this study has been limited to a specific case study region. Further case studies using hedonic price model techniques could measure differences in possible spatial or environmental effects of various neighbouring suburbs.

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The highs and lows of unbalanced bidding models

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Abstract

The unbalanced bidding models developed in the first 50 years, since Marvin Gates first invented them in 1956, have suffered from a significant common flaw. Typically designed as linear programming models, with the objective being to maximise the contractor's profits from a project, they have incorporated constraints on the prices for each of the items such that they are each bound by lower and upper limits. The intent of this was to find optimum prices falling somewhere *within* these limits. Instead, the effect of these models has been that all optimal prices (barring only one) are found to lie exactly *on* the extreme edge of these limits. In effect then, these models serve only to decide which items should be assigned their lowest acceptable price, and which items should be assigned their highest acceptable price. Tests done on a series of simulated hypothetical projects, created randomly by way of an automated process, illustrate this effect, which has previously not being observed. This effect is suggested as being undesirable – these pricing boundaries are vague and heuristically difficult to determine and hence relatively 'soft' in nature, rather than being inelastic and hard-and-fast. The risks - that these limits are designed to avoid – are not of the nature that they are incurred (fully) marginally beyond these limits and yet not incurred at all within the limits. Nevertheless, even though these boundaries are only vaguely definable by nature, these models do somehow need to acknowledge that extreme prices are unacceptable and normal ('central') prices are fine. This problem has been solved with the use of component unit pricing (CUP) theory.

Keywords: pricing, optimisation, unbalanced bidding, risk analysis

1. Background

Unbalanced bidding describes the process of contractors deciding unit prices for each of a project's component items, such that these can then form the basis of their contractual agreement with the client. Prior to this, it is typical that the client and the contractor will have provisionally agreed to the overall tender price for the project as a whole (possibly on the basis of a competitive tender) but then the detailed level of the individually priced items become necessary. These are required in order to provide the basis for determining the interim monthly progress payments, the value of variations and of any escalation adjustments. The item prices form an essential basis of the contract and yet they are difficult for clients to properly assess (Skitmore and Cattell, 2012).

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Contractors can benefit greatly from optimised item prices. Tests done on a hypothetical project showed a contractor enjoying an increase of 150% in profit by way of optimised unbalanced prices, by comparison to the equivalent balanced prices (the latter describing those produced by way of simply applying the same mark-up to the estimated costs of all of a project's items) (Cattell, 2011).

Gates (1956) was the first to identify unbalanced bidding as a strategy. This led to various efforts (Stark, 1968; Ashley and Teicholz, 1977; Teicholz and Ashley, 1978; Green, 1986; Tong & Lu, 1992) to determine a mathematical basis for optimising this, all of which entailed linear programming (LP), except for one that involved quadratic programming (Diekmann, *et al*., 1982). All of these efforts sought to maximise profits and yet recognised that unbalanced bidding is a 'risky' strategy. Cattell *et al.* (2010) identified these risks. The principal mechanism by which to moderate these risks was the universal use of LP constraints on each of the prices, restricting them within defined lower and upper limits. The intent was seemingly that optimum prices would be found that would fall somewhere *within* these limits.

2. What identifies these limits?

None of this research suggested a basis for deciding these limits. It appears that it was intended that subjective human judgement would be sufficient. Presumably, contractors were intended to be adequately able to identify the points at which any single price crossover point would differentiate acceptable pricing from that which is unacceptable. These models do not cater for the combined effect of multiple item prices being at or near these limits and yet, presumably, the risk of many or all prices being 'on the edge' is greater than a scenario where only one price is at or near its limit (at times when the other items are priced more moderately).

3. Unintended consequences

Numerous tests have been made using this LP modelling technique and in all instances, all of the items (barring only one), in each experiment, get priced at their very limit. The models, in effect, only serve to decide which items get priced at their highest extreme limit and which ones get priced at the lowest limit. Furthermore, they serve to consistent identify the one item in each project that gets needed to be priced somewhere within its limits, in order that the summation of the extension of all the item prices exactly equates to that project's overall tender price, which is input into these models as another constraint.

4. Alternative algorithm

The exact same results can be accomplished without the use of linear programming, using a conceptually simpler method that is mathematically less abstract. The objective is to maximise a project's overall expected profit and this comprises contributions from each of the project's constituent items. These contributions have been found (Cattell *et al.*, 2007) to have a linear relationship with the prices of these items, with various slope coefficients (referred to as being their *Beta* coefficient in Cattell *et al.*, 2007). Different items will contribute various proportions towards profits, for every dollar added to their prices. In other

words, given a choice of where to allocate or distribute the overall tender price, amongst all of a project's constituent items, some items will deliver more profit when assigned a dollar, than other items. Clearly then, the objective of maximising profit can be translated to identifying those items that will deliver the most profit / dollar of price and these are then assigned their highest possible prices. This can be accomplished by way of assigning the least prices to those items that will contribute the least profit for every dollar of price. This "unbalancing" of the bid will deliver the maximum profit to the exact same extent as by way of using LP, assigning each item with the exact same price as the technique of LP will also identify.

The algorithm to implement this strategy is as follows:

- sort the items in descending order of their *Beta* coefficient

- assign all the items their lowest acceptable price

- calculate the summation of the extension of all these prices

- calculate the difference (*'Delta'*) between the tender price and this summation

- if *Delta* is less than 0, then report an error (flagging the need to make these minimum prices even lower) and terminate

- as long as *Delta* is more than 0, then starting at the top and looping down through all the items in their sorted sequence, price each item with its highest acceptable price, adjusting *Delta* by way of…

  $Delta \mathrel{-}= Q_n * (P^{max}_n - P^{min}_n)$

  where Q_n = BQ quantity for item *n*

  P^{max}_n = maximum acceptable price for item *n*

  P^{min}_n = minimum acceptable price for item *n*

- if this loop has reached the last item, then report an error (flagging the need to make these maximum prices even higher) and terminate

- else, $P_{n-1} \mathrel{+}= Delta / Q_n$ which will serve to finish off from identifying all of the optimum prices (as defined for the purposes of the LP models that have previously been advocated).

This algorithm should be computationally more efficient than using LP but more importantly (because LP will be very fast, anyway) it is an easier algorithm to understand and to implement. This algorithm bears a strong resemblance to that advocated by Teicholz and Ashley (1978).

For the purposes of this research, this alternative algorithm is important because it provides proof of the cause of the outcome that all of the 'optimum' item prices (barring only one) will be prices that sit at the very edge of their acceptable pricing limits. In effect, all that the LP approach is shown to accomplish is to split the items into two sets: those to be allocated their maximum prices and those to be given their minimum prices, with one item remaining to serve to satisfy the finer details of the tender price constraint.

The problems are, principally, two-fold, as follows:

(1) that the risks from pricing have been found (Cattell *et al.*, 2010) to not transcend from being non-existent within some range to suddenly being excessive outside of some sharp boundary; and

(2) that contractors are, furthermore, believed to be incapable of being precise with being able to recognise and thus set any such boundaries.

However, the precision of these limits is proven to be highly significant to the outcome of the use of these models. There is a 50% chance that any adjustment to any single limit will lead to a different solution (as regards offering a list of optimal prices): with each item adopting exactly either its lower or upper limit in each case.

Nevertheless, there is little basis for contractors to decide these limits and at best they can only do this with a fairly considerable degree of *vagueness*, rather than with any confidence of absolute *sharpness*.

5. Solution

Inuiguchi and Ramik (2000) suggest that Fuzzy Mathematical Programming and, more particularly, that Fuzzy LP is better suited to this nature of problem. Fuzzy LP provides a basis to recognise that, depending on the degree of confidence being sought in the outcome, the solution varies, taking account of the inherent imperfections in the precision to which each aspect of the input can be expressed, whether this is ambiguous in nature (being of either one value or another), or is vague (being, to some degree, fuzzy / blurred or not 'sharp' by nature).

The alternative, more typical approach to such challenges lies with stochastic modelling, such as by way of making use of Monte Carlo simulation. Stochastic models recognise the inherent uncertainty and inconsistency of financial data (amongst other areas of application).

Besides the inherent indefinite nature of the data involved, the other issue lies with recognising that risks increase *gradually* as prices become more extreme. They typically do not transcend from a state where the risks are non-existent to becoming entirely unacceptable, at any price point that is only marginally different. In mathematical terms, this is referred to as the transition from membership to non-membership of the feasible region. Furthermore, CUP Theory (Cattell, 2011) has shown that this rate of transition (from low-risk prices to high-risk prices) is different for different items and should be capable of being

determined. Thus, if a contractor is wishing to reduce their risk, they will find that changing to more moderate pricing for some items will yield more of a change to their risk than with other items. With this in mind, clearly any optimisation of this domain should seek to recognise these differences between items and not treat them all as having the same nature of risk profile. Changes to more moderate pricing with some items can be more effective as regards lowing risk whilst preserving profitability, relative to other items.

CUP Theory is, therefore, based on recognition that the problem with item pricing has not one, but two objectives. The one objective (that has been catered for by way of the abovementioned traditional approach using LP) is to seek the maximisation of the contractor's profit. However, this approach fails to recognise the significance of a second objective: to also minimise the contractor's risk. LP models are limited by catering for only one objective. However, Pareto optimisation facilitates that LP models can be manipulated so as to satisfy two or more objectives – even though the underlying mathematical mechanism (for instance, solved by way of the Simplex Algorithm) is restricted to having only one expressed objective function. Pareto optimisation caters for situations where the multi-objective aspect of a problem is nontrivial, i.e. where satisfying one objective distracts from - or competes with - satisfying another of the objectives. When objectives conflict, there are potentially an infinite number of optimal solutions and the chosen solution will depend on some degree of preference being given to one of the objectives at the expense of the others. This implies some degree of weighting having to be applied to each of the objectives.

In the case of item pricing, a model can be structured so as to have the single objective of maximising the contractor's utility (as with CUP Theory), with utility being expressed as a function of both profit and risk.

6. Conclusion

This paper has provided proof that the popular structure of unbalanced bidding models, in which LP is used to maximise the profit and in which the problem of risk is catered for solely by way of item price limit constraints, delivers an unexpected and unwelcome solution. Rather than avoiding extreme pricing, these models instead serve to induce such pricing: pricing every item at the extreme edge of what is considered acceptable, even when the extent of these edges is difficult to determine.

Whilst almost all unbalanced bidding models have had this form, future models will benefit from a different approach – one that caters for the inherent uncertainties and also that caters for recognition that the risks climb as prices become more extreme and don't simply switch over to becoming simply unacceptable at some magical single point of transition.

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Challenges and Opportunities of Low or Zero Carbon Building: Prospects of Business Models

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Abstract

There is an emerging consensus amongst governments, business sectors and civil societies regarding the urgent need to address the multiple challenges of climate change, environmental pollution, resource depletion and economic instability. The building and construction sector has been identified with the most opportunities for cost-effectively reducing carbon emissions. However, although business opportunities have been identified for low or zero carbon building (L/ZCB), L/ZCBs are generally perceived as more expensive and challenging than conventional buildings. Also, L/ZCBs are often addressed solely from their technological and environmental perspectives, while important economic and socio-cultural aspects have been overlooked or examined implicitly. This paper aims to contribute to the knowledge of the challenges and opportunities of L/ZCB in a systems manner, and to explore how business models can help construction organisations address the former and maximise the latter. The research was carried out through the combination of a comprehensive literature review and case study with a large construction organisation which played a significant role in the UK and internationally. The examination of the challenges and opportunities employed the PESTEL analysis framework (Political, Economic, Socio-cultural, Technological, Environmental and Legal). The case study included a desk study, observations, meetings and personal interviews with senior business and sustainability managers of the company. The results suggest the imperative role of business models for L/ZCB developments. Establishing and innovating business models were considered to present an opportunity for the company to sharpen their competitive edge in the market. A wide take-up of business models of L/ZCBs among construction firms was perceived to fit well the building industry's socio-technical system in addressing the multiple challenges.

Keywords: Low or Zero Carbon Building, Business Models, Socio-technical, PESTEL Analysis, Systems Approach.

1. Introduction

Rapidly growing energy use worldwide has raised concerns over the problems of energy supply and security, which contribute to the multiple challenges of climate change, environmental pollution, resource depletion and economic instability. Practically all major greenhouse gas emitters now have climate change legislation (Townsend *et al*., 2011), which will form the basis of a global agreement to be reached by 2015 (Fankenhauser,

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2012). Buildings, as a whole, contribute the biggest single proportion to total energy consumption in many countries, accounting for up to half of primary energy resources (Butler, 2008; Pérez-Lombard *et al.*, 2008). The building and construction sector has been identified with the most opportunities for cost-effectively reducing carbon emissions and helping to address the multiple challenges (IPCC, 2007). In the UK, the built environment accounts for an estimated 40% of total energy consumption and produces 50% of all UK carbon emissions (CLG, 2007a). The UK government has committed to reduce carbon emissions by at least 80% over the 1990 baseline by 2050 and set 'zero carbon' targets for all new dwellings from 2016 (CLG, 2007a) and non-residential buildings from 2019 (CLG, 2008a). The UK government has described achieving these targets as a 'transformation in its [the construction industry's] own structure and practice' (HM Government, 2010: 2), which requires 'a revolution in the way we build, design and power our homes' (CLG, 2007b: 9).

The UK government's Business Link (2011) elaborated a range of business opportunities introduced by the transition to the low carbon economy in a variety of business sectors, of which a significant one is low or zero carbon building (L/ZCB). It has been suggested that 'Over the next 40 years, the transition to low carbon can almost be read as a business plan for construction, bringing opportunities for growth' (HM Government 2010: 4). However, L/ZCBs are being addressed in many cases solely from their technological and environmental perspectives, while other important aspects, e.g. economic and socio-cultural, have been overlooked or examined implicitly. This approach is problematic, as the construction industry faces multiple challenges in delivering buildings of quality, quantity, affordability and environmental sustainability (Goodier and Pan, 2010). The concept of business models only became widely prevalent with the advent of the Internet in the mid-1990s. Teece (2010) pinpointed that the concept of a business model lacks theoretical grounding in economics or in business studies, and quite simply there is no established place in economic theory for business models. These features inevitably introduce a source of confusion and obstruction to research in business models. While L/ZCBs are generally perceived to be more expensive and challenging, the opportunities and benefits of establishing and innovating their associated business models remain largely unknown. Therefore, this paper aims to contribute to the knowledge of the challenges and opportunities of L/ZCB in a systems manner, and to explore how business models can help construction organisations address the challenges and maximise the opportunities. The exploration is conducted within the UK context, while the discussion draws on the wider knowledge base where possible.

2. Research method

This research was carried out through a combination of a comprehensive survey of the literature and case study with a large construction organisation which played a significant role in L/ZCB developments in the UK and internationally.

The examination of the challenges and opportunities of L/ZCB drew on a systems approach. Research highlights the importance of resisting the temptation to focus on the physical aspects of construction but adopting a holistic approach to sustainable construction development (Pearce, 2003; Butler, 2008). Such a holistic approach is crucial to L/ZCB,

where there may be a tendency to focus rather narrowly on buildings' technical details, yet the far reaching nature of L/ZCBs' 'transformation' (HM Government, 2010: 2) requires a systems approach to address the broader context of L/ZCBs. The systems approach has been noted by several studies within the context of new buildings (Glass *et al*., 2008; Osmani and O'Reilly, 2009; Goodier and Pan, 2010), and more generally in climate change policy (Fankenhauser, 2012). This present paper therefore uses a PESTEL analysis to examine the political, economic, socio-cultural, environmental, technological and legal factors associated with L/ZCB, so that 'a systems approach could shed new light on the problem' (Glass *et al*., 2008: 4535). This PESTEL framework also guided the exploration of ways, in which business models can support L/ZCB developments.

The case study company was an international property and infrastructure group operating in forty countries, with a typical turnover of £900 million for its UK operation. The integrated approach to business of this company spanned activities from identifying and developing land, through construction to property management. The company's long-standing commitment to sustainability has evolved into an aspiration to be a global leader in sustainability. The case study comprised: (1) a desk study of the organisation's websites, brochures, reports and publications on the business' mission, objectives and strategies regarding L/ZCB; (2) meetings with key members of its senior sustainability and business managers, including the Head of Sustainability (HoS) for Europe, the Middle East and Africa (EMEA) who reported directly to the CEO, and the Senior Manager of Sustainability (SMoS); (3) observation of the presentations made by the CEO, and the HoS and the SMoS at two distinguished national conferences, which covered the topic of L/ZCB and the company's practice and business strategies; and (4) personal interviews with the HoS and the Head of Strategy and Business (HoSB) on an individual basis. All these participants had a strategic company-wide remit. For the interviews a list of questions was provided to the interviewees beforehand, which helped to improve the efficiency of data collection and quality of data collected. Each interview took around an hour. All the interviews were audio recorded. Transcripts verified by the interviewees, together with the notes obtained of the meetings and the presentations were used for qualitative analysis. The analysis followed the logic of identifying and verifying codes, themes and patterns.

3. Challenges and opportunities of L/ZCB: PESTEL analysis

The challenges and opportunities of L/ZCB are examined below in each PESTEL aspect. However, these challenges and opportunities are interrelated and should therefore be interpreted together. Therefore, cross-aspect discussion is made where possible.

3.1 Political aspects

Politics presents pivotal opportunities for L/ZCB. The opportunities exist at a number of levels: 1) internationally, e.g. as introduced by EU energy efficiency legislation, the international climate change framework being developed by 2015 (Fankenhauser, 2012), improving cross governmental communication and cooperation, integrating of demand and supply side policies (Glass *et al*., 2008) and government-led 'golden carrot competitions' to stimulate supply chain reform (Lowe and Oreszczyn, 2008: 4480) as up to 86% of a

company's total emissions are via their supply chain (indirect emissions) (Matthews *et al*., 2008); 2) nationally, in the case of UK, for all new domestic buildings to be zero carbon from 2016 and all non-domestic buildings from 2019 (CLG, 2008b); and 3) regionally, e.g. by the London Borough of Merton's game-changing promotion of on-site new build renewable energy generation (Lowe and Oreszczyn, 2010; Osmani and O'Reilly, 2009; CLG 2011).

However, there exist severe challenges to L/ZCB as well. A critical one is the uncertainty of the definition of L/ZCB (i.e. what exactly a L/ZCB constitutes), which remains within the above-mentioned multi-level policy landscape (HM Government, 2010; Lowe and Oreszczyn, 2010; Osmani and O'Reilly, 2009). This definition-related uncertainty, albeit containing technical, economic and socio-cultural dimensions, is fundamentally a political challenge as governments define L/ZCB inconsistently. This inconsistency is illustrated by the inclusion of off-site renewable energy generation for L/ZCB, in the case of the UK, from 2012 (CLG, 2011). The uncertainly of the L/ZCB definition is also directly or indirectly attributed to many other policies, e.g. the UK's loss of stamp duty exemption, unstable feed-in-tariff regime, the way new policies such as the Green Deal and National Planning Policy Framework emerge (see Osmani and O'Reilly 2009), a lack of joined up thinking between difference policy areas such energy and housing and poor communication between government departments (Lowe and Oreszczyn, 2008). This challenge is also global, illustrated by the lack of clear consistent policies addressing climate change internationally (Fankenhauser, 2012). Nevertheless, despite the uncertainty of the definition being a critical challenge, the ability to change the definitions of L/ZCBs presents opportunities for L/ZCBs to be responsive to the changing PESTEL factors, e.g. market demand, emerging technologies, scientific evidence and social trends, which introduces business opportunities to those who pro-actively engage with L/ZCBs.

3.2 Economic aspects

The 'recent sharp economic downturn' is a key economic challenge to L/ZCB (Goodier and Pan, 2010: 4). In addition to the economic instability, climate change and peaking fund resources are likely to result in significant economic contraction, particularly in the Minority World (Glass *et al*., 2008). The scale of the challenges and responses required renders current incremental approaches to building provision reform based on ecological modernisation insufficient (Lowe and Oreszczyn, 2008; Jackson, 2009). There is a growing New Economics literature on degrowth (Sekulova *et al*., 2013), circular (Jackson, 2009), steady state (Daly and Cobb, 1990) and free (Boyle, 2012) economy models and strong sustainable consumption (Røpke, 2009). These perspectives highlight further limitations in current L/ZCB initiatives, including their focus on the metrics of carbon rather than more holistic approaches to sustainability which embrace social justice and socio-culturally inscribed patterns of consumption of, through and within buildings. An underlying commitment to economic growth may predispose policy makers and developers to missed important opportunities or glaring paradoxes. New Economics' implications for L/ZCB building provision remains a significant research gap. Seyfang (2010) suggested small scale, grassroots models of L/ZCB construction have the potential to both upscale and inform mainstream L/ZCB provision. While some commentators identified that small operators remain at the forefront of L/ZCB development (Lowe and Oreszczyn, 2008; Seyfang, 2010;

Peterman *et al*., 2012), these approaches remain on the margins of current policy and practice. Isiadinso *et al*. (2011: 444) considered 'achieving economies of scale as a crucial aspect of the uptake of low carbon buildings.' Furthermore, efficiencies of scale may enable L/ZCB compliance (Pan and Garmston, 2012) and interest in and experience of L/ZCB amongst volume builders is burgeoning (Osmani and O'Reilly, 2009; Bell *et al*., 2012). Second to the challenge presented by the economic growth paradigm is the perception of L/ZCBs as more expensive. Although as Lowe and Oreszczyn (2008: 4479) noted, 'the most cost effective measures in existing and new UK housing have already been undertaken' and L/ZCB is often currently more expensive (CLG, 2011), industry perceptions of L/ZCB's costs exceed reality (NNFCC, 2010; Dunster, 2012). The industry uncertainties regarding both costs and demand for L/ZCB are significant challenges (Lowe and Oreszczyn, 2008), particularly due to the conservative nature of the industry.

However, despite the many challenges, economic opportunities abound. Research suggests there is already significant demand for L/ZCBs (Osmani and O'Reilly, 2009; Bell *et al*., 2010) and there are considerable opportunities for this to grow and support L/ZCB as energy prices escalate, fund resource supplies become less stable and external costs are internalised more effectively (Jackson, 2009; Sekulova *et al*., 2013). There are many opportunities to help internalise external costs within energy and construction which would make L/ZCB the most economically attractive option, these include Tradeable Energy Quotas tax and other pricing mechanisms (Jackson, 2009). While cost challenges render L/ZCB sales premiums neutral, L/ZCB becomes a net boon through the marketing, market differentiation, reputation and early intervention cost saving it represents (Osmani and O'Reilly, 2009). Pro-active L/ZCB engagement can lead to enhanced brand recognition and reputation as well as being more cost effective in meeting L/ZCB standards as they become more stringent (Carter, 2006). L/ZCB also protects against the business risks of future legislation, widespread adoption of carbon accounting methods and increasing costs of current construction methods (Glass *et al*., 2008). Government can enhance these opportunities through fiscal based legislation (Glass et al, 2008) such as the UK's Green Deal, providing grants and facilitating the trend towards socially responsible investment funds accessible to L/ZCB.

3.3 Socio-cultural aspects

The key socio-cultural challenges to L/ZCB include the construction industry's conservative nature and the limited public awareness of and demand for L/ZCBs. Industry challenges include widespread risk-averse attitudes and reluctance to innovation (Lowe and Oreszczyn, 2008), skills shortages (Glass *et al*., 2008), slow take-up of sustainability (Pearce, 2003) and a fragmented structure with few large and many small players (Glass *et al*., 2008; Pan and Goodier, 2012). Many in the industry are unwilling to adopt what they view as untested technologies (Osmani and O'Reilly, 2009). Given the new knowledge, new skills, innovation and holistic/integrated approaches required for LZCB (Peterman *et al*., 2012) and L/ZCB's necessary 'revolution' (CLG, 2007b: 9), the lack of 'collaborative integration of the supply chain and silo-based habits of the industry's institutions' (HM Government, 2010: 7) presents a significant challenge to developing, communicating, implementing and monitoring new L/ZCB products and approaches. Glass *et al*. (2008: 4534-5) note the industry's traditional, conservative disposition 'under-performing legacy' and 'begrudging response' which mean

that ‘In the short term at least, change needs to be imposed top-down, and supported bottom-up with encouragement and reward.’ The industry’s perception of fluctuating (Peterman *et al*., 2012) or low demand for L/ZCBs amongst clients (Osmani and O’Reilly, 2009) and the general public (Lowe and Oreszczyn, 2008) is another challenge, compounded by concerns such as ’sick building syndrome’ due to high levels of air tightness (Lowe and Oreszczyn, 2008) and the aesthetics and space of on-site renewable (Isiadinso *et al*., 2011). This is exacerbated by the industry’s poor reputation and criticisms of greenwash and ‘spin’ (Glass *et al*., 2008).

Nevertheless, there exist important socio-cultural opportunities for L/ZCB. Osmani and O’Reilly (2009) rank them second only to mandatory legislation in their potential to drive L/ZCB. The industry’s highly concentrated nature (Pan and Goodier, 2012) affords opportunities, as well as challenges, for L/ZCB, as once volume builders commit they can rapidly roll out L/ZCB and put greater resources to the challenge, whereas educating, training and committing numerous SMEs may be slower and more difficult. The tension here is that L/ZCB innovation has been driven by small firms and particularly grass roots initiatives (Seyfang, 2010; Peterman *et al*., 2012). L/ZCBs offer reputational benefits spanning from the wide industry to specific projects, which lead to further opportunities. L/ZCBs can help build, rather than ‘consume’ human capital (Lowe and Oreszczyn, 2008), encourage staff to be more IT-literate and informed on specification/design (Harty *et al*., 2007), attract high calibre employees and draw upon a ‘growing carbon culture’ which government as well as industry can build upon (Osmani and O’Reilly, 2009: 1918). The L/ZCB agenda could help transform the industry’s culture, inculcating more team working (Glass *et al*., 2008) and partnerships with local councils (Osmani and O’Reilly, 2009).

3.4 Technological aspects

The technological aspects also see challenges as well as opportunities of L/ZCB. Previous research pinpoints that due to concerns regarding on-site renewable energy particularly and the constraints imposed by volume builders’ standard house sets, ‘Technical and design barriers are one of the main considerations’ for L/ZCB (Osmani and O’Reilly, 2009: 1928). These barriers are related to the socio-cultural challenges identified, with evidence that the main issue is not the limitations or cost of L/ZCB technology, but industry’s ability to embrace it. Dunster (2012) indicated that solar photovoltaic panels’ halving in price within six months during 2012 makes their cost comparable with conventional cladding materials, but the industry has been unable to change its design, sourcing and specification processes at the same rate, whilst 100% renewable/recycled materials can save 10% on the cost of conventional materials to the same L/ZCB standard (NNFCC, 2011). Even greater cost, energy, time and materials savings can be made from off-site L/ZCB construction (Goodier and Pan, 2010) and on-site use of robotics (Glass *et al*., 2008). Technology such as smart meters supports L/ZCB directly and enables such real-time data collection, whilst the growing field of citizen science and collaborative research enhance opportunities for responsive data collection, analysis and engagement. Organisations such as the Transition Research Network and their ability to tap into viral grassroots socio-cultural technologies such as Transition Streets offer significant potential to go much further than Lowe and Oreszczyn’s call to ‘share knowledge from the fringes’ (2008: 4479).

3.5 Environmental aspects

In the environmental aspects, the main challenge relates to extreme weather effects potentially undermining L/ZCBs. For example, climate change triggers flooding more likely, which requires additional tanking that involves the use of materials such as concrete with high levels of embodied energy and other resources. Also, environmental challenges intersect with socio-cultural factors, e.g. the rebound effect (Jackson, 2009; Pan and Garmston, 2012; Isiadinso *et al*., 2011), whereby extreme weather such as heat waves leads to the inappropriate bolting-on of air condition to what are otherwise L/ZCBs. The 'resilience agenda' (Glass *et al*., 2008;) therefore highlights the need for L/ZCB to address adaptation to, as well as mitigation of, climate change and peaking resources (Harty *et al*., 2007) in order to avoid exacerbating problems associated with extreme weather events, but also dwindling fund resource supplies and terrorism (Glass *et al*., 2008). To address environmental concerns has introduced opportunities for L/ZCB. Whilst extreme weather events challenge L/ZCB in some respects, the more extreme they are, the more L/ZCB will benefit, as they further raise the growing awareness of climate change and the triple challenge which L/ZCB is uniquely placed to address. Embracing resilience affords L/ZCB opportunities through forward planning, so that problems become solutions.

3.6 Legal aspects

Previous research shows that the views and practices of housebuilders (Osmani and O'Reilly, 2009) and virtually all aspects of the construction industry (Lowe and Oresczyn, 2008; Pan and Garmston, 2012) respond to mandatory legislation, rather than policies, voluntary schemes or softer mechanisms (Peterman *et al*., 2012). This presents a legal challenge to L/ZCB. Also, the relationship between voluntary and mandatory L/ZCB standards is not simple or fixed. Many L/ZCB standards begin as voluntary and become mandatory, as demonstrated by the UK L/ZCB framework (CLG, 2008a,b, 2011). In addition, the greatest legal challenge to L/ZCB concerns enforcement, with Glass *et al*. (2008) critiquing that L/ZCB legislation lacks teeth and Lowe and Oresczyn (2008: 4477) suggesting that it needs to be 'vigorously and rigorously enforced' to overcome the lack of resources for regulatory development and implementation. Pan and Garmston (2012) found that a lack of awareness and training among both industry and building control officers created uncertainty and contributed to significant discrepancies between mandatory standards and actual building performance. Furthermore, the legal challenges relate to the 'less-than-responsive planning system' (Goodier and Pan 2010: 4). Nevertheless, mandatory standards are the most potent way to support L/ZCB. The legislation can play a facilitative role for L/ZCB, and often gives rise to new business opportunities and new/adapted business models. Also, the legal-side opportunities may be maximised when the transition from voluntary to mandatory standards occurs within a clear consistent timeframe which achieves wide-ranging buy-in.

4. Business models of L/ZCB

Business models are not new phenomena, and their study is an emerging, contested, interdisciplinary field (Teece, 2010). A typical interpretation of business models is that it 'defines how the enterprise creates and delivers value to customers, and then converts

payments received to profits' (Teece, 2010: 173). Mason and Spring (2011: 1033) noted that until 2000 the notion was restricted to internet businesses at the network level, yet its wider adoption has seen it applied almost exclusively to the firm, leading them to argue for dynamic, networked and performative understandings of business models capable of 'zooming in and out' to investigate their operation at the firm, network and industry levels. Building research has been slow to grasp the importance of business models and lags behind the fields such as business and management where the concept has been developed. Also, building research often mistakenly equates business models with competitive advantage theory (Pan and Goodier, 2012) and presents business models as factual statements, rather than being emergent, dynamic and performative as argued by business model researchers (e.g. Mason and Spring, 2011; Teece, 2010).

4.1 Prospects of business models for L/ZCB

Greater attention to business models should help address the challenges and maximise the opportunities of L/ZCB, which are identified through the PESTEL analysis in this paper. There prospects of business models for L/ZCB are multi-fold. First, part of their value concerns business models' agency to shape actions as well as being shaped by the actions of others within firms, networks and across the industry (Mason and Spring, 2011). For example, business models shape demand as well as respond to it (Teece, 2010; Mason and Spring, 2011). This directly relates to the opportunities and challenges regarding industry's assertion of L/ZCB demand (Lowe and Oreszczyn, 2008; Osmani and O'Reilly, 2009). Second, business models' emphasis on a 'deep understanding of the user' (Teece, 2010:190) and initial findings which contradict these assertions (Bell *et al*., 2010) highlights the importance of market research and similar work for L/ZCB and as L/ZCB business models emerge they will stimulate market research and other work deepening industry understandings of users. Third, business models may allow government policy and corporate sustainability strategies more agency in shaping L/ZCB, including opportunities to impact on buildings' in-use impacts and occupants' behaviour patterns.

4.2 Business model take-ups in the building industry

There is a need to address business models across the industry as a whole (HM Government, 2010). Teece's (2010: 189) observed that 'long-lived structural elements – choices made perhaps decades ago in different environments – need to be scrutinized especially thoroughly.' Such scrutiny could help create the socio-technical changes needed for L/ZCB. For example, volume builders' use of standard house types could be addressed through developing business models which integrate more responsive designs capable of the pace of changes in the PESTEL aspects. However, there also exist tensions with using business models to support L/ZCB. For example, it is asserted that business models must be 'non-imitable' (Teece, 2010: 192), while the urgency and scale of the multiple challenges require that L/ZCB business models are rolled out as comprehensively as possible.

5. Case study results

The case study company aspired to become a leader in sustainable development. This aspiration has been driven by a long-standing commitment to sustainability initiated by the founder of the company who as early as in 1973 suggested that the society would soon place emphasise on environmental and social impacts above economics. Although there was limited explicit mission of policy relating to L/ZCB, L/ZCB was embedded in its sustainability objectives including the aspiration that all the buildings it developed and/or operated are zero net carbon, water and waste as a minimum.

The desk study revealed no evidence of explicit commitment to business models of L/ZCB. However, there were elements which indicated the potential for this, including aspirations to engage only with organisations aligned with the case study's aspirations, ethics and values, to operate and ensure its suppliers operate in accordance with the UN Global Compact 10 Principles and to be a recognised leader in facilitating learning and professional development with its suppliers. Furthermore, the company's 2011 *Sustainability Report* identified six Core Values of respect, integrity, excellence, trust, innovation and collaboration. These all pointed to the importance of supply chains, public accountability, innovation and collaboration, areas where business models can support L/ZCB innovation.

Through the interviews it became clear that the company was explicitly and actively involved in L/ZCB developments and innovation, going beyond regulatory requirements and shaping policy through positions on the UK Green Business Council and Green Construction Board. For example, the HoS commented, 'there is no definition yet on what certain code levels are for high rises…so we want to be among the first to do that and we also want to be involved in determining what that looks like and how feasible that is.' The interviewees confirmed the PESTEL analysis in identifying uncertainty as a key challenge, including political and economic and definition-related uncertainty. However, this also encouraged their proactivity in shaping emerging definitions of L/ZCB and turning this challenge into an opportunity.

The HoS identified the importance of legislative drivers to push 'quite conservative, traditional industries' forward, while as individuals and a company they were motivated by L/ZCBs' pivotal role in reducing global carbon emissions. The HoSB added, 'the main drivers are really around reputation, staying ahead of the competition, and also ahead of legislation'. L/ZCB provided opportunities to gain 'a competitive edge as a company in winning tenders and also in convincing clients, consumers to purchase and move into places like this' (HoS). L/ZCBs are 'more attractive for end-users…there are lots of benefits, not only in terms of energy reduction, but also… the social and economic benefits of this agenda, and how it can really add value to our business' and 'around health, productivity and wellbeing of the people within those buildings' (HoSB). Economic challenges were also identified, 'one of the main challenges for the wider industry is getting the whole life costs of the building to work with the right players getting the financial benefits of low and zero carbon buildings' (HoSB). The respondents felt that such challenges could be addressed through education as well as government and industry embracing whole life costings. It is clear that these measures could be supported by business models. The HoSB emphasized that, 'the measures introduced are varied but should appeal to large businesses and also embrace SMEs.'

The company's size and scale meant they operated a range of different business models, with larger projects offering more scope for L/ZCB business models, including working closely with suppliers to develop new energy efficient products and to build and manage. The HoS explained, 'working together with our supply chains, we develop, build and manage, so we can also influence our supply chains' longer term sustainability aspirations.' The company also proactively engaged with their clients and customers. The HoSB elaborated, 'we look at how we can make sure that we are educating future customers and consumers or the users of those homes; that they have also got the right information; and that they get the best out of those buildings.'

6. Conclusions

L/ZCB introduces significant challenges to, but also presents unprecedented opportunities for, the building industry to address the multiple challenges of climate change, environmental pollution, resource depletion and economic instability. By employing a systems approach this paper has examined the political, economic, socio-cultural, technological, environmental and legal aspects of the challenges and opportunities. The results indicate that these challenges and opportunities are interactive and dynamic: exist in no isolation but evolve and interact in parallel. Some challenges might be perceived as opportunities and vice versa, depending on the positions and aspirations of different stakeholders. The political and legislation drivers have vital roles to play in fostering changes within the building industry. The environmental and technological aspects are more embedded in mentality of the industry. However, the role of economic and socio-cultural drivers can be enhanced. All these together generate significant prospects of business models of L/ZCB which can support innovative L/ZCB developments, helping forge pathways to sustainable, closed-loop economic and socio-technical systems. However, business models have received little attention within both the literature and practice of L/ZCB. The approaches already being adopted by industry leaders such as those featured in the case study demonstrate the importance of further attention to business models' role in L/ZCB within policy, research and practice. A wide take-up of business models of L/ZCB should help to accelerate L/ZCB practice and enable the building industry to play its full role in addressing the multiple challenges.

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Development of Durability Verification and Service Life Tools for New Zealand

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Abstract

Materials and construction methods continue to evolve and the empirical knowledge derived from traditional building practice is often insufficient for predicting durability problems with emerging materials and construction techniques. Consequently the capability for robust durability assessment of new products and techniques is an essential platform for supporting an innovative, dynamic building industry.

The New Zealand Building Code (NZBC) is primarily performance-based with prescriptive solutions available for only a limited number of materials. For other materials, the Durability clause within the Code offers only the advice that suitable durability performance may be demonstrated through either laboratory testing, a documented history of use, or by analogy with the behaviour of similar building components.

Therefore, BRANZ has developed a Durability Verification framework for assessing building materials, components and systems under the NZBC. The framework systemises existing durability knowledge and verification methods, identifying critical knowledge gaps to guide future research, and provides useful durability information in a convenient manner to a wide range of potential users. This Durability Verification framework has subsequently been extended to include a Residual Service Life Assessment Tool for New Zealand, a broadly-applicable tool guiding the day-to-day decisions of building industry practitioners concerning residual service life of buildings and building elements.

Ultimately, the fully developed tool will generate an explicit mapping of the behaviour of the materials commonly used in New Zealand's buildings. The mapping will define potential durability and compatibility issues that are known to arise, and provide alerts to gaps in knowledge concerning durability performance and required maintenance. This will enable the designer/builder to be aware of cases where provision of specific guidance is necessary and also allow the New Zealand building and construction sector to acquire the appropriate knowledge, tools and confidence to produce durable buildings that meet or exceed their owner's expectations of performance.

Keywords: Materials Performance, Durability, Service Life, Building Resilience

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1. Introduction

Research into materials performance and a strong demand for robust durability research and information have consistently rated as areas of high industry need across the world. The New Zealand Industry Needs Survey, carried out annually by BRANZ, consistently places Materials Performance at the top of the list of priority topics, for both short and long term research. Materials performance and durability is also currently a key strategy topic within New Zealand's Research Strategy for the Building and Construction Sector.

Functional and durable construction is essential both for the health and well-being of owners and occupiers and the credibility of the industry. Consequently, the consideration of materials performance is critical over the entire building life-cycle, from initial construction to in-service maintenance, and finally renovation, alteration or retrofitting. Furthermore, while operation normally accounts for the largest proportion of environmental costs over the life-cycle of a building, the intrinsic service life of the structure lies at the core of the concept of sustainable construction. Until durability performance can be predicted accurately, the feasibility of assessing the sustainability merits of alternative construction styles at the design stage remains doubtful.

1.1 New Zealand Building Code (NZBC) Durability

Ensuring that buildings have an appropriate durability has always been an important aspect of building regulations. This is emphasised by the current NZBC, which includes the functional requirement that: "*Building materials, components and construction methods shall be sufficiently durable to ensure that the building, without reconstruction or major renovation, satisfies the other functional requirements of this code throughout the life of the building*".

The NZBC is a performance-based rather than prescriptive code, intended to permit innovative solutions and minimise the constraints placed on building design or choice of materials and techniques, providing the mandated minimum performance levels are achieved. The Code's B2 Durability clause is the single exception to this philosophy, setting default lifetimes for building elements depending on their criticality of function and ease of replacement (Table 1). These durability provisions apply to any part of the building which is fulfilling another Code requirement (e.g. structural stability or fire performance) but do not extend to aesthetic considerations. It should be noted that the mandated service life allows for routine maintenance, but not reconstruction or major renovation and building elements shall not be required to satisfy a durability performance which exceeds the specified intended life of the building.

The reason for retaining this prescriptive aspect in an otherwise performance-based code is essentially one of consumer protection: it was considered inappropriate to allow the service life of buildings to be effectively set by market forces, particularly given that a significant proportion of owners would have little expertise in evaluating the relative benefit of construction styles and materials. Note that despite this prescription, the choice of materials for producing building elements of the required durability is left unregulated

Table 1: A summary of the performance requirements for building elements specified by the NZBC B2 Durability clause

Nature of Building Element	Durability Requirement	Typical Examples
(i) Does the building element provide structural stability to the building? (ii) or (iii) Is the building element difficult to access or replace? (iv) or (v) Would failure of the building element go undetected in both normal use and maintenance of the building?	50 years	• Load-bearing walls • Electrical wiring buried in or under concrete slabs • Building underlays behind masonry veneer walls
(vi) Is the building element moderately difficult to access or replace? (vii) or (viii) Would failure of the building element go undetected during normal use of the building but be easily detected during normal maintenance?	(ix) 15 years	(x) Non-structural building envelope cladding (xi) Visible flashings that do not require the removal of the cladding to be replaced
(xii) Is the building element easy to access AND replace AND would failure of the building element be easily detected is 5 years during normal use of the building?	5 years	• External gutters and downpipes • Renewable protective coatings

1.2 Perceived Barriers to NZBC Compliance

Specifying durability in terms of building element service life has a number of drawbacks. These include the issues of perception involved in judging difficulty of replacement and the potential mismatch between Code requirements and the expectation of owners who, for example, are often surprised to discover the roof of their house only needs to last 15 years. Some of the most telling criticism of this approach notes that it may only be truly practical where the building element in question is essentially inaccessible, so that service life is independent of maintenance, and the rate of deterioration under the in-service environment is known. Otherwise, building designers, certifiers and owners assume a significant burden in determining and documenting material and component service life in various environments, based on an assumed level of maintenance. Often the information necessary to do this rigorously is not readily available.

This contention is supported by a previous BRANZ survey of the construction industry on the issue of durability and the B2 clause in particular. Survey respondents across all sectors of the industry cited that a lack of reliable information was a primary barrier to the achievement of durability design (Figure 1).

The absence of reliable information is not unsurprising, given that the same respondents identified ‘trade literature’, ‘industry information’ and ‘past experience’ as the most important sources of information concerning the durability of building materials. It is also notable that the industry places a good deal of reliance on fitness-for-purpose systems appraisals similar to the European Agrément system, but has not yet adopted formal declarations of reference service life, such as those outlined within the ISO 15686 Service Life Planning suite of Standards.

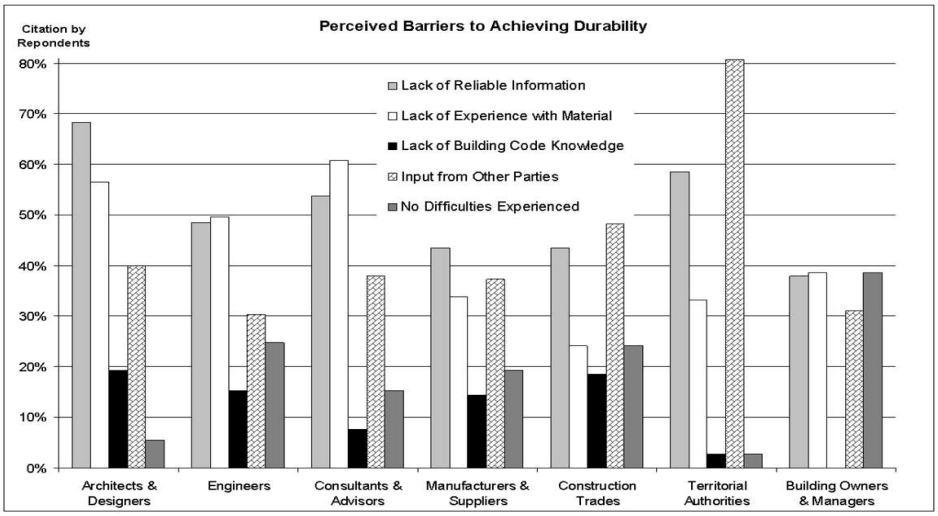


Figure 1: Perceived barriers to achieving the NZBC durability requirements, as identified by surveying the New Zealand construction industry.

Part of this difficulty arises because, despite the unquestioned importance of the subject, there is no broadly applicable methodology available to verify that building materials, components and construction methods will meet the performance requirements of the NZBC B2 Durability clause. Manufacturers and, especially, the statutory bodies responsible for certifying buildings as compliant with the Code, frequently wish to rapidly assess the expected service life of a new material, or even a conventional one in a new environment. The absence of a list of specific test methods that will generate a 5, 15 or 50 year durability rating consequently requires addressing.

For a restricted range of building materials and techniques, the NZBC incorporates the concept of ‘Acceptable Solutions’; prescriptive construction methodologies that, followed to the letter, will ensure Code compliance. Acceptable Solutions primarily exist for time-honoured construction methods (e.g. timber-framed or concrete construction, earth buildings) that draw on a background of many years’ actual service history and development under New Zealand conditions. Even where an Acceptable Solution ordinarily covers durability compliance, the situation becomes complex when new materials with uncertain capability and interactions are introduced.

In cases where an explicit durability evaluation is required, the NZBC documents an approved verification methodology, known as B2/VM1. Unfortunately B2/VM1 offers only the

generic guidance that proof of performance should be demonstrated by in-service history, laboratory testing, or analogy with similar products/situations. However, for most building materials this is an over-simplification of the processes required and collating and evaluating this information in a reliable and appropriate fashion can often be complex. Examples of the need for expert judgement include: considering whether the degradation methods in accelerated tests (heat, moisture cycling, freeze-thaw, UV exposure etc) are appropriately matched to real-world causes of deterioration; assigning quantitative service life predictions on the basis of qualitative rankings of observed durability; and assessing likely variation in performance due the different macro- and micro-climates, materials interactions, intensity of use and maintenance that come with a specific instance of use on a particular building.

The provision of additional information was determined to be a logical next step to addressing these difficulties and removing the barriers to durability design. Although the ISO 15686 Standards provide valuable guidance and a uniform approach to the assessment of durability, they do not provide details on the durability of specific materials, or even prescriptive methodologies for the determination of durability. Consequently, to solve the practical and immediate challenges faced by the New Zealand construction industry, there is a demand for more specific guidance documents that will take into account the properties of construction materials, their potential uses, and their performance in the environments within which they are likely to be used. The BRANZ Durability & Residual Service Life Assessment tools are a response to this need.

2. BRANZ Durability & Residual Service Life Assessments

2.1 Durability Assessment Tool

The Durability Assessment Tool is an initiative to improve the breadth, completeness and cogency of durability information available to the local industry. In essence, it involves the compilation of a database of authoritative and independent durability and compatibility information that covers the building components and materials commonly used in residential construction in New Zealand. The database includes summaries of existing Acceptable Solutions for NZBC B2 for building elements and materials that may comply with publications referenced in NZBC Approved Documents. The delivered tool is intended to be helpful to people with a wide range of knowledge and experience and not to replace the existing Approved Documents as the means of code compliance. Envisaged users include designers, statutory bodies, manufacturers and wholesalers, in addition to building science researchers.

The Durability Assessment Tool is explicitly expected to provide the following benefits:

- A catalogue of existing durability information, including précis of, and references to, current Acceptable Solutions.

- A resource for the development of compliance methods for novel building materials and a means of exposing these ideas to the wider industry for critique.

- An explicit mapping of gaps in durability knowledge for current building materials and environments of use, serving to focus the direction of future research.

- A potential method to demonstrate the compliance of a building with the B2 Durability clause of the NZBC.

The individual entries are organised in the database according to the CBI (Coordinated Building Information classification, typically a four digit code that provides a unique logical slot for identifying each component used in building and construction. The classification system, which is based on the European CAWS (Common Arrangement of Work Sections) system, co-ordinates the five main information sources: drawings; specifications; quantities; technical and research information; trade information and publications.

The Durability Assessment or Verification Database entries are organised under a uniform set of logical topic headings covering the code compliance, verification and underlying science aspects of building materials durability (Table 2). The purpose being to provide a division between the normative and informative material, i.e. code compliance advice, and provides a simplified structure that can be easily modified in case of changes to mandated durable life.

Table 2: Simplified overview of the Durability Assessment Database

Description	General description of the building component or material and its history of use.
B2 Requirement	The current New Zealand Building Code (NZBC) durability requirements for the chosen component.
Acceptable Solution	A summary of B2/AS1 – identifies any current Acceptable Solution contained within an Approved Document to the NZBC, by virtue of which complying building materials and components can be shown to satisfy NZBC performance criteria. These are typically restricted to traditional materials and conventional construction practice and are prescriptive in nature.
Durability	Typically consider what aggressive agents act on selected component and degradation mechanisms by which it may fail.
Compatibility	Potential incompatibilities with other building materials, or environments and applications where it is unsuitable
Unknowns	Summarises any outstanding durability questions and research needs related to the selected component.
References	Provides references to external content, e.g. related BRANZ publications, recognised test standards and scientific literature.

2.2 Residual Service Life Tool

Practitioners, especially Building Officials, Builders and their trainers, require reliable information on in-service materials, and methods by which their remaining lives can be determined. Similarly, building research organisations require a consistent framework to assess materials in-service.

The ISO Standard 15686 defines Service Life as the *period of time after installation during which a building or its parts meets or exceeds the performance requirements* and Residual Service Life has been defined as the *service life remaining at certain period of consideration*. Hence, a residual service life (RSL) prediction for a building is an estimation of the remaining period of time during which the building or its parts will meet or exceed the performance requirements at any given point in time. Examination of the literature suggests that models for estimating Residual Service Life fall into two broad approaches:

- Models based on assessing the degradation of building elements (e.g. EPIQR & Medic);

- Models based on assessing loss of functional capability (particularly the ISO 15686 suite of standards

The ISO 15686 factor method is widely-accepted and has considerable momentum in Europe. This provides a deterministic approach to service life prediction, based on declaration of a reference life for a particular building component under a carefully prescribed set of conditions, plus a series of factors, such as simple multiplicative modifiers, that permit estimation of service lives for the same component under other conditions. The factors account for variations in indoor and outdoor climate, workmanship, maintenance, design execution and in-service loading. However, accurate quantification of the factors requires considerable expertise and experience and, despite the simple approach, considerable thought and work is necessary to derive conclusions from this approach. It is not necessarily well-suited to application by end-users.

The EPIQR tool was developed from collaboration between various European-based research organisations including BRE, CSTB and assesses the state of degradation of the building. The MEDIC tool is used with EPIQR and uses probabilistic calculations to calculate the remaining lifespan of building elements. The EPIQR/MEDIC type models answer typical questions on how to improve specific buildings, necessitating knowledge of past and future building states. These are typically expressed as probabilities of building elements transitioning from one condition to another in a given environment. Often complex models are adopted to provide a sound mathematical basis for the manipulation of transition matrices describing these probabilities. This approach implies reasonably extensive and sophisticated databases and periodic re- inspection; most of the existing tools have been in Europe and North America and would require adaption to local conditions and associated verification.

A Centre Scientifique et Technique du Batiment (CSTB) initiative called EVA, the *Reference Service Life Evaluation Platform*, aims to provide a central database of the service life of building materials and components. EVA is an online implementation of the factor method from ISO 15686 Part 8 *Reference Service Life and Service-Life Estimation*. The database, with an interim English version is intended to serve as a bridge between users, who need the estimated service life data, and the durability specialists providing the reference service life declarations.

The BRANZ Residual Service Life tool is an initiative to develop a broadly-applicable tool guiding the day-to-day decisions of building industry practitioners concerning residual service life of buildings and building elements. Buildings deteriorate with age and old designs may not match well with modern functional requirements. Consequently, cost-effective practices need to be developed for considering maintenance and refurbishment strategies. Understanding the Residual Service Life of existing building elements & components is an essential facet of evaluating said strategies.

The Residual Service Life assessment tool development or FutureFit (Figure 2) involves a simple deterministic estimate involving visual correlation of the condition of a component, or its defects, with an atlas of case study photographs. Although there are only a limited number of cases where degradation correlates with differentiated visual signs of distress in a predictable time sequence, the tool intends to provide useful and specific information to the end-user for a number of key building components. The approach be taken could also facilitate the identification of common defects or material degradation mechanisms by less experienced practitioners.

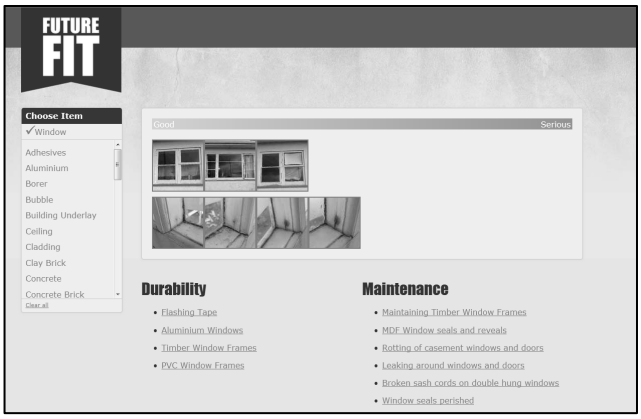


Figure 2: Residual Service Life Tool – FutureFit

Ultimately, the Residual Service Life Tool is expected to provide the following benefits:

- Documentation of methods for assessing residual service life.

- A web-accessible tool for determining residual service life comprising assessment methodologies and photographic illustrations, which may also be downloaded or accessed on handheld devices

- A catalogue of existing residual service life information, including précis of, and references to, current New Zealand Building Code Acceptable Solutions;

- Condition assessments to be carried out on site allowing Auditors to use photographs from the site to compare with condition scales in the office;

- Condition scales for commonly encountered components established and expanded as and when new components were encountered. Differing components constructed of the same material should follow similar patterns for given conditions;

- An explicit mapping of gaps in residual service life knowledge for current building materials and environments of use, serving to focus the direction of future research.

On a broader theme, the intention is to provide the industry with the appropriate knowledge, tools and confidence to reliably identify defects and make sensible decisions on the retention or replacement of building components and materials.

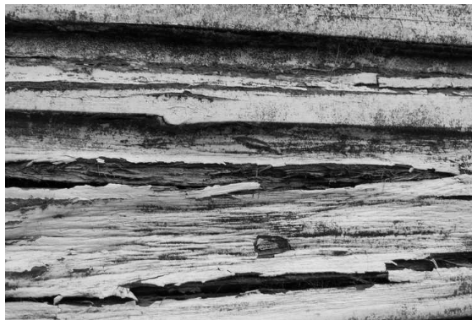
Initials trials of the Durability Verification and Service Life Tools have been carried out within the BRANZ House Condition Survey (HCS), a systematic survey of the structure, type and condition of dwellings within New Zealand. The photographic database (for example Figure 3) was correlated with a five point rating scale and used as the basis for the inspector to provide a condition rating for each component inspected (Table 3).

Table 3: BRANZ House Condition Survey Rating Scale

CONDITION	***Description***			***Rating***
SERIOUS	Health & safety implications, needs immediate attention.			***1***
POOR	Needs attentions shortly - within the next three months			***2***
MODERATE	Will need attention within the next two years			***3***
GOOD	Very few defects - near new condition			***4***
EXCELLENT	No defects - as new condition			***5***
Frequency of defect	***0-10%***	***10-25%***	***25-50%***	***50-100%***



Rating 4



Rating 1

Figure 3: Examples of Weatherboard Condition Rating

The results have assisted in providing an overall picture of the condition of housing in New Zealand, outlining the type and frequency of major defects within residential properties (Figure 4). It is envisaged that further development will enable more robust maintenance regimes to be developed to increase the overall lifetime of the country's housing stock.

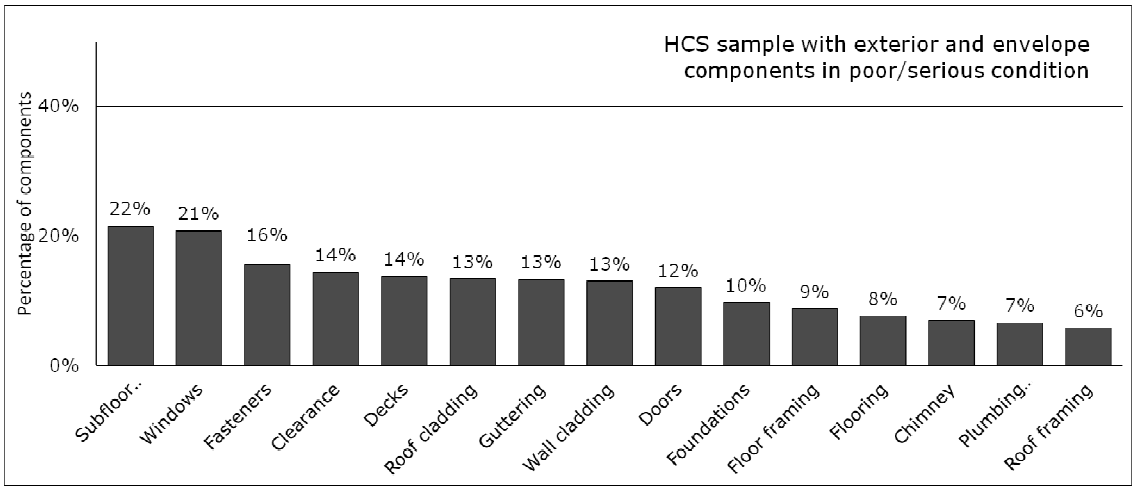


Figure 4: Exterior and building envelope components in poor or serious condition.

3. Discussion and Future Work

3.1 Durability Assessment & Residual Service Life Tool Development

Linkages between the Durability Assessment or Verification Database and the Residual Service Life tool are currently being developed to provide a more robust durability assessment framework for the industry. Initial positive feedback and participation from stakeholders in this research confirm that it is a practical approach to document the progress of some material failures to allow both early identification of defects and to offer insight into material degradation with time. It was also noted that practitioners sometimes need assistance in identifying building materials, particularly when looking at older or discontinued products and the tool offers a route to access experts' knowledge of material failures. However, a number of technical risks have been identified in adopting this approach, which require further work to optimise the database and are currently being investigated.

- Visual appearance may not be diagnostic of the cause of component / element distress;

- Only a limited number of cases exist where degradation correlates with differentiated visual signs of distress in a predictable time sequence;

- The history of a component, such as environmental exposure, workmanship, maintenance, design execution, and in-service loading, cannot be accounted for in estimation of remaining life despite their critical nature;

- Calibration of probability / time for transition of component from one condition state to the next can be uncertain and component dependent;

- The approach may have the potential to focus attention on individual components at the expense of a holistic approach that considers durability of assemblages;

- Misplaced confidence in guidance provided by the tool may discourage more thorough investigation and testing.

3.2 Building Resilience

Although considerable research has been carried out into the resilience of buildings, materials and components by both BRANZ and overseas researchers, there are still substantial gaps in knowledge and information available. Such areas include how these factors are influenced by extreme weather events, how buildings can be made more resilient and how maintenance can extend the service life of materials and the buildings.

Over the last decade New Zealand has experienced a number of extreme weather events, which have been a significant cost to the industry, home-owners, councils, government and the insurance industry. Prior to the Canterbury earthquakes in 2010-2011, 94% of adverse event building insurance claims were for storms, severe floods, snow and landslides. Despite being built in areas of risk, New Zealand's housing stock has limited resilience, which is further compromised by poor maintenance and repair of our existing buildings as shown in BRANZ House Condition Surveys. Research and insurance data indicate that increased costs and building damages have resulted from extreme weather events, this puts the existing stock even further at risk and there is a strong need for our buildings to be made more resilient to such events.

The next stage of the Durability Assessment & Residual Service Life Tool development project will contribute to the development of assessment methodologies to evaluate the resilience of products, materials and buildings that are subjected to extreme weather events. The project will involve a robust investigation into the resilience of buildings and structures, taking into consideration the material and building characteristics, property characteristics, external elements, geographical location and hazards / combination of hazards. The research will build on the knowledge and information gained through the Durability Assessment and Residual Service Life tool development.

4. Conclusions

New Zealand has had a mandatory requirement for durability in its national Building Code since 1992. In theory, this should have stimulated industry awareness of the issues behind achieving appropriate service life of building materials and have fostered an active interest in the development of standards and methodologies that could facilitate good durability design.

In practice, the transition from prescriptive to performance-based solutions has not been without its difficulties and the potential innovative and economic benefits have yet to be fully realised. New Zealand is a small country and there are few independent organisations with the technical resources and breadth of expertise to carry out rigorous assessments of materials durability. This is particularly evident when new, or composite, building systems are introduced to the market.

While based on sound scientific and engineering principles, durability assessment remains as much art as science. This should change as the adoption of uniform assessment philosophies facilitates reliability-based service life prediction techniques. However, from a pragmatic perspective it is still essential that researchers, manufacturers and standards bodies continue to develop and refine predictive test methods for individual materials and their applications. It is hoped that the Durability Assessment Tool will prove a compelling initiative to collect these methods in a convenient and user-friendly form, spread them through the construction industry and stimulate the development of new ideas and techniques Similarly, the adoption of assessing building elements / components guided by the Residual Service Life tool has the potential to assist in determining durability information and predicting service life of these components.

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Effectiveness of Construction 21: Enhancing Professionalism in Singapore's Construction Industry

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Abstract

The Construction 21 report (C21), prepared by a government-appointed high-level committee, aimed to transform the construction industry in Singapore from a Dirty, Demanding and Dangerous (3D) industry to a Professional, Productive and Progressive (3P) industry. To achieve this intended transformation, the report proposed 39 recommendations under six strategic thrusts. Specific targets were set under each recommendation. The report was adopted as a blueprint for developing Singapore's construction industry, and most of the recommendations have been implemented.

A research project was undertaken to review the effectiveness of C21. This paper reports on a segment of the study; it focuses on the first strategic thrust of C21, which was to raise the level of professionalism in the construction industry. A questionnaire-based survey of the main stakeholders of the industry, including clients, consultants and contractors, was undertaken. On the whole, the change programme was viewed by the respondents to be only moderately effective. The industry considered the programmes for enhancingd the level of professionalism in Singapore's construction industry to be the most effective among the six thrusts. The findings also indicate that all the groups of stakeholders are of the view that more needs to be done. Moreover, despite the many improvements which have been realised, the image of the industry has not been much improved.

Keywords: **Construction 21, industry improvement, change programme, professionalism**

1. Introduction

In Singapore, the initial mandate of the Construction 21 Steering Committee was appointed by the Ministry of Manpower (MOM) and Ministry of National Development (MND) to conduct a thorough investigation into many key aspects of the construction industry, from Processes (including practices, techniques, and integrated approach to construction) and Players (including professionalism and skills) to Products (including the exporting of construction expertise). (Construction 21 Steering Committee, 1999). The Committee proposed the

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following vision for the Singapore construction industry: “To be a World Class Builder in the Knowledge Age”. It suggested that this would involve a change in public perceptions of the industry from a Dirty, Demanding and Dangerous (3D) industry to a Professional, Productive and Progressive (3P) industry (Construction 21 Steering Committee, 1999).

The C21 Steering Committee made 39 recommendations under six strategic thrusts. The thrusts were: (i) enhancing the professionalism of the industry; (ii) raising the skills levels; (iii) improving industry practices and techniques; (iv) adopting an integrated approach to construction; (v) developing an external wing (i.e. building up a strong capability to export construction services); and (vi) a collective championing effort for the construction industry (Construction 21 Steering Committee, 1999). The Building and Construction Authority (BCA) (a statutory agency for developing the construction industry, set up in 1984) was identified as the champion agency. Some of the tasks were also assigned to the Construction Industry Joint Committee (which embraces all the professional institutions and trade associations in construction).The report highlighted the following desired outcomes: (i) a professional, productive and progressive industry; (ii) a knowledge workforce; (iii) superior capabilities through synergistic partnerships; (iv) integrated process for high buildability; (v) contributor to wealth through cost competitiveness; and (vi) construction expertise as an export industry.

The C21 report has been used as a blueprint to develop the construction industry in Singapore (Ofori, 2002). The proposals in the C21 report have been used to formulate action programmes for, and to manage, the industry since 1999, and many achievements have been realized. Examples include: (i) information and communication technology (ICT) adoption, stimulated by the need to submit building proposals on-line through the Construction and Real Estate Network (CORENET) and to submit tenders via the government’s business portal, GeBiz; (ii) greater consideration of buildability during design as a result of statutory minimum levels; (iii) the widespread adherence to the construction quality programme; and (iv) greater recognition of continuing professional development.

The literature relating to the C21 report was published in the first few years after publication of the report. The studies evaluated the programmes and focused on the factors and strategies to enable implementation of the recommendations (Ofori, 2002; 2003; De Silva *et al.*, 2004; Dulaimi *et al.*, 2004). However, there has not been any comprehensive evaluation of the level of success of the implementation of the change agenda. The premise of the research is that, some ten years after the publication of the C21 report, it is pertinent to evaluate the progress made, in order to assess its achievements and the continuing challenges facing the industry. The main objective of the study is to ascertain and evaluate against their original objectives, the outcomes from the implementation of the construction industry performance improvement programmes in Singapore since 1999. This paper reports on the segment of the research project which relates to Strategic Thrust One of the C21 report: “Enhancing the professionalism of the industry”.

2. Enhancing professionalism in the industry

2.1 Professionalism at individual level

The C21 report recommended that the curricula of programmes on construction at the tertiary institutions should be restructured. Common modules for engineering and architecture students should be introduced in order to develop multi-disciplinary skills in students, and build a foundation for future co-operation among them. Following this recommendation, at the National University of Singapore (NUS), for example, common modules were introduced in the curricula for the first degree programmes in Architecture, Building and Real Estate. The report also recommended that soft skills, such as professional ethics and management skills, be included in the educational curricula of construction-related programmes at the in the tertiary institutions. Again, at the NUS, soft skills were included as a part of the curriculum for the engineering, building and architectural students.

Another C21 report recommendation was that the universities and polytechnics should collaborate with the professional institutions and BCA to design academic programmes and training courses which meet the needs of the industry, and attract more professionals to attend these courses. New training programmes for professionals and technicians have been introduced by the professional institutions and trade associations such as the Singapore Contractors Association Limited (SCAL) and Singapore Institute of Surveyors and Valuers (SISV). Some of the institutions have set up their own academies. They often collaborate with the academic institutions to provide courses for professionals. In 2007, the then Construction Industry Training Institute (CITI), the training arm of BCA which undertook trades training, was re-structured with an expanded scope of professional education, and renamed as the "BCA Academy of the Built Environment". The academy offers short courses and executive development programmes, as well as a number of diploma, first degree and master's degree programmes (the latter in partnership with overseas universities).

2.2 Professionalism at professional body/trade group level

The C21 report recommended that Continuing Professional Development (CPD) programmes should be made mandatory for the renewal of professional and trade membership. In Singapore, the law requires architects and engineers to be registered before they can practice as professionals. Prior to the C21 report, BCA had initiated a study on CPD for architects and engineers, together with the two professional registration boards, the Board of Architects (BOA) and the Professional Engineers Board (PEB).

The professions have responded to the C21 report recommendation. Participation in CPD programmes was made mandatory for the renewal of practicing certificates by the Board of Architects and Professional Engineers Board. Previously, Singapore Institute of Architects (SIA) and Institution of Engineers Singapore (IES) had encouraged their members to undergo CPD on a voluntary basis. Since 2003, all licensed architects must obtain 20 Credit Points in order to renew their practising certificates annually, with relevant reductions for those above 60 years old (SIA, 2009).

As examples of the professions not subject to statutory control, the Singapore Institute of Planners (SIP) and SISV require their members to attend minimum numbers of hours of CPD in order to maintain their memberships. Since 2006, members of SIP are required to attain a minimum of 20 CPD points over a period of two years for assessment (SIP, 2007).

SISV believes that CPD enables members to stay ahead with developments in the profession (SISV, 2005). Instead of points, SISV requires its members to record the number of hours of participation in CPD activities, and members must attend 60 hours of CPD activities over three years.

2.3 Professionalism at industry level

At the industry level, the C21 report recommended that professionalism can be achieved through the giving of awards, development and application of information technology (IT), and licensing of builders.

BCA recognises to companies and practitioners by giving four kinds of awards (BCA, 2010): (i) Built Environment Leadership Award recognises outstanding industry firms demonstrating excellence and leadership in shaping a safe, high quality, sustainable and friendly built environment in Singapore; (ii) Construction Excellence Awards acknowledges projects on which the participating teams have attained high standards of management, technical expertise, and workmanship; (iii) Green Mark Awards for buildings with high performance in energy efficiency, building management, water conservation, indoor environmental quality, and environmental protection in a building; and (iv) Green and Gracious Builder Award for builders addressing environmental and public concerns arising from construction works, hence enhancing the image of the industry.

The C21 report recommended that the level of application of IT in construction be raised to help re-engineer the work processes in the industry. The goal of the *Construction and Real Estate Network* (CORENET) is to "re-engineer the business processes of the construction industry to achieve a quantum leap in turnaround time, productivity and quality." The development of CORENET was accelerated following publication of the C21 report. CORENET became a major IT initiative led by the MND and driven by the BCA in collaboration with other public and private organisations. The government committed itself to invest S$44 million to develop the infrastructure after C21 (*Framework*, 1999). One of the first steps was to revamp the website to make it more user-friendly. Next, the One-Stop Submission Centre (OSSC) was developed immediately after C21 and was to be ready in 2001 (*Framework*, 1999). The OSSC enabled the industry to submit planning and building plan applications on-line, and also make submissions for structural designs, temporary occupation permits, certificates of statutory completion and fire safety certificates. The submitted information would be validated, and routed to the relevant authorities or applicants for processing or action. Costing some S$7.7 million, the OSSC brought about savings in manpower, material and time in dealing with the 13 building and planning authorities.

CORENET has undergone a number of development phases. Currently, the effort is focused on developing a set of infrastructure and industry projects in order to: (i) provide information services to allow businesses to speed up business planning and decision making processes; (ii) provide government to business infrastructure to facilitate electronic building plans submission, checking and approval processes; and (iii) provide a set of standards to improve business communications. The CORENET project has been a success story that is inspiring similar developments in other countries. In 2008, Singapore was ranked by the World Bank

as the top economy globally in terms of the ease of doing business (IFC, 2008). CORENET was highlighted as one key reforms that sped up the process for dealing with construction permits, reducing the time from 102 days to 38. Almost 99% of applications are now submitted through CORENET.

BCA and other public agencies such as SPRING Singapore and Singapore Workplace Development Authority, offer several incentive schemes to assist construction companies to deepen the application of IT, such as the Investment Allowance Scheme (IAS), Training Assistance Scheme (TAS) and Local Enterprise Technical Assistance Scheme (LETAS) (BCA, 2010). BCA, together with the Industry Foundation Classes (IFC) Implementers Work Group (IIWG) of buildingSMART Singapore Singapore), have been promoting the use of building information modeling (BIM) as the platform to facilitate the integration of knowledge in design and construction, and handing over to facilities management.

The C21 report recommended that all contractors (including sub-contractors) should be licensed in order to improve their standards and professionalism. In 2005, it was announced that a licensing scheme for contractors would soon be launched (Mah, 2005). To be licensed, firms must be financially sound; have good safety records; and employ qualified and experienced personnel to manage the firm and supervise its construction works. The licensing started on 16 December 2008, with the coming into effect of Part VA of the Building Control (Amendment) Act 2007 on Licensing of Builders. There was a six-month grace period for builders to apply for the license. All builders who have been granted or to be granted a permit to carry out building works, as well as builders carrying out work in six specialist work areas,must possess a license issued by the Commissioner of Building Control (*Pillars*, 2009).

3. Research method, sample and response

3.1 Interviews

Nine in-depth, face-to-face, interviews were conducted with 12 key construction practitioners (from the public and private sectors) as shown in Table 1. The interviews were intended to gain a better understanding of the C21 process and the implementation of the C21 report, from the practitioners and administrators who were involved in the preparation of the report, or have been active in the implementation of its recommendations. The knowledge gained in the interviews would enable the questionnaire for the survey to be drafted.

Table 1 Profile of interviewees.

Interviewee	Position	Organisation type
1A 1B	Director Deputy Director	Government
2	Executive Director	Consultancy firm
3	President	Professional body
4A 4B 4C	President and Chief Executive Officer (CEO) Executive Vice President Executive Vice President	Consultancy firm
5	Chairman	Consultancy firm
6	Past President	Professional body

7	General Manager	Developer
8	Executive Director	Trade association
9	Deputy Director	Government

After a review of the literature relating to the C21 process, lists of questions (based on the strategic thrusts of C21) were prepared to guide the interviewers and interviewees. The interview questions sought to find out the interviewees' perceptions towards the C21 report in general. They were mainly asked to comment on the relevance of C21 in the present context and whether it was necessary to refresh the reform programme. They were also asked for their perceptions of the results of the C21 recommendations, in terms of the progress of the process of transformation and its achievements.

3.2 Questionnaire survey

The survey questionnaire sought to ascertain how senior personnel in Singapore's construction industry would rate the effectiveness of the various initiatives based on the 39 C21 recommendations. A five-point Likert scale was used. The respondents were requested to indicate the level of familiarity with, the effectiveness of, their agreement with, and the necessity of, the various statements, as relevant. For example, when respondents were asked to rate each of the statements on the effectiveness of a measure based on the recommendations, 1 represented "very effective", 2 stood for "effective", 3 indicated "neutral", 4 represented "not effective" and 5 stood for "not effective at all".

Three groups of respondents were identified. They were: clients, consultants and main contractors. Two groups of clients were identified: public-sector clients and private-sector property developers. The public-sector clients were selected on the basis of the relevant portfolio of the particular organisations. The private-sector property developers were selected from the list of members of the Real Estate Developers Association of Singapore (REDAS). A total of 174 clients were selected, as shown in Table 2).

Table 2 Distribution of questionnaires and response rates

Respondent	Sent out	Wrong addresses	Sub total	Usable responses	Response rate
Clients (public and private)	174	18	156	22	14.10%
Architectural firms	337	2	335	45	13.43%
Quantity surveying firms	44	1	43	11	25.58%
Engineering firms	143	7	136	29	21.32%
Main contractors	1,671	11	1,660	150	9.04%
Total	2,369	39	2,330	257	11.03%

The consultants, consisting of firms of architects; structural engineers, mechanical and electrical engineers (M&E) (grouped together as "engineering firms"); and quantity surveyors, were identified from lists published by SIA, Association of Consulting Engineers of Singapore (ACES) and SISV respectively. Some 524 consultants were selected.

The target population for main contractors was drawn from companies registered with the BCA under registration heads CW01 (general building) and CW02 (civil engineering). The

contractors are classifieds by tendering limits into A1, A2, B1, B2, C1, C2 and C3. The smallest firms, C3 contractors, can bid for projects of value no more than S$650,000 (US$494,000). A1 contractors are the largest firms; they are allowed to bid for projects of any size. A total of 1,671 contractors were identified.

Within two months of sending out some 2,369 questionnaires, 267 hard copy questionnaires were returned. Of these, 39 were returned because the firms have changed their addresses. Two questionnaires were not used because they were substantially incomplete. In total, 226 usable responses were received in hard copy format. In addition, 31 firms filled up the online version of the questionnaire. In total, 257 responses were usable, reflecting a response rate of 11.03% (Table 2).

The majority of the respondents were holding senior positions, such as managing directors, directors, partners, Chief Executive Officers (CEOs) and chairmen, which were defined as upper management. Upper management was accounted for 58.77% of the respondents. The middle management level, which comprised general manager, project manager, contracts manager, operation manager, business development manager, and administrative manager, was accounted for 28.51% of the respondents. The professionals, which included engineers, quantity surveyors and architects, accounted for 10.96% of respondents. Administrative staff formed 1.75% of the respondents. Most respondents (79.82%) have worked for more than ten years. This means that they had been working in the industry during the implementation of the initiatives in the C21 report. The high number of senior people with many years of working experience responded to the questionnaire gave validity to the survey results. These factors made the questionnaire ratings dependable, and the views expressed by the respondents noteworthy.

There were 85 responses from the consultants. Of these, more than half (52.94%) were architectural firms, 18.82% were civil and structural engineering firms, 12.94% were quantity surveying firms, 9.41% were multi-disciplinary firms and 5.88% were M&E engineering consultancies. The number of staff of companies ranged from one to 420 (in a multidisciplinary firm). Most consultants responding to the survey were small firms employing one to ten persons. The turnover of the consultants ranged from S$30,000 to S$40 million.

Of the 150 contractors who responded to the questionnaire-based survey, only 135 contractors filled up their BCA grades. Of these, the C3 category took up 41.48%. A1 and A2 contractors accounted for 8.15% and 2.22% respectively. Among the 143 contractors who provided information about the number of staff, 84.51% employed 100 persons or less. The largest contractor employed 1,300 staff. Average turnover was S$22.98 million, with turnover ranging from S$80,000 to S$600 million.

3. Analytical methods applied

Reliability of the questionnaire was examined to determine internal consistency; which is whether all items in the questionnaire measured the same thing. Cronbach alpha (α) is a measure of reliability; it typically varies between 0 and 1. The closer alpha is to 1, the greater

is the internal consistency. In the study, the Cronbach alpha was 0.943, which is very high. It indicates strong internal consistency among the items in the questionnaire.

Mean ratings were calculated from the feedback received, first the overall mean and then mean ratings for the three different categories of respondents: clients, contractors, and consultants. The purpose was to ascertain whether different construction industry participants had different views about the various initiatives presented. Statistical t-tests of the mean were carried out to check the entire likely response to the issues raised in the questionnaires, based on the sample's ratings. Analysis of variance (ANOVA) was undertaken to test equality of different population means. The test was undertaken to identify whether the views from different groups of respondents on various initiatives were similar.

4. Results and discussion

5.1 Interviews

As encouraged by the C21 report, BOA and PEBoard made CPD compulsory as a pre-requisite for renewing the practising certificates. SIP, SISV and others also require members to undertake minimum CPD. However, it is important to strike a balance. As Interviewee 2 explained, *"If you enforce it strictly, you may lose some members, but gain some respect as an institution."* Interviewee 6 noted that CPD may be more effective for certain professions than others; for example, he felt it is more effective for architects than for quantity surveyors.

The interviewees agreed that CORENET has been the most significant achievement of C21. The C21 report recommended that all contractors, including sub-contractors, be licensed to influence their standards and professionalism. According to Interviewee 8, who was involved in the preparation of the C21 report, there had to be many compromises along the way.

C21 recommended that an industry-wide code of conduct spelling out industry standards with regard to the working relationships among the various players be developed. The interviewees disclosed that the codes of conduct were drafted, but they were not implemented, because, according to Interviewee 2, who took part in drafting the codes, the codes were considered by the members of the CIJC to be too general and so the document was considered to be unnecessary. Interviewee 6 noted that it is unreasonable to attempt to formulate an industry-wide code of conduct. In the opinion of that interviewee, it would not possible to enforce such a code as there could be no sanctions; he suggested that regulation of the industry should not go to that extent.

In summary, the interviewees agreed that the level of professionalism in the industry has improved. They also noted that there is scope for further progress. Interviewee 4A noted: *"If you want professionalism, then you must downplay regulation, or have regulation with a lighter touch, and allow peer pressure to raise standards. We can say that professionalism has been achieved when the industry does the right thing without too many regulations."*

5.2 Questionnaire survey

Respondents were asked to express their views of the effectiveness of the C21 report in addressing the problems of the construction industry on a scale of one to five (1 = “very effective”, 2 = “effective”, 3 = “neutral”, 4 = “not effective”; and 5 = “not effective at all”). The results (Table 3) show that the respondents gave a moderate vote of confidence (average of the means of 2.77). Although there were no significant differences among the scores of the three different groups in the sample, the clients (average of the means of 2.68) and the main contractors (average of means of 2.71) gave a slightly stronger vote of confidence than the consultants (average of means of 2.89).

Table 3 Mean rating and ANOVA for effectiveness of C21

	Mean rating				ANOVA	
	Whole sample	Clients	Consultants	Main contractors	Sig. level	*F*
How effective do you think the C21 initiatives have been in addressing all the problems of the construction industry?	2.77	2.68	2.89	2.71	0.115	2.181

Comparing all the results on the six strategic thrusts, the highest rating in terms of effectiveness was accorded to Strategic Thrust One: “Enhancing the professionalism of the industry”, with an average of the means of 2.39. This average of the means showed that the respondents agreed that the implementation of Strategic Thrust One had been more effective than that of any of the other thrusts and the C21 programme in general. Also, among all the particular measures, the increase the use of IT in general (average of means of 2.26) was considered most effective.

For Strategic Thrust One, all the means were between 2.26 and 2.50 (Table 4). It indicated that the firms moderately agreed that the measures had improved the professionalism of the construction industry. However, the clients had different opinions from the contractors and consultants on the degree of effectiveness of different measures. For the clients, it was the licensing of all contractors that had contributed the most to enhancing the professionalism of the construction industry. For contractors and consultants, it was the increase in the use of IT that played the most significant role.

Clients perceived industry awards to have the lowest rating in terms of effectiveness. Consultants gave lowest rating to the same measure, and the mandatory requirement of the CPD programmes. Main contractors gave the lowest rating to the increase use of CORENET programmes, while consultants gave it a high rating.

Table 4 Mean rating and ANOVA for Strategic Thrust 1

Variables	Mean rating				ANOVA	
To what extent do you believe the following measures have improved the *professionalism* of the industry?	Whole sample	Clients	Consultants	Main contractors	Sig. level	*F*
Various courses offered by the educational	2.34	2.18	2.39	2.34	0.45	0.79

institutions, professional bodies, and BCA Academy, designed to meet the needs of the industry.					2	6
The mandatory requirement of the Continuing Professional Development (CPD) programmes for the renewal of professional and trade membership.	2.50	2.18	2.61	2.49	0.087	2.463
Industry awards to promote and recognise achievements such as quality of work, productivity, innovation, and green performance.	2.45	2.36	2.60	2.38	0.104	2.280
The increase in use of IT in general.	2.26	2.32	2.21	2.27	0.750	0.288
The increase in use of CORENET programmes.	2.39	2.23	2.20	2.53	0.004	5.598
Progressive strengthening of Contractors Registration System.	2.42	2.23	2.45	2.43	0.460	0.779
The licensing of all contractors (including sub-contractors).	2.34	2.14	2.33	2.38	0.391	0.943

5. Concluding remarks

Efforts to improve professionalism in the construction industry in Singapore have included actions by individual professionals, professional institutions and trade associations, and at the broad industry level, following specific recommendations outlined in the C21 report. The respondents to the field study agreed that C21 had been effective in addressing some of the problems of the construction industry. In their opinion, measures taken to enhance professionalism had been effective. The initiatives under Strategic Thrust One were adjudged by the respondents as being the most effective in the C21 programme. The study also showed that practitioners consider CORENET to have been the most significant achievement resulting from the recommendations of the C21 report.

The findings from the study also indicate that much more can be done in the effort to enhance professionalism in the construction industry. There is a need for holistic co-ordination of the training programmes for professionals. The industry and academic institutions should work together to develop syllabuses that are in line with developments in industry practices and procedures. The implementation of CPD programmes for construction practitioners was considered by the respondents to have been successful. However, there is a need to ensure that the practitioners do not participate in CPD programmes just simply to collect the points, or amass the hours necessary for registration or membership renewal. There should be a system within each firm and institution to ensure that the practitioners retain, actually apply and also share the knowledge gained from such programmes.

The awards given at the industry level in Singapore construction have motivated construction firms to achieve excellence in many aspects. The development and application of IT in the industry has been greatly deepened, and has moved ahead with the use of BIM as the platform to facilitate the integration of knowledge and information. Here, Singapore is among the world's leaders. The licensing of all contractors (including sub-contractors) has also been useful for raising the standards of professionalism of the contractors.

To build on the achievements in enhancing professionalism in construction in Singapore, there should be continuous monitoring and periodic review of initiatives and policies as circumstances change. There should also be effective multi-stakeholder collaboration on performance improvement, involving the industry, government, clients and universities.

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Usability: managing facilities for social outcomes

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Abstract

The paper argues for the development of usability concepts, methodologies and tools, in considering the effects of the built environment from a user, organisational and community perspective, in order to have a positive influence on social outcomes.

Since it was formed over ten years ago, the CIB W111 on Usability has been exploring concepts, methods and tools, developed in the evaluation of all kinds of consumer products, applied to the built environment. In the most recent phase of this work, conducted over the past three years, an international network of partners has collaborated to focus on the usability of learning environments achieving their objectives through a series of case studies and associated workshops. The work has sought to identify and evaluate the ways in which users (and other stakeholders) in projects are involved in decision making about building use and the methods and tools they used to understand, as well as to design and manage the relationship between activities and places.

The paper describes and reviews the development of the field of research on usability. It concludes that the action and use of facilities is strongly related to experiences of the users and thus their possibility and will to perform. People create their own places in the facilities created by professionals and there has to be an approach that opens up for questions like what use and why do an organisation want a specific solution. If professionals and laymen could meet, understand and define the emerging properties of a workplace, they could better manage and design the facilities for improved social outcomes.

Interpretation and analysis of the built environment (and support services) based on how it is socially constructed will enable integration of organisational use and the facilities provided to arrive at an understanding of usability. The concept of usability brings the organisational space to the fore and by doing so supports the actions needed. The paper concludes that usability will not be fully understood without understanding the social constructs of the users – the organisational ecology of narratives or constructs.

Keywords: Usability, organisational ecology, facilities management, social outcomes

1. Introduction

Facilities are defined as tangible assets that support an organisation (CEN, 2006). As such, facilities are managed in an organisational context and the physical assets are embedded in a service to support achievement of the organisation's primary objectives i.e. they are

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business support services. However, whether in the private, public or third sector, facilities should benefit stakeholders in the organisation, in communities and in society.

In the public sector and in social enterprises, social and environmental objectives are explicitly identified and managed. Increasingly, in the private sector, companies now recognise broader corporate responsibilities, not as an optional marketing strategy (as in CSR), but as an essential element of business success, In response, new concepts such as creating shared value (CSV) are being developed, with the need for new ways of evaluating the benefits derived by key stakeholders (Porter, 2011).

The paper reviews the development of the field of research on usability from the last decade. The recent work has focused on how users and other stakeholders are involved in decision making about buildings-in-use and in projects and the available methods that support this.

The paper argues for the development of usability concepts, methodologies and tools, in considering the effects of the built environment from a user, organisational and community perspective, in order to have a positive influence on social outcomes.

2. Usability of facilities

Usability is an intriguing challenge for architects, designers and facilities management (FM) as it concerns how a space, an artefact, is used and the effects of that use. It is an equally challenging concept for managers and organisational strategists as it includes the physical setting in which an organisation performs its activities. This makes usability of facilities a topic at the centre of the relationship between what we do, how we do and where we do it.

Since it was formed almost 10 years ago, the International Council for Building Research and Documentation (CIB) working group on usability (W111) has been exploring concepts, methods and tools, developed in the evaluation of all kinds of consumer products, applied to the built environment (Alexander, 2005, 2008a, 2010a). In the most recent phase of this work, conducted over the past three years, an international network of partners has collaborated to focus on the usability of learning environments achieving their objectives through a series of case studies and associated workshops. They sought to identify and evaluate the ways in which users (and other stakeholders) in projects were involved in decision-making about building use and the methods and tools they used to understand, as well as to design and manage, the relationship between activities and space.

A starting point was the definition of usability in ISO9241–11 (related to the “Ergonomic requirements for office work with visual display terminals”) as “the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use” (ISO, 1998). Usability in the built environment is context dependent, a product of user experience related to the social relations amongst users and to the interaction between users and facilities (Fenker, 2008). Usability has been found to be strongly related not only to relationships between people and physical settings, but also to clear strategies for the organisation of work and the use of facilities. The approach of looking at buildings as a means to fulfil strategic objectives and not only as a way to house people and activities is supported by the work of Becker and Steele (1995), Horgen et al. (1999) and Grantham (2000).

The research has enabled broad conclusions to be drawn about the nature of usability as a concept and its application in the built environment and has challenged the basis of conventional approaches to briefing and post-occupancy evaluation. In summary, the group sees usability as “a cultural phenomenon that can only be improved through a better

understanding user experience, considered as situated action in a specific context" (Alexander, 2008b). Here we elaborate the concept of usability, discuss practical implications for FM and for the development of management processes and raise specific issues for usability research in the built environment. We argue usability as a core concept for managing organisational ecology.

3. Changing the perspective

Studies of the usability in the built environment originate from the field of FM and other disciplines e.g. cognitive psychology, where the focus and interest have shifted from a technical perspective on building quality to the actual use of buildings. This shift represents a significant change from looking at buildings as end products and measuring their technical qualities and functional performance to looking at buildings as a means for the occupying organisations, or core businesses in the prevailing language of FM, to achieve their overall goals and objectives. Another consequence of this shift has been for buildings to be regarded as artefacts that interact with organisational processes and information technologies rather than defined objects (Gjersvik & Blakstad, 2004a, 2004b; Fenker, 2008; Nenonen & Nissinen, 2005).

Much recent effort in construction research in Europe and the UK has been focused on creating a client-oriented, knowledge- and value-based industry. Interest in considering the client and user perspective has increased. A growing number of international research networks have recently been established, including various working groups of CIB. CIB concerns construction and built environments, and many working groups take a sectorial perspective, i.e., they are concerned with the actors in the building process rather than the users of the output, the building. A sector-based perspective is clearly needed in order to develop and stimulate innovation in a field such as construction. However, the logics of use must also be recognized as a governing factor for the planning of facilities rather than a focus on professional knowledge to determine what is most appropriate or what is best practice. The most recent CIB workgroup (W118) was created as a clients and users forum. This is a step towards trying to understand this relationship, albeit in a project context.

However, CIB W111 is the only group that focuses specifically on a user perspective. The application of the concept of usability in the built environment presents a number of key challenges to conventional construction and property perspectives. Nine characteristics of a usability approach have been identified and contrasted with, for example, conventional built environment approaches (Jensen, Alexander & Fronczek-Munter, 2011):

1. User focus—usability puts a focus on the user and the organisation rather than the building.

2. Demand driven—usability recognizes the dynamic requirements of organisations (and communities), derived from the strategic objectives.

3. User experience—usability is primarily concerned with the perceptions of users rather than the intentions of designers and service providers.

4. Contingency quality—usability is contingent on user values rather than an inherent function of the built environment.

5. Context of use—usability considers facilities in the context of use rather than as a project (context of action).

6. Process oriented—usability is considered as a process rather than as product or service provision.

7. Service production—like all services, facilities are co-created by service users.

8. Relationship management—usability implies changing relationships with users.

9. Learning process—usability exchange of knowledge amongst users, managers and service providers.

These characteristics are rooted in a pragmatist philosophy, ultimately derived from Peirce (1905), starting from what works well is what is worth achieving. This is also based in the work of Dewey (1977) and his development of activity-based pedagogy where theory, practice, reflection and action are connected. This approach is based on the development of knowledge derived from use, which is what understanding usability also is about. It is the effect of what is done that is at the core of usability, not the specification of what functions shall be performed. Elsewhere, Granath and Alexander (2006) reflected on some of these theoretical aspects of usability research.

4. User experience—the core of usability

If use is what happens, how do we grasp it, understand it and deal with it? There must be ways of describing and thereby understanding the effects of use; otherwise, it cannot be communicated and reflected upon. Fenker (2008) describes usability as a process that can only be understood as a social construction where the building acts as a sort of stage. According to him, “the artefacts are bearers of a set of possibilities and constraints as well as, most importantly, activity and social practices.” Alexander (2010) argues for greater emphasis on user experience and suggests reconsidering the original triumvirate of efficiency, effectiveness and satisfaction to substitute experience for satisfaction. Recent work on service design and space management draws upon work about experience design (Shedroff, 2011). So far, there is a lack of ability to combine subjective, often qualitatively described user experience with objectively defined standards and requirements of built environment. The user experience is based on individual perceptions and they cannot be objectively measured. However there exist various ways to capture the knowledge of user-experience and create descriptions of the non-measurable, intangible conditions. (Nenonen et al., 2012)

This development is also denoted in service management, where customers’ experiences rather than specification of service gain more importance. Ultimately the customer is considered a co-creator of the service experience. The use of facilities has the same characteristic; we as humans interact with it. Alexander (2012) extends this thinking to consider the co-creation of value in FM, whilst Jensen et al (2011) relates it to the concepts of user driven innovation and co-design and to the idea of lead users (von Hippel, 2005),

One approach to explain the concept of usability in a way that makes it easier to understand and use for practice is presented in the USEtool handbook (Hansen et al 2011). Usability can be understood by focusing on:

- For what? What objectives should be achieved? And what activities actually take place?

- For whom? It is important to define which user groups are in focus, as there are several potential user groups to take into account.

- Where? Users' experiences should be related to space or place. In usability evaluations there is a need to relate users' experiences to specific physical surroundings. The definition of usability clearly underlines that usability is dependent on context and specified users' perception and experiences

- Why? Discovering factors that enhance/inhibit effectiveness is not sufficient. The next step is to understand why. This is essential when the knowledge acquired is to be applied in order to generalize and provide knowledge for the benefit of later projects, or to improve existing solutions.

Usability evaluations are based on different user's experiences and assessments on how well the buildings perform regarding different parameters. A building's performance can never be seen or understood in isolation from an organisational and technical perspective, as those aspects interact and influence each other. Discussing use implies a view on who is the user, and one has to be critical of conventional concepts of users. Olsson, Blakstad and Hansen (2010) suggest a tendency to oversimplify the way that users are addressed and challenge the predominant assumption that there is only one group of users. They identify categories of users and their roles at different stages of the building life cycle. They highlight different user roles and perspectives at different project phases. The perspective that is applied determines which user groups are included in a planning process or discontinuities in user involvement. In a usability perspective, different tools for usability analyses may be needed when studying usability from different user perspectives. This opens up a debate on value beyond value management and it brings culture and governance into the discourse. Who is a user and why are they a user? Whose needs and interests should be at the core of usability analysis and guide possible design?

Themes that have been central to usability research were reflected in the chosen theme of the CIB work group W70 on FM conference in São Paulo— FM and the Experience Economy—following Pine and Gilmore's (1999) seminal work in service marketing. Da Graca (2010) argued that this should now be the focus of FM responsibilities and stressed the need to open the way to demand management focusing on the user experience. Professionals working with facilities need to understand user behaviour, user needs and user experiences and need to manage and systematize the user experience. There is a need to learn how to understand and design experiences as good FM briefing leads to effective design. There are necessary tools but they need to be put to work. He suggests that research in this area is essential and that FM practice should focus on the user experience, looking at the demand side, managing experiences and putting the resources to work.

This challenge is illustrated in a study following the implementation and use of tools for usability evaluation in FM and Corporate Real Estate organisations. Blakstad and Hansen (2012) found that this had limited effects on practice in most of the organisations they studied. There where however exceptions. The cases with the most successful implementation, which had actually led to new practice and new "contexts of use", had used the most resources on implementation, and continued the research relationship with the researchers to develop own staff with competence to carry out the evaluations. The study suggested that focus on usability in practise can only be drivers for development in cases where key players have awareness and competence, and where the need for change is seen as urgent enough to justify the amount of resources needed to both analyze the situation and implement the change.

Contingent user values are not easy to explore using conventional techniques such as post-occupancy analysis, and there have been calls for multi-method approaches (Blakstad,

Hansen & Knudsen 2008) and a greater range of methods for understanding user experience (Alexander, 2008a). This is highly important as there must be methods that manage to bridge from the facilities professionals, architects and engineers to the everyday user without imposing professional knowledge in such a way that the user's perceptions are depreciated.

5. The usability brief—a key instrument in facilities management

Much recent effort in the research has focused on developing tools to operationalize the usability concepts, particularly for briefing and evaluation. To date, those who work in the building industry have not been sufficiently interested in evaluating the use of buildings they have helped to create. Does the building function as intended? Are there problems related to function or room use? How efficiently is the building utilized? How satisfied are the users? By not evaluating the use of buildings through asking such questions, vital opportunities for improvement and for coming up with new solutions have probably been missed.

Traditional briefing	**Inclusive briefing**	**Usability briefing**
Concerns new building/construction	Concerns all client/user needs in developing facilities	Concerns user needs in existing facilities
A definite phase at an initial stage of construction	A continuous process with changing focus in different phases of building life cycle	A continuous process at different phases during occupancy
An expert based information collection	A guided learning and dialogue process	A co-learning process
Users mainly involved as data sources	Users actively involved as part of a corporate change process	Users as co-producers
The result is a brief, i.e. a requirement specification	The result is acceptance of solutions based on a brief	Brief as an evolving 'bulletin board'

Table 1: Traditional, inclusive and usability briefing

A usability perspective has consequences for methods used in design and planning today. Briefing has been highlighted in several studies as a bearer of clients' and users' needs and requirements and a key instrument in getting what one wants. The recent work by CIB W111 on usability has similarly highlighted the importance of briefing as a means to achieve usability. Jensen et al (2011) have compared the characteristics of the concept of usability briefing with traditional briefing and so-called inclusive briefing In Table 1.

However, these findings raise a further series of issues and a possible agenda for future research and have interesting implications for the way we think about briefing, particularly when usability is seen as a contingent quality rather than as the inherent functionality of the physical environment.

Hudson (forthcoming) argues that much of the existing work on briefing is based on premises that it can be reduced to a rational process, that it is part of a finite project, that the final outcomes of this project are buildings or other physical facilities and that user requirements have an external objective existence that can be captured in the briefing

process. He goes on to suggest that the usability work suggests the limitations of these premises and argues that a new approach to briefing may be necessary.

This approach might be characterized by an emphasis of briefing as creative exploration of possibilities rather than requirements capture, a focus on the social construction of requirements and their evolution over time and a focus on human satisfaction rather than physical facilities. The professionals' capability to integrate and translate becomes important here and implies a responsibility to manage user needs and feed them forward to the subsequent project without losing the understanding of the social processes from which the facilities have emerged.

6. Usability appraisal—how to understand and interpret the use of facilities

Usability evaluations are based on different user's experiences and assessments on how well the buildings perform regarding different parameters. By considering a building as a tool, we should be interested not only in how the building itself functions, but also how the building impacts value creation in the user organisation. The user organisation should ask itself: what do we want to achieve? What do we want the building to contribute? How can our premises create added value for the organisation? We have seen that many user organisations have little awareness of those aspects. Instead a building is merely seen as floor space or workplace, without much consideration: a return for the rental. For instance, a business that wants to stimulate co-operation and learning should be interested in how the workplace supports these goals; a kindergarten that wants to encourage involvement by the children should consider how the facilities promote their mastery of their environment. Over the past 5 years, a EuroFM research group has explored the concept of added value of FM, with a strong connection to the CIB W111 Usability group (Jensen et al. 2012).

For building owners and users, an increased focus on usability represents both a challenge and an opportunity. The challenge lies in the fact that the user organisation may want quick changes and a high degree of customization to achieve maximum effectiveness. If not handled wisely, this may result in unnecessary tailoring for tenants, which can drive costs up and be difficult to change later. In this type of situation it is essential that solutions are flexible so that they can readily be changed as needs change. At the same time, an increased focus on effectiveness represents an opportunity for building owners and FMs, as having expertise and premises that can contribute to increased customer satisfaction may be an advantage.

A building's performance can never be seen or understood in isolation from an organisational and technical perspective, as those aspects interact and influence each other. Hence, usability is complex and has been described as a "wicked problem" (Blakstad et al., 2008). Such problems are characterised by no definitive formulation of solutions, and they are open to multiple interpretations (Rittel & Webber, 1973). The solution is simply the one that in a certain context is most satisfactory. According to Blakstad, addressing "wicked problems" requires multi-method strategies using a triangulation of methods and evaluations with multiple perspectives.

This aligns with findings from studies showing that evaluations work best when they are based on several methods and aspects, depending on objective, purpose, focus, competence and resources (Frechtling, 2002). All this implies that usability evaluations are complex, that there is a need for simplification and that the evaluator possesses both theoretical and practical knowledge and skills (Baird, Gray, Isaacs, Kernoghan & McIndoe, 1996). Blakstad et al. (2008) describe how different methods and tools were explored and

tested according to their relevance and validity for evaluation of usability in several Norwegian cases. An important discussion is whether the results or findings from those evaluations can be considered as valid and reliable, and whether context dependent knowledge from usability evaluations can be feed forwarded to new projects or be generalized and added to a more generally applicable body of knowledge (Hansen et al, 2010). One may always discuss the external validity of qualitative methods. According to Halvorsen (2008) the main question is not if results may be generalized but if knowledge can be transferred to other settings. As pointed out earlier, few of the available methodologies aim directly at evaluation of usability related to organisational objectives. However, they found that many traditional research and evaluation methods had potential to be developed for the purpose of usability evaluation.

Hansen, Blakstad and Olsson (2012) review usability evaluations and the feedback on users' experiences of their environment. The value of such evaluations for feed forward into new projects or improving existing facilities lies mainly in the ability to understand users' experiences and to translate them into adequate products and solutions. Consequently, the results of research related to evaluation should be quickly and easily accessible to clients, designers, decision-makers and others involved in the building process. At its best user feedback provides a learning process for different stakeholders. Kärnä et al. (2009) stress the importance of a systematic approach and of continually improving the flow feedback.

7. Usability of learning environments—a thematic focus

Over the 10 years of W111 research the working group has compared case studies from different sectors, first of all focusing attention of the usability of workplaces and then broadening to include industrial, educational and healthcare environments.

From 2009 to 2011 the work of CIB W111 on usability has mainly focused on the usability of learning environments (Alexander, 2010a; Arge, 2010; Jensen and Oesten, 2010). The lead was taken by the UK, in collaborative work with the Centre for Effective Learning Environments (CELE) at the Organisation for Economic Co-operation and Development (OECD), in a project to develop tools for evaluating the quality of educational environments (EQES). Research by PriceWaterhouseCoopers (2010) concluded that school context must be taken into account when assessing the impact of a school building program and that, new buildings alone, are insufficient to change pupils' attitudes and behaviour. They suggest that the real challenge is to link the transformational agenda to changes in pedagogy and leadership in schools.

This view is supported by the Norwegian work on usability. One of the case studies showed a university college with a very high score on building performance and coloration between program and completed building, but still showed a lack of usability due to change in pedagogic, increased student number, lack of changing culture among the department. In another case we found a high degree of pride and high academic score among the pupils, in spite for a building performing really badly (Hansen et al., 2006).

Reporting on evaluation research conducted in the UK, Alexander (2010a) argued that school facilities should be considered in the context of the communities they serve and as a prime means of transforming education. Effective learning environments successfully combine appropriate social and digital environments with the physical environment (Beard, 2012). Creating quality learning environments, which are more broadly accessible in the community, can also play a catalytic role in regeneration. To improve usability, the parallel processes of pedagogy and facilities planning must be reconnected, users must be empowered and communities must be offered the opportunity of managing their assets. And

professionals must utilize a usability perspective concerning for whom and why. The majority of conventional evaluation methodologies, particularly Post Occupancy Evaluation (POE) and Practitioner-focused Facility Evaluation (PFE) methods and tools, fail to address strategic objectives, consider buildings out of context and tend to focus on the characteristics and performance of the physical environment, rather than on the effects on users and on benefits realization. The evaluation of schools must take account of three key dimensions according to their role in the development of sustainable communities, in educational transformation and in the quality of the learning environment.

Assessing the usability of learning environments against these criteria, using appropriate research-based methods and tools, will require the development of new skills. It also suggests the need to develop different relationships amongst key actors in co-production processes. This is a challenging agenda for the FM of learning environments.

The objective of FM is to provide the setting and services that support the effectiveness of organisations that contribute to the development and creativity of the occupants and provide community benefit. The key is establishing the strategies and processes that connect effective utilisation of the physical, environmental and human resources to create positive outcomes for all stakeholders, through the whole life of the facilities. Stakeholders include owners, occupiers and operators of the facility, all service users and providers, the local community and representative agencies.

Seen in this way, FM is the brokerage of processes amongst all stakeholder interests and between stakeholder constructs. Myerson (2012) and Vischer (2012) argue that, in the experience economy, learning and co-creation are key processes. Elsewhere, Beard (2012) and Thomas (2012) describe learning itself as a complex process conducted via conversation, in a broad sense, including symbolic change and reflection or silent conversation and kinaesthetics.

8. Management for usability

Jensen (2010) has suggested that a focus on buildings in FM is concerned with how the corporate needs for facilities can be provided and optimized in both a short- and long-term perspective. Therefore, every phase of the life cycle of buildings is important. He proposed that continuous briefing and continuous commissioning are two interrelated concepts that, together with the concept of learning buildings, can be used to integrate the management of buildings and usability. Just as learning organisations need a specific form of management, where traditional hierarchical structures are removed and a shared vision is defined and accepted, so learning buildings need a similar specific form of management.

The management tasks to obtain usability include formulation of visions, strategies and requirements for the long-term development of buildings in the planning phase; involvement of users in defining needs and requirements and deciding on design solutions in continuous briefing; and on-going monitoring of performance and usability to capture new needs and requirements for changes during the use phase of buildings. In short, FM is about connecting use and space. FMs should be the obvious profession to take on this important management role in close collaboration with the top managers and users in the organisation.

9. Framework for use—a structure for discourse

Recent reflections on Nordic contributions to the usability research have led to the introduction of a framework – USE*frame* - to conceptualize contextual dimensions of usability. The framework is based on a perceived need to bring usability studies into one

structure and to relate what had been done in the different studies. This led to a discussion about a framework that also would enable the positioning of previous research by the research team members as well as the positioning of other research related to usability.

A framework developed by the research team is illustrated in Figure 1 and is further discussed by Lindahl, Hansen, Nenonen and Blakstad (2012). It illustrates steps in a process of understanding and mapping use to support action in projects or FM processes. It is a framework that can be used to describe processes as well as to map and relate projects or studies.

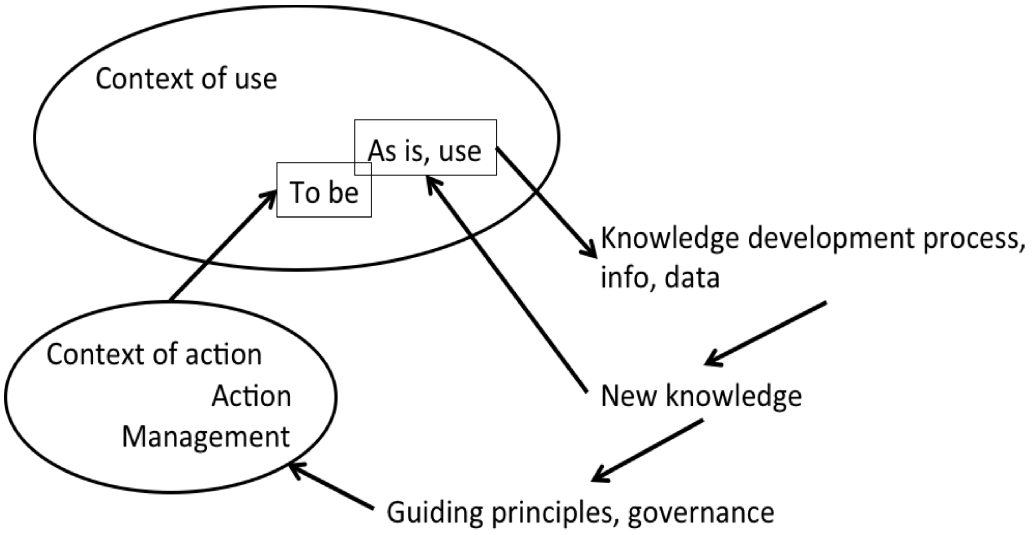

Figure 1 USEframe

A typical FM loop could be from “as is, use” via development of new knowledge, supported by the USEtool and back to daily use, i.e., to “as is, use” in “context of use.” This is an iterative process of change and possibly improvement. New knowledge can also be forwarded in a structured form, in a proprietary information system, to projects and action to create new workplaces via projects in the “context of action” domain. This then results in plans for new or changed facilities, the future use, “to be.”

Based on the research carried out in Nordic FM and usability projects we argue that there is a substantial amount of research and development (R&D) concerning facilities in use that already today allow for the possibility of sustaining usability of facilities. However, these are not clearly related and there is a mix between management-oriented research that focuses on the “context of action” and usability-oriented research that focuses on “context of use” and subsequent development of knowledge and briefing.

The framework USE*frame* provides a possibility to map and discuss this material (Hansen et al., 2012; Lindahl et al., 2012). With the creation of CIB W118 clients and users and the previous CIB workgroups W65 Organisation and Management of Construction, W070 FM and Maintenance, W096 Architectural Management and W111 Usability, understanding and delivering what the users need appears well covered. However, much of the research has focused on methods and processes.

While this is relevant, we already know that clear information, participation and knowledge dissemination is beneficial. While continued development of methods and processes is needed, there is also a lack of R&D of theory concerning users and their activities in the facilities the construction and FM sectors deliver. As much as researchers like to practice nearness in cases, there is now a need to step back and reflect in order to develop a theory to sustain the field of understanding the effects of facilities in use.

The delivery world of methods and processes has its own set of social constructs - i.e., it is one ecology; the user world is another. Usability research needs to think through the mind and narrative of the user world. Mental and cognitive maps are the source to understand this. Macdonald (2012) shows that, in a healthcare setting, strategic FM can be seen as a translation between the two. Higher usability was delivered by FMs who reached out to relate to the users and translated user requirements into appropriate service delivery.

10. Usability—managing facilities for social outcomes

The paper has argued for the development of usability concepts, methodologies and tools, in considering the effects of the built environment from a user, organisational and community perspective, as an essential approach for managing facilities for social outcomes.

On one hand usability has its significance in the relationship between people and building. On the other hand the usability is connected to various co-operation, communication and co-creation processes between different people. Nevertheless the usability research so far has been able to map and frame processes and methods in connection to usability of built environment. The service design approach provides more insights for capturing the user experience. Evidence for usability is based on user experience, may be linked to discussions on evidence based design, which may be seen as a way of designing based on actual use, i.e. evidence for what really works given a certain context.

This paper suggests that further research in the field of user orientation of the built environment is strongly needed. The overview of the area shows that there are many different approaches which vary in theoretical foundations, methodologies and stage of development, but they are in most cases not incompatible and they use many similar research methods. Further research should focus more on direct interactions with and involvement of users and mostly qualitative research methods are needed. It is important to distinguish between different types of users and apply methodologies involving users both as individuals and in groups and organisations.

Jensen et al (2011) have adapted the USEframe to make suggestions for future user oriented research (Fig 2) with a distinction between the three areas: Developing, Finding and Explaining.

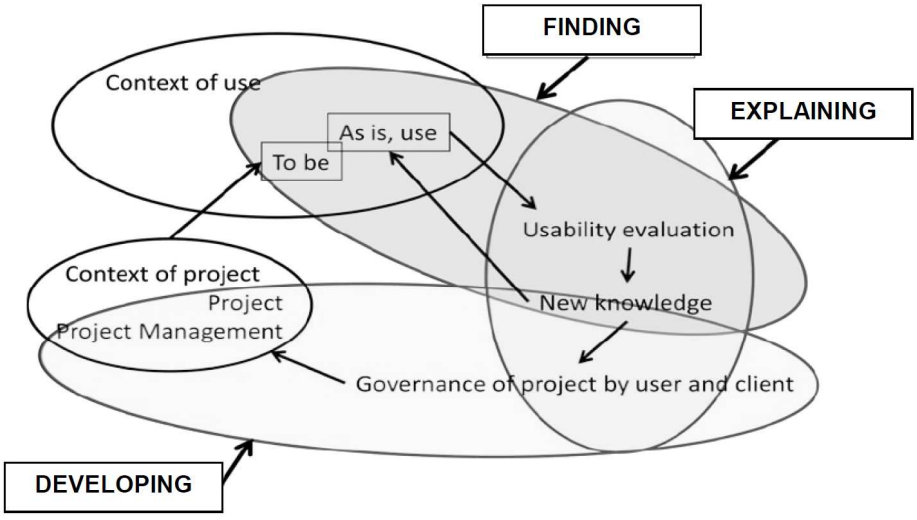

Figure 2 USEframe – cyclical processes

The development of knowledge and tools within USE*frame* will help structure the further implementation of usability knowledge and tools in practice. A crucial question is how

research can contribute to, on one hand, strategic/practical development in organisations and, on the other, the design and construction processes. USE*frame* illustrates this and aims to support discussion at the interface of research and practice. This will then also address the validity, reliability and generalizability of usability research.

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Measuring Enrichment Liability in the Context of Unfinished Construction Projects

Aimite Jorge[1]

Abstract

Most aspects of construction projects mainly fall under contractual regime. However, when things go wrong such as when the project is abandoned for various reasons, they may create two different scenarios: A contract that is breached and a fixed structure left on the land of one party, which constitute an incomplete benefit transferred. The transfer of such benefit is initially made with a legal ground, but that ground has since ceased to exist. If some aspect of that benefit cannot be recovered under a contract, enrichment rules may be competent to solve the problem. How to measure the different aspects of that enrichment is however a problem that may have different interpretations according to different conceptions of the foundations of enrichment liability in a particular legal system. This article explores the measure of enrichment in such cases of failed bilateral contracts scenarios working from South African perspective. It argues that in cases of failed bilateral contracts generating an enrichment situation, sanctioning a dual measure of enrichment in a legal system may be an appropriate avenue.

Keywords: Remedies, Unjust Enrichment, Failed Bilateral Contracts

1. 1. Introduction

Where parties enter into a contractual relationship, it is not always the case that the contract will be performed without mishaps. The source of that mishap may be a previously undiscovered situation or a subsequent event. But it is germane to a contractual relationship that it is a risk taking endeavour in the sense that the parties to such an endeavour will have expectations as to the outcome of the contracting process, some of which may not be fulfilled. Where the contractual relationship comes to a halt for any unforeseen reason, the courts, in the absence of prior agreement to the contrary, will play the role of risk allocator. Cases of unfinished construction projects are illustrative of this risk allocation situation. In these cases what exactly happens is that a risk of loss has emerged or materialized and it must be decided by the court where that risk lies. Depending on how the agreement comes to a halt, the situation may create an unjust enrichment of one party at the expense of the other. However, although the availability of an enrichment remedy does not depend on a breach of contract, nevertheless there is usually an overlap between enrichment and contractual liabilities where the breach of contract does result in an unjust enrichment.[1]

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In this paper I explore the issue of enrichment liability in failed bilateral contracts in the form of abandoned or unfinished construction projects. The aim is to analyze the extent to which unfinished construction projects transcend the realm of mere contract breach, as they are prone to creating residual enrichment claims. Depending on the particular circumstances of each case, failed bilateral contracts generating an enrichment liability should be scrutinized more carefully when it comes to measuring the extent of the enrichment. The analysis and discussion is mainly worked out from South African perspective but with wider view in mind.

The discussion is structured as follows: First, a very brief excursus of the notion of ineffectiveness of contracts due to breach and frustration of purpose. Second it describes what an unfinished project is and uses an illustrative example of an unfinished motorway among others. Third, brief description of various payment/pricing methods and their possible implications. Fourth, a brief analysis of the measure of enrichment, and finally the conclusion.

2. 2 Ineffectiveness of contracts due to breach and frustration for 'impossibility.

The situation of an ‘enrichment claim’ arising from breach of contract in so far as the measure of recovery is concerned may be complex and ambivalent. It may depend on whether the claim is for services rendered pursuant to a contract which is subsequently terminated by breach, or whether it concerns other contractual situations. There is also no single encompassing view on the issue for all legal systems. Amongst the practical answers is the view that the calculation of the enrichment relief in cases of breached contracts should be made by reference to the market value, because a contractually based limitation is flawed for two reasons: (i) first because such 'limitation may not reflect a number of benefits financial and otherwise, that may flow from the ability to complete performance’ (Maddaugh and McCamus (1990) pp427-428) [2],. Secondly, such measure may deprive the innocent party of ‘an opportunity to reduce the anticipated losses to be sustained by full performance through a possible range of cost reduction techniques’.

Another practical view contends that in cases of contracts for services, there should be two different approaches in cases of breach. It first should depend on whether the alleged breach is related to what is sometimes described a breach a warranty or a breach of a condition. If the defendant merely breached a warranty, that is to say, the defendant’s breach of contract does not substantially deprive the plaintiff of what he expected to receive, then, the solution is that neither party is excused from further performance (McInnes (2002) pp 163, 214).[3]

In contrast, if it is a breach of a condition, that is to say, the defendant’s breach does deprive the plaintiff of what she/he expected to receive (a fundamental breach), then, the innocent party should generally have a choice as follows: first, he may affirm the contract and insist upon completion of the agreement as initially contemplated. If he does so, he must then fulfil his end of the bargain. However, he is also entitled, under an action in breach of contract, to claim compensatory relief with respect to losses arising from the defendant’s act of breach. secondly, as alternative solution, he may terminate the contract and thereby release both

parties from the need to perform any primary obligations that remain outstanding. If he exercises this later option, he again may have a choice as follow: he can bring an action in breach of contract and claim compensatory relief with respect to losses arising from the defendant's act of breach. Alternatively, he may be able to bring an enrichment action and claim restitution of any benefits that he conferred upon the defendant (Waddams (1999) ch.16).[4] Despite the above said, normally even if the claimant terminated the contract on the basis of the defendant's breach of a 'condition' (fundamental breach), the plaintiff cannot escape the consequences of a bad bargain by means of contractual relief. He is generally entitled to choose between expectation damages and reliance damages. Obviously each option is compensatory in so far as it aims to repair a loss. The former pertains to benefits that the plaintiff expected to receive under the contract, whereas the latter pertains to losses that the plaintiff incurred as a result of relying upon the agreement. In either event, however, relief will normally be refused to the extent that the claimant entered into a losing contract (McInnes, (2002) 52 *Univ Toronto* LJ pp211-212); Byan (2007) pp150-155.[5]

If termination is not due to breach, but due frustration of purpose on account of impossibility, then the solutions of common-law systems differ from the civilian-legal systems. One of the main differences between the legal systems on the doctrine of impossibility of performance comes down to the primary remedy for breach each system subscribes to. On the one hand, if a system provides that its primary remedy is specific performance,(Schwartz (1979) 89 *Yale LJ* p271)[6] then, as a logical consequence, if performance of the obligation becomes impossible, the obligation is discharged.[7] That is so because the courts cannot enforce an obligation that is impossible – *impossibilium nulla obligatio*.[8] On the other hand, if a system subscribes to the damages (compensation) approach as the primary remedy for contractual breach, save exceptions, then on the occurrence of the '*impossibilium*', the value can always be given, unless it is entirely infeasible.

3. 3. What is an Unfinished Construction Project?

An unfinished construction project normally is a building (or any other architectural structure such as a bridge, a road or a tower) where construction work was either abandoned or put on hold at some stage in the process. In extreme cases, the project may actually exist in a design form only. Some unfinished projects in design forms are in a blueprint or a white print alone.[9] But the concept of unfinished construction projects in this paper refers to an actual building or structure which either has been started but been abandoned during construction; or is actually being built, but the process is constantly delayed or the progress of the work is at the speed of a snail. Sometimes a construction or engineering project remains unfinished at various stages of its development. Examples of unfinished works abound around the world and there is no need to single out one example, save to say that some buildings or structures are partially constructed and can be used in their current unfinished state or forms, while others remain mere shells. In some interesting cases the projects are intentionally left with an unfinished appearance.[10] But other projects or works are in the process of a near-perpetual construction.[11] A home example in South Africa of an unfinished structure is the Cape Town freeway Eastern Boulevard12 in Foreshore. This Cape Town project was conceptualized as part of a ring-road in the 1960s (Morris (1951)[13] and has yet to be completed. Construction was halted in 1977 allegedly at the time that there

was no justification in terms of traffic demand for the completion of the inner viaduct. Close to the 2010 Soccer World Cup in South Africa residents were asking what response the city would give to visitors of such an unfinished project in a very touristic area leading to the Cape Town world cup stadium. Unofficial justifications given varied but all seemed to agree that the motorway would not be finished any time soon due to Cape Town municipality budget constraints (Kane (2011)[14]. In its current design form apparently there are no private companies willing to take up the project to finish it either at a reasonable cost.

For the purpose of this paper the descriptive example of the unfinished Cape Town Eastern Boulevard freeway will partially serve to illustrate some features of the construction-contract model that might have been used in that process and other related problems. Recent announcement in the news state that the Cape Town freeway structure is finally now at the mercy of University of Cape Town civil engineering students to come up with innovative ideas, new designs and proposals to resurrect the project by 2014.[15] Obviously when the students' ideas are put into proposals and plans, new tenders will be invited again after an existing plan idling for 30 years. This Cape Town freeway gives us insight into common problems facing unfinished projects. Such problems usually have roots at the inception stage. Nonetheless, the aim of this paper is on enrichment measures on failed bilateral contracts. One will simply look at the model of construction contract used in such projects to understand the implications on the remedies.

One of the questions that arises in such examples is whether ordinary allocation of risks in breach of contract resolved all the problems or whether the unfinished work might have produced an enrichment situation for one of the parties or both. Before addressing specifically this question, a quick look at some prominent payment and pricing methods in construction contracts used within the industry today.

3.1 3.1. Lump sum payments and unfinished projects.

One potential problem that can create enrichment scenario in unfinished project is a contract for a lump sum and cost-plus payment.

Amongst the functions of construction contracts is serving as means of pricing construction. At the same time the contracts also structure the allocation of risk to the various parties involved. Because of this, normally the owner is a position to decide the type of contract to be used for his/her project and to set forth the terms in a contractual agreement. For this reason it is important to understand the risks of the contractors associated with different types of construction contracts. In the process of contracting, the parties my have chosen a specific pricing models to their contract such as a lump sum contract,[16] unit price contract, cost plus fixed percentage contract,[17] cost plus fixed fee contract,[18] cost plus variable percentage contract, target estimate contract or guaranteed maximum cost contract. A detailed discussion of each of these pricing methods is beyond the scope of this paper. A single illustration of the architectural services may suffice to highlight the main point for this paper.

Normally architects (and other specialty services) are often remunerated a certain percentage of the overall cost of the project.[19] Sometimes other pricing criteria are used, as just mentioned above. The question that arises here is to what extent such percentage of the project is fully due to the architect/engineer where their work and role in the project, for example, would involve not only supplying the drawings for the contractor, but also ensuring that those drawings are implemented as specified in the contract documents such as a continuous observation role of the contractor's work at different stages? Is the full percentage due if the project is unfinished?

To illustrate this point let me consider the following: In many construction projects, earthwork covers foundations and underground plumbing, while a gypsum board covers ceilings and wall framing.[20] In a normally progressing construction project the timing of such observations would be different. The task of earthwork and underground plumbing would be at the initial stage of the construction. The task of observing the gypsum board and wall framing at a later stage. That is so because if the architect were to observe the work after the components are hidden would defeat the purpose of observation. Despite these tasks being at different stages of the project, an architect may have billed the owner a lump sum for the whole work. When the project is left unfinished, the problem may arise as to what sum is the owner liable in the process. If the owner is liable for the full percentage amount of the original overall cost of the project, part of that sum would be paid to the architect when it was not due. Conversely, if the contract provided that the architect would only be paid for the observation task at the end of the project, the owner would be left with a standing structure that may constitute an actual enrichment a benefit acquired. In the first example, there is a possibility of partial payment, or if deposits were already made, a set-off could be used for the part performance. But that does not solve the whole problem.

3.2 3.2. Unfinished projects transferred to new investors

When unfinished buildings can partially be used in their unfinished state or where the project was initially publicly funded and the right to the structure is directly transferred to investors either to finish the project, or to completely alter it, several problems may develop. Some projects, such as for example apartment buildings, may have had certain buyers pay in advance of construction for their future apartments in order to secure the best spots in the building. When that project is abandoned or progresses extremely slowly and at some stage the right to the building is directly transferred to an investor, original buyers who might still be willing to keep the same apartments may find themselves paying significantly extra amounts for essentially the same product they bought earlier. In these situations, a double sword problem arises. If the new investors willing to finish an unfinished building project opt to stick with the previous buyers at the same price they bought the apartments at the project's inception stage, the investors stand to lose because the market price might have shifted significantly at that stage. If the buyers relinquish their right to the previously bought property in an unfinished building, the investor may gain an undue benefit for keeping the structure that is more valuable than they will refund to the buyers. What are the remedies in these circumstances?

Can the buyers simply be satisfied for a claim for damages when the building project goes unfinished? Do damages solve the whole problem in these circumstances or are there residual remedies available to the buyers?

And where buyers had paid in advance but the currency significantly fluctuated between the time the building was abandoned and the time the rights to the building are transferred to a new investor, and the currency is now weaker, there arise the possibility of an unjustified enrichment of one of the parties.

3.3 3.3. What can be gleaned from the situation of unfinished construction projects?

In effect the situation of unfinished construction projects is to an extent a reflection of a losing contract. There is no unanimity about what exactly a losing contract entails. The expression ‘losing contract’ itself is ambiguous. There, is however, some convergence: all legal systems abhor applying enrichment liability to contractual relationships. Such an aversion of the legal discourse in applying enrichment rules to contractual settings usually protects the contract itself. The rationale of not applying enrichment liability is to prevent opening unnecessary loopholes where one of the parties might be tempted to terminate a losing contract thereby subverting the regime of risk allocation voluntarily undertaken under the agreement. The difference however with unfinished projects is that the contract has in effect come to an end. What is really at issue is winding up the consequences of such a failed bilateral contract. The fact that the work has been left unfinished, obviously shows that *prima facie* the contract was breached, because there is no reasonable person who would enter into a contract to leave the project unfinished.

Be that as it may, in principle, all contract breaches occur because the contract is a loser for one side, although not all such contracts are considered ‘losing contracts’. Using illustratively using an economic concept of profitability, sometimes it is observed that ‘not all ‘losing contracts’ are jointly unprofitable, and not all jointly unprofitable contracts are ‘losing contracts’’ (Cohen (1994) 80 *Virginia LR* p1270).[21] A 'losing contract’ is one in which the breaching party is not the ‘loser’ but the party who appears to be advantaged by the contract; that is to say, the (apparently) wrong person breaches’. The problem can occur, ‘in contracts that are jointly profitable and contracts that are jointly unprofitable. However the restoration remedy is normally appropriate in both cases’.[22] In losing contract cases the court need not decide whether the contract is jointly profitable. The joint profitability determination matters when the court must choose between expectation and reliance.[23]

The interrelation of contractual and enrichment actions in the losing contract scenarios is however a difficult issue.[24] Basically the theoretical difficulty encountered in determining whether or not an enrichment claim ought to be available in the case of a losing contract lies in the fact that the question can be approached from different perspectives. It 'may be viewed in terms of contractual principles only or from the point of view of unjust enrichment or a combination of both’ (Harker (1980) *Acta Juridica* pp84-85).[25] If the problem is approached exclusively in terms of contractual terms, then unfinished projects should simply

be seen as mere cases of rescission or cancelation of a contract. In this case the reliefs available under these forms of breach should suffice to satisfy the aggrieved party.

On the other hand, 'a defaulter's contention that the aggrieved party's negative expectancy be taken into account certainly will lack appeal where he has been given nothing, except a broken promise, in exchange for the performance received'.(Palmer (1978) § 4.8)[26] Therefore, in such cases considerations of unjust enrichment become applicable. Since justice does not require the party in default be permitted to retain an amount (or value-benefit) for which he gave nothing, merely by reason of the fact that the aggrieved party would have lost that amount had he (the defaulter) performed the contract which in fact he did not perform. In essence, if the issue is viewed solely in terms of unjust enrichment, the focus is laid instead on the assets unjustly held by the party in default. Because considerations of enrichment do not emphasise the aggrieved party's benefits and losses under the contract, he is therefore entitled to restitution, in kind or in value, of the performance rendered unless justice requires otherwise (Harker 1980) *Acta Juridica* pp 86-87); Du Plessis (2012) pp387-389).[27]

In essence the discussion of unfinished projects is really about risk allocation.[28] In pursuing the task of risk allocation in such cases the obvious starting point will always be to consider the parties' own intention in relation to the risk at the inception of the agreement. Such intention may be ascertained by reference to the terms of the contract. Normally it will be assumed that a rational individual entering into reciprocal exchanges will have made arrangements for events which create a risk of loss. (Visser (2008) pp173-174).[29] Some parties are naturally risk averse; others are risk neutral, and yet others are naturally risk takers. Accordingly, those who are risk averse may have made arrangements through the use of different mechanisms to ward off any supervening risk. Ordinary mechanisms are the use of 'force-majeure' clauses, exemption clauses, the designation of a term as condition or a warranty or a cancellation clause (Oughton and Davis (2000) pp246-247).[30] These and like devices serve to allocate the risk of loss according to the terms of the contract. If the other party was prepared to accept the risk , a normal risk taker, the reason may be that he believed to have been in a better position to cover the risk either by insurance or otherwise. If such party is less risk averse than the other party and was prepared to take the consequences if the risk did arise, then he should suffer the consequences. But that is not necessarily clear in the cases of unfinished construction contracts. In these cases, it is also necessary to take into account the type of contract used and other ancillary issues.

For example, the parties may have made provisions for the use of a CMAA contract style. The CMAA model is mostly used in complex projects ((Metha (2010) pp13-38)[31]. This Construction-contract method makes a general contractor redundant as it envisages an independent construction manager (CM). In this CMAA contractual model, the owner retains a CM (construction manager) as the owner's agent to advise on several issues, including costs, scheduling, site supervision, site safety, construction finance administration, and the overall building construction. It must also be observed that the CM is not a contractor, but simply a manager who plays no entrepreneurial role in the project (unlike the general contractor, who assumes financial risks in the project).

In the CMAA construction-contract model the owner usually awards multiple contracts to various trade and specialized contractors, whose work is coordinated by the CM (Metha 2010) p 23; Pressman (2012).[32] Hence using this model, for example, the structural framework of the building may be erected by one contractor; masonry work done by another, interior drywall work by yet another, and so on. In this model, each contractor is referred to as the prime-contractor who may have one or more subcontractors.

Thus, the owner, by assuming part of the role of the general contractor, eliminates the general contractor's mark-up on the work of the subcontractors. The owner may also receive a reduction in the fee charged by the architect for contract administration. Although these savings are partially offset by the fees that the owner pays to the CM, there can still be substantial savings in large but technically simple projects.

The CMAA construction contract model is particularly attractive to owners who are knowledgeable about the construction process and can participate fully in all of its aspects, from bidding and bid evaluation to the closeout phase. However, this advantage comes at a price. In the CMAA construction contract model essentially occurs that the owner assumes liability risk. In the design-bid-build (Meyers (2004) pp118-121); Metha (2013) p23) [33] model such liability risk is assumed by the general contractor. Again, because of the multiple prime-contractors and subcontractors the CMAA model does not localize the ultimate responsibility at single point among the various prime contractors. In this model, each prime contractor has a direct contract with the owner. Because of such direct contract with the owner, the CM (*contract manager*) does not have much leverage to ensure timely performance. Therefore, the likelihood of a project being left unfinished also increases.

From the above example it becomes evident that it is important to construe the language of the contract when it fails. When the project is left unfinished it is important to ask whether the problem is one of ‘impossibility’ or frustration or of mistake at the inception stage. For example, if the parties did make provisions for an event which would not otherwise be regarded as frustrating event, the court may ask whether the relevant provision is worded so as to cover the event of an unfinished project.

4. `5. Conclusion

The discussion above highlighted that an enrichment claim can arise from failed bilateral contracts. However, where an enrichment claim arises from those scenarios, one must be careful whether mutual exchanges have occurred. In the cases of unfinished construction projects the issue comes down to how the parties allocated the risk at the inception stage of the contract. If there was no clear allocation of the risk, an important consideration in the risk allocation process will be to establish what party is the least cost avoider. In this regard, a relevant factor is that one of the parties to a contract may have been in a better position than the other to prevent the risk of loss from materializing, in which case, rules of risk allocation may suggest that this is the person who should accept the risk of loss.

In the same vein, it is said that a person who brings about a frustrating event through his own actions cannot rely on the rules of frustration of contract, on the basis that the law does

not give relief in respect of self-inflicted frustration. Similarly, a person who could have performed his contractual obligation in some other perfectly reasonable manner may be required to accept the risk of loss and will not be able to treat the contract as frustrated when the manner of performance which he had contemplated is no longer possible. This principle is sometimes reflected in the rule that an external event must frustrate the common intention of both parties to the contract. Put differently, in cases of failed bilateral contracts generating an enrichment claim, the measure of enrichment is normally that which was received and not necessarily that which survives or remains in defendants' hands at *litis constatio*. Loss of enrichment or change of position in these cases is normally not applicable.

ENDNOTES

[1] The concepts of unjust and unjustified enrichment have different meanings, but in this paper they will be used interchangeably when they refer an enrichment claim as a whole.

[2] Maddaugh P and McCamus J (1990), *The Law of Restitution*, 1st Edition pp 427-428.

[3] McInnes M (2002) 52 *Univ. Toronto LJ* 163, 214 footnote 181.

[4] Waddams S, *The Law of Contract*, 6th Ed. (Toronto, 2010) ch. 16.

[5] McInnes M (2002) 52 *Univ. Toronto L J* 211-212.

[6] See Schwartz A (1979) 89 *Yale LJ* 271. For view see Holmes OW (1998) 78 *Boston Univ*. *LR* 699 (originally published in 1897); Posner R, *Economic Analysis of Law* (5th Ed. Boston, 1998). See also *Bank of America Canada v Mutual Trust Co* (2002) 211 DLR (4th) 385, para. 31).

[7] Where a contract becomes impossible of performance after it has been entered into, the general rule in (Roman law) is that it then ceases to be binding (*Wilson v Smith* 1956 (1) SA 393 (W) at 396ff.

[8] D. 50.17.185 and also D. 45.1.140.2; *Wilson v Smith* 1956 (1) SA 393 (W) at 396 and *Bischofberger v Van Wyk* 1981 (2) SA 607 (W) at 610-612.

[9] An example of this is the California-Santa Fe Bullet train Project that was never built; its costs at the time was estimated at US$ 2.1 Billion, but according to many other estimates, it would have escalated to more than US$ 5.3 Billion by the time the project would have been completed.

[10] Intentionally leaving a building in unfinished state was more the follies of Europe in the 16th and 17th Centuries.

[11] An extreme example of these perpetual constructions is Antoni Gaudi's Sagrada Familia in Barcelona, Spain, which has been in construction for 120 years and is now projected to finish in the year 2026.

[12] A completed section of Easter Boulevard is now partially renamed Nelson Mandela Boulevard.

[13] Morris SS, (1951) *Metropolis of Tomorrow: Report of the City of Cape Town, City Engineer Department.* Morris was the Cape Town City engineer from 1949 to 1977 and was influential in conceiving the Eastern Boulevard.

[14] Kane L (2011) "Building the Foreshore Boulevard: The Politics of Freeway 'Artefact'" SATC 2011 at repository up.ac.za (university of Pretoria) [accessed 28/11/2012]

[15] City of Cape Town News: Cape Town freeways and future (all available online

http://futurecapetown.com/wp-content/uploads/2012/09/aereal_freeway.jpg

http://futurecapetown.com/2012/10/finishing-the-foreshore-freeways/#.UK-V6YeTyNA

http://futurecapetown.com/tag/cape-town-freeways/#.ULh-jKyTyNA [accessed 28/11/2012]).

[16] In a lamp sum contract, he owner in effect assigned all the risk to the contractor. The contractor, in turn, can be expected to ask for a larger mark-up in order to cater for unforeseen contingencies.

[17] Cost plus fixed percentage contract is normally used for constructions involving new technologies or in cases of extremely pressing needs such as in the urgency of construction of military installations. In this type of contract, the owner usually assumes all risks of costs overrun, because the contractor will receive the actual direct job plus a fixed percentage. In these cases the contractor has little incentive to reduce job cost.

[18] In this type of contract, the contractor receives the actual direct job cost plus a fixed fee. The contractor will have some incentive to complete the job quickly since its fee is fixed regardless of the duration of the project. The downside here is that the owner still assumes the risks of direct job cost overrun while the contractor may risk the erosion of its profits if the project is dragged on beyond the expected time.

[19] Current Fees tariff in South Africa were published on 2 December 2011 for the year 2012; *Government Gazzette* N. 34788; Board Notices 194 of South African Council for the Architectural Profession, applicable 1 January 2012.

[20] International Building Council (2009) *International Construction Code* 101.

[21] Cohen GM (1994) "The Fault Lines in Contract damages" 80 *Virginia LR* 1225, 1270-1271.

[22] Cohen (supra) 1270-1271.

[23] Cohen (supra) 1271-1272.

[24] Palmer GE (1978) *The Law of Restitution* § 4.9.

[25] Harker JR (1980) "The Nature and Scope of Rescission a Remedy for Breach of Contract in American and South African Law" *Acta Juridica* 61, 84-85.

[26] Palmer GE (1978) *The Law of Restitution* § 4.8.

[27] Harker JR (1980) The Nature and Scope of Rescission as Remedy for Breach of Contract in American and South African Law" *Acta Juridica* 84; Du Plessis (2012) *The South African law of unjust enrichment* pp 387-389).

[28] Because the issue is really about risk allocation in these cases, and if there is an enrichment claim, it arises out of a failed bilateral agreement, the claim in these cases should always stick to the value received ant not necessarily opting for value remaining.

[29] Visser DP (2008) *Unjustified Enrichment* 173-174.

[30] Oughton D and Davis M (2000) *Sourcebook on Contract Law* 246-247.

[31] CMAA stands for '*construction-manager-as-agent*' while CMAR (which is not described here) stands for '*construction-manager-at-risk*'.). Other contract models are DNB (*design-negotiate-build*); DBB (*design-bid-build*); DB (design-build); IPD (Integrated-project-delivery). For further details see Mehta M et al (2010) *Building Construction Principles*, *Materials and Systems*, 2nd Ed 18-33.

[32] Mehta M et al (2010) *Building Construction Principles* (supra), 2nd Ed 23; Pressman A, "An Integrated Practice in Perspective. A New Model for the Architectural Profession" (2012) posted at http://archrecord.construction.com/practice/projDelivery/0705proj-1.asp (retrieved 15 Nov 2012).

[33] Mehta M et al (2013) *Building Construction: Principle, Materials and Systems* 3rd Ed 21; Meyers D (2004) Construction Economics 118-121.

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A Case Study of Construction Productivity after the 2011 Christchurch Earthquake in New Zealand

Kelvin Zuo[1], Suzanne Wilkinson[2], Jeff Seadon[3]

Higher productivity is desired in the construction market. The recent earthquakes in Christchurch have resulted in changes in the way that the construction sector works. The changes in the sector present an opportunity to study the effects on improving productivity and to apply the lessons learnt to the wider New Zealand construction environment. This paper reports on initial results of a pilot case study in Christchurch over residential buildings utilizing a composite approach. The research proposes to examine productivity of different residential buildings for each phase (e.g. deconstruction, rebuild and ongoing maintenance) and a number of buildings in each phase at different stages (e.g. floor, outside walls, roof, etc.) for case studies. Interviews in the research with different stakeholders involved in the whole life cycle of residential buildings (e.g. architects, engineers, builders, etc.) identify potential areas for productivity improvements. The study aims to answer what legislative and process changes have been made for Christchurch deconstruction, rebuild and on-going maintenance and its short-term and anticipated long-term effect on productivity.

Keywords: Construction Productivity, Christchurch, Case Study

1. Introduction

The construction industry is a significant part of the overall economy. According to Arditi and Mochtar (2000), the construction industry accounts for 6–8% of an economy's Gross Domestic Product (GDP). An improvement in construction productivity performance not only would produce direct benefits in the sector, but could also provide substantial cost savings. An increase of 10% in the UK construction labour productivity is equivalent to a saving of £1.5 billion to the industry's clients, sufficient to procure approximately 30 hospitals or 30,000 houses per year (Horner and Duff 2001). In New Zealand, the building and construction sector contributed around 4% of the GDP in 2010, almost the same as agriculture. This is less than in other countries, with the sector representing 7% of GDP in Australia, 8% of GDP in the UK and 9% of GDP in the USA (Building and Construction Productivity Partnership 2012). The workforce of construction industry in New Zealand represents 8% of those in employment. In the last 10 years, 14% of all new employment in New Zealand has been in the building and construction sector (Building and Construction

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Productivity Partnership 2012). A Government Productivity Taskforce recently found that construction sector productivity in New Zealand is declining and is low compared with other industries and other countries (Department of Building and Housing 2009).

The Building and Construction Productivity Partnership has developed a set of indicators believed to affect construction productivity improvement in New Zealand at firm, sector and national level (Building and Construction Productivity Partnership 2012). Factors believed to affect productivity such as increased investment in education and training, more innovation and better integrated supply chain have the potential to lead to construction productivity improvements. Figure 1 shows the productivity indicators and the impact of these at the organisational level. The Productivity Partnership is committed to improving construction productivity by 20% by 2020, by making improvements to the ways in which the construction industry operates under different indicators. Canterbury offers a unique opportunity to study changes in productivity because the region is undergoing such rapid changes to its construction sector following the earthquakes. The region is actively seeking ways to become more productive as the rebuild intensifies.

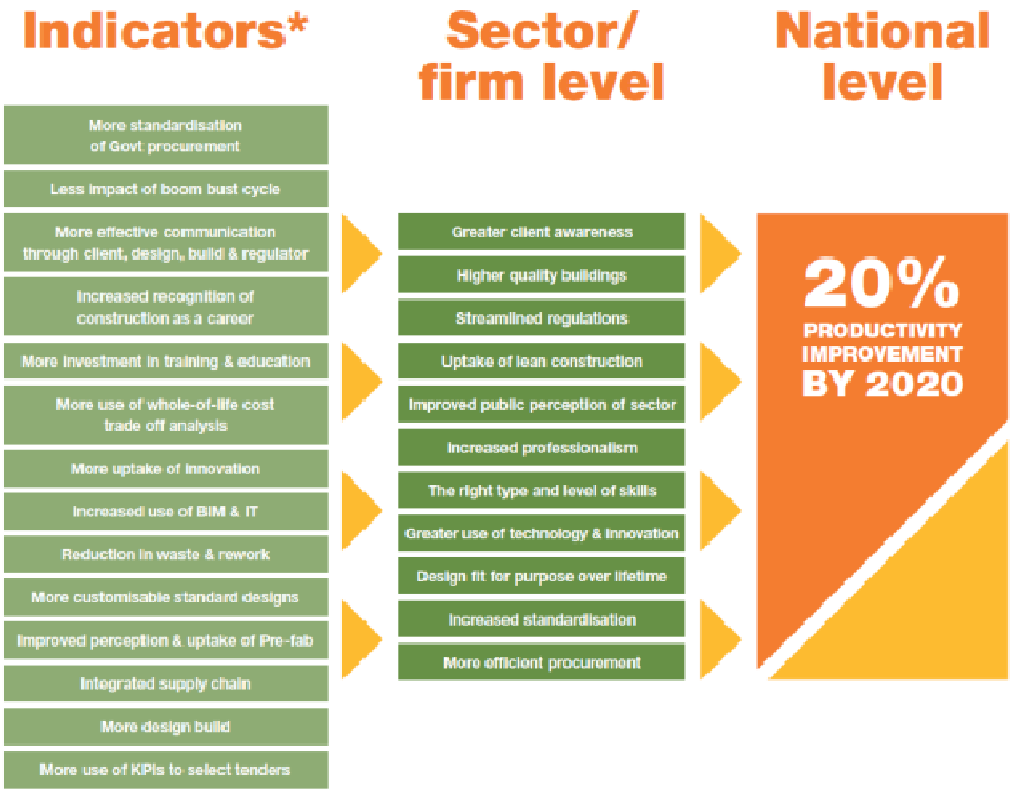

Figure 1: Key drivers of productivity improvement in New Zealand (Building and Construction Productivity Partnership 2012)

The 2010 and 2011 earthquakes in Canterbury have resulted in changes in the way that the construction sector operates, in particular in some of the processes being used. The rebuild programme may offer opportunities for improvements in some of the factors, such as more standardisation, more innovation and better waste management. This paper presents findings from a research project which examined changes to the construction sector in

Canterbury and the effect of these changes on construction productivity. The paper highlights positive and negative changes and recommends the positive lessons are applied beyond Canterbury, so that the whole of the New Zealand construction sector can benefit from potential productivity improvements. The research reported here focuses on the productivity changes in construction components and processes as experienced through construction residential projects in Canterbury after the series of earthquakes.

2. Research Design

The paper covers the following areas: 1) The impact of recent legislative/regulatory changes on construction productivity in Canterbury; 2) Whether construction process changes have been made in Canterbury, and the effects of any changes on construction productivity; 3) The construction productivity factors considered to be most important by interviewees. Case studies of different residential buildings at different life cycle phases were carried out to get a whole of life perspective as shown in Figure 2. Interviews were carried out with construction stakeholders involved in the full life cycle of residential buildings.

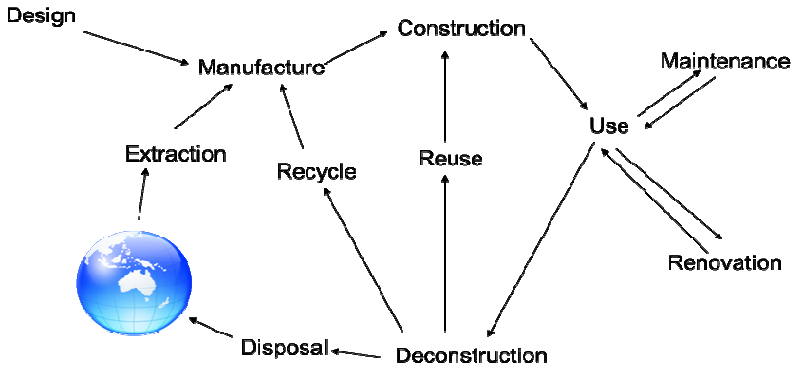

Figure 2: The Whole Life Cycle of a Building (Seadon 2012)

The principle for the selection of construction projects for case studies in this research was to cover the Canterbury residential building sector in deconstruction, rebuild, and maintenance phases. The interviews were conducted with key stakeholders involved in the projects. Interviewees include representatives from the contractor, the consultant/designer, and the government authority. Each interviewee provided the following information: 1) Interviewee and project information; 2) Legislative/regulatory changes – the top five legislative changes which have the most impact on construction productivity were identified (the impact could be either positive or negative); 3) Process changes – Information on the process changes during the Christchurch deconstruction, rebuild and on-going maintenance were provided. The top five process changes in terms of their impact on construction productivity were identified; 4) Productivity factors – The top three factors under each productivity category: external, internal (labour), and internal (management) were identified. The top five productivity factors from all categories irrespective of which group they belonged to were listed; and 5) Long-term effects – Information on the long-term effects of the top changes in legislation and processes on construction productivity were identified by interviewees based on their experience as were the practices that have the potential to improve construction productivity.

The interviewees were asked to describe a typical deconstruction, rebuild, or maintenance project they are currently operating in Christchurch. The locations of surveyed projects covered the whole of Christchurch area, with the majority of them in more severely damaged eastern and southern suburbs. Most of the reconstruction projects were under the Design and Build (D+B) arrangement for residential buildings, with minority were adopting the prefabrication method (factory built then transported and assembled on site). The typical duration of the project ran from 3 to 5 months, with around 10 people required for the building process. The exceptions were projects managed by the larger contractors, with scopes ranging from 3 to 5 years and investment in hundreds of millions of dollars. The contract price of a residential rebuild project varied with an average of NZD $353,000. A total of 14 interviews were conducted in the first two weeks of July 2012. Interview profiles can be found in Appendix 1.

Specific reference to a known project is intentionally avoided to ensure the anonymity of the interviewees. The information/data is collected in a consistent way across different types of projects and is presented in the same unit/format for comparison. The selection of interviewees is one per project. The selection of interviewees in this research was based primarily on their specific role/function and experience in the construction industry. It covers almost every industry functions as demonstrated in Figure 2, the whole life cycle of a building, with the majority of them on design, construction, and maintenance. Besides the government official, the interviewees have an average of more than 16 years' experience in the construction industry, with the longest one reaching 35 years. Less than 30% of them were assigned to their current position after the first Christchurch earthquake on Sep 2010, more than 70% of the interviewees were already in a senior management role before the earthquake happened.

3. Research results

3.1 Legislative and regulatory changes

The legislative and/or regulatory changes that have been made as results of the 2010 to 2011 Christchurch Earthquakes are summarised in the Christchurch Earthquake Recovery Authority (CERA) website (CERA 2012). They include changes to legislation that have been made in response to the earthquake, including Orders made under the Canterbury Earthquake Recovery Act 2011, and Orders and Regulations made under the Canterbury Earthquake Response and Recovery Act 2010 and under other legislation. Among those, the ones that are directly related to the on-going Christchurch deconstruction, rebuild and maintenance are mainly addressing the following aspects to facilitate: 1) The Earthquake Commission (EQC)'s repair of residential land and property in Canterbury; 2) Reserves to be used for response and recovery efforts; 3) Councils to deal with dangerous building situations (Building Act related issues); 4) Resources Management Act related issues; and 5) Other relevant issues such as the rating valuations, balancing rebuilding and protecting historic places, or registration of imported heavy vehicles for recovery purposes, etc.

Some of the legislative/regulatory changes listed on CERA website (2012) that are not directly related to the purpose of this research (deconstruction, rebuild, and maintenance process) are not considered. However, they might indirectly influence the recovery of the

Canterbury built environment, such as those in relating to social security, education provision, energy, transportation, local government, and tax administration.

From the research for this project, the top five legislative changes which have the most impact over construction productivity (the impact could be either positive or negative) were categorised as follows: 1) Canterbury Earthquakes Recovery Act 2011 (CERA Act) related issues, such land zoning, geotechnical report requirements, etc.; 2) The Earthquake Commission's (EQC) regulations around release of the funding for reconstruction projects and engineering assessment; 3) Building code changes; 4 Health and safety regulations; and 5) Orders in council/regulations facilitating the deconstruction process, such as allowing temporary accommodations on site, logistics allowing shifting wide loads, and fast-track demolition

The most mentioned legislative change was the CERA Act 2011 relating to land zoning issues, different foundations and geotechnical reporting requirements. The impacts felt from the CERA Act 2011 were: slowing down reconstruction; bureaucratic red tape around zoning and the slow process of obtaining geotechnical and engineering evaluations. The positive potential long term effects of CERA Act 2011 were thought to be seen in improvements made to the land through taking time to be thorough with evaluations. The second most mentioned change was EQC's policies in relating to the release of funding for reconstruction. Most of the interviewees regarded the EQC related regulation changes as negative on construction productivity. The significant volume of the work contributed to the slow process. The comments received were: work not being able to start until EQC have released payouts; tightening of EQC sign-off which were slowing processes; lack of communication from insurance and EQC. However, it was also felt that realistic expectations were needed of EQC and the insurance process because of the number of people available to undertake the work compared with the volume of work required. The relationship between EQC and insurance companies and its impact on homeowners needed to be further improved.

Building code changes were identified in the interviews as key changes affecting productivity. However, unlike CERA Act 2011 and EQC, most of the interviewees (75%) who mentioned the building code changes regarded them as necessary, more practical (such as allowing more space for slab deflection parameter), and improving the industry, and were positive about their impact on construction productivity long-term, if not immediately. Code changes create a more resilient building system against future events. However, there was concern expressed at the different building requirements for foundations which would slow the rebuilding process and required different equipment to undertake the work. Building code changes created different relationships with different subcontractors, and required new understanding of the legislative requirements for different types of work.

Health and safety regulations were affecting productivity reported by the interviewees, including scaffolding requirements and personal protection policies increasing thus slowing the work. Comments were received that health and safety regulations were making the reconstruction process take longer and costing more, but were necessary. Deconstruction and recycling related regulations reported by the interviewees were facilitating the re-build process. Deconstruction and recycling related regulations such as relocating houses,

transportation, and fast-track demolition, moving loads day and night, were beneficial according to responses. Ratings of overall impression of legislative and regulatory changes experienced so far on Christchurch construction productivity as either positive (increase productivity), neutral (do not affect productivity, or decrease initially but will benefit productivity in the long term), or negative (decrease productivity) is shown below.

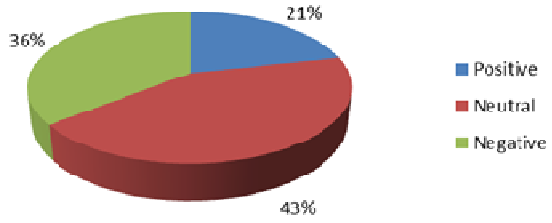

Figure 3: overall impression of legislative and regulatory changes on Christchurch construction productivity

3.2 Process Changes

The construction process changes experienced during the current recovery in Christchurch were identified. The top five process changes in terms of their impact on construction productivity were listed as: 1) Local councils' consenting process; 2) The availability of skilled labour; 3) EQC and insurance; 4) Unresolved land issues; and 5) Internal process changes.

More than half of the interviewees ranked local councils' consenting process as top in their impact list on construction productivity. The majority of comments received were negative about the experience, feeling the process has slowed the rebuild. The comments referred to taking a long time to obtain consents; fear of the Council being unable to cope; impractical requirements; confusion; a business as usual process being used; and the costs of consents increasing. New staff in Council positions and the lack of clarity around procedural requirements were part explanations for the delays. Adequate and advanced planning for consents and inspection were practical suggestions to contractors to avoid delays. Increased difficulty in recruiting skilled labour and qualified engineers for rebuild was seen as impacting productivity. Interviewees believed that as the Canterbury reconstruction is still at a very early stage, the shortage of skilled labour would become more significant especially if related issues, such as temporary accommodation needed for construction workers, are not managed well. Additional issues rose with skills and labour included the potentially incompatible labour skills with different build methodologies and the integration of different cultures within the construction team.

Insurance companies and EQC were generally seen to be having a negative impact on productivity. Comments such as requiring itemised quotes and reducing rates were impacting on time and cost. Homeowner exhaustion was commented on as affecting the rebuild, including having to engage with reappraisal requirements or having problems getting the insurance resolved. Homeowner expectations needed to be better managed.

Disagreements between EQC's assessment and the insurance company's assessment on their portions of the settlement payment were further compounding the problem, slowing the rebuild. Sorting out multi-event assessments, early assessment and later assessment differences were causing problems and slowing the rebuild process. Unresolved land issues, such as land zoning status and subsequently different building requirements for different types of foundation, are interconnected with insurance, local councils' consenting processes, and legislative changes. Unresolved land issues are a result of the legislative changes following the Canterbury earthquakes. Without resolution the Council cannot issue consents and EQC and insurance cannot settle claims. Clearer information on the land repair expectations is required. Within the interviewees' organisations changes have been taking place that affect productivity, these are referred to as internal process changes. Examples given were: 1) Creating own in-house design/ engineering consultant team; 2) Longer design and planning processes; 3) Changes in business operating; and 4) Changes in procurement methods.

Because of the difficulty of finding engineering consultancy firms to undertake work, one contractor reported that they formed their own in-house engineering team to support the increased amount of new work. Longer design and planning processes are being experienced due to the increased volume of work and more reporting requirements in the process. These were referred to by some interviewees from the contractors' side as "internal bureaucracy" of additional reporting requirements in the design and planning phase to the designer and council. With workload increasing, subsequently changes have been experienced on the way a typical privately-owned construction firm, with less than 5 employees, operates its business. Changes such as: procedural changes, i.e. moving from chasing an inquiry to choosing work; dealing with different stakeholders, such as the insurers; more up-front costs; more time and more communication; better budgeting and more networking. The procurement methods used in the Canterbury recovery, especially on large scale projects, are changing from the traditional design-bid-build model to more collaborative and integrated arrangements, such as the Alliance model. This might not be observed in the relatively smaller size projects in residential market yet, but the overall desire for more efficient procurement methods is reported. As work progresses there are expectations for more efficient processes through the Project Management Offices (PMOs) making procurement faster. Overall impression from the interviewees of the impact of the process changes experienced on construction productivity as either positive (increase productivity), neutral (do not affect productivity, or decrease initially but will benefit productivity in the long term), or negative (decrease productivity) are presented in Figure 4.

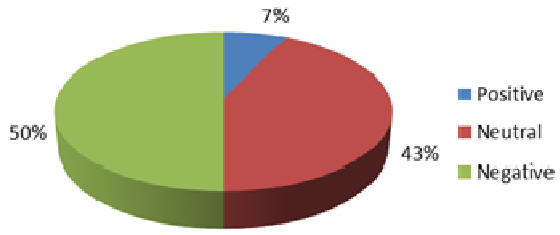

Figure 4: Overall impression of process changes on Christchurch construction productivity

3.3 Productivity factors

Productivity factors were categorised into 3 major groups: 1. External – factors affecting productivity which were beyond the control of management; 2. Internal – Technological (Labour) factors affecting productivity – factors within control of management, focusing more on the technology and labour; and 3. Internal – Administrative (Management) factors affecting productivity – factors within control of management, focusing more on administration.

3.3.1 External factors

The top 3 factors identified in External Category - factors affecting productivity which are beyond the control of management, were: 1st: Possible aftershocks; 2nd: Availability of skilled labour; 3rd: Size and complexity of the project. The most common external factor affecting productivity was the influence of continuous aftershocks on reconstruction progress. 93% of the interviewees chose "possible aftershocks" as an influencing factor, and 43% ranked it top of their list. The uncertainty associated with these aftershocks brings slow progress on land zoning, damage assessment, and insurance settlements. The availability of skilled labour was ranked as the second most important external factor influencing construction productivity in Christchurch. The third issue ranked was the size and complexity of the projects, 86% of the interviewees chose size and complexity of the projects and 43% ranked it within the top 2 in the external category.

3.3.2 Internal - Technological (Labour) Factors

The top 3 Internal – Technological (Labour) factors affecting productivity – which are factors within control of management, focusing more on the technology and labour were: 1st: Quality of craftsmanship; 2nd: Quality control and quality assurance practices & Wages and benefits; 4th: Worker attitude and morale. Quality is critical for project success. Decreasing quality decreases productivity as rework and waste become problems. Proper processes are required to make sure quality is to the required standard but training to meet the standard was required, especially as the rebuild increases pace. Standardization of building methods, materials used, quality assessment methods, model houses, etc. or generally, standardisation of the construction industry, was thought to offer a way to control and improve quality. Worker attitude and morale was believed to be an important factor influencing construction productivity. When asked about the current situation, interviewees gave more negative comments than positive ones on worker's attitude and morale based on their direct experience. There is a mix of factors that are driving this, such as the anticipation from the workers (of better wages and on-going contracts) and the lack of actual reconstruction jobs. Frustration has arisen from perceived low pay rates and the feeling of the repair and rebuild work not being well organised. Poaching between companies and constant changes in companies can affected company morale. It is happening and is feared that the situation will get worse.

3.3.3 Internal – Administrative (Management) factors

The top 3 factors identified in the internal – administrative category are: 1st: Changes in drawings and specifications; 2nd: Lack of cooperation and communication between crafts; 3rd: Lack of detailed planning. 64% of the interviewees selected "changes in drawings and specifications" and 36% ranked it as the top productivity influencing factor under the internal-administrative category. The lack of cooperation and communication between crafts leads to difficulties in coordinating subcontractors and ranked as second most internal productivity influencing factor. Lack of detailed planning ranked as third most influencing administrative factor affecting construction productivity.

3.3.4 Overall ranking of productivity factors

The most important issues influencing construction productivity in the recovery were ranked in the following order: 1st: size and complexity of the project; 2nd: possible aftershocks & availability of skilled labour; 4th: wages and benefits; 5th: quality of craftsmanship. The focus should now be on those issues most likely to bring productivity improvements, such as improving the availability of labour, improving wages and benefits, focussing on quality and worker morale during the rebuild.

3.4 Applicability of lessons learnt in Canterbury to other parts of New Zealand

From the research, some of the lessons of the Canterbury rebuild could transfer to other parts of New Zealand. The New Zealand industry could collectively benefit from Canterbury recovery experience in terms of increased construction productivity in the long term. For instance, the alliance model could encourage more collaboration and partnership arrangements. Relationships between regulators, the construction industry and the insurance industry have built up quickly in Canterbury, and any positive experience, such as better understanding and collaboration among these parties could be transferred to other parts of the country. Lessons in speeding up processes and accelerating projects could be transferred to other parts of the country. Training of a workforce could be a benefit to the future New Zealand construction industry. Bringing in overseas employees with different skills, cultures and education will affect the construction industry and could lead to potential long-term productivity improvements.

3.5 Reaching a 20% increase in productivity by 2020

43% of the interviewees were unsure about the goal of reaching 20% increase in productivity by 2020, with positive and negative answers equal. No obvious common themes or patterns were observed, but most of the negative comments were concentrating on issues such as the lack of resources, and the lack of willingness to change from New Zealand's 'fragmented' construction industry. In order to reach the goal of 20% increase in productivity by 2020 the research found that there needed to be fundamental changes to the way the industry operates, such as new ways of thinking, constructing, educating and new processes. Suggestions were made by the interviewees on the practices believed to have the potential to improve construction productivity in Canterbury and New Zealand. The following six areas

were offered: 1) Prefabrication; 2) Management training for the construction sector – e.g. lean project management principles; 3) Chance for collaboration and new ideas to be accepted; 4) Training of more skilled labour; 5) Standardization; and 6) Innovation and technology- education and trialling.

Prefabrication for reconstruction is well supported by the interviewees to increase construction productivity because it generally makes rebuild cheaper and quicker. But the difficulties in achieving a greater market share of prefabrication in New Zealand were acknowledged. Shifting the view and perception of people of a prefabricated building from ones of a 1980's classroom to a new modern sustainable residential building is one of the challenges for prefabrication. Proven quality record about the prefabrication houses and the availability of commercially available materials (in large quantity, competitive price, etc.) for building/assembling prefabrication houses are needed. However, the market for prefabrication still appears small so the rebuild offers a chance to use prefabrication on a wider scale bringing productivity improvements to the construction industry. The prefabrication is not being called for because of a lack of understanding and acceptance of the idea among the potential homeowners. Canterbury rebuild provides a chance to trial new ideas such as prefabrication. Demo houses and villages were built up in Christchurch (organised by Prefab NZ) to showcase new building ideas hoping the demand will increase.

The Canterbury reconstruction offers a chance to grow and expand management training for the construction industry. Adopting new management techniques such as lean project management to deliver better value with less waste was mentioned as a potential positive impact. In addition, the recovery provides the opportunity to try new ideas and more collaborative contractual arrangements into the construction industry, such as the alliance model for project delivery. Typically the alliance model is used on larger and more complex projects where there is a large amount of uncertainty as the size and duration of the project has to justify the investment in setting it up both commercially and culturally, and the participating organisations need to develop and nurture a culture of collaboration throughout the system beforehand in order to manage such projects. These criteria fit in well with the Christchurch reconstruction situation and are reflected in the interviews. Companies reported the rebuild had provided the environment for sharing building ideas, sharing and solving problems and improved networking. The trust experienced and more collaborative relationship established during the rebuild process will benefit normal time construction in the future.

The more significant skilled labour shortage is a concern for the reconstruction, so smarter ways of training and educating are required to produce more skilled labour. This necessitates better wages and benefits to attract and retain labour. There will be productivity gains felt across New Zealand in terms of better skilled and qualified labour. Standardization to speed up the construction process could bring productivity improvements. Standardization in design, quality control, building methods and procedures were all possibilities for productivity improvements. A greater level of research and development into more innovative, fast build processes would increase productivity. The general impression from the answers to the last part of the interview was that the recovery provides a chance for trialling more innovative technologies.

4. Conclusion

The Canterbury earthquakes have presented an opportunity to change the construction industry and improve construction productivity. This paper highlights the main areas of the negative impact on construction productivity caused by some of the legislative and process changes for the industry in Canterbury. Legislative changes have forced consideration of different ways of operating. The majority of the criticism was seen around land zoning issues, councils' consenting process, and EQC and insurance related issues which had the effect of slowing down the reconstruction process. The long term effects of those legislative and process changes on construction productivity in Christchurch will bring opportunities for innovation, more collaboration, and better value for money. Capturing changes to processes and improvements in construction productivity during the rebuild will have significant positive impact on productivity in New Zealand.

Lessons learnt from Canterbury experience in terms of disaster preparedness will no doubt be applicable to other parts of the New Zealand. The majority of interviewees believed that the construction industry will benefit from Canterbury recovery experience. Possible productivity improvements could be made from improving the availability of skilled labour, improving quality, focussing on worker morale and encouraging innovative procurement practices and these improvements will also benefit New Zealand. Gain in productivity will come from industry standardization in design, better building methods, such as prefabrication and better management training. Fundamental changes to businesses that transfer the knowledge gained from legislative and process changes to ensure integration and consistency of interpretation across the whole supply chain will be required.

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Appendix 1

The information of interviewees and associated construction projects are summarised below:

	Interview #	1	2	3	4	5	6	7
interviewee info	Job category	Architect	Engineer	Project Manager	Project Manager	Project Manager	Project Manager	Govt Authority
	industry functions of the company	Design, Construction, Renovation	Construction, Maintenance	Construction, Recycle, Maintenance	Design, Construction, Maintenance	Design, Construction, Maintenance, Deconstruction	Construction, Maintenance	n/a
	Position	design director	Project Engineer	Managing Director	Director	Project Director	Branch Manager	
	Position yrs	6	3	10	1	2	1	1
	Construction industry yrs	8	5	25	6	12	35	n/a
Project info	Location	CHCH East	CHCH	CHCH North	CHCH South	CHCH East	CHCH South	n/a
	Main works	Residential D+B	Residential and commercial	Prefab House	Residential D+B	Infrastructure around residential buildings	Residential	
	Duration (months)	4	36-48	3	4~5	60	2	
	People (direct/indirect)	30 (10/20)	n/a	10 (4/6)	10	180 (130/50)	10	
	% completed	5%	30%	10%	85%	10%	90%	
	Total contract price	$475,000	n/a	$200,000	$446,000	$450,000,000	$171,000	
	Schedule status	on schedule	n/a	ahead of schedule	on schedule	on schedule	on schedule	
	Cost Status	on budget	n/a	on budget	on budget	over budget	on budget	
	Contract type	D+B	charged to EQC/Management contractor	Prefab D+B	D+B	Alliance	fixed price, package deal	
	Accidents	0	0	0	0	minor first aid	0	

	Interview #	8	9	10	11	12	13	14
interviewee info	Job category	Project Manager	Project Manager	Project Manager	Engineer	Project Manager	Project Manager	Project Manager
	industry functions of the company	Design, Construction, Maintenance	Design, Construction	Design, Construction, Renovation	Design, Construction	Deconstruction, Disposal, Recycle	Construction, Maintenance	Design, Construction, Maintenance
	Position	CEO	Managing Director	Director	Engineer	Branch Manager	Managing Director	Manager
	Position yrs	8	6	5	4	3	8	4
	Construction industry yrs	22	15	20	8	20	24	11
Project info	Location	CHCH South	CHCH	CHCH East	CHCH East	CHCH	CHCH	CHCH East
	Main works	Residential	Residential, New dwelling	Residential	Residential	Residential and commercial	Residential	Residential
	Duration (months)	3	3	4	4~5	1	3~4	3
	People (direct/indirect)	10	8	12	16	9	12	10
	% completed	30%	15%	60%	10%	80%	30%	60%
	Total contract price	$315,000	$400,000	$450,000	$460,000	n/a	n/a	$275,000
	Schedule status	on schedule	on schedule	on schedule	on schedule	Late	n/a	on schedule
	Cost Status	on budget	over budget	on budget	below budget	over budget	n/a	on budget
	Contract type	D+B	D+B	package	variation of NZS3910	package	n/a	package
	Accidents	0	0	0	0	0	n/a	0

Interviewees and project information

Toward a Typology: cost overrun causes framework in infrastructure projects

Fahad Saud Allahaim[1] , Dr. Li Liu[2]

Abstract

The cost overrun of infrastructure projects potentially poses significant financial risks to the investment parties involved. Substantial cost overrun has been identified in infrastructure-project data from across 20 nations in five continents. Studies, in fact, show that the average cost overrun of infrastructure projects presents substantial fiscal risk (Flybjerg & COWI, 2004; Odeck, 2004; Flybjerg et. al., 2009). Yet, over the last several decades, the magnitude of cost overrun of infrastructure projects has failed to improve, suggesting that no significant learning has occurred in mitigating its detrimental effects.

The possible causes of cost overruns are numerous. They are dependent upon the unique characteristics and context of individual projects. According to Flyvbjerg et al. (2004), the two main causes of cost overruns are: optimism bias and strategic misrepresentations. Other studies have identified a spectrum of various causes for cost overruns. These include: technical factors such as lack of experience; the project size, design error, overall price fluctuations, inaccurate estimations, and scope changes (Love et al., 2011; Memon et al., 2011). The spectrum of possible causes makes the planning and management of projects especially challenging.

The objective of this research is to propose a conceptual framework to classify the causes and corresponding approaches to the management of cost overruns along pre-defined dimensions. The typology is developed according to the following steps: firstly, the empirical literature on infrastructure project cost overrun causes is reviewed and catalogued; secondly, based on the review a typology of cost overrun causes has been developed to provide a theoretical framework which organises and describes, parsimoniously, the pattern of relationships between types of causes, overrun and corresponding management approaches - thus simplifying the seemingly complex pattern of relationships. The typology study organises the main causes in four types (financial uncertainty, novelty, complexity, and time pressure) and develops a conceptual framework that identifies and explains patterns of relationships among causes, overrun and the corresponding management approaches within each category. Such a typology can be used to aid the assessment of

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cost overrun causes for large infrastructure projects and to effectively mitigate risks of significant overruns. Finally, we propose a plan to validate the typology empirically.

Keywords: Causes of Cost Overrun, Cost Overrun, Infrastructure Project, and Typology.

1. Introduction

Cost overruns in infrastructure projects are common around the world. High profile examples include: the Big Dig project in Boston which had a cost overrun of 500%; the Wembley Stadium that experienced a 50% cost overrun; and the Scottish Parliament Building that was over three years late and experienced more than 900% cost overrun (Love et al., 2011). In Australia, the Western Australian Perth Arena had an original contract value of AUD 168 million, but a cost overrun of more than three times this amount (Love et al., 2011). According to Flyvbjerg et al. (2005; 2009) the average cost overrun for infrastructure large-scale projects could range from 20.4% to 44.7%; and nine out of 10 projects have cost overruns worldwide. Cost overrun is found across 20 nations and five continents covered by this study. Over the past 70 years, there have been no systematic improvements in cost overrun of infrastructure projects (Bruzelius et al., 2002).

Various causes of cost overruns have been identified. Studies have shown that technical factors lead to cost overruns, including lack of experience, project size, mistakes in design, overall price fluctuations, inaccurate estimations, etc. (Memon et al., 2011). Love et al., (2011) conducted a study on the causes of cost overruns via case studies on a hospital and a school**.** They found that technical factors (such as design errors) are the major causes leading to cost overruns.

According to Flyvbjerg et al. (2004), however, there are two basic reasons why projects experience cost overruns. Firstly, optimism bias encapsulates the systematic propensity of decision makers to be over-optimistic about outcomes of planned actions. Secondly, strategic misrepresentations are the misleading actions used in politicisations and economics, and by planners, to ensure projects proceed (Flyvbjerg, 2006). Traditional estimation practices have been shown to be particularly vulnerable to these detrimental effects, resulting in poor estimation accuracy in previous studies (Flyvbjerg et al., 2002).

It is apparent that there are a large number of causes of overruns and many share similar patterns of impact on overrun costs. Therefore, it will be functionally useful and conceptually meaningful to develop a typology of causes based on their impact on the overruns of infrastructure projects. Based on the review of empirical literature on the cost overrun of infrastructure projects, a typology of causes has been developed to aid the assessment of cost overrun causes for large infrastructure projects.

Below, background literature is reviewed and the research method is described. Then, based on the causes identified in the literature review, a typology of causes of cost overrun has been empirically developed. The proposed plan of validating the framework is explained. Finally, conclusions are drawn.

2. Theoretical Background

Cost is one of the main considerations throughout a project's lifecycle and can be regarded as a significant parameter of a project and the driving force of project achievement. Despite its proven significance, it is not rare to observe a construction project failing to achieve its objectives within the specified, or even the approximate, estimated cost. Cost overruns vary significantly in scale from project to project. Yet, cost overrun is common to infrastructure projects (Azhar et al., 2008). Understanding the causes of cost overruns is critical to the success of infrastructure projects. Past studies have found significant, yet common cost overrun of infrastructure projects.

Pickrell (1990) carried out a study for the US Department of Transportation covering US rail transit projects with a total value of US$24.5 billion. The total capital cost overrun for eight of the projects was calculated to be 61% ranging from -10 to +106%. Another study by the Auditor General of Sweden (1994), covering 15 road and rail projects, revealed that the average cost overrun of eight road projects was 86%. The range for road projects was from -2 to +182%, while the average cost overrun for the seven rail projects was 17%, ranging from -14 to +74%. Another study by Fouracre et al. (1990), carried out for the UK Transport and Road Research Laboratory (TRRL), covered 21 metro systems in developing countries. The outcomes of the study showed that six metro projects had cost overruns above 50%. Two of these projects range up to 500%. Three had cost overruns in the range of up to 100%, and the remaining four ranged up to 50%.

Skamris and Flyvbjerg (1996, 1997) conducted a study in Denmark, in which they compared the accuracy of cost estimates on large-scale infrastructure projects. The study considered cost estimates of seven tunnels and bridges before the decision was made to build. The major conclusion from this study is that cost overrun of 50–100% is common for larger transportation infrastructures, and that overruns above 100% are not unusual.

Studies on causes of overrun have identified a wide spectrum of causes. Frimpong et al. (2003) identified 26 factors that cause cost overruns in the construction of ground water projects. They found that, according to the contractors and consultants, monthly payment difficulties were the most important cost-overrun factor. Owners, however, ranked poor contractor-management as the most important factor. Although there were some differences in viewpoints among the three groups surveyed, there was a high degree of agreement among them with respect to their ranking of the factors. The overall ranking results indicated that the three groups felt the major issues which can cause extreme groundwater project-cost overruns in developing countries are: monthly payment difficulties; poor contractor management; poor technical performances; material procurement; and escalation of material prices.

In Kuwait, a study was done by Kouski et al. (2005) in which cost increases in the construction project was examined. The study found the three most important causes of cost overruns are contractor elide, material related problems and owners' financial constraints. Other studies have identified four of the most important factors that cause cost overruns as:

design changes; inadequate planning; unpredictable weather conditions; and fluctuations in the cost of building materials (Kaming et al., 1997; Chimwaso, 2000).

Flyvbjerg et al. (2002) carried out a study on the cost overrun of road projects. Based on a sample of 258 infrastructure transportation projects valued at US$90 billion, they found that cost estimates used to justify the go-ahead of these projects are systematically misleading. They concluded that the underestimations observed cannot be explained by error, but are best explained by strategic interpretation - which is tantamount to deceitfulness (Flyvbjerg et al., 2002). They thus warn legislators, administrators and those who value honest numbers not to trust cost estimates and benefit-cost analysis produced by project promoters (Flyvbjerg et al., 2002).

Around the globe, many other researchers have been attracted to cost overrun. Asian and African countries have attracted particular attention. In Southeast Asia these researchers are: Kaming et al. (1997) in Indonesia; Ogunlana et al. (1996) in Thailand, Sambasivan; and in Malaysia, Soon (2007). Chan and Kumaraswamy (1995), Chan and Kumaraswamy (1997) and Lo et al. (2006) studied cost overrun in Hong Kong, and Acharya et al. (2006) studied it from a Korean perspective. Chang (2002) conducted surveys in the US. In Middle Eastern countries where petroleum and natural gas exports have played an important role in the economy, researchers are: Faridi and El- Sayegh (2006) in UAE, Koushkiet al. (2005) in Kuwait.

In Africa, Frimpong et al. (2003) conducted studies in Ghana, as did Mansfield et al. (1994), and Aibinu and Odeyinka (2006) in Nigeria. In Vietnam, large-scale projects were studied by Long et al. (2004a) to identify project success factors, and by Long et al. (2004b) to identify ordinary and general issues. Regarding these issues, the Vietnamese government declared the infrastructure project cost-overrun issues as the biggest “headache” (Le-Hoai et al., 2008, p.368) in recent times, especially with government-related funded-projects (Ministry of Planning and Investment in Vietnam, 2003, as cited in Le-Hoai et al., 2008).

Skamris et al. (1996) concluded that in most previous studies, technical factors such as changes in design and technological innovation can be explained as causes of cost overruns. However, there remains a considerable portion of divergence that cannot be clarified by technological causes alone (Odeck, 2004). In fact, Wachs (1990) pointed out that the probable cause of cost overruns in infrastructure projects is due to the inaccuracy of cost forecasts.

On the other hand, Flyvbjerg et al. (2004) argues about the main causes of the cost overruns. They postulate that these causes affect projects throughout their life cycle, and are due to misinformation in policy and the management of the project. Why projects experience cost overruns is firstly due to optimism bias that encapsulates the systematic propensity of decision makers to be overoptimistic about outcomes of planned action. Secondly, they relate to the strategic misrepresentation (deceitfulness) that misleads actions used in politicisations and economics, and by planners to ensure the projects proceed (Flyvbjerg 2006).

Doty and Glick (1994) typologies could constitute theory. Shenhar and Davir (1996) claimed that typologies are complex theories that can be subjected to rigorous empirical testing if typologies are properly developed and fully specified. According to Doty and Glick, "typologies do not provide decision rules for classifying organisations. Instead, typologies identify multiple ideal types, each of which represents a unique combination of the organizational attributes that are believed to determine the relevant outcome(s)" (1994, p. 232). Construction of a conceptual framework through a typology approach, as outlined by Doty and Glick, are required to meet the following criteria: "(a) constructs must be identified, (b) relationships among these constructs must be specified, and (c) these relationships must be testable" (1994, p. 233).

In this paper a new typology for cost overrun causes is proposed. First, causes of cost overrun in infrastructure projects have been identified from the literature review. Then, the causes have been grouped into types based on how they impact overrun. The limitation of understanding cost overrun causes creates differences in mitigating the causes effectively. Therefore, it is important to develop a conceptual framework to reduce the complexity of causes, and to facilitate effective understanding in management of such causes. By mapping studies to identify frequent causes of cost overrun through the literature review of data, we have identified a set of "ideal types". Furthermore, the typology will be useful in predicting the dependent variables, when fully developed.

3. Conceptual framework of cost overrun

Through a comprehensive literature review, most of the causes that have frequently occurred are listed in the table below and measured, based on frequency. This has resulted in the identification of more than 90 causes of cost overrun, which are presented in table 1A in the appendix. Then, we developed a rough-cut typology by grouping factors sharing similar patterns of how it impacts on cost overrun (by identifying relationships between cause and overruns), fitting the factors identified to the rough-cut typology for further refinement. The causes have then been grouped into to four types based on how the causes impact on overrun.

Table 1: A typology of cost overrun causes

Causes of cost overrun	Frequency	Relationship to overrun	Ideal types	Description of each ideal type
Increase in material prices, Inflation, Difficulties in obtaining construction materials at official current prices, Increase in wages, Labour cost increased due to environment restriction, Monthly payment difficulties from agencies, Cash flow during construction, Financial difficulties of owner, Financial difficulties of contractor, Slow payment of completed works, Fluctuation in money exchange rate, High interest rate charged by bankers on loans, Cash flow and financial difficulties faced by contractors, Shortage of materials, Deficiencies in cost estimates prepared by	32%	Increases the volatility of input costs and thus the chances of overrun. Induces tendency for under estimation of costs.	Financial Uncertainty	This type represents factors impacting on the volatility of input costs for the project (Odeck, 2004)

Causes of cost overrun	Frequency	Relationship to overrun	Ideal types	Description of each ideal type
public agencies, Optimism bias, Fraudulent practices, Practice of assigning contract to lowest bidder, Inaccurate estimates.				
Lack of experience of project location, Lack of experience of project type, Inadequate contractor experience, Unexpected subsoil conditions, Poor technical performance, Impractical and complicated design, Inadequate modern equipment (Technology), Unpredictable weather conditions, Unexpected geological conditions, Unforeseen site conditions, Site constraint, Rock and soil suitability, Earth conditions, Deficiencies in the social structure, Social and culture impact, Problem with neighbours, Heritage material discovering experience in contract, and Inaccurate quantity take-off.	20%	Increases the uncertainty of tasks and outcome, thus making planning and estimating difficult.	Novelty	How new the project and the project solution is to the industry (Shenhar & Dvir, 2007)
Deficiencies in the infrastructure, Labour problems, Insurance problems, Problems related to work security, Problems related to workers' health, Additional works, Contractor's poor site management and supervision, Shortage of site workers, Lack of communication among parties, Mistakes during construction, Relationship between management and labour, Slow information flow between parties, Inaccurate site investigation, Rework, Changes in material specification and type, Design error, Project size, Incomplete drawings, Inadequate specifications, Lack of skilled labour, Equipment availability and failure, Number of works being done at same time, Lack of constructability, Scope Change of the project, Insufficient equipment, Labour disputes and strikes, Owner interference, Obstacles from government, Laws and regulatory framework, and Delay of preparation and approval of drawings. Disputes on site, Political complexities.	38%	Increases the complexity of coordination of parties and tasks, thus making it harder to meet preset targets.	Complexity	Project complexity can be defined as consisting of many varied interrelated parts' and can be operationalized in terms of differentiation (the number of varied elements, e.g. tasks, specialists, components) and interdependency (the degree of interrelatedness between these elements) (Baccarini, 1996)
Unrealistic contract duration and requirements imposed, Incorrect planning and scheduling by contractors, Delay in material procurement, Poor design and delays in design, Late delivery of materials and equipment, Delay in decision making, Reasons that yield construction delays, Inadequate planning and scheduling, Delay in payment to supplier/ subcontractors and Insufficient time for estimate.	10%	Forcing project team to take short-cuts, crashing, concurrent tasks/projects which are known to cause delays and overrun	Time pressure	This represents the urgency of the project, namely how much time there is to complete the job (Shenhar & Dvir, 2007)

The four types identified in Table 1 are the ideal types of each group, which are; 'financial uncertainty', 'complexity', 'novelty', and 'time pressure'. Each type will be ranked based on each variable. Figure 1 shows the framework of cost overrun and the scale of each type.

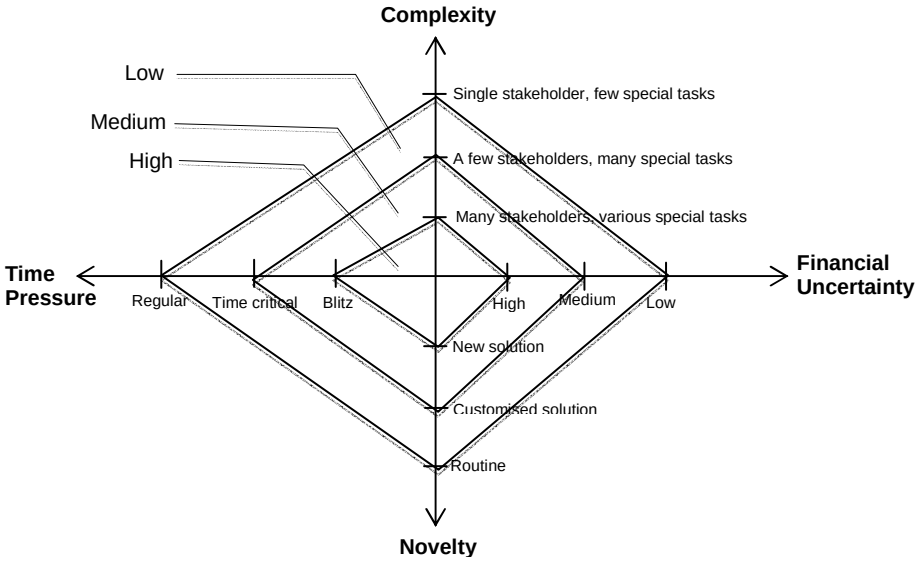

Figure 1: cost overrun framework

4. Research design

The research design of this paper is divided into three stages; empirical literature review, construction of a theoretical framework by using typology, and empirical validation. The typology has been developed via the following steps:

First, the empirical literature on infrastructure project cost overrun causes has been reviewed and catalogued. 26 studies on infrastructure projects have been selected (transportation, health, education, power and water). The selection is based on countries and citation of the publications. The literature covers developing and developed countries. The period of the literature reviewed is between 1990 and 2011.

Second, based on the review, a typology of cost overrun causes has been developed to provide a theoretical framework that organises and describes the relationships between types of causes, overrun and corresponding management approaches. Thus, the seemingly complex pattern of relationships has been simplified. The typology study organises the main causes in four types: financial uncertainty, novelty, complexity, and time pressure. It develops a conceptual framework that identifies and explains patterns of relationship among causes, overrun and the corresponding management approaches within each category. Such a typology can be used to aid the assessment of causes of cost overrun for large infrastructure projects and to effectively mitigate risks of significant overruns.

Finally, we have proposed a plan to validate the typology empirically. A survey has been used to validate the conceptual framework of cost overrun. The reason to conduct the survey in Saudi Arabia is twofold. First, the construction boom which started in 2005 is expected to go through a period of accelerated growth over the next few years, with a value of projects estimated at US $629 billion (Al-alrabia, 2012). The other reason is due to the lack of research on cost overrun in infrastructure projects in Saudi Arabia.

The survey questionnaire has been designed and distributed to experienced project managers and executive managers. The questionnaire poses specific questions to the respondents' that have most recently completed infrastructure projects (e.g. education, health, transportation, water, power and IT) with a contract value over 50 million Saudi Riyals (US $14 million), excluding operation and maintenance variables. The questionnaire consists of three sections: general information about the participant's experience; causes of cost overrun; and the frequency and severity of each of these causes, including the extent of cost overrun, respectively.

The first section contains questions about participants and their organisation, work experience, academic qualifications, the number of projects constructed within 20 years. In the second section, the participants are asked to scale the frequency of 40 cost overrun causes using this scale: (Never (N)=1, Occasionally (OC)=2, Sometime (S)= 3, Often (O), =4, Always (A)= 5). Furthermore, they are asked to scale the severity of the same causes within the following scale: (No significant (NS)=1, Some effect (SE)=2, Moderate (M)=3, Significant (S)=4, Extremely significant (ES)=5). They are also asked about their most recent involvement in a project regarding the overall major causes of cost overrun. The last section of the questionnaire elicits general comment in reference to the study.

Currently, we have received approximately 85 responses to the online questionnaire. The average experience of participants is 15 years with the average age of respondents being 45 years old. Water and transportation projects overall experienced cost overrun of 40%-60%. The overall causes were reported to be poor design, unclear project scope (owner), lack of experience of the contractor and consultants, poor planning and programming, and corruption between the contractor and subcontractor.

Subsequent to these findings, we will empirically examine a data set from the survey being conducted in Saudi Arabia to validate our framework. We will use factor analysis for the validation, due to the fact that we have developed a measure of cost overrun causes for the survey (explained above in this section). According to Thompson (2004) there are two discrete classes of factor analysis: exploratory factor analysis (EFA); and confirmatory factor analysis (CFA) to empirically validate the typology framework.

EFA is a statistical method used to uncover the underlying structure of a relatively large set of variables. EFA is a technique within factor analysis whose overarching goal is to identify the underlying relationships between measured variables (Finch and West, 1997). It is commonly used when developing a scale and serves to identify a set of latent constructs underlying a set of measured variables (Kline, 2010). It is not required to have any specific hypotheses about how many factors will emerge, and what items or variables these factors will comprise (Suhr, 2006).

CFA, on the other hand, is a special form of factor analysis. It is used to test whether measures of a construct are consistent with the understanding of the nature of that construct. As such, the objective of CFA is to test whether the data fits a hypothesized measurement framework. This hypothesized framework is based on analytic research

(Thompson, 2004; Schmitt, 2011). When developing a scale, it should use EFA before moving on to CFA (Thompson, 2004).

As a result, first, we will use EFA technique to inductively generate an alternative conceptual framework of the level grouping of cost overrun framework causes. Subsequently, we will test the ability of each of the competing frameworks to account for the underlying structure of the data, using CFA technique.

5. Conclusion

The purpose of this paper was to develop a conceptual framework to aid the assessment of cost overrun causes for large infrastructure projects, to identify the major types and to measure the relationship between causes and overrun. We were also interested in seeing how various causes would impact on cost overrun. Since there are many studies identifying various causes, we synthesized the empirical literature on infrastructure project cost overrun causes and analysed the frequency of cost overrun causes. The potential contribution of this study is in identifying an empirically derived typology of cost overrun causes, comprising financial uncertainty, novelty, complexity, and time pressure. Within each type, there exist similar patterns of relationships between causes and overrun, whilst the patterns between types are different.

Based on developing a conceptual framework from the literature review, the design seeks to empirically validate the typology framework. Therefore, this paper proposes a plan to validate the typology empirically via a survey that has been conducted in Saudi Arabia. We have used the questionnaire data for the analysis. The design is comprised of three steps. The first step is to construct the conceptual framework through typology theory. The next step is to validate the framework using two techniques of factor analysis which are: exploratory factor analysis (EFA); and confirmatory factor analysis (CFA).

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Appendix A

Table 1A: Mapping previous study

Causes of cost overruns	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	Σ
Increase in material prices.	1		1	1				1				1			1				1			1		1		1	10
Inflation.					1		1	1		1		1					1			1							7
Difficulties in obtaining construction materials at official current prices.		1				1															1						3
Increase in wages.	1		1						1																		3
Price fluctuations.		1			1			1											1			1					5
Materials cost increased by inflation.			1			1					1						1							1			5
Labour cost increased due to environment restriction.	1																				1						2
Monthly payment difficulties form agencies.			1						1														1				3
Cash flow during construction		1					1																				2
Financial difficulties of owner.						1														1							2
Financial difficulties of contractor.						1		1													1						3
Slow payment of completed works.	1							1																1			3
Market Conditions.		1					1				1						1					1					5
Fluctuation in money exchange rate.			1		1			1																			3
Delay payment to supplier/ subcontractors.			1							1													1				3
Deficiencies in cost estimates prepared by public agencies.			1																	1							2
Deficiencies in the infrastructure.		1			1			1																			3
Labour problems.	1						1																				2
Insurance problems.		1							1										1					1			4
Problems related to work security.	1					1	1															1					4
Problems related to workers' health.			1					1																			2
Additional works.			1					1													1		1				4
Inaccurate quantity take-off.	1								1																		2
Lack of experience of project location.				1				1					1	1		1		1								1	7
Lack of experience of project type.				1				1					1								1						4
Contractor's poor site management and supervision.						1			1			1										1					4
Inadequate contractor experience.			1																								1
Shortage of site workers.			1					1	1												1						4
Lack of communication among parties.	1				1															1							3
Unrealistic contract duration and requirements imposed.								1			1								1					1			4
Mistakes during construction.			1					1												1		1					4
Relationship between management and labour.	1							1																			2
Slow information flow between parties.		1							1										1				1				4
Inaccurate site investigation.			1					1													1						3
Lack of coordination between parties.																				1							1
Rework.		1							1											1							3
Unexpected subsoil conditions.																						1					1
Deficiencies in cost estimates prepared.	1					1			1											1							4
Poor technical performance.	1				1																	1		1			4
Design changes.						1			1																		2
Incorrect planning and scheduling by contractors.		1								1								1									3
Delay in material procurement.							1																1				2
Poor design and delays in design.			1			1													1								3
Late delivery of materials and equipment.	1							1												1				1			4

Causes of cost overruns	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	Σ
Changes in material specification and type.								1														1					2
Design error.		1																									1
Project size.	1	1		1		1		1	1	1			1		1	1		1		1		1	1			1	15
High interest rate charged by bankers on loans.			1					1														1					3
Incomplete drawings.			1				1																1				3
Inadequate specifications.	1							1													1			1			4
Lack of skilled labour.			1																								1
Waste on site.		1							1											1		1					4
Equipment availability and failure.	1																										1
Delay in decision making.								1																		1	2
Poor financial control on site.		1							1												1	1					4
Number of works being done at same time.							1																				1
Lack of constructability.								1														1					2
Impractical and complicated design.																				1							1
Change in the scope of the project.	1					1					1	1										1					5
Insufficient equipment.	1	1			1		1	1	1										1		1			1	1		10
Inadequate modern equipment (Technology)						1			1																		2
Optimism bias.				1									1	1	1												4
Fraudulent practices.		1						1													1						3
Disputes on site.	1							1																			2
Labour disputes and strike.								1													1						2
Owner interference.		1																									1
Lack of experience of local regulation.								1																			1
Obstacles from government.								1																			1
Political complexities.		1					1													1							3
Practice of assigning contract to lowest bidder.					1															1			1				3
Strategic misrepresentation.													1	1	1												3
Laws and regulatory framework.						1		1																			2
Unpredictable weather conditions.	1	1			1	1		1	1			1							1		1	1	1				11
Unexpected geological conditions								1																			1
Unforeseen site conditions.							1																				1
Site constraint.		1																									1
Rock and soil suitability.								1											1								2
Earth conditions.								1																			1
Deficiencies in the social structure.	1					1			1										1				1		1		6
Social and culture impact.	1																										1
Problem with neighbours.					1		1														1						3
Heritage material discovering.			1																								1
Reasons that yield construction delays.								1															1			1	3
Inaccurate estimates.					1			1															1			1	4
Delays		1				1		1			1				1	1						1		1		1	9
Escalation of material prices.			1																	1			1			1	4
Low bid.	1		1																	1				1			4
Poor management assistance.								1																			1
Cash flow and financial difficulties faced by contractors.			1				1		1														1				4
Delay preparation and approval of drawings.	1																			1			1				3
Inadequate planning and scheduling.								1													1						2
Insufficient time for estimate.	1							1																			2
Experience in contract.						1														1			1				3
Shortage of materials	1		1			1		1												1					1		6

(1)Arditi et al., (1985); (2)Mansield et al., (1994); (3)Kaming et al., (1997); (4)Flyvbjerg et al., (2002); (5) Frimpong et al., (2003); (6) Le-Hoai et al., (2008); (7)Memon et al, (2010); (8)Memon et al., (2011); (9)Mahmid & Bruland (2011); (10)Love et al., (2011); (11)UMTA (1990); (12)Office of program Policy Analysis and Government Accountability (1996); (13)Flyvbjerg, Holm, & Buhl (2003); (14)Priemus, Flyvbjerg & Wee (2008); (15)Flyvbjerg, Holm, and Buhl (2004); (16)Odeck (2004); (17)Roxas Jr. & Chalermpon (2008); (18)Singh (2009); (19)Long et al (2004); (20)Ameh et al (2010); (21)Kaliba (2009); (22)Omoregie (2006); (23)Creedy et al (2010); (24)Achuenu and Kolawole (1998); (25)Morris (1990); (26)Danata et al (2006).

The Role of Multi-criteria Decision Techniques for Sustainable Construction of Chinese Residential Buildings

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Abstract

The increasing urbanization in China has created a high demand for housing and other infrastructure. Meeting this demand has huge resource implications with potentially harmful effects on the environment. A sustainable approach to construction is therefore a way forward to ensure that the competing needs for housing, economic development and protection of the environment can be achieved. This paper reports on the early stages of a research into sustainable construction in China. The aim is to explore how multi-decision techniques can be used to assess the sustainability of different structural systems (e.g. load-bearing bricks, concrete and steel frame construction) for residential building construction. The concept of sustainable construction is defined and various criteria for achieving it are identified. A review of various multi-criteria decision techniques is provided and a conceptual framework for an evaluation system for assessing different structural systems in the context of the residential building process in China is proposed. It is expected that this framework will provided the basis for a more detailed study to validate and test its effectiveness in making credible decisions on the choice of building systems for sustainable construction in China. The paper concludes with an outline of how this detailed research will be conducted.

Keywords: sustainable construction, multi-criteria decision, residential building

1. Introduction

The increasing world population and the shortage of adequate housing create a huge demand for future residential building with an expectable demand for sustainable solutions. This situation is more obvious in China, where urbanisation increased from 18% to 43% between 1978 and 2005 (Wu, 2007), and with the urban population expected to reach 926 million by 2025 (Living Steel, 2010). Taking the two biggest cities for example, Shanghai requires an additional 1.3 million square metres of new residential housing annually to house

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its swelling population and Beijing has more construction than in the entire European continent. Against this background, the Chinese construction industry has developed very quickly and it accounts for a large share of the energy consumption, waste generation, and use of natural resources. Over the last 20 years, the process of Chinese urbanization has followed a pattern of the high input and consumption. However, limited resources and the capacity of the environment cannot support the rapid economic and social development if the traditional model of development continues (Li, 2008).

The construction process in China has seen a major change from a more state-driven process before the Open Door Policy in 1978 to a more market-oriented system since then (Chan et al, 1999). The key players in a typical process include the Preparatory Office (PO) (or project bidding agency), Design Institute (DI), Contractor and Construction supervision unit (CSU) (Chan et al. 1999). The PO is a temporary organisation which manages the project and "is responsible for all the necessary functions other than those performed by the design institute and contractor" (Chan et al. 1999). The DI (equivalent to Architect/Engineer functions) is responsible for preparing conceptual and detailed designs; the contractor carries out the building works but not responsible for procuring materials (the PO is responsible for this); and the CSU supervises construction as an independent third party (Chan et al. 1999).

The residential building construction process in China is broadly similar to that in Western countries. However, due to a heavy reliance on labour-intensive processes, it is less efficient and the generation of waste is generally higher; and the pace of development doesn't usually keep up with advances in technology. The separation of design and construction (i.e. the DI and Contractor functions described above) also leads to a lower design service level. The consumption of raw materials such as steel, cement, concrete and timber are relatively higher. In aspects of construction management, the lack of comprehensive information management systems leads to a relatively less efficient process, especially with respect to frame structure construction. The reliance of labour-intensive processes for frame construction on site often leads to increased costs, poor quality, longer duration of projects and safety issues which have a negative impact on worker's health and the building environment. The need for sustainable construction in frame building systems is therefore apparent.

The frame building system used in Chinese residential buildings is mainly comprised of three alternatives, which are steel, concrete, and load-bearing bricks. Other materials such as stone, bamboo are also used (Qu et al. 2012) but to a lesser extent in the industrialised housing sector. It is necessary to make credible decisions on the choice of suitable frame structure in building systems development, both for the sake of protecting the environment and for rapidly supplying the high-quality housing demanded by society. How to choose the most suitable frame structure building system in a rapid urbanization process is a multi-criteria problem. The objective of this paper is therefore to explore how multi-decision techniques can be used to assess the sustainability of different structural systems (e.g. load-bearing bricks, concrete and steel frame construction) for residential building construction. The concept of sustainable construction is defined and various criteria for achieving it are identified. A review of various multi-criteria decision techniques is provided and a conceptual

framework for an evaluation system for assessing different structural systems in the context of the residential building process in China is proposed. Preliminary data from a survey of typical projects in China will be used to test the conceptual framework. The paper concludes with recommendations for future research.

2. Sustainable construction

There has been a growing movement towards sustainability since the latter half of the twentieth century, leading to the development of various concepts of sustainable construction. Sustainable construction is part of the larger concept of “sustainable development”. One of the earlier definitions of sustainable development (as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” - Bruntland, 1987), has led to many other conceptions of sustainability and sustainable construction.

Similar terms that apply to the sustainability of buildings include: “eco-building”, “sustainable building” and “green building” (Adler, 2011). Sustainable construction has a rich content which include resource efficiency (energy, integrated design, third-party commissioning, enhanced security), construction and demolition practices, recycling, environmental sensitivity (learning from the locals, site selection and development), water and landscape, sewage treatment, designing for people and productivity (building design and materials, maintenance, more natural indoor environment, quality lighting, individual environmental control) (Atkinson et al, 2009). Sustainable construction applies not just to the building product, but to the construction process, construction strategies, building and infrastructure design and orientation, project management, maintenance and so on. It can therefore refer to: all decisions and actions during the design and construction of buildings, which are designed to ensure that both the process and outcomes of construction over the lifecycle of a building are sustainable (i.e. have net positive benefits with respect to the social, economic and environmental aspects of sustainability).

Sustainable construction with respect to frame building system can be generalized from some sustainable construction evaluation concepts (Cinquemani and Prior, 2011). The most important and globally used environmental assessment methods were investigated and a generic model for the development of an effective environmental assessment method intended for the establishment of environmental sustainability, was developed by Alyami,.and Rezgui (2012). With respect to China, the Ministry of Housing and Urban–Rural Development has established the evaluation criteria for green building (CNS, 2006). Five criteria for sustainable construction of residential frame building systems can be identified from this government study. Firstly, it should be concerned about the frame construction sites and assess the issues arising from the building’s construction and management on man, environment and land. Secondly, it should be concerned about water efficiency during the frame construction stage and assess the water use efficiency of the building process. Thirdly, it should be concerned about energy and atmosphere and assess the energy use in the frame construction, the sustainable use and management of electricity, coolants, and the extent of the use of renewable energy. Fourthly, it should be concerned about materials, resources and assess the frame building materials used, their sourcing, the proportion of

recycled materials in them, ease of their recycling, sourcing from sustainable forests that protect man and the environment. Fifthly, it should be concerned about the efficient and effective management of the cost, quality, duration, safe and benefit for technology development demands. (CNS, 2006

In the context of China, which is facing rapid urbanization and industrialization, sustainable construction in relation to frame building systems should include other variables in addition to those mentioned above. Because the new urban population need their living space urgently and the government's finances are relatively limited, some balance should be attained with respect to environmental protection, social benefits and economic benefits. Specifically, sustainable construction related with the frame building system in China should also consider: less material consumption, less energy consumption, less land use, less water consumption, pollution control, construction cost control, construction duration control, housing supplying efficiency, benefit to housing industry technology development, benefit for living culture. The selection of the most suitable frame building system during the urbanization should therefore be in accordance with sustainable construction principles.

3. Multi-criteria decision techniques

Multi-criteria decision techniques have increasingly been applied in many kinds of research. This is especially the case in sustainable development, due to the multi-dimensionality of sustainability, with respect social, environmental and economic considerations.

Multi-criteria decision techniques are mainly divided into three categories which are: elementary techniques, unique synthesizing criteria techniques and outranking techniques (Wang, 2009). The elementary techniques include two methods which are weighted sum method (WSM) and weighted product method (WPM). Weighted sum method (WSM) uses each criteria score and multiplies the weight and sum to get the resulting cardinal scores. The score of the optimal alternative is the maximum. WPM is different from WSM, which is applied with the multiplication instead of sum it. The unique synthesizing criteria include Analytical Hierarchy Process (AHP), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), Grey relation method, MCDA (Multi-Criteria Decision Analysis), and combined fuzzy methodology. AHP is a type of weight sum method and applied popularly in many domains. TOPSIS is a method where the ideal alternative has the best level for all criteria whereas the negative ideal is the one with all the worst criteria values (Hwang, 1981). Grey relational method belongs to grey systems theory whose principle of grey relation method is similar to TOPSIS, and uses the grey relation degree to show the closeness between the alternatives. MCDA combined fuzzy methodology has been applied to solve problems related with availability and uncertainty of information as well as the vagueness of human feeling and recognition. The outranking methods have the characteristic of allowing incomparability between alternatives which is important in situations where some alternatives cannot be compared for various reasons (Wang, 2009).

From the view of the construction model, multi-criteria decision techniques are mainly divided into three methods. Firstly, AHP (Analytical Hierarchy Process) and some decision rule-based methods can solve multiple criteria evaluation problems utilizing prior articulation

of preferences. These kinds of methods transform the problem into essentially a single criterion problem which requires the decision maker's preference information at the start of the process. Secondly, other methods are to solve multiple criteria decision problems using prior articulation of preferences by constructing a value function such as goal programming. The detail process after the value function is established; the resulting single objective mathematical program is solved to obtain a preferred solution. Thirdly, some methods require preference information from the decision maker throughout the solution process which is referred to as interactive methods or methods that require progressive articulation of preferences. These methods have been well-developed for both the multiple criteria evaluation (Geoffrion, et al. 1972; Köksalan and Sagala, 1995) and design problems (Steuer, 1986). Multiple criteria design problems typically require the solution of a series of mathematical programming models in order to reveal implicitly defined solutions. The representation or approximation of "efficient solutions" is of interest. This category is referred to as "posterior articulation of preferences," meaning that the decision maker's involvement starts posterior to the explicit revelation of "interesting" solutions (Karasakal and Köksalan, 2009). If the mathematical programming models contain integer variables, the design problems become harder to solve.

4. Research methodology

The problem of evaluating the sustainability of frame construction has multiple conflicting criteria which include environmental protection, economic benefits and social benefits that need to be considered in making decisions. The problem consists of a number of alternatives which include brick, concrete and steel frame development. So the sustainable frame construction in residential buildings is a typical multi-criteria problem. It is very suitable for the AHP model. AHP is a useful multi-criteria decision technique developed by Saaty (Saaty, 1980). AHP technique can be used for quantifying relative priorities for a given set of alternatives on a ratio scale toward evaluating the sustainable construction model, and it can apply the judgment of experts (based on experience). It stresses the importance of the intuitive judgments of a decision-maker and the consistency of the comparison of alternatives in the multi-criteria decision-making process. AHP has already been applied in many fields related with sustainable development (Chatzimouratidis and Pilavachi, 2008, 2009; Ramanathan and Ganesh, 1993, 1995; Kablan, 2004). Based on the review of multi-criteria techniques above and considering that this preliminary research is aimed at developing a conceptual framework for the sustainable assessment of different structural systems in the context of the residential building process in China, AHP was chosen as the most appropriate evaluation method.

The research undertaken involved a review of government guidelines and other related literature, an investigation of case study project data, and interviews with experts. The case study projects were chosen in Wuhan city, which is located in the centre of China. Data from three different frame structure residential buildings were collected from the contractor. The investigation was made as a comparative analysis table which provided a reference for the interview with the experts. The interviews were conducted between 1 April and 1 May 2012. The interviewees consisted of 16 professionals who were familiar with sustainable construction in residential buildings and had more than 15 years of experience in the

construction industry. To ensure representation of different project stakeholders, 9 of the experts were from the contractor company, 5 of them from the design company, and the remaining 2 were from the consulate company (i.e. Construction Supervision Unit). They were interviewed to obtain comparative scores between the factors based on the AHP method, which aids to establish the matrix of pairwise comparisons for determining the weights for each criterion. The relative importance can be scaled from 1-9 depending on the level of importance. Based on the matrix, criteria weights and the degree of consistency achieved in the pair-wise comparison are measured by a consistency ratio indicating whether the comparison made is sound. After obtaining the weights, each performance at the given level is then multiplied with its weight and then the weighted performances are summed to get the score at a higher level. The procedure is repeated upward for each hierarchy, until the top of the hierarchy is reached. The overall weights with respect to the goal for each decision alternative are then obtained. The alternative with the highest score is the best alternative (Wang 2009). The calculation process was done with MATLAB.

5. Conceptual evaluation framework

The AHP evaluation model of three frame building system consists of three levels including objective level, criteria level and alternatives level. The objective is to realize the overall optimal goal, which is to balance the needs of society, economy and the environment, in the selection of the most appropriate frame type. The criteria level includes environmental protection, economic benefits and social benefits. The environment protection criteria are composed of five indexes, which are: material-saving, energy-saving, land-saving, water-saving, and pollution control.

As to the material-saving, 55kg of steel and 221.5kg cement are required to construct 1 square meter of residential building. 1500kg of ore is required to produce 1 ton of steel. With respect to cement, 1100~1200kg of limestone, 150~250kg of clay, and 160~180kg of coal are required to produce 1 ton of cement clinker. All these materials are non-renewable (Tang, 2008). The material-saving criteria can be measured with respect to whether it is beneficial to apply lightweight high strength building materials, or to apply the industrial standard component during the design stage in order to reduce consumption during the construction stage of the frame structure building system. As to Energy-Saving, 6-litres of oil per square meter are required each year (equivalent to 8.57kg of coal) to heat a typical European residence, while 12.5kg of coal are required for a typical Chinese residence (Lu, 2005; Hu and Wang, 2009). The energy-saving technology criteria can be measured with respect to whether the frame structure building system is easier to connect with energy-saving windows and walls, which can reduce heat transfer through setting insulation layer on the wall and applying seal technology on the window; or whether it is easier to connect with energy-saving roofs and floors which can prevent heat transfer through the improvement of the thermal performance of the roofs and floors; or whether it is easier to connect with solar systems, for water heating system and power generation.

Land-saving can be measured with respect to whether the frame structure building system improves the intensive use of the land; enhancing the efficiency of the use of land; choosing the flexible load-bearing structure so as to achieve the rational division of the living space;

promoting new wall materials so as to save land resources, which is also meaningful to reflect the right choices and options for society (Yin 1993). Water-saving can be measured with respect to how the frame structure building system is beneficial in reducing the usage of water during construction, to connect with the recycle system so as to save the water consumption (Ren, 2009). As to Pollution control, the emission from the housing industry accounts for 25% of the total national greenhouse gases. It discharged 1.6~2.0 ton of CO_2 and 0.5~0.7 dust to produce 1 of ton steel. The amount of CO_2 discharged from the cement industry exceeded 13 billion ton while the amount of the dust exceeded 7000 thousand ton and the amount of the exhaust exceeded 600 thousand ton (Zhao, 2008). It can be measured with respect to whether the frame structure building system is beneficial in controlling noise, dust, surface water pollution and traffic congestion. For example, the use of clean “dry techniques” in steel construction can reduce pollution. The economic benefits criteria are made up of three indexes, which include construction cost, construction duration and main material consumption. The social benefits criteria are made up of three indexes, which include rapid housing supply to the society, benefit for the construction industry and benefit for living culture. Alternatives level includes three frame structure building system alternatives which are steel structure frame, concrete structure frame and brick structure frame. The established evaluation system is shown in Figure 1.

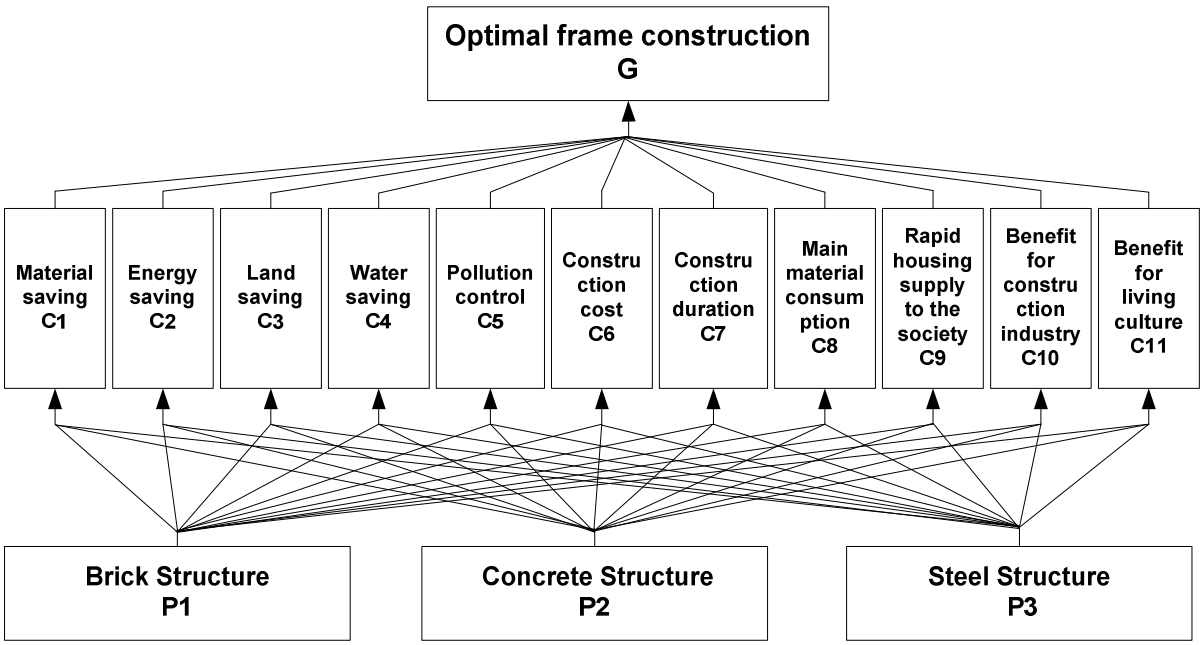

Figure 1: Evaluation framework for selecting frame structure building system

6. Preliminary testing and discussion of results

The preliminary testing of the conceptual framework involved a calculation of the AHP model. The scores were obtained from the judgment of experts and some indices were derived from the investigation of three kinds of frame building systems. Table 1 presents the results from a typical Chinese residential building construction project (in Wuhan, central

China). The comparative values were sent to the experts as a reference for them to provide their matrix of pairwise comparisons for determining the weights for each criterion. The matrix and the calculation process of each criterion were carried out in MATLAB.

Table1: Comparative analysis of three frames

Index			Unit	Steel Structure	Concrete Structure	Brick Structure
Index 1	Section steel consumption		Kg/m^2	35	0	0
Index 2	Steel bar consumption		Kg/m^2	12	30	15
Index 3	Cement consumption		Kg/m^2	30	140	75
Index 4	Gravel and sand consumption		Kg/m^2	150	800	650
Index 5	Timber consumption		m^3/m^2	0.0002	0.05	0.15
Index 6	Material logistics		T/m^2	0.3~0.6	1.0~1.2	1.3~1.5
Index 7	Land occupation		Given the brick structure as 1.0	0.3~0.4	0.8~1.0	1
Index 8	Water and power consumption		Given the brick structure as 1.0	0.5~0.6	1.2~1.5	1
Index 9	Construction noise		Given the brick structure as 1.0	0.5	1.5	1
Index10	Construction sediment volume		Given the brick structure as 1.0	0.2~0.3	0.7~0.8	1
Index 11	Demolish rubbish volume		T/m^2	0.355	1.25	1.95
Index 12	Labour consumption		day/m^2	3.5	5.5	7
Index 13	$Cost/m^2$ (construction area)	Multi-storey building	Given the steel structure as 1.0	1	1	0.87
Index 14		High rising building	Given the steel structure as 1.0	1	0.98	No exist
Index 15	$Cost/m^2$ (usable area)	Multi-storey building	Given the steel structure as 1.0	1	1.03	1.05
Index 16		High rising building	Given the steel structure as 1.0	1	0.99	No exist
Index 17	Construction duration		Given the steel structure as 1.0	1	1.45	1.95
Index18	Building life		years	70	70	50
Index19	aseismic performance			strong	Middle	weak
Index20	The working environment			good	middle	middle
Index21	Degree of industrialization		%	90%	50%	30%

The 11 criteria (C1 to C11 in Figure 1) comparison matrix and the calculation of the result of their weights are provided in Table 2 as an example. The pairwise values in Table 2 were derived from the experts. Following this overall comparison of the 11 criteria, each criterion (e.g. C1 = material saving) is compared against each frame alternative (i.e. steel, concrete and brickwork). An example of this (using criterion C1) is provided in Table 3.

Table 2: The criteria comparisons matrix and calculation result of weight*

G	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	Weight
C1	1	1/6	3	5	1/5	1/3	5	3	5	9	7	**0.1071**
C2	6	1	7	8	3	4	5	6	7	9	8	0.3081
C3	1/3	1/7	1	2	1/5	1/5	2	1/3	2	5	4	0.0432
C4	1/5	1/8	1/2	1	1/7	1/6	1/2	1/5	1/2	3	2	0.0228
C5	5	1/3	5	7	1	2	5	3	6	9	8	0.1940
C6	3	1/4	5	6	1/2	1	5	2	6	9	8	0.1454
C7	1/5	1/5	1/2	2	1/5	1/5	1	1/4	2	4	3	0.0358
C8	1/3	1/6	3	5	1/3	1/2	4	1	4	8	7	0.0848
C9	1/5	1/7	1/2	2	1/6	1/6	1/2	1/4	1	5	3	0.0306
C10	1/9	1/9	1/5	1/3	1/9	1/9	1/4	1/8	1/5	1	2	0.0139
C11	1/7	1/8	1/4	1/2	1/8	1/8	1/3	1/7	1/3	1/2	1	0.0143

***(Consistency ration is：0.0749；C1 to C11 represent the 11 criteria specified in Figure 1)**

Table 3: Comparison of criterion C1 against alternatives (P1, P2, P3)*

C1 Material Saving	P1 Brick Structure	P2 Concrete Structure	P3 Steel Structure	Weight
P1 Brick Structure	1	1/5	1/3	**0.1095**
P2 Concrete Structure	5	1	2	0.5816
P3 Steel Structure	3	½	1	0.3090

***(Consistency ration is: 0.0036)**

This process is repeated for all the criteria (C2 to C11) against the alternatives (not presented here because of space limitations). The overall weight for each alternative (P1, P2, and P3) (provided in Table 4) is obtained using equation 1, where P and C represent the alternatives and criteria, respectively; ***j*** and ***i*** represent the resulting weight of each alternative (e.g. Table 3) and criteria (Table 2), respectively.

$$\sum_{j=1}^{3} \sum_{i=1}^{11} Pj\ Ci$$

Equation 1

So from equation 1, the overall weight for P1 (Brick) is: *(**0.1095**x**0.1071**) + (0.1047x0.3081) + (0.1095x0.0432) + (0.1047x0.0228) + (0.1047x0.1940) + (0.6144x0.1454) + (0.1047x0.0358) + (0.1047x0.0848) + (0.1095x0.0306) + (0.1095x0.0139) + (0.1220x0.0143)* = ***0.1800*****.** [The first set of values in bold are from Tables 3 and 2, respectively. The other values are similar calculations as in Table 3, and the resulting weights in Table 2]. The weights for P2 (concrete) and P3 (steel) were calculated in the same way with results presented in Table 4.

Table 4: The overall weights for the alternatives P1, P2 and P3

Alternatives	Overall Weight
P1 Brick structure	0.1800
P2 Concrete structure	0.3521
P3 Steel structure	0.4679

From the calculation results (Table 3), it can be seen that the weight of the steel structure is the highest. This implies that steel structure satisfies the overall goal of optimal frame construction. This result also suggests that the policies that encourage developing steel structure residential building are likely to be very important for sustainable construction in China. However it should be noted that this calculation result is based on the scores given by the experts. If another group of experts were interviewed, the result may not be the same, which embodies the characteristic of the AHP method. Another point to note is that this preliminary test was based on a project in the centre of China and may not reflect the situation across the country because of huge differences in different parts of China. For example there are wide variations in the market price of materials, energy, water (criteria C1, C2 and C4 in Table 2); the value of the land (criteria C3); the cost of construction (criteria C6), the level of demand for residential buildings (criteria C9); all these factors can change the result of the evaluation. However, this model is a useful framework for applying multi-criteria techniques to assess the sustainability of structural frames of residential buildings.

7. Conclusion

The increasing urbanization in China has created a high demand for residential buildings. Meeting this demand has huge resource implications with potentially harmful effects on the environment. A sustainable approach to construction is therefore a way forward to ensure that the competing needs for residential building, economic development and protection of the environment can be achieved. Through the comparative analysis of some evaluation tools, an evaluation index system and AHP model was established. And based on the scores given by the experts, calculated through MATLAB software, the result is that the most suitable frame structure building system of the residential building in this particular case is steel structure which can optimally balance between sustainable construction and the development of the society. Further research is however required to extend and test the model in other project contexts.

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Complexity and Sensemaking in Construction

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Abstract

Mainstream construction project management is based on a linear conceptualization of time. The fundamental task of management is taken to be the organizing of a project in such a way that the diverse parts of the project play together; each part facilitating the operation of the whole, and avoiding that some operations obstruct other operations.

At the same time, complexity is recognized in the construction literature as being a major obstacle to efficient and effective building. Complexity temporalizes construction, and entails shortage on relevant information and unpredictability for builders. This produces uncertainty and risk, as operations have to be based on guesses about the future state of affairs. Reduction of risk can be achieved by improving on the ability to formulate successful and effective predictions. The question posed here is whether this is best done with the traditional approach to project management, or if it is necessary to focus more on collaborative involvement of stakeholders, with emphasis on creativity and self-organization, rather than management command and control.

It is here proposed to see the question about what is the best approach to construction project management as a question regarding how to cope with complexity. With inspiration from novel social theory, it is argued that dealing with complexity is related fundamentally to processes of sensemaking.

The communication in a construction project and in one specific project meeting is analysed. The main finding is that although command and control related communication and retrospective sensemaking play a significant role, more complex communication encompassing future oriented sensemaking and sense-giving take up a lot of time and plays a major role in the way complexity is dealt with in the project.

Keywords: Communication, Complexity, Construction, Sensemaking, Time.

1. Introduction

In the dominating approach to construction practice today, the institution of universal, clock time, linear project schedules, and labour agreements regulating time use are all key

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elements. Construction project management is based on a linear conceptualization of time. The fundamental task of management is taken to be the organizing of a project in such a way that the diverse parts of the project play together; each part facilitating the operation of the whole, and avoiding that some operations obstruct other operations (Morris and Pinto, 2007). As in F. W. Taylor's well known time studies from the early 20th century, the objective is to minimize the obstructive potential of dependencies, and to rationalize work by simplifying operations and reducing movements, resulting in maximum output being produced with a minimum of cost.

This highly mechanical and linear formulation of the issue of organizational efficiency has been challenged from several sides. For example, social scientists at the Tavistock Institute in London in the early year of Taylor-inspired rationalization pointed out the limitations of the approach: People are not machines but social beings, and people have to be dealt with by management in completely different ways than machines (Emery and Trist, 1965). Other, more recent research has shown that the successful integration of diverse people across professions and knowledge domains is instrumental for effective problem solving and production efficiency. Multidisciplinary teams in situations of high complexity depend on tacit knowledge and on integrating innumerable clues in order to establish coherence, and to achieve effective problem solving. No outside coordination based on predefined categories and schedules can cope effectively with this, as the involvement, commitment and creative efforts of those involved are essential for outcomes (Oborn and Dawson 2010).

In the research literature on construction and on construction project management, the notion that construction projects are complex is widely accepted (Cicmil and Marshall, 2005; Gidado, 1996; Winch, 2010). There is also broad agreement that effective management is a basic precondition for project success. But on the key issues how complex projects should be coordinated, and what the actual role of management should be in making complexity manageable, there are diverging views. In fact, in the study of construction project management, it can be argued that two irreconcilable positions stand against each other: On the one hand, construction activities and project organizations are understood as depending fundamentally on centralized power and temporally linear managerial co-ordination for efficacy and efficiency. On the other hand, construction is conceived of as complex processes depending fundamentally on self-organization, creative problem solving, and on negotiation of multiple temporalities.

In social theory efforts are currently being made the concepts of *temporality* and *emergence* are being positioned pretty much in the bull's eye of this theoretical debate (Emirbayer and Mische, 1998). Theories of complex, dynamic systems (for example Luhmann, 1984); a concept of time as a lived and continually redefined amalgamation of past, present and future (Mead, 1932), and not least process oriented theory of sensemaking in complex organizations (Weick, 1979 and 1995; Weick and Sutcliffe, 2007) are increasingly being recognized as valuable in this effort.

The objective in this paper is to draw on insights from this developing theoretical field, in an exploration of the seemingly irreconcilable perspectives on how to cope with complexity in construction, and what the basic function of management is in this context. Looking at project

management and complexity through the lens of sensemaking; which of the opposed perspectives come closest to a true rendering of realities in construction projects, and in efforts to cope with complexity in construction?

2. Complexity and sensemaking in construction

Both social and technical systems are temporal phenomena. Elements and relationships are of many different kinds and can be transformed over time in diverse ways. This implies that systems can be very complicated phenomena to map and to understand. But what does it mean that systems are complex? Luhmann (1984) answers this question by considering the number of possible linkages between elements in systems. Complexity arises in systems *as elements are increasingly unable to establish direct relationships to all other elements*, as the number of elements in a system go up and the number of potential linkages goes up much more. Elements have a limited capacity to link with other elements. As systems grow, the number of possible direct links that are not actually established increases rapidly, and the lack of direct links establishes complexity in the system. Complexity is essentially the somehow patterned, but unpredictable dynamics that is produced by the actual relating that occurs between elements in a system.

Two general implications concerning the coping with complexity in a system are obvious: First, that integration (establishing relationships) is essential for all efforts to deal with complexity. Second, that since the multitasking ability of all elements is finite there can be no way to integrate a large system completely.

Distinguishing between complexity of a building as a material object and the complexity of a building process as such, it can be argued that both are complex and dynamic systems, even though one is much more obviously dynamic than the other. The fundamental source of complexity in the building and in the building process is not in itself the many elements and their manifold linkages, but rather the lack of linkages between elements, the temporal variability of dependencies, and the many indirect dependencies between seemingly unrelated elements. Linkages between elements are organized, but not always in obvious ways.

In the planning and coordination of building operations, tasks and contributors are conceptualized by designers and project managers as elements within a system of systems. For instance, in the progress plan, particular tasks make up diverse elements, with a number of dependencies indicated or implied between each of them. Firms, individuals, materials, machinery, plans (such as drawings) make up other subsets of elements, and also between these there are dependencies. This means that the project is made up to be a system, much in the same way as the building itself. The systemic nature of the project is co-created by stakeholders, and presumably this co-creation is nurtured by project management.

Integration cannot be complete in large systems, hence there will always be elements that are indirectly linked, and systems functions that are hard to decipher. In principle, then, there will always be effects of systems events that have to be experienced, since they cannot be predicted. The link between cause and effect is opaque. This is why visitors to building sites often see only chaos, where people with more experience see the situation as meaningful and as more ordered. Experienced construction workers, technical sub-contractors and

project managers are knowledgeable in the sense that they have the ability to make sense of events in complex situations, and they are generally savvy when it comes to making guesses, and to make productive decisions even when relevant information is scarce.

Sensemaking is an activity closely intertwined with complexity, and that it is a basic mechanism for people and organizations to cope with and manage complexity. Karl Weick, at the same time building on and contributing to the literature on designing and managing complex organizations, has conceived of sensemaking as a cognitive process that people engage in primarily when it – in a literal sense – becomes painfully obvious for them that their existing ideas about reality is inadequate.. According to Weick, sensemaking is a process that tends to be triggered by chaos; at instances when it is realized that the world is different from what it was expected to be. Weickian sensemaking is basically retrospective. People contemplate experiences, draw on available information and try to make sense of occurrences and cause-effect relationships that can help relate the present with the past (Weick, 1979, 1995).

Gephart et al. (2010) makes the point that sensemaking is not always made in a response to crisis. Active sensemaking can also be triggered by a need to understand what will happen in the future. Forward looking pro-active human beings may well engage in sensemaking as a preparation for their own future, and for the future of others. Gephart et al. furthermore refer to works by Maitlis and others, when they define the term sense-giving as influencing others to make sense of things in a way that reflects their own preferred redefinition of reality (Gephart et al., 2010, p 278; Maitlis, 2005; Maitlis and Lawrence, 2007).

3. Analysing sensemaking in construction

3.1 Analytical approach and methods

Are construction activities and project management basically depending on centralized power and command and control, top-down managerial, temporally linear co-ordination for efficacy and efficiency, or should the root causes of effectiveness and efficacy in construction be sought in ongoing processes of broad decisionmaking involvement, self-organization, distributed creative problem solving, and active negotiation of multiple temporalities? The research on this, reported in the following, is based on empirical analysis of original data that have been gathered in an ongoing, mission critical construction project over a four year period. The project was carried out by a major Norwegian contractor in Oslo, and encompassed five different buildings; four new structures and one refurbished 14 floors apartment building.

Construction projects go on in construction sites, but in reality activities that are important for the project are distributed both in time and in space that extends far outside the perimeters of the site itself. This fact and the complex nature of construction projects make the conduct of comprehensive analyses of communication and sensemaking in construction extremely challenging. In order to understand realities of construction, grasping what goes on in meetings gives only a limited view of the whole effort, but it is still relevant and important. Meetings are significant arenas for the diffusion of information and for active decisionmaking,

and are not least crucial for managerial involvement in the construction process. It is much easier to evaluate communication taking place in formal project meetings, than in the project as a whole. But it is impossible to understand fully what goes on in a meeting for observers that are not knowledgeable about the broader context, and about the specific project and the stakeholders involved in it.

The design of the analysis and the data gathering effort reported here was divided in two phases. In the first phase, a broad mapping of the project was undertaken. Stakeholders and roles were mapped on the level of individuals and organisations. Since the project and stakeholder involvement was constantly changing, this mapping of actors and activities was longitudinal in nature, and corresponding to the methods for longitudinal data collection in innovation projects laid out by Poole, Van de Ven et al. (2000).

Four years of research involvement in the construction effort meant that the project was observed during its pre-design and design phases, and then for two years in its actual production phase. In the design phases, observation in engineering and design meetings was combined with face-to-face interviews with participants carried out in their own offices off the building site (f. ex. in the architect firm). Later, in the production phase on-site, data was gathered both in ongoing engineering- and design meetings, in progress meetings and in other coordination meetings (cfr. table 1), and more interviews were carried out with participants on site and off site. In addition, regular visits were made to the construction site, in order to monitor progress of operations and to have informal conversations with workers in the operational context. All formal meetings attended were digitally recorded and about a dozen were fully transcribed.

Table 1: Categories of project meetings and typical participants

Meeting	*Participants*
Engineering- and design meetings	Architect Consulting engineer Representatives of technical subcontractors Representatives of the main contractor: Project manager, site manager engineering- and design manager, and selected foremen from main contractor
Progress meetings	Site manager, project leader (only sometimes), foremen, group leaders from main contractor Foremen and group leaders from sub-contractors
Other coordination meetings	Relevant people from contractor and subcontractors; representative of builder; representative of relevant public agencies, etc.

In the second phase of analysis the transcription of one particular progress meeting was singled out for closer scrutiny. This meeting had a duration of 1 hour and 31 minutes, had 9 participants (table 2), and took place in May 2011. Actual construction work had been ongoing for more than a year, which meant that the project organization was fully formed and many routines were well established.

Table 2: Meeting participants

N.	*Role*	*Employer*
1	Site manager	Main contractor
2	Safety manager	Main contractor
3	Forman carpenters	Main contractor
4	Foreman masons / concrete workers	Main contractor
5	Foreman tinsmiths / ventilation workers	Sub-contractor tinsmiths / ventilation
6	Forman plumbers	Sub-contractor plumbing
7	Safety representative (carpenters)	Main contractor
8	Group leader (bas) carpenters	Main contractor
9	Trainee (project management)	Main contractor
10	Researcher	Research group

3.2 Coding and analysis

The complete transcription of the meeting was coded using the software package "Nvivo".[2] The core analytical unit was defined as statements, which could make up one or more complete or incomplete sentences. Statements could be made by one or more people, as sentences could be started by one person and continued by one or more other people.

Exhibit 1: Example of content and structure of generic information loops

Utterances (Participant number, ref. table 1)	***Statement type***
Sequence 1 – adjusting work operations to project plans	
(8) What is to be casted on the 13th floor? (3) That is the small support for.. (2) the floor element put down in front.. (8) Yeah, that's right	Goal statements
(1) Isolation materials [have to be inserted] under wet room cabins, plastic film [has to be] removed	Instruction statements
(1) and the 13th floor remains, [I believe] it maybe still does	Monitoring statement
(1) This is not extremely urgent…	Instruction statement
(3) No, but I think he has… (3) … I haven't heard anything more (2) Has it [still] not been taken care of? (3) I believe it has been taken care of (1) Yes? Under the cabins? (9) Yes, I think so (1)	Monitoring statements
(1) Then [you have to do the] sixth floor on Tuesday. (9) [But] Wasn't everything [that remains of this] supposed to be done at the same time?	Instruction statement
(8) Cabling is ready up there, I could see. On the floor. Sixth floor.	Monitoring statement
(1) Well, then I suppose it will be 6th, 7th and 8ht floor, in one go.	Instruction statement

The coding scheme was developed before and during the data analysis. Coding took as a starting point the theoretical claim from Winch (2010) that the fundamental unit in construction project communication is generic information loops. These encompass instructions to workers, reports on outcomes of operations, and information on managerial decisions. Working with the transcript, it was found that a number of statements could be associated with this kind of information loop. There were statements giving information about goals; statements formulating work instructions; and statements communicating results of monitoring of outcomes. An example of this communicative structure is found in Exhibit 1,

[2] See: www.qsrinternational.com

which contains a brief excerpt from the communication in the meeting. The excerpt is part of the transcrition from the recording and has been translated for the use in this paper.

Observing communication in meetings over a long period of time, it was found that as observers' knowledge of the context (the building project, the stakeholders and the people) increased, it became easier to distinguish nuances and ambiguities in what is being said. Categorization of statements was not always straightforward, as real life statements often had several levels of meaning and had diverse intended effects when looked upon as "speech acts". One example here, found in Exhibit 1, is the point where the site manager states that "this is not extremely urgent..". This was a statement that sounded ironic or joking, and which could be interpreted as a goal statement ("referring to the work plans, this is not urgent"), a monitoring statement ("looking at what is happening on site, this does not appear urgent") and as an understated instruction statement ("this is actually really urgent"). The analysis showed that ambiguities of this kind often were settled in the course of the conversation itself; the dialogue, often in subtle ways, served as a negotiation to settle agreements on the proper understanding of situations and the specific meaning of statements.

One such particular and recurring negotiation was found to concern the general mode of dialogue and indicated the way to what proved to be a powerful extension of the coding scheme: In situations where management would rely on monitoring, goal and instruction statements, other participants in meetings would repeatedly try to pull the discussion in the direction of more open negotiations. In the first case, reference would be made retrospectively to existing plans and the dependencies taken into consideration when planning. Progress was measured against plans, and work efforts *tuned* accordingly. In the second case, meeting participants would consider current and future efforts, and themselves judge on dependencies and to what extent experienced and foreseen dependencies where adequately taken care of.

By scrutinizing the transcribed communication it was found that the latter kind of communication encompassed statements that apparently were monitoring statements, but that in reality were analytical statements that described factual circumstances in order to establish a fundament for problem solving with a degree of freedom from established plans and programmed actions. It was found that very much of what was going on in the meeting had to be characterized as negotiation and problem solving. The communication encompassed factual statements establishing current status (Factual statements), normative statements establishing the desirability of current and possible future states of affairs (Evaluative statements), creative proposals about how to solve problems (Generative statements), statements that aimed at bringing the problem solving discussion to a conclusion (Concluding statements), and sometimes statements summarizing an actual decision (Decision statements). These statements form a different kind of logical structure, or a different type of information loop than the generic loop discussed above (and by Winch). A fragment of communication that illustrates what this kind of information loop could look like is found in Exhibit 2. (Seqence 2 is the immediate continuation of the dialogue rendered in Exhibit 1.)

Exhibit 2: Example of content and structure of complex information loops

Utterances (participant number, cfr. Table 2)	*Statement type*
Sequence 2 – agreeing on priority in future operations	
(1) Well, then I suppose it will be 6th, 7th and 8ht floor, in one go.	
(9) Yes, but then it cannot be completed by Tuesday, I believe	Factual statement
(1) No. Right. That's OK	Evaluative statement
(8) I really wish we could also do the ceilings of the wet rooms at the same time	Generative statement
(7) Yes, in fact, it is not good that they [the electricians] go in and put cables on the floor	Evaluative statement
(7) because then we cannot go in there without stepping on the cables, and then the ceilings have to be left for later	Factual statement
(3) I thought he was not supposed to put cables there before everything was ready	Factual statement
(7) It is not really necessary to do it [the cables] this early	Evaluative statement
(8) No,	Concluding statement
(8) wait with cables on the next level, [it should be made sure] that they don't put the cables in [before the ceilings are ready]	Decision statement
Sequence 3 – agreeing on future safety measures	
(5) There is not so much more work to be done, but the rescue lift and the plan for using it is no longer operational […]	Factual statement
(5) If there is more work to be done high up that requires the use of belts, then we should deal with this.	Generative statement
(4) We need a new plan (9) Yes (8) The lift, yes. (5) The lift and.. (1) Yes, because we have removed that place (8) Yes	Concluding statements
(4) I believe there is a need for an upgrading of the first aid kits, and of the signs are about to [fall down]	Evaluative statement
(4) So I think we should deal with this and make it look a bit more orderly	Concluding statement
(9) I think there are some belts on the roof	Factual statement
(5) This ought to be in order when they start to use belts again	Evaluative statement
(1) Right, we should make a new (3) plan	Decision statement
(4) Yes. And follow it	Concluding statement

Whereas the generative information loops are retrospective in the sense explained above, the more complex information loops tend to be future oriented, and are often concerned with sense-giving, that is with influencing other participants to arrive at a certain understanding of issues at hand. The selected sequences illustrate this.

When coding the material, statements would be associated with generic and complex information loops only if they were uttered in the context of producing decisions. Other things participants in the meeting said where not coded into these categories. This could be statements with a social content such as greetings, content related to personal or private issues, or business issues not related to the ongoing project. To give an impression how much time was used on the different types of communication, a counting has been made of the number of words assigned to the two different forms of communication in the analysis. The results of this exercise are displayed in table 3.

Table 3. Types of communication in meeting

Decisionmaking logic / Statement type	Retrospective sensemaking	Future oriented sensemaking and sense-giving	Decisionmaking communication in all
Goal statements	5,2 %		
Instruction statements	6,2 %		
Monitoring statements	23,8 %		
Factual statements		20,2 %	
Generative statements		7,4 %	
Evaluative statements		4,9 %	
Concluding statements		8,8 %	
Decision statements		2,0 %	
Total	35,2 %	43,3 %	78,5 %

4. Discussion: Sensemaking strategies to rein in construction complexity

Sensemaking is a way of coping with complexity, and retrospective, future oriented sensemaking and sense-giving can be considered as different approaches to reining in complexity. When emergence is accepted as an essential phenomenon in construction, it becomes obvious that one cannot simply rely on pre-made plans and programmed actions to make sure construction efforts progress as desired. Retrospective sensemaking, evaluating current issues in the light of original plans is not in itself sufficient. This has been illustrated in the empirical analysis in the previous section. Managerial decisionmaking based on processing of information from generic information loops is a fact of life in the project investigated. But innumerable dependencies have not been dealt with in the plans, and ongoing operations cannot be regulated only looking at present performance in the light of original plans. Information loops with a different logic from the generic command-control loops have to be established, and information from these loops has to feed into decision making of a different kind. This decisionmaking is of a negotiated nature, and is based on dealing with lack of information and uncertainty by way of future oriented sensemaking, and sense-giving. It seems from the research carried out here that creating a shared sense of purpose and a common frame of reference is very important for this process. Integration and communication across specialty areas is necessary and balancing of bottom up and top down communication on actions and strategies is something that is strived for in the communicative practice in the meeting.

Future oriented sensemaking and influencing sensemaking efforts of others (sense-giving) corresponds to the important strand in the literature on construction and the management of construction projects preoccupied more with creative problem solving, emergence, social relations and on the need for integration of actors and actions in complex project contexts, than with command and control in hierarchical project organizations (Bresnen et al., 2005; Chan and Räisänen, 2009; Cicmil et al., 2006; Gidado, 1996).

As has been stated earlier, this perspective contrasts sharply with the more dominating perspective on project management, which is linear, rationalistic and concerned with

planning, execution and control and commonly associated with the so-called Project Management Body of Knowledge.

Neither of the two approaches ignores complexity, but each of them prescribes a different strategy for coping with it. The basic idea in PMBOK is to structure complexity by way of hierarchical organization, and to base project management on a linear conceptualization of time and of phased development. By defining goals clearly and precisely up front, stages in development can be programmed. In this way, it is distinguished between relevant and irrelevant dependencies, and integration of elements are structured in an economical way; hierarchically and based on a linear timeframe. Project management is tasked with specifying operations and operational procedures, in a way strikingly similar to what was prescribed already by F. W. Taylor about one hundred years ago (Taylor, 2011).

When this approach to building project management is described and interpreted today by a leading scholar such as Graham Winch, the message is that the actual centre of sensemaking efforts is located in the information processing that is an integral part of the command and control function of project management (Winch, 2010). This is sensemaking in the retrospective, Weickian sense. It concerns interpreting past events and comparing them with pre-defined, planned goals, and occurs as part of the monitoring of operational outcomes.

What is shown in the analysis here is that this approach to coping with complexity is inadequate in itself. Many more dependencies crop up during the construction project, and the up-front structuring of dependencies and integration of elements is very far from complete. A lot of time is used by participants in project meetings to establish what the current situation is like, and how it should be understood in the ongoing flow of actions and events in the construction effort. The complex information loops that form the medium for these negotiations embody future oriented sensemaking and sense-giving and depend on participation, collaborative involvement and with balancing bottom up and top down communication in a way that is distinguishing this kind of communication from the command-control oriented structure of the generic information loops.

Looking for what triggers active sensemaking, it is seen that rather than being triggered by chaos, future oriented sensemaking and sense-giving is routinely triggered in situations where project participants perceive complexity to be so high that important cause-effect relationships are opaque for them, and effects of systems events hard to foresee. Active systems integration is carried out in future oriented sensemaking and in sense-giving efforts, and in practice on site; in the active ordering of work efforts.

5. Conclusion

As a strategy to rein in complexity, the traditional management centred approach is pro-active in the sense that it focuses on everything that can be designed and planned up front. But what goes on in terms of sensemaking is retrospective. Building design, project goal setting and organizing are considered to be the outcomes of structured and analytical efforts taking place before the actual building starts on site. Integration is thought to be hierarchical,

with crucial lines of command established in the organization, and with physical elements of the building linked consistently with the hierarchical structure of the project organization. Inter-linkages between subsystems are to be designed at the top level; organizationally by the project management, technically by the architect or designer that establishes the basic template for integration of subsystems.

It is uncontroversial to state that sensemaking is essential in construction and for the management of complex construction projects. But the analysis in this paper has given more controversial results, indicating that the mainstream management centred thinking employing mainly retrospective sensemaking is inadequate. It has not been shown that generic information loops and traditional, top down command and control interactions are irrelevant or non-existent. The analysis has demonstrated, however, that this management approach does not dominate in the particular construction project that has been studied in detail. Rather, traditional management practices exist side by side with a different mode of communicating and of making decisions, particularly in complex situations. Hence, retrospective sensemaking is complemented by future oriented sensemaking and sense-giving, and traditional management is complemented by a remarkably different approach focusing on dialogue and involvement, in the pragmatic efforts to cope effectively with the complexity of coordinating work and making sensible decisions.

What takes place in this case is not retrospective sensemaking aiming at confirming or revising the plans for operations, it is rather proactive problem solving oriented towards the future. Communication encompasses explicit and implicit negotiations, concerning what alternatives ought to be pursued. This communication actively opens up and expands the space for possible outcomes. It does not relate solely to pre-established goals, plans and regulatory frameworks, although these certainly play an important role as factors to be considered in the negotiations. In meetings that work well from a communicative point of view, project management is able to draw on and benefit from the competence and creativity of all stakeholders present at the meeting. In this way, communication is integrating and mobilizing necessary resources to deal with unexpected situations that always emerge in large numbers in the course of construction projects.

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A FRAMEWORK FOR IDENTIFYING CONSTRUCTION COMPANIES BEST PRACTICE: A PANACEA FOR CORPORATE PERFORMANCE FAILURE

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ABSTRACT

This paper is a review of literature on measurements of corporate performance of construction companies in the South African construction industry and the need for improvement in performance measurements. Despite the accrued benefits of performance measurement as an effective performance improvement tool capable of helping construction companies identify performance gap and compare their performance with the best in class, yet performance measurement and its benchmarking are not being given the required attention. Where performance measurements are carried out they are not properly implemented or are being used only to benchmark performance for informal comparisons sake, such as, competitor rates and bid prices. For construction companies to identify best practice, the performance measurement models as a management improvement tool has to be devised with respect to construction companies' characteristics and used in bringing out desired improvements in performance. This may not be a reality without a comprehensive and methodical framework to achieve the desired result in identifying performance gaps and best practice that can lead to high performance. This paper examines the strengths and weaknesses of existing frameworks and identifies the key requirements suitable for developing a framework for construction companies taking into consideration both financial and non-financial measures. Literature has it that 'one-size-fit-all' approach is not in existence in performance measurement, and that non-recognition of existing features of companies environment is a process for probable operational failure of the models. The development of a 'generic' and 'internationalised' approach to the performance of firm's as seen in South African construction industry is almost impossible to achieve. Therefore, there is a need to align company's performance measures to their strategic objectives to identify best practices and promote continuous improvement.

Keywords: best practice, construction industry, performance measurement, performance measures, frameworks

Introduction

In the South African construction industry, performance of construction companies has been reported to be below optimal level which many authors argued accounted for its low productivity, decline in the industry contributions to Gross Domestic Product (GDP) and as well as operational failures and liquidation (Dlungwana, Nxumalo, Huysteen, Rwelamila and

Noyana 2002; Martin and Root, 2012). Though, to a certain level, many of these reports are based on sketchy evidence as there are no much empirical studies to drive home most of these perceptions. Thus performance measures through which organisations assesses their level of performance and compare with others within or outside the industry is required. Construction companies must measure their performance on a regular basis and draw comparison with their previous performance in order to identify performance gap and identify best practice (Gupta, 2004; Dansoh, 2005). Unfortunately, where performances measurements are being carried out by construction companies they are rather not properly implemented or being used only to benchmark performance for informal comparisons sake, such as, assessing their performance level against competitor rates and bid prices. For example, the South African construction industry has not been given the required attention beyond academic and industry sponsored research (Construction Industry Development Board (cidb), 2012).

The performance of the construction industry both in the developed and developing countries has been a source of concern for both industry practitioners and the academia. Several and recent studies focus on performance improvement within the construction industry ((Kagioglou, Cooper and Aouad, 2001; Beatham, 2003; Bassioni, Price and Hassan, 2005). It is made clear that construction companies lack effective and efficient methods for measuring their performance and identifying best practices (Luu, Kim, Cao and Park, 2008). There seems to be incongruence between cross-cultural features and managerial differences which depict inapplicability of many of the identified performance models in different countries (Luu et al., 2008; Horta, Camanho and Costa, 2010; Yang, Yeung, Chan, Chiang and Chan, 2010; Wang, El_Gafy and Zha 2010; Ali, Ibrahim And Al-Gahtani, 2012)

In this paper, the needs for performance measurements are examined and existing performance measurement models are explored to identify their strengths and weakness. The key requirements for developing a framework for construction companies taking into consideration their characteristic features, financial and non-financial performance measures is also determined. With respect to these, a conceptual model is proposed that could assist with identifying best practices by construction companies operating in the South African construction industry.

Performance measurement in construction industry

Yang et al. (2010) posit that performance measurement in the context of construction centres on three different levels namely; project, company and stakeholders' levels. Further, the perspectives of performance measurement has expanded beyond project performance measurement which focus on cost, time and quality to company performance measurement which is usually evaluated using traditional accounting system. Though, traditional accounting systems have been criticised and considered inappropriate, short term, lag indicators, static metrics, backward looking measures, reactive, descriptive and lagging indicators in assessing organisations performance. Consequent upon the criticism, the soft measures of performance that focus on non-financial performance are being considered (Bourne, Mills, Wilcox, Neely and Platts, 2000; Kaplan and Norton, 2001).

The review provided in this paper looks at the corporate performance of organisations within the construction industry. It presents some integrated approaches and multifaceted corporate performance measurement, developed since the late 1980s that combine both financial and non-financial measures Ghalayin and Nobble, 1996; Neely, 1999). Wongrassmee, Gardiner and Simmons (2003) categorised the models into groups. For instance, there are models that lay emphasis on self-assessment such as the Deming Prize (Japan and Asia), Baldridge Award (USA), and European Foundation for Quality Management Award using Business Excellence Models (Europe). Other models were designed to assist leaders/managers measure and improve business such as Capability Maturity Matrices, Performance Pyramid, Effective Progress and Performance Measurement (EP^2M) and the Balance Scorecard (BSC). However, some of the most frequently used frameworks in construction industry are discussed briefly in the following sub-headings.

The balance scorecard

The balance scorecard was introduced by Kaplan and Norton (1992) as a management tool to assist companies to identify and clarify their vision and strategy and put them into actions (BSC Institute, 2006). The tool incorporates four main measurement perspectives and with a wide range of potential sub-measures (Kagioglou et al., 2001). The four perspectives in BSC (Andersen, Lawrie and Shulver, 2000; Parker, 2000; Kagioglou et al., 2001) include:-

(i) financial: if companies succeed, how should they look at their shareholders?
(ii) Customer: to achieve company vision, how must the company look at their customers?
(iii) Internal business process: to satisfy customers, what management process must the company excel at?
(iv) Innovation, learning and improvement: to achieve company vision, how must the organisation learn and improve?

Amaratungal, Baldry and Sarshar (2001) posit that the BSC provide a balance between economic and operating performance. Accordingly, the strength of BSC is identified by Kagioglou et al. (2001) as follows:

(i) Guarding against sub-optimisation by forcing senior managers to consider all important operational issues
(ii) Communicating objectives and vision to the organisation
(iii) If implemented properly, focusing organisational efforts on a relatively small number of measures with relatively low costs.

The model integrates all the key stakeholders (owner, employees and customers) and strike balance between financial and non-financial measures with adequate attention on short and long term strategic objectives as well as lagging and leading indicators (Phusavat, 2007; Chiang and Lin, 2009). BSC provides a management team the means to unite and focus a common strategic agenda, alignment and build consensus. It also provides an obvious strategic link between business / operational units' strategy and 'corporate' to create strategic continuity. BSC provides a way by which individuals and teams can evaluate their

contribution to the success of the strategy, ultimately linking reward and compensation to performance and develop the bottom line by making better resource allocation and investment trade-offs. However, BSC has been criticised to be top-down approach only that do not offer interaction between top executive and the firms employees and thus not a useful tool for benchmarking activities as a way of promoting best practices (Kanji and Moura, 2001; Andersen et al., 2001; Chiang and Lin, 2009).

European Foundation for Quality Management Excellence Model

European Foundation for Quality Management (EFQM) is an organisation established by 14 European companies in 1988 to help organisation achieve improved performance. EFQM introduced a business excellence model in 1991, as a framework that could be used by organisations to measure and improve their entire performance. The model is developed on eight basic concepts of excellence: leadership, customer and stakeholders' focus, result orientation, management by process and fact, people development and involvement, continuous learning, innovation and improvement, partnership development and corporate social responsibility (Wu, 2009). Bassioni et al. (2005) developed the construction EFQM excellence model for adaptation in the construction industry and listed its enabling criteria to include: leadership; customers and stakeholder focus; strategic management; information and analysis; people, partnerships, suppliers, physical resources, intellectual capital, and risk work culture; and process management. Business Excellence Model such as EFQM achieve business excellence as continuous improvement model through being a useful framework capable of performing regular health checks of all business processes. The model identifies best practice and performance gap by allowing both internal and external benchmarking of firms business processes, but without proffering solutions (Andersen et al., 2001). The model also increases decision making efficiency and leadership capabilities assessment of a firm. However, it has complex underlying criteria scoring system which make benchmarking become difficult without it being carried out by trained and experienced personnel. It also requires the use of external assessors Therefore, its efficiency and effectiveness as a viable strategic management tool is in doubt.

Key Performance Indicators

The generally held view is that the construction industry is complex and fragmented and these characteristics impair its performance. According to Anumba and Evbuomwan (1995) the fragmentation of the construction industry creates management problems that render it ineffective and efficient relative to other industries. Recognising these inadequacies, the UK Government instituted a Construction Task Force to confront the industry to commit itself to change, so that it reaps the benefits of fundamental improvements in design, quality, sustainability and customer satisfaction (Beatham, 2003). The Construction Best Practice Programme (CBPP) and the Movement for Innovation (M4i) were set up by the Task Force and their terms of reference was to clearly define the requirements needed to deliver targeted improvements (Beatham, 2003). CBPP and M4i came up with key performance measures tagged Key Performance Indicators for the industry. The indicators include; client satisfaction (product & service); defects, predictability (cost & time); profitability; productivity; safety; construction cost; and construction time. According to Bassioni (2004) the main

target of these initiatives was to give a clear indication of overall construction industry performance using the performance measures of projects and organisation. KPIs track long-term trends in performance, and specifically, to demonstrate whether the construction industry was achieving the industry improvement targets. It provides companies with a simple method of establishing a performance measurement system in an organisation. It improves organisation management decision making. However, KPIs are regarded as lagging measures that barely provide opportunity for change and as such it is lowly rated in the areas of improvement, innovation and in identifying best practices in construction organisations. KPIs lack a holistic viewpoint on the relationship among different indicators.

The South African Construction Excellence Model (SACEM)

The South African Excellence Model (SAEM) is an internationally recognised model for business performance evaluation developed by the South African Excellence Foundation (SAEF). The model was launched in 1997 and became operational in 1998. The South African Construction Excellence Model (SACEM) is an adaption of SAEM which enables business self-assessment in the construction industry. The SACEM is a comprehensive tool developed to promote the concept of TQM in the construction industry at all levels (Dlungwana et al., 2002). There are eleven criteria to evaluate organisation performance. The criteria include; leadership; policy and strategy; customer and market focus; people management; resources and information management; process; impact on society; customer satisfaction; people satisfaction; supplier and partnership performance and business result (Dlungwana et al., 2002). Basically, the criteria were developed using the EFQM and Malcom Balridge National Quality Award criteria as points of departure (South African Excellence Foundation, 2004). The model's strength lies in its ability to serve as a risk management tool for construction clients Construction company's' risk profiles will be easily identifiable and managed appropriately, the model also promote the concept of 'total quality management' at both the corporate level as well as the construction site level. The model can serve as a useful performance benchmarking tool for contractors. The model is complex and measure many criteria, it is requires rigorous self-assessment application for it to be effective. Therefore, the shortcomings of BEM are apparent in the model and as such cannot precipitate best practices in isolation.

Best practice

Zairi (1992) views practice as the characteristics that describes both the internal and external business behaviour of an organisation. Organisational practice if flawed, could lead to performance gaps. Zairi (1992) that an identified gap could be related to business process, structure of the firm, its management system, human factors or the firm's strategic approaches. Best practice therefore, is that which is exhibited by organisations that produce superior results, determined through a systematic process, and judged as exemplary, good or successfully demonstrated (Business Performance Improvement Resource, n.d). White and Plotnick (2010) view best practice as a method, process, activity, incentive or reward that is believed to be more effective at delivering a particular outcome than any other technique, method, process, etc. White and Plotnick (2010) contend that the underlying idea is that with proper processes, checks, and testing, a desired outcome can be delivered with

fewer problems and unforeseen complications in any organisation where best practice is to be adapted. In other words, best practice is the most efficient (least amount of effort) and effective (best results) way of accomplishing tasks, based on repeatable procedures that have proven themselves over time for large numbers of organisations (White and Plotnick, 2010). Therefore, it is quite difficult to have or provide a limit to representation of 'best practice' as there is no consensus on how best practice could be identified or what constitute a best practice. Thus, the working definition of best practice in this review is as defined by Prax (2000) cited in Maire, Bronet and Pillet (2005, p. 52) as every practical, knowledge or know-how which showed its effectiveness or its value in company or part of the company and which is applicable to another company or part of the company". According to Zahorsky (2003) best practice involves finding and using ideas and strategies from outside a company and/or industry to improve performance in any given area.

The Business Performance Improvement Resource (n.d) identifies various difficulties involved in the process of improving by learning from best practice, key among these are:

(i) Having sufficient knowledge of systems and processes to be able to compare against others
(ii) Knowing where to find best practices
(iii) Knowing whether a particular practice is suitable for situation
(iv) Adapting the practice to organisation
(v) Finding the time and other resources for the above

Fundamental tacit assumption of Business Best Practice was stated by Wareham and Gerrit (1999) who identify the underlying tacit assumptions of best practice to include: homogeneity; universal yardstick; transferability; alienability and stickiness; and validation.

The need for a framework

Different definitions of framework exist in literature, Yusof (2000) cited in Deros Yusof and Salleh (2006) defines framework as a set of theory or knowledge used by an individual as a basis for his judgement or decisions. Deros et al. (2006) assert that failure or poor implementation approach of new approaches to improving quality and performances of organisations necessitate the design of frameworks. Put succinctly, Aalbregtse, Hejka and McNeley (1991) reiterate the reasons for having frameworks:

i. Illustrating an overview and communicating a new vision to organisations;
ii. Forcing management to address a substantial list of key issues which otherwise might not be addressed;
iii. Giving valuable insights into organisation's strengths and weaknesses, and its overall strategic position in the market-place; and
iv. Supporting implementation and to improving the chance of success because this will provide not only overview but also more detailed information describing the content of each framework element and its relationship to other elements.

Framework is a systematic identification of process or procedure that will guide the thinking and implementation of change efforts or where failure requires adequate attention. As a result, Medori and Steeple (2000) itemise the required steps to be followed or put into consideration in developing a framework and these include the following:

i. Procedures for selecting and implementing measures;
ii. Ability to identify whether existing measurement system is up to date and measuring critical issues (i.e. audit capability);
iii. Selected measures should be congruent with company strategy and have strong relationship with six core competitive priorities (quality, cost, flexibility, time, delivery and future growth), and
iv. Facilitates rapid selection of measures from a data bank; and workbook approach (step-by-step methodology).

Performance measurement frameworks in construction

The revolution in performance measurement systems in the business environment has made a myriad of frameworks and models available from diverse backgrounds for measuring corporate performance (Neely and Bourne, 2000). The revolution that led to the development of these frameworks was as a result of inability of the conventional metrics to give a complete picture of organisational performance in the ever changing market that characterises business environments (Stone and Banks, 1997). Many of these archetypes or models evolved for adoption in business come with significant diversity both in design and implementation. Brown and Devlin (1997) define performance measurement framework as a complete set of performance measures and indicators derived in a manner that is consistent to set of rules and guidelines stated in performance measurement systems. The most frequently adopted frameworks in construction identified by Robinson, Anumba, Carrillo and Al-Ghassani (2005), are analysed to assess their strength, weaknesses or criticisms, typical application and their key success factors. The comparison is summarised in table1 to provide sound basis for understanding and implementation of the conceptual framework proposed in this paper.

Proposed conceptual framework

The conceptual framework proposed in this paper is shown in figure 1. The framework builds on the existing frameworks to engender useful understanding in identifying best practices that would enhance organisational performance. The approach suggested include gathering of performance data internally by studying and understanding own business processes with the use performance measurement systems tools. Simultaneously data is collected externally may be through databases and/or, visits to organisations considered to be industry leaders.

The comparison of both internal and external data helps in the identification of practice gaps between current and best practice, so that the development of a framework to improve the business process could commence. The next steps are employed to develop overall model of the process involved and to identify core business areas that require benchmarking (top-

down approach, BSCs) and focus on the core business process (bottom-up approach) using Business Excellence Model (BEM) to carry out self-assessment which is essential to develop metrics or measures of performance. These criteria are the basic and common features of the analysed models.

Consequently, it is imperative that organisations draw on the strengths of these two models (BSCs and BEM) which could be used to identify the core business and provide adequate attention to the core business areas to engender continuous improvement. This will enhance the deployment of corporate strategies that will lead to optimum or high performance in business environment. Price (2003) accordingly, recommends that measurement tools such as BSC and the BEM are better positioned to achieve the linkages between performance and strategy and should be modelled. Therefore, to attain and sustain continuous improvement in performance and bring about the required change in business sphere the conceptual framework proposed is a necessity. The conceptual framework has specific pertinence to the organisation as a strategic and diagnostic tool if adopted and capable of providing a healthy foundation upon which other business and management processes could be built. Though, the conceptual framework is still at formative stage and part of an on-going research which will be validated at a later stage through survey amongst industry practitioners and the academia. The framework will provide opportunities for firms to evaluate their performance, identify performance gaps and have better understanding of suitable 'best practices' by comparing their performances against best in class companies.

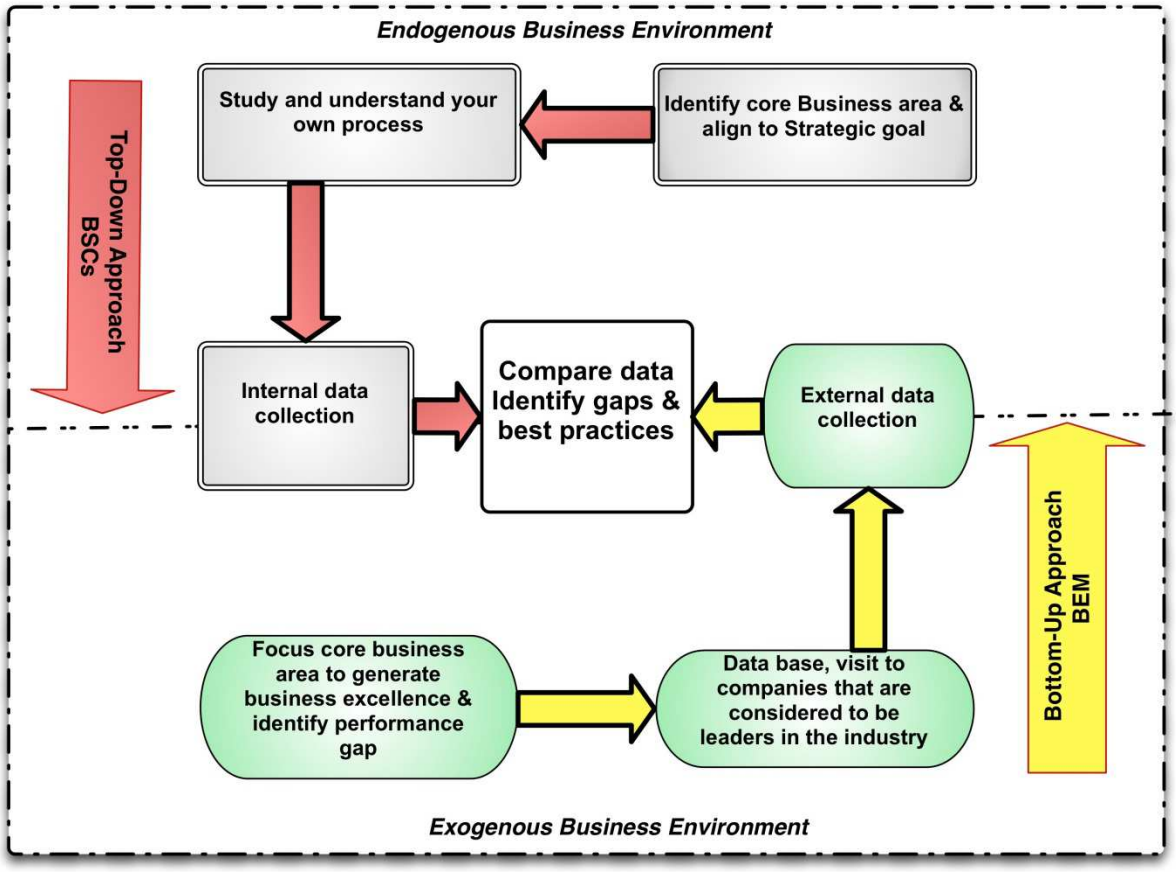

Figure 1: A proposed conceptual framework for identifying best practices

Conclusion

It is universally acknowledged that the dynamism of the present construction market and the trends towards more sophisticated, specialised and customer-oriented services in the construction industry requires a more efficient, proactive and effective approach to performance measurement. Therefore, a 'one-size-fit-all' approach is inadequate in performance measurement, particularly for the dynamics nature of construction operations. Non-recognition of the external features of an organisation's environment is a recipe for operational failure of any performance model. Analyses of existing frameworks for measuring corporate performance in the construction industry make it clear that total commitment and sponsorship by the entire management team is required to attain optimal performance, irrespective of the framework applied. However, this paper argues that the rational starting point in any performance measurement is the identification of performance gaps and industry/organizational best practices. The conceptual framework developed demonstrates the needed combination of internal and external analyses and top-down/bottom-up approaches that could enable the achievement of optimal performance levels and improvement. The existing performance measurement models comprise of non-prescriptive pattern that tend to be difficult for organisation management to achieve a perfect complement between an organisation and available performance measurement models. Therefore, the conceptual framework proposed offers itself as a diagnostic and strategic management tool that could be used in implementing and identifying continuous improvement efficiently in particular organizational types for company to achieve optimal performance. Future research is required to test the feasibility of the framework and how it could be implemented as a strategic performance model effectively.

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Investigating the competencies for Serviceability of urban areas

Renita Niemi [1], Suvi Nenonen [2], Juha-Matti Junnonen [3]

Abstract

The serviceability is connected generally to the business processes and even to the descriptions of variety of building types. However the discussion of urban development is more connected to master plans and long term processes instead of capturing the service aspects and service dominance logic. In order to fill that cap, serviceability could be discussed through creating a holistic framework by connecting the structure of the *network city, service dominance logic* and *servicescape.* The intention is to capture the shift from traditional *designscape* to servicescape. Van Schaik (2009) emphasizes importance of socio-spatial systems as a structure of urban development. The urban system is both a social and physical system at the same time; it is too complex to handle using only a layered approach, because it is impossible to maintain a distinction between separate layers, especially those representing subsystems or sectors. The socio-spatial system is concerning activities, which provide a platform for different stakeholders to act in the new way. Additionally Hiller (2009) states that cities as complex systems are made of two sub-systems: a physical sub-system (buildings linked by streets, roads and infrastructure) and human-sub-system (movement, interaction and activity).

The purpose of this study is to analyse the created framework of serviceability capabilities in the context of socio-spatial systems. The empirical data is gathered from case study from Helsinki metropolitan area. The used methods are document analysis and participatory workshop. The results indicate that the shift towards servicescape as one crucial element of socio-spatial system is dynamic by its nature. The question is not about the shift from one stable solution to another updated version but the shift is more towards activity-based urban development. The issues like learning, communicating, changing, connecting, collaborating and controlling are the important determinants. The outcome of this study is adding an activity-based perspective to urban development discussions.

Keywords: serviceability, network city, service dominance logic, servicescape, socio-spatial

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1. Introduction

The processes of urban development have been the interest in many researchers but more than the focus in urban design research is in solutions and outcomes. The interest in this paper is to understand *the process of urban development and to focus on especially to socio-spatial systems.*

The space can be studied as absolute, relative and relational phenomena. Absolute space is geometrically defined container, where artefacts and humans are placed with geographical co-ordinate. Relative space relationship between artefact and peoples is related to the context. Relational space forms by interactions between social relationships and connections in certain context. (Koskela 1994.)

In the past, urbanists have considered the socio-spatial systems with limited view as only a container of social activities. Space contains actions and social relations, which intimately involve in our daily lives. It affects the way we feel and what we do. In turn people alter space and construct new environments to better fit their needs. Shields (1991) use the term social spatialisation to designate the on-going spatial construction of the spatial at the level of the social imaginary (collective mythologies, presuppositions) as well as the interventions in landscapes (for example built environment). Therefore, a dual relationship exists between people and space; people act according to social factors (gender, glass, race, age, status) within given and in reaction to a given space. When a city converts a vacant lot into a basketball court, the type of activity and interaction of group of persons within the space will change. On the other hand, people create and alter space to express their own needs and desires. (Gottdiener M and Hutchison R 2011.)

The socio-spatial systems approach is linked very closely to the research of usability of built environment, which has been on going about 10 years in CIB W111 workgroup. This group has defined the learning environments as 'the socio-psychological, physical and digital settings, in an organisation or community context, in which learning occurs and which affects learners achievement and attitudes'. (Alexander, CIB W111, 2009.)

Usability in the built environment is context dependent, a product of user experience related to the social relations amongst users and to the interaction between users and facilities. Usability has been found to be strongly related, not only to relationships between people and physical settings, but also to clear strategies for the organisation of work and the use of facilities. Usability is the relationship with the user and space about *efficiency* (easiness to perform with little use of resources), *effectiveness* (deliver of desired effect) and *satisfaction* (feelings, attitude) (ISO 9241) and in addition to that usability is time, place, context and situation bound concepts. Warell (2001) states that product designers suggest two categories for functionality: technical functionality and interactive functionality.

Serviceability is related to the interactive functionality. The serviceability of the urban area is a multidimensional phenomenon, which aims to respond to the single question: *Is the area fit for its purpose*? It is the capability of the area to perform the function(s) for which it is designed, used or required to use. In order to capture the phenomenon it is important to

develop the framework of serviceability. The framework provides a starting point for the discussion of new approaches to the urban area and city development, which tend to analyse stable and long-term master plans instead of dynamic and process-orientated phenomena in areas. The shift towards *socio-spatial analysis* is needed and sustainability as a megatrend can be one driver to more dynamic approaches, both in practice and research, and provide good insights into understanding the serviceability of the areas in general.

The *framework of the serviceability* of the urban area is based on a matrix connecting Dupuy's (1991) "three levels of operators that [re]organize urban space" model and service dominant (S-D) logic, as described by Vargo & Lusch (2008). This matrix frames the servicescape (Niemi & Nenonen 2011).

A suburb of Helsinki metropolis is analysed by these chosen criteria. At first the elements of framework are described.

2. Framework for serviceability of urban area

The approach of this serviceability is discussed through three main topics: the structure of the network city, service-dominant logic and servicescape.

The first perspective on the serviceability of urban areas has to include the different players and actors of the urban area. One can analyse them by using Dupuy's levels and differentiating the operators. There are three levels of operators that (re)organize urban space. The first level operator consists of *different physical networks* (the road network, telephone network, rail network, etc.). The second level operator (of the *production network*, *consumption network* and *domestic network*) and third level operator (of the network of an *urban household*) are virtual networks. They are both dependent on the first level operator to create interactions between people. (Dupuy 1991.)

The second perspective on the serviceability of urban areas is performed through service-dominant logic. Service-dominant (S-D) logic is a unified understanding of the purpose and nature of organizations, markets and society. The global economy is moving towards models in which "service logic" dominates (Vargo and Lusch 2004) challenging traditional ways of evaluating productivity, innovation and growth. The primary components of S-D logic are: (1) *the conceptualization of service as a process, rather than a unit of output*; (2) *a focus on dynamic resources, such as knowledge and skills, rather than static resources, such as natural resources*; and (3) *an understanding of value as a collaborative process between providers and customers*, rather than what producers create and subsequently deliver to customers. (Vargo and Lusch 2008.)

The third perspective explains the components of servicescape. The socio-spatial system is connected by definition to interaction between people and buildings. In order to understand the platform where the interaction happens one has to be able to capture both the tangible and intangible platform for that. This platform can be defined as servicescape.

Booms and Bitner (1981) define *servicescape* as “the environment in which the service is assembled and in which seller and consumer interact, combined with tangible commodities that facilitate performance or communication of the service”. It is also suggested, that employee satisfaction, productivity and motivation can be influenced by servicescape (Becker 1981; Davis 1984; Steele 1986; Sundstrom and Altman 1989). Three important aspects of servicescape within a building suggested by Bitner (1982) include: 1) *Ambient Conditions* (e.g. temperature, air quality, noise, music, odour, etc.); 2) *Space/Function* (e.g. layout, equipment, furnishings, etc.); 3) *Signs, Symbols, and Artefacts* (e.g. signage, personal artefacts, style of décor, etc.).

The servicescape concept is scalable and has been studied in connection with urban environments and areas. Julier (2005) discusses *designscapes* as the design hardware of buildings, streets and public spaces and how they are used to differentiate and communicate. On the other hand, this is reviewed as a reference to the marketing strategies of place branding. The emotional software of brand identity programmes, as carried out through literature, websites, the copyrighting of slogans and other largely two-dimensional platforms comes into view. Hall (2008), states that place branding lies at the intersection of tourism, geography and marketing. Contemporary place branding requires the use of hardware, in the form of servicescapes and designscapes that are developed via architecture, design and heritage; and software, in the form of branding, marketing and promotion. Rosenbaum and Massiah (2011) state that a servicescape comprises objective, measureable and managerially controllable stimuli but also subjective, immeasurable and often managerially uncontrollable social, symbolic and restorative stimuli, which all influence customer approach/avoidance decisions and social interaction behaviours. Furthermore, customer responses to social, symbolic and restorative stimuli are often the drivers of profound person–place attachments. As Rosenbaum and Massiah (2011) propose, a servicescape paradigm that links marketing, environmental/natural psychology, humanistic geography and sociology is relevant.

Servicescape is a tapestry of ambient conditions, space and functions and as well as visual objects and it offers a ground for serviceability description. The serviceability framework for appraisal areal performance is formed by three factors; characteristic of area, strategic intention and emergence. In this paper we focus on areal characteristic by five themes: changing, connecting, communicating, collaborating, controlling. The strategy intention creates relationship between different domains of functions, integrates time horizon and links meanings with ends. Here the weight is on sense of direction. Emergent development is related to systems of existence and it refers to entity resulting form the rising and new phenomena, feature or activity level. Here the weight is on adjusting (Fig.1).

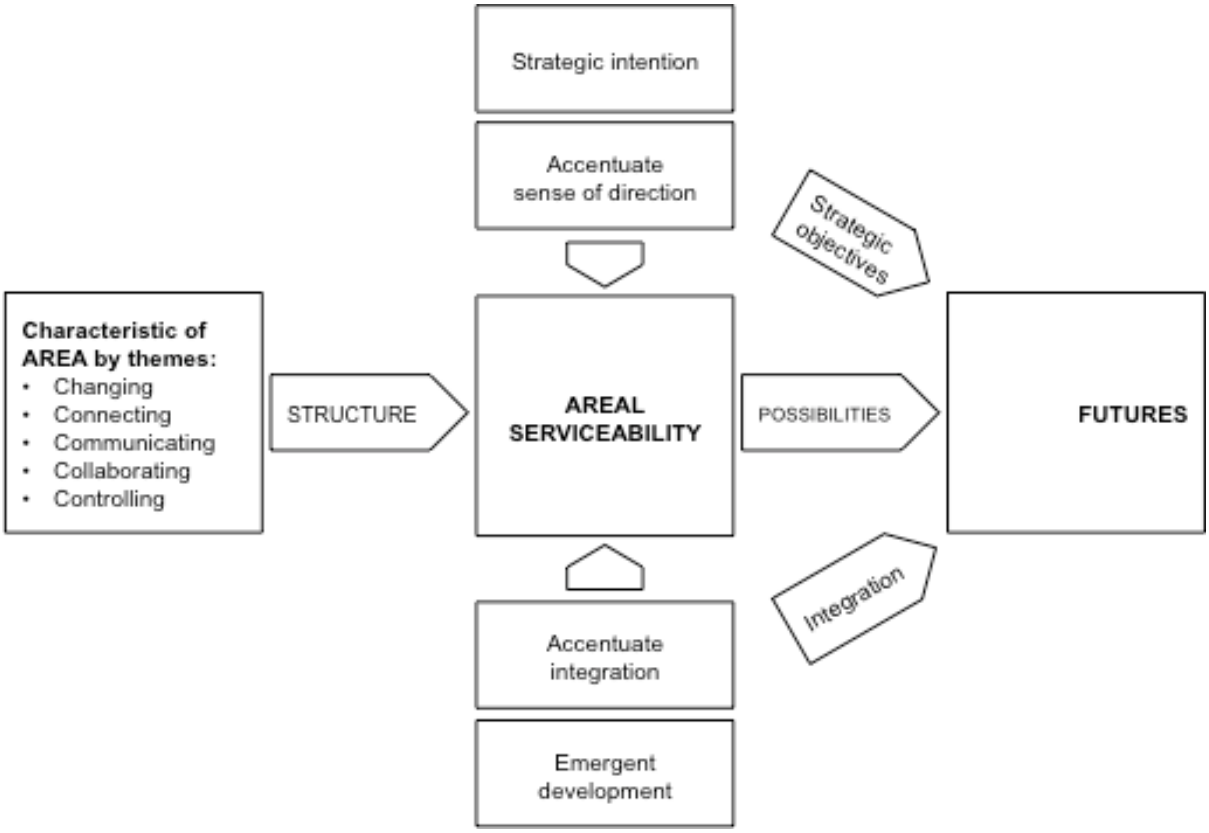

Figure 1: A Conceptual framework of Serviceability

The structure for analysing the case is formed by using the elements of perspectives the network city and service-dominant logic will provide a servicescape as a platform for the area. This serviceability factors are linked with capability cluster which are described next:

Changing

The *change* is a natural phenomenon of a development, but *how to react for* a change. Changing occurs both physically and perceptually and it is more about changing a *mindsets*. Often a change is not an instant but rather phenomena, which consist of different phases and sequences. Temporary projects, which become transformative and the place can have “meanwhile uses”- functions. The main question how to manage the speed and disruption of change and the uncertainty; unpredictable changes in politics, economics, and technologies. One solution is to become more resilient and adaptable from spatial, organisational and operational perspectives. Involving people in early phase of development process decreases the unwillingness for change. Flexibility and resilience is the capability to recover from the changes.

Connecting

In order to connect people, place and every day practices and businesses we need to understand physical and perceptual connection. Connectivity is a capability to connect the physical environment as well as, the connection between different communities with help of

social media and social networks. Even the usage of social media is vivid; it is not replacing the actual social contacts around different topics. With the help of the connectivity, different kind affordance can be offered like networking of activities and business, cultural and social relationships within the site and externally. Connectivity is noticed as flow of networks or transportation networks (e.g. roads, streets pipes, aqueducts, power lines) or nearly any structure, which permits either vehicular movement or flow of some commodity or people. It combines different modes of transport, for example, walking and car to model multi-modal journeys. Connectivity is ability build or maintain link between two or several areas, like the relationship to the sub region and the city centre.

Communicating

Communication is capability to interact with different people and a city offers a platform for living and interaction. Communications is about sending a message and interact with others. Identity, image and brand are related but means different things. *Brand* simplifies the message and creates the motivation hook. A brand can be seen as a collective agreement of the image. *Identity* is more about who you are, what you think about yourself and how you present yourself. Identity should express personality. Visual identity is name, logo, website, advertising. *Image* is how others view you. It is the feeling or opinion about the service, product, company or person. Feelings are difficult to manage. Branding techniques can be applied to any product, service, company or person and even for area. Capability to create experiences: sense of place and diversity. Often decision are based on feelings and therefore it is important that those who are involved in planning process are aware of this phenomena and creates (communicates) solutions, which in best possible way supports the end user choice.

One-way communication is based on informing; consulting or advising and is seen as top down communication. Two-way communication (bottom up) is a process in which participants create and share information in order to research mutual understanding. Communication can raise awareness and change perceptions to support cultural, behavioural and physical change. (Worthington et al. 2012.)

Collaborating

Collaboration is capability to collaborate informally and formally. Complexity, and the value of diversity are two key phenomena of to day; regional development projects encountered questions are "wicked", "messy" and "fuzzy", and simply one of the profession or industry cannot solve them alone. The partnerships are in public or /and private sectors, which for instance helps in sharing resources. Collaboration should not be seen as restrictive practices, the best way is creatively balancing conflicting interests. It is about working across different scales, interests, functions and cultures and this helps to build up community spirit. The collaboration can be informal or formal process, which is deriving the service provision. New partnerships, public-private-people partnerships finding common and shared values within the public and private actors.

A continuous series of small events is essential to gradually raise awareness and change perceptions. Initially engaging individuals in the community who are willing to be pro-active

and responsible, who then spread a climate of confidence and opportunity for change, results in a paradigm shift.

Controlling

Controlling is a continuous management process, which has a forward looking attitude. Controlling is balance between creating and reinforcing the vision and mission and then managing the process of change through combination of regulatory controls and behaviour (Worthington et al. 2012). Questioning the hierarchy in city planning, not top-down but bottom up, which have the local line and specific area and actors. It is interesting to follow development of area management and areal operators besides the development of the physical environment and the temporal development and control. Control can be managed through working partnerships between key stakeholders with agreed goals such as a strong leadership is finding project champion who has the ability to keep the different parties aligned and engaged. Orchestrating a process of change and sustaining other champions who are committed and keep the project alive. (Worthington et al. 2012.)

3. Method

A suburb of Helsinki metropolis is analysed by these described created serviceability themes. The information is basically collected from authority interviews and consultants report of the area. A co-workshop was held, which gave input to a structure for future analysis. The participants were from different countries and they had several years experience in areal development projects. The study follows the structure of exploratory case study in order to evaluate relevance of the created framework.

4. Case Pitäjänmäki

Pitäjänmäki is one of the Helsinki suburbs and has all the potential to be success area. It is *accessible* and located around 10 kilometres to the northwest/west of Helsinki Central railway station and it is a station on the VR commuter rail network. There are several bus connections from Helsinki city centre, which takes only ten minutes to Pitäjänmäki. Additionally, there is cross traffic in metropolitan area.

The Pitäjänmäki of today is a suburb of 16 565 (2011/12) residents and approximately 22,500 jobs. The main dwelling area in Pitäjänmäki is located on West and East Reimarla on both side of Konalatie road. The neighbourhoods containing detached and semi-detached housing still hold some buildings from the villa community period

Development of the Pitäjänmäki (P) can be seen as transformation form traditional industry to ICT and knowledge-based industry. The railway connection has had an important role in area development. The Strömberg factories started in 1911 and the first privately owned Krönckel brewery in the mid-19th century. This first period can be seen as *(P1.0) Brewing industry and Engineering works*. Next step was taken at eighties when the ICT related industry started to grow (P2.0 /Piimäki) and now on 21th century it is to define common vision and motivation to create "*positive twist*" in (P 3.0). This positive twist is about creating

new concepts for the office premises and residential use. Piimäki is one of the largest concentrations of IT-related jobs in Finland (Nokia, ABB, etc.) The area still contains traditional industry as well like groceries, cosmetics, electrical device production, jewellers, paint and a diverse selection of smaller businesses.

The Pitäjänmäki surroundings are open and active only during office hours. Pitäjänmäki and Konala form a continuous service area. The basic services are better than average in Helsinki (day-cares, schools, health centre, pharmacy, library, church, post office and plenty of recreational services in activity centre). The only what is missing according to inhabitants is the swimming pool. The trend is the same as elsewhere in reducing the commercial service like banks and corner shops.

5. Findings of the case

The analysis is based on description of the area, accessibility and services, which is structured by following themes: changing, connecting, collaborating, communicating and controlling.

Diversity is a good way to describe case area. There are different-aged properties and extremely varied businesses. These can be seen as strengths to build on. But on the other hand there is out dated stock of real estate and high underutilization and low rental level. On the year 2010 vacancy rate was over 12% and the companies kept on leaving from the area. The rents were at giveaway prices, but still the real estate owners were not succeeding to find tenants. The situation has continued ever since. The real estate owners have definitely thought to change the purpose of the usage for a hotel, residential building or even to demolish the building.

To secure the sustainable development it is a need for vitality and new business ideas. The challenge for the owner of the real estates is to create new business models and practices. There have been several development projects with the city and local actors. The inspiring example has been Manchester-case with the idea of a new living room for the citizen and visitors; the disaster has turned to a positive boost for a change making.

The other good example is to transform city streets over to public space uses like in Dumbo-case in New York. A triangle on Pearl Street underneath Manhattan Bridge was once a car parking spot and was turned to "*a new living room for the neighbourhood*" an oasis of green with chairs, table and umbrellas and art. The implementation was rapid; in two months local collaboration transformation was completed.

Changing *(The history, current status and future, vision of the areal development)*

On the average cities or suburbs has taken generation to mature as well as Pitäjänmäki, which has several historical layers in business life. The important milestones of the area development is firstly the beginning of traditional industry and later the transformation to ICT and knowledge-based industry. Robust industry and diverse history works as a competitive advantage (for the idea of the area and concepts of space). In Pitäjänmäki there are several

head quarters for companies. The *current status and the future* are influenced partially by structural change in economics and recession. Even Pitäjänmäki has centralized location at the metropolitan area and good accessibility and public transportation. The *owners* meet impossible economical equations, which does not improve the investing in developing in a future.

Communicating (*General Areal characteristic, atmosphere and imago of the area)*

It is considered that Pitäjänmäki has a weak and fuzzy general image, pedestrian traffic, parks and recreation area and too homogeneous business mix. In order to improve the functionality and vitality of the area the business-related development and increasing services is needed. A concentrated area marketing and communication enables to build a strong areal image.

Connecting (*Accessibility, access, features and use of street and traffic networks and areas)*

The central purpose of the city is to enable social and economic transactions of ideas and goods between people. Successful places require the appropriate balance of interconnectedness, movement, awareness, encounter and exchange at every scale to provide environments in which different kinds of human activity can unfold and thrive. Cities can connect or separate by bringing people into social or economic relationship or keep them apart. To maximize development opportunities, connections should be considered across scales, functions and time (Worthington et al. 2012).

There is one remarkable weakness in traffic of Pitäjänmäki; the main street is used for through-traffic. There is also lack of parking places or they are placed unevenly. According to a study one way to improve the area functionality and general image is to invest in transportation and transportation services and perhaps speed up the realization of the planned rail traffic.

Collaborating

The next phase for Pitäjänmäki is to create a positive twist in order to return a positive imago and attractiveness. This is done by recognition of the area uniqueness and also competitiveness. Quite important is to recognise the possible opportunities area. There is a need to produce proposals for action and also a model for economically resilient solution. It is crucial to improve further the area development procurements. There is a need to increase participant knowledge, capability and common understanding.

The future is in workplaces, living, services, and transportation and recreation services, which have huge impact to the area vividness functionality and comfort. The main idea is to create a holistic plan and divide area in fields of operation sectors. The collaborating is on city level as a formal plan but Pitäjänmäki has also active inhabitants community, which can be consider as informal. Pitäjänmäki has been develop rather fragmentally during different decades and it needs a holistic plan or roadmap which to follow. The idea is to create/

update not only for today but also for the future activity-based solutions, which can be either temporary or permanent by nature. It is not from inception to completion and occupation; it needs to be replaced by the well-accepted practices of community consultation and participation in the process.

6. Conclusion

The purpose of this study was to analyse the created framework of serviceability capabilities in the context of socio-spatial systems. The empirical data was gathered from a case study in Helsinki metropolitan area. The goal of this paper was *investigate the competencies for serviceability of urban areas* and to classify the key elements that create service-based competitiveness.

In order to assess areal serviceability we need to know history, current status and future and even the vision of the areal development. General areal characteristic, atmosphere and imago are relevant when assessing communication. Connecting is physical, social and virtual accessibility, features and use of street and traffic networks and areas. Controlling has forward-looking attitude and is crucial in transforming processes.

Five C's (changing, connecting, communicating, collaborating, controlling) helps structure the material in hand but it definitely needs a support material, quantitative facts and figures in order to make more tangible analyses and to allow comparison between the approaches.

Cities are seen as self-regulating systems. Cities are in continuous flux, adapting to the changing environmental, political, economic and social context (Worthington et al. 2012). Five C's fits best in analysing open- ended project spread over time within, which defined projects with clear goals, budgets and deadlines could be identified. Nevertheless the used approach is also scalable in city and in district scales and particularly in observing certain everyday practices.

The research is descriptive by it is nature and serves as a starting point for testing the proposed model. The reliability of the model is based on the fact that the perspectives are gathered using both the literature and interviews. The five C's doesn't offer strong evaluation tool but it helps in recognizing different phenomena's in city development. However, the validity of the proposition is still weak and need to be tested in future research in a specific manner. The proposition will be transformed in the iterative process, during further studies.

The outcomes offer a potential input for discussions on the objectives of urban economics and planning. The results support increased awareness and understanding the serviceability of urban areas as a process orientated and user-systematic way. The proposed framework for areal serviceability is utilized in designing new greenfield area and, furthermore, in responding to changes in existing areas.

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Optimising delivery solutions for social & affordable housing, Abu Dhabi, UAE

James Eyre[1], Richard Hart[2], Gerard Connolly[3]

Al Falah Community Project – a social housing case study

With a shortfall of approximately 3.5 Million affordable homes across the Middle East and North Africa (MENA) region, the United Arab Emirates (UAE) faces a current estimated demand from 390,000 low income Emirati households (source; Gavin J (2012) - Jones Lang LaSalle). The Abu Dhabi Urban Planning Council (UPC) announced in March 2009, more than 50,000 homes will be provided over the next twenty years. Efforts were intensified in 2010 through the Emirati Family Housing Programme to create 'complete communities' of over 13,000 villas with regard to the above requirements within four years. The 'Arab Spring' and continued regional unrest places particular stress on such delivery programmes, with uprising's arguably spurred by the clear over-supply of luxury and upscale housing in many markets (amongst a multitude of other associated issues of marginalization), at the expense of the aforementioned MENA Nationals' requirements.

Projects such as the Al Falah Community development in Abu Dhabi are high profile and stringently controlled. The scheme's master-plan consists of five 'villages' presenting 4,857 villas and a range of community amenities, providing sustainable neighbourhoods serving modern needs and lifestyles whist preserving and promoting the traditional Emirati identity and preferred style of living.

This paper discusses the delivery solutions applied by El-Seif Engineering Contracting for construction of 2069No. villas across two villages of the Al Falah development; achieving low-cost and modularized delivery within an efficiently sequenced and fast-paced construction programme. Critical areas of this study are; Regional procurement, precast and pre-fabricated/ modular construction methodologies, planning, programming and progress monitoring solutions, client & stakeholder interface and handover management structures.

Considerable scope exists for the transfer of the principles and systems discussed, to future affordable and social housing projects across the region and further a-field, where unique challenges have been overcome and lessons learnt offering multiple potential extensions. Possible integration of Public-Private Partnerships for sustained growth is also particularly relevant in the current financial climate.

Keywords: Pre-cast, Modular, Pre-fabricated, Rolling-wave, Control-log.

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1. Introduction – Government & Societal demands

The Abu Dhabi Urban Planning Council (UPC) initial target is to create 'complete communities' of over 13,000 villas for future Emirati generations over the next four years; “Our objective is to answer the housing owner's aspirations by providing them with first-class communities that address their modern needs while enabling them to enjoy a lifestyle in harmony with our culture," said His Excellency Falah Al Ahbabi, General Manager UPC.

The situation in Abu Dhabi is such that tens of thousands of Emiratis have applied for government housing and remain on a waiting list up to five years long. This housing crisis has resulted in spectacular rent increases and forced many people to commute from cheaper areas, such as Buraimi in Oman. The Al Falah Community development will provide 4,857 villas of the demand with each of its five ‘villages’ arranged around a series of landscaped ‘Village and Neighbourhood Centres’. Also incorporated is a ‘Town Centre’ containing a mosque, market square and mix of local shops and offices.

2. The Solutions - Case Study - Al Falah Community Project

2.1 Regional Procurement

The El-Seif Engineering Contracting solution for Villages 2 & 3, 2069 No. villas of the Al Falah complex, critically integrated indirect stakeholders for assurance of a stable supply stream. Subcontracting work packages to locally owned and operated companies under a ‘management contracting’ procurement option, allowed for El-Seif management control to mitigate variable performance/ standards and comprehensively align deliverables to project milestones. By also subcontracting the supply and application of secondary materials on a unit-rate and contra-charging for primary materials (purchased by El-Seif and issued based on site ‘store requests’), control of material wastage was effectively transferred to the subcontractor and significantly minimized as a result.

Further subdivision of the work breakdown structure allowed for split allocation of subcontracts for certain work items which are common to all villas, although variable between villa types (Modern, Andalucian, Gulf Heritage design and 3, 4 & 5 bedroom units respectively). This provided the opportunity and flexibility for companies to compete for progressive allocation of further work packages based on a rolling production-schedule. With a similar approach applied by the project developer, a long-term client-contractor portfolio relationship is beginning to be established. This in turn allows for back-to-back relationships to be integrated into the supply chain and accordingly the partnering of critical delivery items with major subcontractors, notably for electromechanical (MEP) installations and precast concrete superstructures. In return for sustainable work flow, price may be more favourably negotiated at all levels, whilst benefits to delivery performance are realized through established relationships and familiarity with the work approaches amongst teams, driving continuous improvements and gains in efficiency.

2.2 Precast Construction - Repeatability and adaptation to re-build or remote-location settlements

Construction in the UAE cannot be compared with that in other developing economies with equally if not more critical needs on far-reduced budgets. With a far reduced scope of required facilities and amenities however, a public-private partnered, precast approach could provide equally robust, affordable, repeatable, mass accommodation, sustainably and most importantly at a rapid rate of production.

The monolithic structural design of each villa (See Figure 1, showing mechanisms for vertical and horizontal alignment and continuity once grouted), places dependence on diaphragm action between precast shear wall elements and a cast in-situ, reinforced concrete screed, to resist lateral loads from earthquake or wind actions. Pre-stressed hollow core planks transfer loads from floor areas, principally to external walls and to the corresponding edge/ ground beam forming the full raft foundation perimeter. Whilst raft and edge beam thickness and percentage reinforcement detailing will vary according to loads and sizing of superstructure elements, the above noted design is largely transferrable to sites of common ground bearing capacity and with a similarly deep groundwater table.

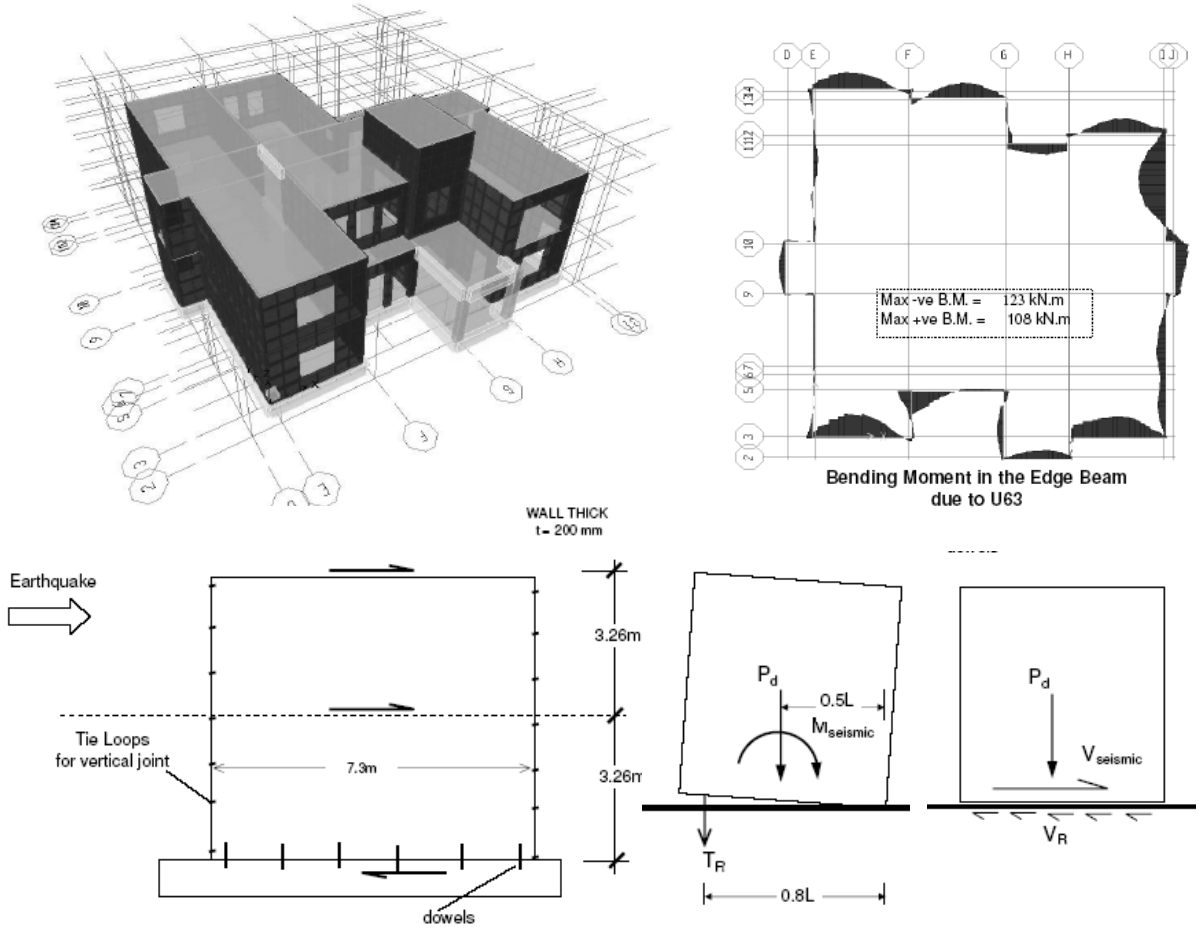

Figure 1: Structural Design System

Quality of finish is also an important factor in architectural design. For Al Falah the implemented approach involved factory casting of one precast panel face against a table-mounted formwork, with the second side surface-finished using mechanical floats, the quality of which can vary considerably. Close monitoring of the float-finished surface is necessary to mitigate significant remedial treatment/ repairs and to establish an optimal duration to spend on this activity to maintain desired quality. Requirements are clearly dependent on chosen textured or non-textured paint systems for internal and external applications accordingly. In a possible alternative to the above process, precast panels can be prepared to a rough finish to receive a site applied sand-cement render, to complete in a single operation a more consistent finish for direct application of internal paint. This is particularly relevant where conventional block and plaster partition walls have been incorporated, with inevitable interface misalignments to be overcome.

Care to ensure continuity of insulation throughout the building envelope to mitigate thermal bridging, will facilitate a potentially high-performance U-Value of a precast envelope (0.47 $W/m^2.K$ being achieved with the typical, un-modified, 200mm thick precast insulated 'sandwich' panel elements utilized on the Al Falah villas). With minimal design modifications, a typical 'Design Limit' U-Value of 0.3 $W/m^2.K$ for wall constructions may be achieved with a precast system when completed with windows and final finishes (based on UK Building Regulations Approved Document L1A, or Target average of 0.320 $W/m^2.K$ based on UAE Estidama, RE-R1). The otherwise variable quality and thermal conductivity of in-situ cast concrete (approx. 1.85 to 1.4 W/m.K) can also be more carefully controlled and enhanced when cast in a factory environment.

2.3 Concurrent infrastructure and villa construction

Concurrent infrastructure and villa construction via independent contracting organizations (Ghantoot and El-Seif respectively) presented many co-ordination conflicts, particularly where milestone completion dates are combined and shared access required at multiple phases; from concurrent villa-erection vs. deep drainage, to wearing course asphalting vs. villa finishes, snagging and handover, amongst others. A degree of trade overlap will inevitably occur to accommodate construction of main-line deep drainage, particularly where gravity-feed systems are used over long distances. Such systems commonly require wide land area for deep excavation to mitigate more expensive temporary shoring structures wherever possible.

Were phased handover not essential, a segregated construction sequence to permit continuation of infrastructure works separate from villa construction, followed by a mid-project handover would be favourable. Alternatively, introduction of sufficient lag between activities to permit concurrent working would prove more advantageous. In more remote locations this will also expedite enabling works/ construction of a means of access to a new community development from an offsite located production facility.

Undoubtedly, use of universally accessible Building Information Modelling (BIM) technology would have assisted to resolve conflicts as presented above and notably those faced at the villa boundary wall and infrastructure hard landscaping interface. Many conflicts appeared as

a result of variable terrain levels and required interconnections between villa and infrastructure-contractor constructed drainage components. A ‘cloud-based’, 3D modelling service would likely facilitate more timely review of design modifications for such conflicts and perhaps eliminate many on-site if incorporated into an Early-Contractor-Involvement (ECI) design environment. To integrate infrastructure and villa contractor and critically subcontractors into this process at an early stage (promoting ownership and involvement), a real time model/ visualisation would arguably allow for streamlined and more immediate design and construction-phase planning and decision making by all stakeholders.

2.4 Use of modular components with precast superstructures

Whilst explored as a potential solution, modular bathroom units were not utilized on the Al Falah project, although they offer potentially considerable advantages and savings in just-in-time delivery, quality consistency and minimal materials wastage, where price can be more competitively negotiated considering the ‘economies of scale’. Further benefits are achievable with improved ‘returns to scale’ in the production function through technological advancement, to ultimately reduce the Long Run Average Costs (LRAC) of production, perhaps over repeat projects.

With incorporation of a pre-fabricated bathroom pod installed at the precast erection stage (See example in Figure 2), Table 1 illustrates a clear time saving of approximately 8 No. programme days per villa, when considering the contract durations and labour units modified pro rata for a typical three bedroom villa, consisting of 7 No. wet areas. A significant advantage of early completion of bathroom units is a reduced dependence of bathroom MEP final-fix installations and associated testing & commissioning inspections on ceramic tiling completion. In a direct comparison when blockwork requirements are removed, a total unit-cost per bathroom of less than 340 times local market hourly labour rates, would likely prove economical (excluding ceramic, paint and sanitary ware/ finishing items and accessories materials costs estimated at upwards of US$1000).

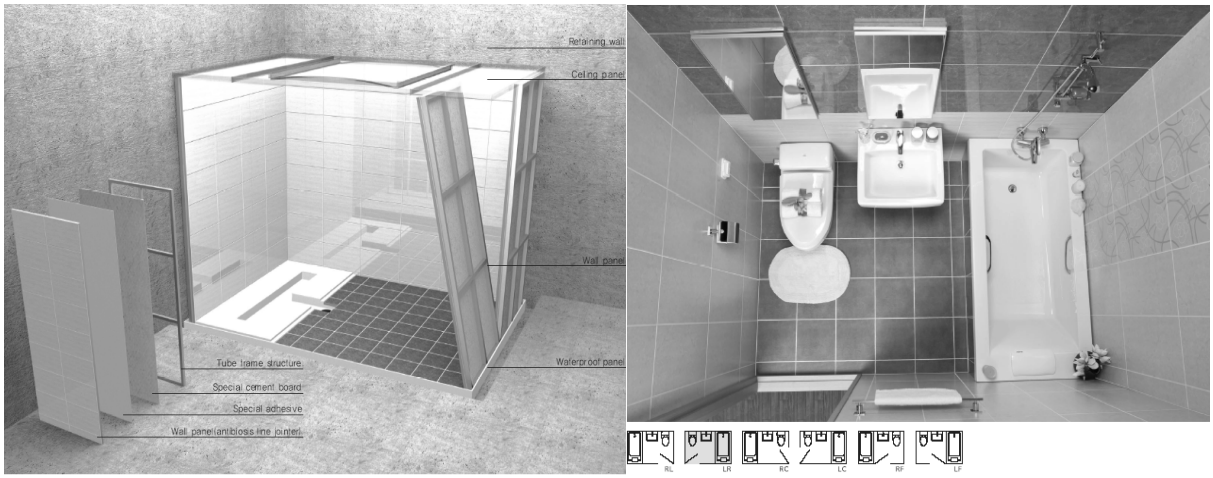

Figure 2: Potential modular bathroom system (Design type: Daelim Batos© DBR)

Table 1: Pre-fabricated 'modular' bathroom vs. in-situ construction

	In-situ construction method		Pre-fabricated method	
Item Description	**Duration (Programme Days)**	**Labour units (Labour days)**	**Duration (Programme Days)**	**Labour units (Labour days)**
Construction and plastering of blockwork partitions	0.56	8.05	-	-
Installation of bathroom pod & sanitary items	-	-	3.00	2.00
Partition wall inspection	1.00	-	-	-
Application of wet area bituminous waterproofing	1.01	0.57	-	-
Wet area waterproofing testing and inspection	1.00	-	-	-
Installation of ceramic tiling (floor and wall)	1.00	8.19	-	-
Ceramic inspection	1.00	-	-	-
Ceramic grouting	0.01	0.61	-	-
Application of internal paint	1.08	1.64	-	-
Installation of vanity frame and countertop	0.20	1.31	-	-
2nd Fix bathtub installation and plumbing	2.40	9.84	-	-
2nd Fix inspection	1.00	-	-	-
Final fix sanitary ware and accessories installation and plumbing	0.45	2.59	-	-
Final Testing & Commissioning	1.80	2.86	1.50	2.86
Total Programme Days	12.51		4.50	
Total Programme Days saving	0		8.01	
Total Labour units		35.66		4.86
Total additional Labour units		30.80		0
Total labour costs (per unit hourly labour rate)	356.55		48.60	
Budget cost - Manufacture, installation, testing & commissioning x 10% O/H & Profit, excl. Materials (per unit hourly labour rate)			338.75	

Assumptions: 1st fix activities common to both pre-fabricated and in-situ constructed methodologies. 2nd Fix inspections conducted in factory, not affecting project duration for pre-fabricated method.

NB: Potential savings through substitution of alternative materials in pre-fabricated method e.g. ceramic tile bedding, waterproofing requirements - above comparison based on like-for-like materials usage.

2.5 Construction-phase planning and programming

"The critical challenge has been to consistently produce and build five villas per day. As a leader in the UAE precast industry, Gulf Precast mobilised seven of its plants to achieve this requirement, including a mobile production facility that was directly installed and commissioned on-site".

"Precast is ideal for large villa projects, as it fosters substantial cost-savings through economy of scale and allows to significantly reduce the construction time."

“As precast elements are produced in a factory environment before being assembled on-site, all components are controlled and inspected before being transported, which allows for better quality and sustainability.” Comments from Gulf Precast CEO, Elias Seraphim, speaking to *Construction Week* magazine on the Al Falah development, at the “Precast for All” seminar in Dubai, May 2012, adding some explanation to the now forty percent share of the use of precast in concrete construction aspects of the UAE’s industry.

Precast production was optimized utilizing seven partially and fully-automated factories including a mobile production facility that was directly installed and commissioned on-site. All factories operated on three shifts including night working and concurrent electromechanical installations, largely eliminating site based 1st fix activities. Conventional, site cutting, chasing and patching for electromechanical containment/ piping was no longer required (with the exception of bathroom areas as discussed above). 1st fix activities were ultimately limited to floor conduit/ pipe routing connections between wall-embedded services, primarily cast into raft foundations and structural screeds for ground and first floor systems respectively.

“Fast assembly considerably limits the exposure of working at height, making precast much safer than traditional methods,” added Seraphim. Inclusion of proprietary edge protection in the precast manufacturing process can effectively mitigate the need for works at height to install fall arrest systems. Bespoke safety measures designed and implemented by El-Seif efficiently controlled precast erection operations and roof parapet protection for follow-on trades. Panel and stair-mounted edge protection was installed on completion of ground and first floor walls respectively.

A typical villa erection team of 4-5 No. workers once mobilised at a villa plot can complete erection of approximately 15 No. precast wall panels over a ten hour shift, completing a full floor installation of an average 25 No. panels in two days. Subsequent level and alignment using push-pull props, grouting, first floor beams installation, levelling, alignment and grouting, first floor hollow core floor planks and final cast-in-situ structural screed is completed over 11-15 days. All precast activities are executed by up to five independent, dedicated teams of no more than 4-5 No. workers. Work teams are accompanied by a single, 50-Tonne capacity, mobile crane, moving to three un-loading/ placement location arrangements per activity.

“The precast system, ready for paint, took from about 1,850 man-hours; the cast-in-place system ready for paint took about 6,700 man-hours….Using precast fabrications reduces labour costs by up to 25%, compared to conventional concrete.” Comments from Max Jordan of Fluor Middle East, on the Al Falah development, “Setting the Pace” – *Construction Week* magazine, July 2012.

The only significant disadvantage in the use of precast has been its effect on construction sequencing. With production distributed across multiple factory facilities, delivery timing to maintain a ‘block-by-block’ logic sequence was not possible owing to the mix of villa designs and bedroom-capacities within each block (as Figure 3 illustrates). A four week look-ahead (rolling wave plan/ programme) approach combined with daily production outputs and as-built records was critical to success.

Also essential to maintaining progress of five villas per day on average, was careful consideration and often build-up of critical-chain duration buffers. Anticipation of manpower supply problems/ shortages for the above prompted the crashing of substructure activities, allowing significant resource levelling to assist finishing works. This early decision permitted the expected, scattered precast production and erection programme to continue, given advanced completion of wider areas of raft foundation substructures.

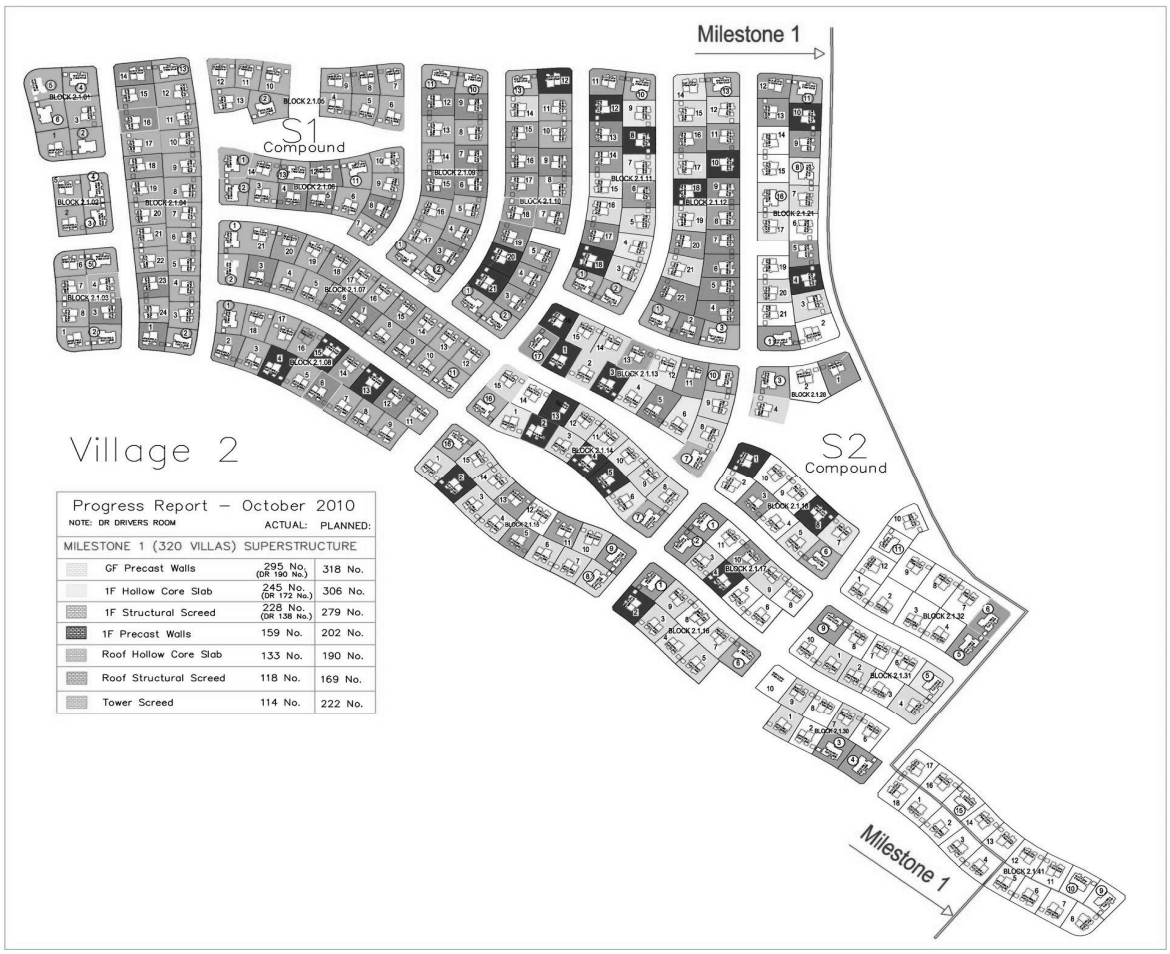

Figure 3: Superstructure progress report summary October 2010 – Plan overview of scattered precast erection sequence

2.6 Management Information Systems (MIS)

Practically, owing to the vast scale of the Al Falah project and requirements for tracking the work efforts and productivity of upwards of a six thousand man workforce, the direction of site personnel and multiple subcontractors required close structuring through a daily stop-shift meeting. Accompanying the above co-ordination meetings, a single, project-wide control log, in the form of a customised Excel spreadsheet was used for the measurement and monitoring of Schedule Variance. Following inputs of cumulative progress by section managers for substructures, superstructures and finishes works and by concerned subcontractors for MEP clearances and boundary wall erection, completed or percentage-completion achievements are accurately recorded.

The final control log (extract provided in Figure 4) may be manipulated/ filtered, but has been designed to highlight and tabulate pending and imminent priority areas for completion, in addition to a day-rate/ daily output calculation. The log is also segregated to represent the achievement of individual sections, an important inclusion on a project of this scale where daily diarised reporting is often inadequate. This provided the basis/ visual guidance for investigation and accurate reporting of unplanned events and remedial actions necessary to prevent reoccurrence across larger numbers/ wider areas of villas.

The updated control log is subsequently integrated into an Earned Value Analysis on a monthly basis and forms an essential component of the Contract Variance Unit Costing cost-control system. This system is used for monthly reporting and to proactively determine deviations from target price.

2.7 Operations management structure/ client interface

Handover and snagging disassociated from primary construction activities allowed for a strong client interface to be maintained and dedicated client-needs focused team for interrelated show-villa/ public-relations facilities, tenant orientation and client/ consultant change requests. This management of the interface with the project developer/ Project Management Consultant (PMC) and accordingly the UPC was critical to the projects' success.

AL FALAH PROJECT - WEEKLY PROGRESS RATES														
6-Jul-12			REV. 03 FINISH DATE	REQ. RATE	MILESTONE 3: VILLAS REMAINING					29-Jun-12		6-Jul-12	
					Stage:	272	247	241	250	Village 3	Av / Day	Village 3	Av / Day
INTERNAL FINISHES	Roof Cluastra				142	-	4	38	100	648	4.2	671	3.8
	And. GRC Installation *91 / 67 / 83 / 67*		14-Aug-12	3.2	107	-	-	16	91	216	0.0	216	0.0
	Roof Shaft (4 Course)				307	1	2	59	245	637	10.0	703	11.0
	Roof Shaft Precast Capping 108				415	4	35	130	246	548	7.2	595	7.8
	And. Clay Roof Tiles		5-Sep-12	3.7	193	-	43	59	91	91	1.7	115	4.0
	Wet Area Waterproofing	Gd	2-Aug-12	7.3	168	-	-	-	168	803	5.3	842	6.5
		1st		5.7	133	-	-	-	133	652	4.5	680	4.7
		Driver	(2nd July)	7.4	171	-	1	2	168	799	5.0	839	6.7
	MEP Wet & Dry Area Clearance	Gd			137	-	2	-	135	830	5.3	873	7.2
		1st			108	-	2	-	106	673	4.3	705	5.3
		Driver			-	-	-	-	-	977	0.0	977	0.0
	Ceramic CRI Approval	Int	30-Sep-12	6.6	490	-	134	106		486	6.2	520	5.7
		Ext	30-Oct-12	7.2	716	-	247	175		279	1.7	294	2.5
		Driver	(30th July)	7.1	527	-	160	114		405	6.0	483	13.0
ACTIVITY:			REV. 03 FINISH DATE	REQ. RATE	Villa Equivalent Completed		Pending			Cum (m2)	Villa / Day	Cum (m2)	Villa / Day
Floor Ceramic (Av 392m2)			30-Sep-12	6.7	517		493			188615	6.71	202621	5.95
Wall Ceramic (Av 132m2)				6.5	528		482			64511	6.92	69724	6.58
Internal Paint (Av / Villa 1121 m2)			26-Aug-12	11.4	511		499			535587	2.87	572631	5.51
External Paint (Av / Villa 748 m2)			8-Sep-12	5.0	735		275			536905	4.06	549420	2.79

Figure 4: El-Seif Engineering Contracting, Progress Control Log extract

3. Conclusions & Recommendations

The current emphasis within the MENA region is on the construction of social not affordable housing for mid to low-income families, whilst funding remains readily available. Land prices are a particular factor in the gulf-states, forcing affordable housing schemes to remote and isolated areas that demand considerable accompanying investment in utilities and infrastructure services. State-owned land however offers a key opportunity for developers to be transferred ownership in order to sell to low-income buyers/ tenants through long-term equity and grant finance structures for individuals, at a lower cost. Revenue streams can therefore be controlled for developers, whilst rental and unit pricing may be controlled by government.

Traditional Engineering, Procurement and Construction (EPC), design-build methodologies are unlikely to meet the Gulf's rapidly expanding demand for low-income housing, where governments must look beyond one-off project procurement to establish integrated infrastructure, utilities and accommodation construction schemes and teams for sustained growth.

The advantages and repeatability of precast solutions, potentially combined with modular, pre-fabricated components can provide rapid structures, complying with the highest of quality and sustainability standards. Development of co-located production and construction sites will secure long-term delivery solutions for isolated and remote locations where planning and operations management solutions such as those developed by El-Seif Engineering Contracting on the Al Falah project, facilitate rapid deployment and maximum flexibility.

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Data Fusion of Real-time Location Sensing (RTLS) and Physiological Status Monitoring (PSM) for Ergonomics Analysis of Construction Workers

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Abstract

Previous research and applications in construction resource optimization have focused on tracking the location of material and equipment. There is a lack of studies on remote monitoring for improving safety and health of the construction workforce. This paper presents a new approach for monitoring ergonomically safe and unsafe behavior of construction workers. The study relies on a methodology that utilizes fusion of data from continuous remote monitoring of construction workers' location and physiological status. To monitor construction workers activities, the authors deployed non-intrusive real-time worker location sensing (RTLS) and physiological status monitoring (PSM) technology. This paper presents the background and need for a data fusion approach, the framework, the test bed environment, and results to some case studies that were used to automatically identify unhealthy work behavior. Results of this study suggest a new approach for automating remote monitoring of construction workers safety performance by fusing data on their location and physical strain.

Keywords: construction worker behavior, ergonomics, physiological status monitoring, remote location sensing, workforce safety and health.

1. Introduction

The construction industry is continuously trying to improve work site conditions. However, in 2008, 28,340 nonfatal occupational injuries resulted in musculoskeletal disorders (BLS 2008)

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and 3,020 workers suffered from lower back pain. Among various well-known reasons, construction activities are typically characterized as physically demanding tasks that are often performed in harsh environments (Hartmann and Fleischer 2005; Schneider and Susi 1994). As a result of the continuous and repetitive exposure to physically demanding work, strains and sprains are the most common type of work-related, nonfatal injuries. Furthermore, the continuous exposure to an excessive level of physical strain can lead to physical fatigue, which may result in decreased productivity and motivation, inattentiveness, poor judgment, poor quality work, job dissatisfaction (Abdelhamid and Everett 2002), and increase in the risk of developing worker-related musculoskeletal injuries (MSIs) or cardiovascular disorders (Mathiassen 1993).

Previous research found that lower back injuries are among the most common MSIs (Hootman et al. 2002). These occur when the demand of work exceeds the capacity of a worker's body, or the worker repetitively performs heavy activities. MSIs can also be found in other parts of the body, such as the shoulders, wrists, andknees. MSIs are usually caused by overexertion, which is a leading cause of time-loss injury for construction workers (BLS 2008). An overexertion occurs when either the demand of work exceeds the capacity of a worker's body or the worker repetitively performs heavy activities. Statistics shows that more than one quarter (25.7%) of the overall disabling workplace injuries are due to overexertion (Zaidman 2008). Overexertion is not only the most common event category, but also the most expensive, resulting in $12.4 billion in direct costs to businesses. In addition, substantial indirect costs are caused through overexertion, such as (temporary) replacement of personnel and the human cost in terms of pain and/or (long-term) disability (Liberty Mutual Research Institute for Safety 2008).

Examples of injuries caused by overexertion include those related to inappropriate execution of manual material handling (MMH) tasks, such as lifting, pushing, pulling, holding, carrying, and throwing. The complex interaction of factors that determine physical load or exposure intensity makes it challenging to assess the performance of MMH activities in the construction environment (Paquet et al. 1999). The dynamic nature of construction work also makes it a challenge to measure ergonomic exposures and MMH factors systematically (Tak et al. 2011). Moreover, the Occupational Safety and Health Administration (OSHA) does not provide ergonomic standards. Instead, it utilizes a lifting guide issued by the National Institute for Occupational Safety and Health (NIOSH) (Water et al. 1994).

Since heavy load lifting frequently leads to MSI, the identification and localization of repetitive material handling activities is crucial to better understand MSI ergonomics. Previous studies suggest that ergonomic- and physiology-related attributes, such as posture, body acceleration, and heart rate can be measured using remote sensing technology. One example is Physiological Status Monitoring (PSM) technology. Commercially-available PSM devices have shown to provide reliable information during dynamic construction activities (Gatti et al. 2011). The problem with PSM is, however, that is does not record nor relate the location of a test subject wearing the PSM technology to the location where unsafe lifting events occur.

Other technology, such as real-time location sensing (RTLS) devices, exist that can deliver such location data. An example of such location sensing is the commercially-existing Global Positioning System (GPS) or Ultra Wideband (UWB) technology. Recent research in construction has shown that sufficient accuracy is provided to track construction personnel with these technologies (Cheng et al. 2011).

This paper aims at fusing data of PSM and RTLS to match physiological and location information of construction workers. The objective is to detect the workers' physical characteristic in a spatio-temporal relationship, demonstrate the capability of identifying MSI hazards automatically, map such unsafe acts to the work environment, and finally recommend changes to work site set up. The authors have conducted multiple experiments where workers were instructed to perform specific manual material handling tasks of heavy load lifting. By using a data fusion approach, the authors have synchronized and analyzed the data streams from (1) Physiological Status Monitoring (PSM) (that continuously monitors activity factors of construction workers) and (2) Ultra Wideband (UWB) technology (that records real-time worker location). This study is limited to fusing information from two specific sensing technologies (UWB and PSM). All tests were performed in a controlled study environment. Working activities that were recorded with UWB, PSM, and video camera technology occurred indoors and on the same elevation level. This study focuses only on activities associated to the construction personnel, especially, heavy load lifting. Social, legal, or behavioral impacts on workers using UWB and/or PSM technologies were not part of the scope of this study.

2. Methodology

Data fusion of real-time location tracking data and worker physical information has not been tested in construction. To fill this gap, this study evaluates the performance of a data fusion approach for UWB and PSM data. The researchers designed a novel testbed to measure and analyze the ergonomic and positioning factors of repeated material handling activities. Results to an experimental approach are presented. Opportunities and barriers using UWB and PSM data recording are discussed.

The components of the experimental test bed are illustrated in Figure 1. For later control measurement, all activities were taped with video cameras. The data analysis process is shown in the flowchart in Figure 2. Data analysis consists of four major components: work sampling, data synchronization, activity identification, and localization. An empirical approach was selected (explained later) for identifying ergonomically unsafe worker motions, for example, lifting heavy loads without bending the knees.

Since the study environment was indoors and little obstructions were present, a commercially-available UWB localization system was selected to track the real-time location of test persons participating in the test cases. UWB tags were placed on the helmets of the test persons, and on relevant static locations in the test scenery (e.g., to identify material bay, rest, and water supply areas). The UWB system itself consists of a central processing hub, which triangulates

the position of the incoming radio frequency signal from multiple UWB receivers based on the Time-Distance-of-Arrival (TDoA) principle. These antennas were distributed systematically around the work environment and outside of any of the participating test person's travel paths. The UWB receivers were connected to the hub via shielded CAT5e cables and a static tag functioning as a reference location was placed in the center of the monitored area.

A variety of commercially-available PSM systems exist. PSMs can be described as non-invasive ambulatory wireless telemetry systems. They can autonomously and remotely monitor workers' physiological status without hindering or interrupting their routine activities for several hours. The system utilized in the experiment was composed by a chest belt that hosts conductive fabric sensors and module with a mobile transmitter. The selected device had the ability to perform live data transmission wirelessly through a USB radio receiver, which was connected to a data logging PC. As an alternative to real-time transmission, PSMs allow for local data logging. The selected PSM system monitored and recorded physiological and motion data using wearable electrocardiograph (ECG) sensor, respiration sensor, and a 3-axial accelerometer. It transmitted the data in real-time to the receiver via a radio frequency signal. Among various parameters, PSM measured the heart rate and the thoracic bending angle. Heart rates were deducted from ECG data. The three-axial (vertical, lateral and sagittal) accelerometer was used to generate the subject's default activity data measured in Vector Magnitude Unit (VMU). VMU was measured as a portion of the gravity acceleration (g). The system built-in module used the VMU values to derive the subject's thoracic bending angles from the 3-axis gravity compensated value calculated over the previous 1.008 second epoch. The angle was derived as a scalar with positive and negative values, where zero degree represented the vertical right-up posture.

Meanwhile, a network camera was utilized to visually record the experiments. The timeline of the video was regarded as a metric, which means the temporal information from both sensors had to be synchronized to the video time. Visual analysis of the video recording was implemented to establish a ground truth validating the result of the inappropriate posture identification.



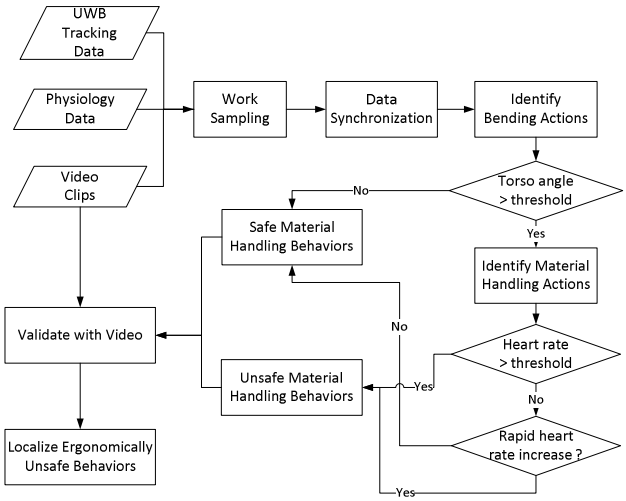

Figure 1: Testbed for experiments ***Figure 2: Locate ergonomically unsafe acts***

3. Experiment

Three experimental settings were designed to simulate construction tasks. To avoid potential interference of ambient influences, all experiments were conducted in a controlled indoor technology testbed environment. Written informed consent was obtained and the subjects were instructed about the experiment by a trained lab technician. The training covered three main topics. First, subjects were trained on how to properly wear and operate UWB and PSM. Secondly, correct material handling techniques and PPE (i.e., gloves, foot guards, knee pads, hard hat, and goggles) utilization were explained. Third, working areas and construction tasks were described. The three simulated construction tasks consisted of: (a) Experiment No. 1: Building a wall: one test subject builds a wall using 23-lb concrete blocks. One installation and one material area is available; (b) Experiment No. 2: Assembling a raised deck: one subject assembles a deck using plastic supports and 16-lb concrete tiles. One installation area and two material storage areas exist; (c) Experiment No. 3: Assembling and disassembling a raised deck: one subject disassembles a deck and stores material in a material laydown area, the other subject uses the material from the laydown area to assemble a raised deck in a second work area. Assembly and disassembly are spatio-temporal dependent activities. The subjects share two storage areas, but have their own installation area available.

4. Results and Discussions

4.1 Sampling UWB Data

The tracking data collected from UWB was sampled by the traveling speed, which was implemented to identify several zones where the subjects were (more or less) static. According to the experimental tasks, the subject had to stop when he was operating in the installation, deinstallation, material bay, rehydration, and rest areas. Hence, it was assumed that ergonomically unsafe behavior, especially bending with heavy loads, only occurs when the subject was standing or moving with very low speeds. Since the UWB tag was mounted on the subject's helmet, head motions such as nodding and shaking may result in many small to zero movements of the UWB tags (which may lead future research to install location tracking devices on the worker's clothing, preferably the belt). Moreover, subjects moved slowly within the work zone to complete the work task. A speed threshold based on statistical analysis was implemented to determine the subject's walking and staying status.

4.2 Event-Based Data Synchronization

Sensing data from multiple sensors were synchronized with the video time, where the time clock of the video was considered as the ground truth. The general principle to synchronize timelines among sensors was to compare the time clock of manually set time flags, e.g. when a recognizable event occurred in the UWB data, it should also appear at the corresponding moment in the PSM data set. Examples are entry or exit in a work zone, rapid velocity changes, and/or rapid posture changes such as bending motions.

4.3 Automatic Identification and Mapping of Ergonomically Unsafe Behaviors

Since musculoskeletal disorders were accounted for the first reason of nonfatal occupational injuries in construction, a particular emphasis was placed on identifying the ergonomically unsafe behaviors among the dynamic construction activities. Specifically in these experiments, one of the goals was to identify the working behaviors such when the subject was bending (or lifting) with heavy loads. To demonstrate how multiple sensing technologies can assist the evaluation process of ergonomic behavior, synchronized tracking and physiological data were fused. An analysis of the signal propagation pattern between heart rates and posture angles provides additional reasoning into the subject's behavior.

Safety guidelines for manual material handling state "to reduce the strain on the back, a subject should maintain a posture of the upper body as vertical as possible when lifting or placing heavy loads" (Water et al. 1994). No further official statement has been made on what constitutes a safe bending angle (most likely since a detailed determination depends upon a variety of factors, including work environment and a subject's physical characteristics). In this experiment, the subject's material handling activities are classified into two categories: safe and unsafe (see Figure 3). The individual in this figure was not a subject in the study.



Figure 3: Safe and unsafe work task

While a subject is conducting physically demanding activities such as lifting and placing loads her/his heart rate is higher than normally. According to rules set by NIOSH (2007), material handling with up-right body posture is safe. Histograms of the subject's heart rate while the bending angle exceeded 25 degrees were developed. Two Gaussian distributions were differentiated. One has the mean at 91 bpm (beats per minute) and the other at 106 bpm. The higher the heart rate value is, the more oxygen a subject consumes. High heart rates in this experiment were directly associated with a subject carrying a load. The two Gaussians connected at 99 bpm, which implies the transition between bending with and without load. The threshold was set slightly higher to 106 bpm to differentiate safe from unsafe lifting/placing motions.

Defining and applying only a heart rate threshold probably would not account for other factors that influence the heart rate, for example, subject fatigue or very fast transitions between work activities. Therefore, a pattern analysis for heart rate changes was performed. Several changes in the heart rate pattern can be noticed that correspond to the subject's posture angle: (1) the posture angles were found to be lower than the threshold value when high heart rates were observed (time span from 1,000 sec. to 1,100 sec; the subject might have already been tired due to the rapidly changing motions); (2) both the heart rates and posture angles were found at a low level or less than the threshold value (time span from 1,030 sec. to 1,050 sec.; which implies the subject's torso was in vertical up-right position and recovering to the normal situation); (3) the heart rate maintained at a high level while the posture angle increases and exceeds the threshold value (time span from 1,100 sec. to 1,125 sec.; which indicates bending motions with loads; the heart rate maintained at a high level because the body was not recovered from the previous motion); and finally (4) rapid increments were observed on both heart rate and posture angle (associated with several seconds delay: time span from 1,045 sec. to 1,052 sec.; and simultaneously, time span from 1,105 sec. to 1,110 sec.; these also demonstrate bending motions with loads). The first two patterns have heart rate and posture

performance values indicating safe behavior. The last two patterns relate to unsafe work behavior.

An additional consideration to analyze PSM data might be the analysis of the slope change of heart rate values. The changing rate (slope) of the heart pulse when the subject bended more than 25 degrees consists of three isolated peaks: the first one is at 0 bmp/min, the other two peaks were at 1.2 and -1.1 bmp/min. The first peak implies that the subject's heart rate is maintaining, which indicates no physical action or idle status. The other non-zero peaks are symmetrically around the first peak representing the transitional period of the subject's heart rate from the idle status to physical active status or the other way around. Since this research focuses on unsafe behavior related to workers bending with heavy loads, the positive peak (1.2 bpm/min) on the changing rate is utilized to differentiate a physically demanding bending from normal activities.

4.4 Localization of Unsafe Behaviors

Fusing the heart rate data and the posture data from PSM provides the capability of differentiating safe from unsafe material handling activities. As one of the objectives of this research was to map unsafe acts to a work setting to assist future decision makers in designing better (ergonomically safe and healthy) work environments, the next step was to fuse the spatio-temporal data collected by UWB and physiological data. Trajectory and PSM information of one subject performing a concrete wall installation for Experiment No.1 are shown in Figure 4. The weight of each concrete block was 23 lbs. The distance between assemble and disassemble of wall was about 12 meters. The blue color in Figure 4 represents the walking paths of the subject between the installation and de-installation areas, and to/from the rehydration area. The location where the subject squatted safely is show in green. The red color denotes unsafe bends with a heavy load.

During the 62 minute long experiment, 105 ergonomically safe and 93 unsafe motions were automatically identified and mapped. Figure 5 shows the analysis of all unsafe bends over the observation time. The unsafe lifts indicated in red color relate to labor (install a concrete wall) that is physically very demanding and leads to exhausting. Manual video analysis confirmed that the subject followed more frequently safe bending practices at the beginning of the work shift. The guidelines were followed when handling heavy materials during the first 8 minutes of the experiment. Although the observation time was too short to find statistically significant results for an increase in unsafe acts over time, the number of unsafe lifts slightly increased towards the end of the work shift. Fatigue may have played a role leading to more unsafe lifts at the end of the shift.

As a general practice, work site layout could be improved. Since the worker carried the material by hand from the deinstallation to the installation area, a change to the work environment is suggested. Providing the worker with a wheel barrow or a flat cart eventually would have simplified the task and made it safer/healthier to perform. As of additional note, the subject

should take frequent breaks. As the algorithm automatically found, the subject rehydrated only once at the 59 minutes into the experiment, and since the work task had already been completed, spent the remainder of the observation time at the rehydration station. The subject did not take any other break(s).

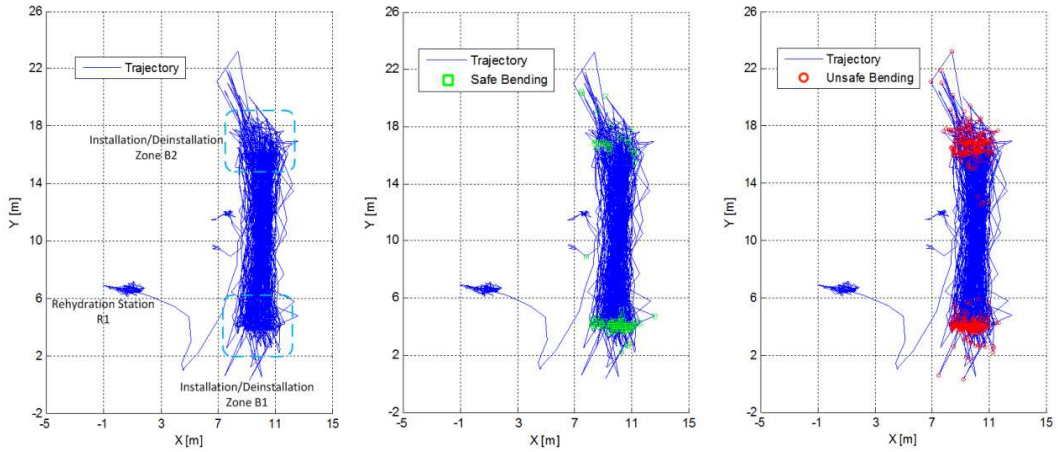

Figure 4: Localization of trajectory, and safe unsafe materials handling motions

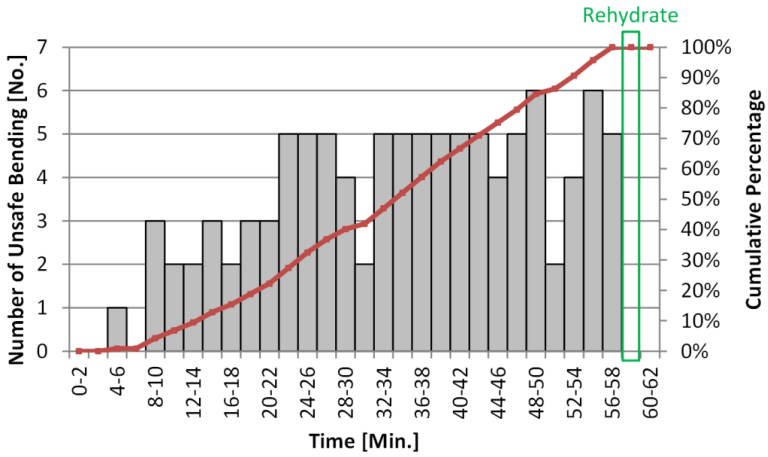

Figure 5: Unsafe bending over time

4.5 Validation of UWB/PSM Data Fusion Approach with a Video Camera

The detecting of unsafe/unhealthy material handling activities was validated through a manual analysis of the video data that was recorded for all three experiments. The analysis of work activities using video served as ground truth. The results from the video were also divided into two categories: safe and unsafe bending. Results from video and UWB/PSM data were compared against each other to conclude on the error rate of the developed automatic ergonomics algorithm. On average the data fusion approach of UWB and PSM performed accurate detection of unsafe bending with an average success rate of more than 90%.

False positive cases were due to rapidly changing postures. The utilized PSM technology yet has to be adapted to construction environment and may not have always reported a subject's heart rate precisely. A typical example for such an event is when a subject performs several unsafe bending acts in a very short sequence of time (basically one after the other, also called rework or adjustment work to the same concrete block). As the subject does not carry a load during the second time of bending, but the heart rate is still elevated (the body has not recovered yet), the developed algorithm interprets the PSM signal as another unsafe bend. The false negative cases are another type of error, representing situations where the algorithm considers an unsafe lift as a safe motion. This error occurs because the PSM recordings of a subject are always slightly delayed (up to one second) during physically very demanding activities. A typical example is when a subject bends and lifts a heavy load, then very rapidly stands up, and walks away. As the subject's torso angle is high at the moment of the lift, the heart rate might still be slow. The developed algorithm assumes wrongly identifies a safe lift.

These two types of errors can be reduced by calibrating the physiological factors such as heart rate for each individual. Usefulness of the developed approach may also depend on improvements in technology, for example, existing PSM technology has not been configured to suit construction industry applications. Measurement error can also be solved by increasing the data collection frequency and adding a physiological response function to compensate for signal delays. Since a subject's physiology response mechanism depends very much on the individual, it will be a future research task to develop a uniform model that fits most users in the construction industry. Further study is necessary on the developed rules, such as the relationship of bending angle and heart rate, thresholds, and their interactions to precisely identify ergonomic hazards.

5. Conclusion

Rapid technological advances such as UWB and PSM technology have facilitated the monitoring of the position and physiological status of construction workers. Traditionally, data from these sources have been independently used and eventually analyzed to infer about the status of entities being observed. Using a set of experiments conducted in an indoor facility, this paper demonstrated that UWB and PSM data can be fused to automatically identify and localize the ergonomic related unsafe working behaviors. The results show that current technology is satisfactorily reliable in autonomously and remotely monitoring subjects during simulated construction activities. Partially validated through video analysis, these results suggest that data from these sources can be successfully fused to augment real-time knowledge of construction workers' status. Nevertheless, the selected monitoring technologies show limitations that have to be addressed to fully validate the proposed algorithm. For example, the bending threshold utilized to differentiate the squat from normal posture is ambiguous because of constraints in the existing technology. Therefore, the connection between the bending threshold and the performance of the PSM in dynamic situation requires further study. Whereas this study focused on identifying occurrence and location of unsafe worker behavior, the analysis of the locations where repetitive unsafe behaviors occur could lead to identifying underlying ergonomic issues

with work the environment. To evaluate this potential, the authors have planned to repeat apply the research results on a field study. In summary, the present work showed that potential construction applications of some technologies lie in the integration of various technology-specific data sources.

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Teaching Construction in an International Society through Study Abroad and Service Learning in Costa Rica

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Abstract

One goal of Purdue University, the College of Technology, and the Building Construction Management Department is to infuse global awareness in both undergraduate and graduate students. A study abroad course is one way to accomplish this goal. International experiences, especially service learning, give students an extended application of knowledge outside of their comfort zone. Students must apply their knowledge to solve problems while also dealing with the newness of an international place. A study abroad trip to Costa Rica includes a service learning project fulfills this requirement. Service learning enhances the student's learning through applying work ethic, critical thinking, problem solving, social issues, and reasoning to real world projects (Batchelder & Root., 1994; Hatcher & Bringle, 1997 & Eyler, Giles, & Braxton, 1997). A faculty member has partnered with the Rotary International in Costa Rica to make this experience happen. The experience adds to their marketable skills when entering the workforce. Most students in this department tend to be kinesthetic learners so participating in a hands-on service learning project allows them to apply technical knowledge and utilize management skills. This paper outlines the development, facilitation, and evaluation of a study abroad experience in Costa Rica.

Keywords: **Service learning, undergraduate education, Study Abroad, Globalization**

Introduction of Service Learning

The original fathers of curriculum believe that there was a link between community engagement and actions which apply knowledge (Dewey, 1933). Service learning is already a very well researched topic. According to the National and Community Service Trust Act of 1993, it is defined:

> "A method under which students or participants learn and develop through active participation in thoughtfully organized service" (National, 1993)

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Not all see Service Learning as an academic replacement for the pencil and paper calculations or controlled lab experiments, but those who support these have had positive results. The Kolb (1984) model for learning aligns well with service learning because it allows for all types of learners and it involves concrete experience (Kolb, 1984). Broader definitions have been used to outline the relationship between the service and the learning.

> "a type of experiential education in which students participate in service in the community and reflect on their involvement in such a way as to gain further understanding of course content and of the discipline and its relationship to social needs and an enhanced sense of civic responsibility." (Hatcher & Bringle, 1997).

A very popular diagram to visualize this concept is through the Furco diagram in Figure 1. The main objective of this model is to differentiate volunteering and field experiences to overlap with the academic component to produce a true service learning experience.

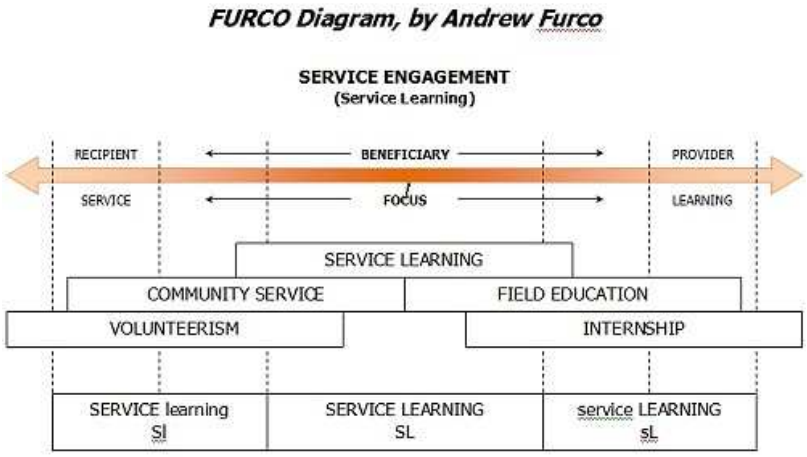

Figure 1: Furco Service Engagement Diagram (Furco, 2002)

Much of the research concludes that service learning enhances the student's education including the areas of: work ethic, critical thinking, problem solving, social issues, and reasoning projects (Batchelder & Root, 1994; Bringle & Hatcher, 1999; Hatcher & Bringle, 1997 & Eyler, Giles, & Braxton, 1997). When these service learning activities have occurred during a study abroad program, the outcomes included: cultural awareness, foreign language skills, and construction materials and methods (Connell & Lu, 2009 & Farrow & Kramer, 2009). Some of the common outcomes reported by the students include:

- Greater motivation
- Ability to integrate
- Development of leadership and communication skills
- Accessing understanding in different ways

- Teamwork
- Project planning
- Life-long learning

The final part of the service learning experience is to ensure that the students are connecting the activity to the academic objectives (Eyler, 2001). Figure 2 shows the Kolb Learning Style model which aligns well with a service learning project. Students work through the learning cycle as they experience different abilities. The concrete experience ties the students to the feelings they are facing. The reflective observation is done as the students connect existing knowledge with how it can be applied to a service project.

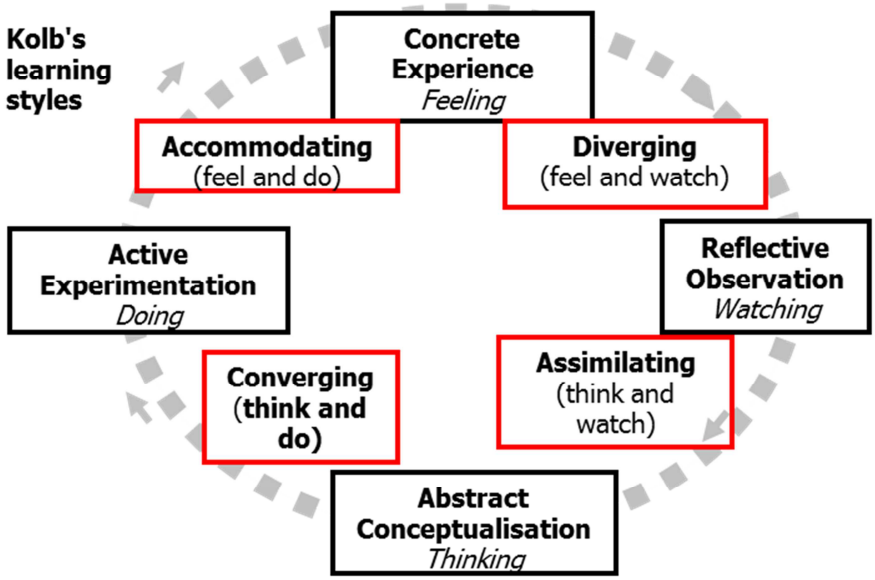

Figure 2: Kolb learning styles model adapted based on Kolb 1984

The international component also involves the abstract conceptualization of thinking about what is going to happen before the active experimentation occurs. This is done by reflection activities throughout the experience. It is important to assist the students into differentiating the learning experiences. The reflection should connect with, but not be limited to, academic context and learning objectives, personal experience, connection to and implications for the profession/discipline, and or social/community issues. Methods of facilitating the reflection process include: written questions, notebooks, journals, blogs, small group discussions, readings, or any combination. Many teaching points may not be seen as learning by the student if he or she does not reflect. Another aspect of the learning may not be technical, but rather about communication or social learning which is more difficult to assess. The interaction with the students during reflection and through facilitated discussions showed the moments of awareness of their surroundings.

Development of Costa Rica Service Learning Program

A core curriculum learning outcome at Purdue University in the United States is global awareness. A study abroad course is one way to accomplish this goal. International experiences give our students an edge over other students and allow them to apply their knowledge to solve problems outside of their comfort zone. This study abroad program was developed through shadowing an existing program and making connections in country for future trips.

The College of Agriculture at Purdue University has a long history of study abroad programs so this program was used as a model for development of a Building Construction Management (BCM) course. The initial Costa Rica trip and project was done with this program. Construction management (CM) students in partnership with agriculture students embarked on a 20-day trip to Costa Rica in May 2011. The original trip with Agriculture students included traveling to remote areas of Costa Rica and allowed only one day in the capital city of San Jose. The service projects were located in the Limon, Guacimo, and Iroquois Community. This is approximately 80 kilometers Northeast of San Jose. There were 10 students who worked on the renovations on a health clinic in the community, and a room addition on a home. This trip let to relationships and knowledge of the country that would be the basis for the BCM experience.

The outcomes for this trip became the basis for the BCM department experience. Some lessons learned include changing the timing of the trip from May to March. The CM students have a requirement of 800 hours of work experience to obtain a Bachelor of Science degree so a Spring Break trip, rather than a May to June trip, better accommodates their schedule. The trip was also connected to an embedded course which met twice per week throughout the semester, before and after the trip. This allowed the students to learn about the culture, practice the language, plan for the service project and apply for grants to fund the service project. It also served as a chance for some team building to enhance the overall experience of the trip.

Facilitation of the Project

The number of students permitted to take the trip will have a minimum of 10 and a maximum of 20 students. Students must have successfully completed one semester of courses and be in good standing with the university to apply for the study abroad program. Both undergraduate and graduate students are invited to participate. Graduate students would be expected to take a leadership role on the service learning activities if participating. Students in the College of Technology are targeted, but the course will be open to students outside of the college. In Spring 2013 19 students are enrolled in the course and include not only BCM, but Animal Science, Aviation Technology, Nursing, and Electrical and Computer Engineering Technology. All food, travel to and from Costa Rica, travel in Costa Rica, excursions and accommodations will be covered in the cost of the course. Spanish lessons will be included in the course to assist the student in communication within Costa Rica. All of the tours scheduled for the trip include an English speaking guide. The course content will include: culture and history of Costa Rica, common building practices, geography, and language. Materials and methods of building

materials including topics related to sustainable and green products and connecting with the Technical Institute of Costa Rica. Costa Rica has the motto of *Pura Vida* translates pure and life so students would stay true to this by exploring the sustainable solutions to building methods in Costa Rica. The session after the trip will be to reflect and document the service learning experience.

The students met twice a week before the trip to learn about the culture, history, food, and language of Costa Rica. Team building activities were developed to help the students bond as a group to make the trip a positive experience for all. Students completed pre trip reflections and assignments to assess the impact of the experience. There was a high level of stress and anxiety when they were reflecting on what to expect. They not only become comfortable with each other, but through the pre-planning they become more confident. Students from past trips serve as guest speakers and a graduate student from Costa Rica also serves as a teaching assistant.

The highlight of this course is a week-long trip to Costa Rica during Spring Break. The daily schedule is shown in Table 1.

Table 1: Daily Activity Schedule in Costa Rica 2012

Date	Day	Activity
9-Mar	Fri	Travel
10-Mar	Sat	Culture, Coffee tour and Museums
11-Mar	Sun	Culture, Volcano, Earthquake damage and waterfalls
12-Mar	Mon	Construction site tour, project pre planning and material purchasing
13-Mar	Tue	Service Project
14-Mar	Wed	Service Project
15-Mar	Thu	Technical Institute of Costa Rica and Hydro Electrical plant tour
16-Mar	Fri	Travel

Student participants began at the university took a bus to the airport together and boarded a flight. Upon arrival in Costa Rica, they were met by a bus to take them to the accommodations. The students stayed in San Jose, Costa Rica in the La Sabana neighborhood. The lodging was a hostel type home where a large dormitory room was one for male and one for female students. The faculty advisor had a private room. The neighborhood was across from a large park, the national football stadium, and within walking distance to shopping and dining needs. An activity room at the hostel had internet and a pool table. Breakfast was provided and supplemented with local fresh fruits.

The first two days of the trip were tourist type events with the Coffee plantation tour, Museums in downtown San Jose, shopping, a volcano crater, waterfall, butterfly sanctuary, and aviary

tours. Upon completion of those days, work would begin on the project. A meeting with representatives in Costa Rica gave us the information needed to purchase materials. Students toured a construction site. The project utilized Lean Concepts for project productivity including the last planner system. The construction site project was a seven-story hotel and casino a group photo is shown in Figure 3.



Figure 3: Students visiting construction site in Costa Rica

Representatives from Rotary International were utilized to organize the service learning project. Every community in Costa Rica has a school for up to sixth grade. In remote areas, there are sometime maintenance needs that cannot be completed by the local population due to lack of materials, funds, or skills. Before arriving in Costa Rica the students were informed that they would be working in a school. Paint and tile would be provided for this project by the Rotarians. Students received a grant of $700 in spring 2012 and $1475 in Spring 2013 from the Purdue University provost's office to purchase the remaining materials which included brushes, mortar, grout, rollers, etc. After the construction site tour, the students visited the Epa (construction big box store) to purchase materials. The project was described as painting and tile work in a school cafeteria. Some specific needs included some shelving for pots and pans. Colors for the school were determined by the government so a special mix was prepared at the store.

The service project became a challenge at all levels for the students. The learning styles of the students were revealed as some watched and pondered the situation before becoming actively involved in the doing. Some students were outside of their comfort zone and took longer to become a part of the work. Small children at the school watched the process and transformation of the school. An evaluation of the situation after day one of the project revealed the students connection, commitment and ownership of the project.

Evaluation

Much of the learning was done through observing the surroundings. Comparing and contrasting U.S. versus Costa Rica to better understand construction materials and methods were a major

theme. The team work also challenged students to step up and utilize leadership, communication and coping skills to complete the project in a safe and timely manner. Student reflections from the Costa Rica project indicated that they enjoyed helping the community and interacting with the community. Comments related to problem solving skills included:

1. Materials were not like the U.S. so we had to use what we were given
2. Shortages of materials required solutions which would not be used in the U.S.
3. Culture differences required problem solving and Spanish knowledge

As part of every class, student evaluations were given at the end of the semester. Student rated the course a 4.9 on a 5.0 scale (5.0 being strongly agree). Additional questions were added to evaluate the service learning component of the course. Table 2 shows the questions and the group mean for the class.

Table 2: Course Evaluation Service Learning Questions and Score out of 5.0

Student Evaluation Questions	Mean
Learning was more meaningful in this class than other classes I have taken	4.9
I took more responsibility for my learning in this class than I typically do in other classes	4.7
The community service was relevant to the academic course materials and content	5.0
I was more motivated to learn in this class than in other classes I have taken	4.0
I felt my contributions were appreciated by the community partner	5.0
The class made me realize that it is very important that I help others in my lifetime	4.9
I think all students should take a service learning class	4.9

Additionally the instructor had the students complete a writing assignment and reflection on the trip. Some of the student quotes from the reflections are included below:

“During this trip, I grew as person. Traveling with a group of people I did not know very well was a scary experience in itself. But the whole group agreed that we wanted to get as much as we could out of the trip, which was very helpful in making the trip a fun experience

“Having an open mind to try new things made the trip wonderful and a great learning experience.”

“A study abroad trip is something I had always heard people talk about but I did not realize how much I could learn from study abroad until I did it myself.”

“The service project during our trip to Costa Rica I believe was a big success and not only an educational experience, but also a life enriching experience. One of the main reasons I chose to go to Costa Rica was because I wanted to give back and make a difference in another person and families lives. The service project for me was what made the whole trip complete and made it a success. The service project had a large impact on me as a person as well as the entire community.”

“My trip to Costa Rica was an experience of a lifetime. I am so glad that I was able to find personal funding to go on this trip, as it was worth every penny.”

“I can’t really pin point to one thing I loved the most because I love everything I saw and got to experience in Costa Rica.”

Conclusions

Service learning courses align well in construction management programs and can be useful in creating positive community engagement. Faculty can grow from the experiences through collected data that can be used to create scholarly work or build new projects. Students, faculty, and community partners can continue to find ways to fund projects with grants aimed at making these connections and continuing the solutions to solve grand challenges and problems facing humankind. This experience fulfills the learning outcomes for Purdue University’s common core and continues to create opportunities for synergy and collaboration and instill the sense of lifelong learning in all students who participate. It becomes a model for other courses to follow as a sustainable experience for students.

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Personal Protective Unit Position and Orientation of Proximity Detection and Alert Technology for Heavy Construction Equipment Operation

Eric D. Marks[1] and Jochen Teizer[2]

Abstract

The nature of construction sites often promotes hazardous conditions requiring workers and heavy construction equipment to operate in close proximity resulting in many interactions between ground workers and heavy construction equipment. Approximately one fourth of fatalities experienced by the construction industry in 2010 resulted from workers being struck-by an object or piece of construction equipment. The primary objective is to evaluate the capability of radio frequency (RF) remote detection technology to reliably provide alerts when the position and orientation of the personal protection unit (PPU) component of the system are varied. Field experiments designed to emulate typical interactions between ground workers and heavy construction equipment are completed. Various positions and orientations of the proximity detection and alert system's PPU component were created and evaluated based on typical worker movements based on construction tasks. Experimental results indicate that both the position and orientation of the proximity detection and alert system's PPU component impact the reliability of the system's ability to provide alerts during hazardous proximity conditions. Specific positions and orientations were deemed reliable and effective when deployed in the construction environment. The purpose is to generate data and knowledge of proximity detection and alert systems for eventual implementation of proximity detection and alert systems on construction sites.

Keywords: Heavy construction equipment, pro-active safety, proximity alert technology, workers-on-foot.

1. Introduction

Construction sites are characterized as dynamic environments each having a unique size and working conditions. Interactions between multiple construction resources including construction personnel, heavy equipment and materials are characteristic of construction sites. Hazardous proximity conditions are present when heavy construction equipment is operating in close proximity to ground workers. These conditions result in an increased risk

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of injuries and fatalities for ground workers through contact collisions between workers and heavy equipment.

Interactions between heavy equipment and ground workers on construction sites have been investigated in previous research efforts. A majority of this work focused on injury and fatality statistics of contact collisions between ground workers and heavy equipment. Pratt et al. (2001) found the repetitive nature of construction tasks can cause workers to experience a decrease or absence of awareness. Other research has cited limited operator visibility as a factor in creating hazardous proximity conditions on construction sites (Teizer et al. 2010).

In the past, the construction industry, including private companies and governmental agencies, have been slow in adapting and implementing automated technologies when compared to other industries (Pratt et al. 2001). The freight industry, transportation, ship building, mining, railroad operations, and manufacturing have been testing and implementing various prototype safety technologies including proximity detection and alert systems. Completed case studies from these industries and others have shown emerging safety technologies including proximity detection and alert systems can be used to provide ground workers another layer of protection through technology.

A lack of scientific evaluation data and results through experimental trials currently exists for construction safety technologies including proximity detection and alert systems. Evaluation through experiments designed to emulate the construction environment are needed for these safety technologies. Specifically, experiments that simulate ground worker movement and the resulting performance of the proximity detection and alert system is required for eventual deployment of these systems on construction sites.

2. Literature Review

Construction sites have a unique scope and set of working conditions. These sites are characterized by dynamic interactions between various resources including ground workers, heavy equipment and materials. Workspace on construction sites is often limited due to the unstructured and seemingly random movement of resources. Construction resources often function in close proximity to one another resulting in dangerous proximity situations for ground workers. Incidents in which construction equipment strikes a ground worker can result in an injury or fatality. As injury and fatality statistics indicate, hazardous proximity situations on construction sites remain a key problem in the safety of construction workers.

The following review covers injury and fatality incidents associated with hazardous proximity situations in the construction industry. The review also discusses current safety best practices in construction, real-time proximity detection and alert systems, and reviews methods for testing these systems. A research needs statement is derived and presented at the end of the review.

2.1 Construction Heavy Equipment-Human Interaction Statistics

The construction industry continues to experience one of the highest workplace fatality records per year when compared to other industries in the US. The construction industry experienced 721 fatalities in 2011, 17% of which resulted from workers colliding with objects or equipment on construction sites (CFOI 2011). These 123 construction fatalities resulting from workers colliding with objects or equipment accounted for 2.6% of the nation's workplace fatalities experienced in 2011. Since 2003, the construction industry averaged 197 fatalities per year resulting from workers being struck-by construction equipment or other objects (CFOI 2009).

Heavy equipment-ground worker interaction also result in worker injuries which negatively impact the success of a project through decreased worker productivity, increased company medical costs, etc. In 2010, the construction industry recorded 24,710 injuries caused by workers colliding with equipment and other objects which accounted for 12% of all construction worker injuries in that year. Since 2003, the construction industry averaged 45,746 injuries resulting from workers colliding with equipment and objects on construction sites (CFOI 2011).

2.2 Causes of Heavy Equipment-Human Interaction

Research efforts in hazardous proximity situations between construction workers and equipment have resulted in many root causes of the current problem. Characteristics such as the harsh outdoor environment and the often repetitive nature of construction tasks can cause workers to decrease their awareness of surroundings (Pratt et al. 2001). Three general problems that result in hazardous proximity situations between construction equipment and ground workers: 1) Outdated or never implemented policies including a lack of knowledge of existing risk factors, 2) all incident causation data is collected after-the-fact resulting in limited real-time incident information if any is available, and 3) no real-time information is gathered during the incident.

Another study found that most heavy equipment-human accidents result from missing safety features on heavy equipment (OSHA 1990). The missing devices included components required to alert workers of their close proximity to the equipment. Other preventative measures including maintenance checklists for construction equipment and internal traffic control plans (ITC) were also investigated as possible causes of heavy equipment-human interaction problem on construction sites.

2.3 Safety Best Practices

Previous research efforts in construction safety have mainly focused on training and education. Much of previous research focuses on construction safety best practices in design, education, and training for safety. These safety best practices do not generate feedback during performance of the work task and are unable to provide alerts in real-time to construction personnel.

The Occupational Safety and Health Administration (OSHA) has developed and implemented several passive safety regulations requiring devices such as hard hats, reflective safety vests and other personal protective equipment (PPE). These regulations are passive attempts to improve safety in construction, but are incapable of providing real-time alerts for workers during hazardous proximity situations. Other regulations including incident recording and worker safety training can increase the awareness of equipment operators and ground workers in dangerous working conditions.

2.4 Real-Time Pro-Active Proximity Detection and Alert Technology

Automation has been found to simplify and improve some important construction engineering and management problems (Navon and Sacks 2006). Technology implemented on construction sites for safety can be categorized as reactive and proactive. Reactive technologies require data collection and analysis processing effort after an event occurs. Proactive technology collects and analyses data in real-time in order to alert construction personnel of potentially dangerous situations instantaneously. Real-time safety technologies implemented on construction sites have been proven reliable to provide alerts to workers and equipment operators in real-time when a hazardous proximity situation exists (Teizer et al. 2010). Construction safety technologies provide ground workers with an additional layer of protection when other safety best practices are not followed (Teizer et al. 2008).

Many technologies thought to be capable of alerting workers in real-time during hazardous proximity conditions such as RADAR (Radio Detection and Ranging), sonar, Global Positioning System (GPS), radio transceiver tags, vision, etc. have unique limitations when deployed on construction sites such as availability and strength of signal, weight, size, and power source (Ruff 2001). Other studies investigated several of the previously mentioned technologies as potential proximity detection and alert systems in the construction environment. Parameters such as read range, alert method, precision, reliability, and capability of performing in an outdoor environment were used to assess each proximity detection technology (Teizer et al. 2007). Radio frequency technology demonstrated potential to satisfy many of the tested constraints.

2.5 Test Methods for Proximity Detection and Alert Systems

Testing methods have been developed to evaluate the capabilities and reliability of proximity detection and alert systems. Manual methods of measuring and marking proximity alert distances for a camera and radar system were used for construction sites (Ruff 2005). These methods have been used for measuring proximity detection and alert systems (GPS units) on large capacity haul trucks during a surface mining operation (Steel et al. 2003). Three mobile vehicles and six stationary objects were fitted with the proximity detection and alert system. The system's reliability was evaluated through field trials of interactions between large capacity haul trucks and ground workers.

A lack of scientific evaluation data exists for new and existing automated safety technology for implementations on construction sites. Proximity detection and alert systems using radio frequency technology need to be thoroughly evaluated through current or newly developed

experimental methods, case studies, and resulting data analysis. A need exists to evaluate various mounting positions and orientations of proximity detection and alert system components.

3. Objective and Scope

The objective is to evaluate the effectiveness of various positions and orientations of proximity detection and alert system components to provide alerts in real-time to construction personnel when deployed in a simulated construction environment. The different positions and orientations of the system's components are designed to simulate ground worker movements. When heavy construction equipment and ground workers are in too close proximity, components of the proximity detection and alert system should be positioned such that the hazardous proximity conditions are detected and a real-time alert is activated. The scope includes hazardous proximity situations between heavy construction equipment and ground workers on outdoor construction sites.

4. Methodology and Results

Each set of experimental trials was designed to investigate the effectiveness of various component positions and orientations of the proximity detection and alert system in an outdoor environment. The experiments were designed to test various mounting locations of proximity detection and alert system components on existing Personal Protective Equipment (PPE) for ground construction workers. Typical movements and static positions of ground workers were also used to design the experimental trials.

4.1 Technology Tested

The real-time proximity detection and alert system utilizes active Ultra-High radio frequency (UFH) technology to detect proximity breaches of construction equipment and ground workers. If two or more construction resources are in too close proximity to one another, the sensing technology will activate alarms to warn construction personnel through devices called Equipment and Personal Protection Units (EPU and PPU respectfully). These two components are further described:

1. An in-cabin construction equipment protection unit (EPU) equipped with a reader, alert mechanism, and single directional antenna that serves as a transceiver device by transmitting and receiving tag information including the timestamp, tag identification and magnitude of the reflected radio frequency signal and

2. A personal protective unit (PPU) equipped with an alert mechanism, chip and battery in a small rectangular tag (8.5 cm by 5.5 cm). This tag can be installed on a hard hat or safety vest of a construction worker. Both the EPU and PPU components can be viewed in figure 1.

The EPU component of the proximity detection device can be powered by the existing battery on the piece of equipment. A signal broadcasted by the EPU is intercepted by the

PPU and reflected back to the EPU which activates an alert instantaneously in real-time when the devices are in close proximity to one another. The EPU provides an audible alert which creates ample noise so that the equipment operator is able to hear the alert above normal construction sounds. The alert is only provided to the equipment operator because he/she ultimately has control to stop or correct the hazard. Figure 1 shows the PPU mounted on a worker safety vest (left) and the EPU installed on a tripod and cart (right).



Figure 1: Proximity Detection and Alert System PPU (left) and EPU (right)

The EPU's signal is broadcasted in a radial manner and loses signal strength as it moves farther from the EPU location. During the experimental trials, the strength of the signal emitted by the EPU remained consistent. The EPU's antenna should be installed in locations such that the line-of-sight to objects is not obstructed. The proximity detection and alert system evaluated also possesses data logging capabilities. The accompanying data logging function of the system records the tag identification number, EPU identification number, time stamp of the proximity breach and the Received Signal Strength Indication (RSSI).

4.2 Experiments

Several experimental trials were designed and executed to evaluate various PPU positions and orientations on ground workers. The objective of these experiments was to identify the best position and orientation among multiple variations for the proximity detection and alert system tested. Each experiment was conducted in an outdoor environment designed to emulate conditions of an actual construction site. For each set of experimental trials, the weather conditions were mostly clear, mostly sunny, and the temperature was 75 degrees Fahrenheit. The test bed for these trials was a clear, flat, grass ground surface with no obstructions. A Robotic Total Station (RTS) was used to place markers along a straight path perpendicular to the face plane of the EPU antenna. Markers placed at consistent 3 meter intervals outlined the walking path for the test person. The test bed for these trials is shown in figure 2.

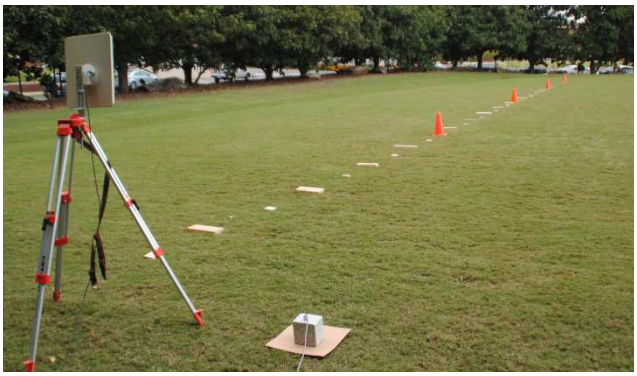

Figure 2: PPU Position and Orientation Test Bed

The EPU's antenna was attached to a tripod in order to exclude any objects from obstructing the line-of-sight between the EPU and PPU. The EPU antenna is directional meaning it is only capable of reading 60 degrees in both directions parallel to the face plane of the antenna. The centroid of the square antenna face was positioned 1.15 meters vertically from the ground surface which was the average elevation between the top of hard hat and center of the safety vest of the test person. The face plane of the EPU's antenna was perpendicular from the ground surface.

The test person started outside of the proximity detection and alert system's detection range (approximately 40 meters from the antenna) along the path outlined by the markers. The test person equipped with a PPU approached the EPU antenna on the straight marked path at a constant walking pace (4 meters per second). Once the alert was activated, the test person stopped and measured the distance from the stopped position to the EPU's antenna using a commercially available laser distance meter. This procedure was repeated ten times for each combination of tag position and orientation.

Eight combinations of tag positions and orientations were tested during the experimental trials. For the purposes of this experiment, the term "position" was defined as the location of the face plane of the device in relation to the ground surface. For example, a horizontal position is represented by the face place of the device being parallel to the ground surface and perpendicular to the EPU antenna face. Likewise, a vertically positioned device has the face plane perpendicular to the ground surface and parallel to the EPU antenna face. Both of these tag positions can be viewed in figure 3 where the tag is mounted on a hard hat in the vertical position (left) and horizontal position (right).

Four different tag orientations were used in combination with the tag positions. The orientations were based on the location of the tag in relation to the EPU antenna or the sky. Each of the four tag orientations was given a number (1, 2, 3, or 4) depending on the location of tag components such that each of the four possible orthogonal tag orientations was tested. Each subsequent orientation after the first initial orientation (orientation 1) was achieved by rotating the tag counter clockwise 90 degrees. The diagram in figure 4 shows how the tags were oriented in relationship to the EPU's antenna or the sky and ground reference. The experimental trials were conducted on three PPU tags.



Figure 3: PPU mounted on a hard hat in the vertical position (left) and the horizontal position (right)

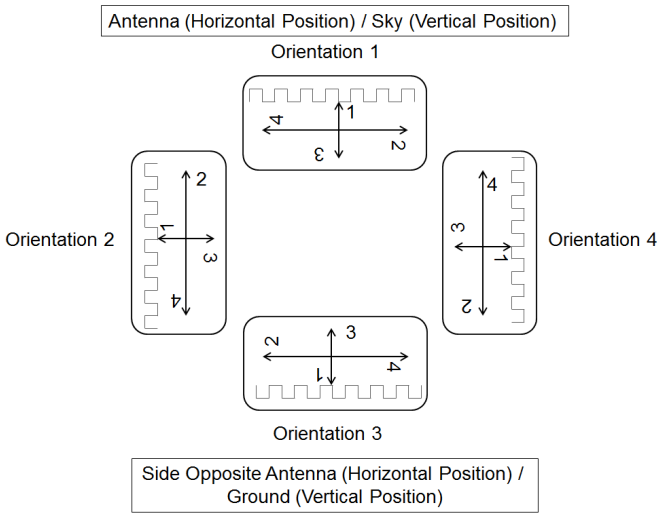

Figure 4: PPU Orientation in Relation to the EPU Antenna and Ground Surface

A statistical analysis was performed on the data gathered for the three tags during the experimental trials. Table 1 shows the statistical analysis of the alert distance results from the tag positioned horizontally on top of a worker hard hat. The mean value, minimum value, range (which is the maximum value subtracted from the minimum value), and standard deviation are calculated from the ten trials of each tag. The best performing orientation values of each tag values are bolded for each tag. Best performers were classified as trials having the highest mean value, lowest range value, and lowest standard deviation value when compared to the other orientations of the same tag.

Orientation 1 had the highest mean value, lowest range between the maximum and minimum distance, and the lowest standard deviation value for tag 1 and 3. These results were analysed for each of the four orientations for the following tag locations with the tag position in parenthesis: 1) Top of the hard hat (horizontal), 2) side of the hard hat (vertical), 3) front of the hard hat (vertical), 4) back of the hard hat (vertical), 5) Front pocket of the safety vest (vertical), 6) back pocket of the safety vest (vertical), 7) side of the shoulder (vertical), and 8) top of the shoulder (horizontal). Results of each of the eight individual configurations were compared to select the highest performing position and corresponding orientation. Table 2 shows the best performers of each possible tag position and orientation combination when compared to the four other configurations on the hard hat. A similar table

was created for the safety vest summary values. The orientation of each tag is denoted in parenthesis beside each value.

Table 1: PPU Tag Orientation on the Top of a Hard Hat

		Tag 1	Tag 2	Tag 3
Orientation 1	Mean:	**37.7 m**	38.8 m	**37.8 m**
	Min.:	36.8 m	38.0 m	37.0 m
	Range:	**1.3 m**	**1.5 m**	**1.3 m**
	Std. Dev.:	**0.6**	**0.8**	**0.7**
Orientation 2	Mean:	21.9 m	10.8 m	11.3 m
	Min.:	19.0 m	10.0 m	9.5 m
	Range:	5.8 m	**1.5 m**	3.0 m
	Std. Dev.:	2.9	**0.8**	1.6
Orientation 3	Mean:	34.1 m	12.7 m	37.4 m
	Min.:	32.0 m	12.0 m	36.3 m
	Range:	4.3 m	**1.5 m**	2.8 m
	Std. Dev.:	2.1	**0.8**	1.4
Orientation 4	Mean:	13.5 m	12.3 m	12.6 m
	Min.:	9.8 m	11.0 m	11.5 m
	Range:	5.5 m	2.8 m	5.3 m
	Std. Dev.:	3.0	1.4	2.7

Table 2: PPU Tag Orientation Summary on the Hard Hat

		Tag 1	Tag 2	Tag 3
Top	Mean:	**37.3 m (1)**	**38.8 m (1)**	37.8 m (1)
	Min.:	11.5 m (4)	10.0 m (2)	12.5 m (2)
	Range:	1.3 m (1)	1.5 m (1)	**1.3 m (1)**
	Std. Dev.:	0.6 (1)	0.8 (1)	**0.7 (1)**
Side	Mean:	8.9 m (1)	5.7 m (1)	8.6 m (3)
	Min.:	1.5 m (3)	4.3 m (2)	4.5 m (2)
	Range:	**1.0 m (1)**	1.5 m (2)	5.3 m (2)
	Std. Dev.:	**0.5 (1)**	**0.3 (3)**	0.8 (2)
Front	Mean:	36.5 m (1)	38.2 m (1)	**38.4 m (1)**
	Min.:	4.5 m (4)	5.0 m (4)	12.5 m (4)
	Range:	3.0 m (1,2)	**0.5 m (3)**	1.5 m (2)
	Std. Dev.:	1.5 (1)	**0.3 (3)**	0.8 (2)
Back	Mean:	10.8 m (2)	28.8 m (3)	26.8 m (3)
	Min.:	2.0 m (4)	3.0 m (4)	4.0 m (2)
	Range:	1.3 m (2)	6.3 m (3)	7.8 m (3)
	Std. Dev.:	0.7 (2)	**0.3 (4)**	1.0 (1)

The top of the hard hat in orientation 1 recorded the highest mean value when compared to the other configurations. Orientation 3 had the lowest standard deviation value when mounted on both the side and front of the hard hat. Overall, orientation 1 was the best performer in most of the mounting positions on the hard hat. The tag mounted on the top of the hard hat had the highest number of top performing orientations when compared to the other mounting locations. However, the front mounting location statistical values were very similar to values recorded when placing the PPU tag on the top of the hard hat.

A similar analysis was performed on placing the PPU tag on a workers vest in four locations previously mentioned. Placing the tag on the front pocket of a safety vest recorded the largest mean value for all three tags, and all alert distance readings occurred when the tag was in orientation 1 or 3. The test person was able to touch the antenna before activating an alert during the approach when the PPU tag was located on the back of the safety vest and on the side of the shoulder.

5. Conclusion

One leading cause of construction fatalities is collisions between workers and objections or construction equipment. The construction industry must seek to achieve zero fatalities and injuries for all construction projects, and one method is to generate knowledge about real-time safety technologies such as proximity detection and alert systems. The purpose of this research was to evaluate the effectiveness of various positions and orientations of proximity detection and alert system components to provide alerts in real-time during hazardous proximity conditions. Results from the review and experiments suggest that proximity detection and alert systems can reliably alert ground workers during hazardous proximity conditions, and that tag position and orientation can increase the effectiveness of these systems. The executed experimental trials tested the various PPU positions and orientations attached to a reflective safety vest and construction hard hat. The audible alert of the system was to a sufficient volume so that it can be heard over the other loud construction noise.

When testing the PPU's best orientation among the four configurations on the construction hard hat, orientations 1 and 3 on the top and front of the hard hat were the best performers when compared to the other configurations evaluated. Orientations 1 and 3 on the front of the safety vest had the highest alert distance. After testing the tag placed on the side of the shoulder and back of the safety vest, the test person was able to reach the EPU antenna before an alert was activated in several independent approaches. The results indicate that the tags experience polarization effects when positioned vertically in orientation 2 or 4. More testing should be completed on these tag locations such as a test person approaching the EPU antenna while positioning his/her body such that their back is facing the EPU antenna.

The completed field trials for the proximity detection and alert system were deemed successful, but other parameters could potentially influence the system such as impacts on the signal propagation. These factors include the EPU antenna mounting location, other construction resources such as materials, specific alert range for individual pieces of construction equipment, and impacts of an integrated system of multiple EPU's and PPU's on an active construction site. These factors and others will require investigation to further

evaluate the effectiveness of implementing a proximity detection and alert system in the construction environment. The system should eventually be deployed in extensive field trials conducted over extended project durations. During these long term field trials, data can be recorded, analysed, and used to improve positioning of workers and equipment to assist in the development of new safety concepts including advanced safety education and training courses.

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The pitfalls of redevelopment projects in suburbs in Finland

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Abstract

Worldwide in the growing cities a significant amount of housing is situated in the suburbs built in the 50hties, sixties and seventies. Today those suburban residences are confronting massive reconstruction needs but inhabitants and owners are lacking financial resources and knowledge to organise large renovation projects. This article is aiming to identify and describe the obstacles, which are seriously endangering renovation redevelopment projects in suburbs and to show some possible enablers to solve these obstacles. We approach this phenomenon from the inhabitants´ point of view.

This research is based on a case study in a suburb in the city of Helsinki called Siltamäki. This area is a typical seventies housing areas. The research direction on this study is action research and the method used is case study. We followed renovating and areal redevelopment projects on this area and compared inhabitants´ expectations and wishes with the possible realistic outcome. We also studied the physical renovations needs of the real estates in order to find the key reasons why those renovations are not materializing and crucial projects are postponed. In this research we identified following four types of obstacles that are hindering renovation projects. These obstacle types are:

- Governance obstacles: decision making is unpredictable in Housing companies
- Co-Creation obstacles: in the renovation projects there is no adequate place for the user knowledge
- Diversity obstacles: inhabitants´ interests are confronting
- Ownership obstacles: no stakeholder is taking the primary responsibility of the final outcome of the projects in the wholeness

Keywords: redevelopment, suburb, sustainability, housing company, and co-working.

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1. Introduction

Worldwide suburban residences are confronting massive reconstruction needs and the increasing urbanisation trend demands more housing in the cities. In order to improve sustainability of the suburban areas it is important to densify suburban areas by complement building in the middle of existing housing. Even if this phenomenon is global, has Finland some very special characteristics problems that can be solved only by understanding the habitants' point of view.

The goal of this article is to describe, which circumstances prevent and delay renovation projects in suburbs. Additionally this article will explain some special characteristics of Finnish housing stocks and forms of housing possessions.

First in this paper we describe some characteristics of Finnish housing history and present situation. Second we describe our case study and the all the stakeholders that are involved to a renovation project and finally we identify four types of obstacles that are preventing and delaying renovation projects in Finnish suburbs.

2. Background

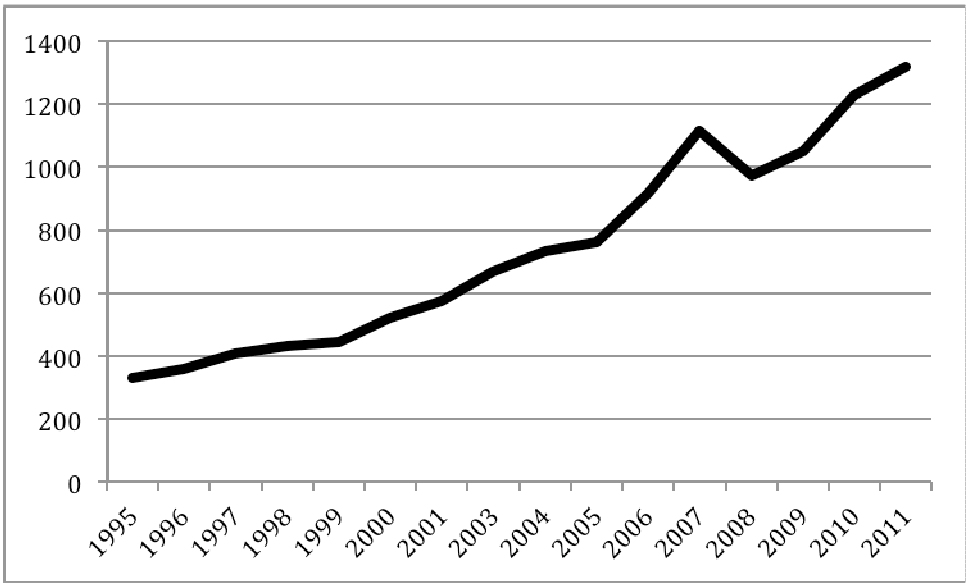
The Finnish urbanisation started late only in the beginning of the 20th century. In the beginning of the century only 12 per cent of inhabitants lived in urban areas when at that same period already 30 per cent of the inhabitants of the Western Europe dwelled in cities. But in Finland when the urbanisation begun it was rather intensive having its peak in the years 1969 – 1975 and this pheromone was faster in Finland than elsewhere in Europe. (Laakso and Loikkanen 2004). Still after a hundred years of urbanisation only 66 per cent of Finnish citizen dwell in cities compering to other EU countries ´ average of 80 per cent.

This short but heavy migration caused a strong demand of reasonable housing. This problem was solved by building with industrialised methods large suburban areas of blocks of flats with similar design. The main attention on that time was on the physical environment of housing areas and the social and functional aspects were neglected. Today these suburban housing areas form more than half of the Finnish housing assets and demand large renovation operations due the ageing of the building structure. Also the demand of energy efficiency of housing requires renovations on these areas. On this moment of evitable renovations one consideration is complement building in the middle of existing housing. This densifying would better the sustainability of an originally spacious area and provide a stronger customer base for the services. (Junnonen and Karhu 2012)

In Finland home ownership is widespread in all forms of housing, including apartments as well as detached houses and row houses. Two-thirds of housing stock consists of owner-occupied homes. A Finnish specialty is dwellers owned housing companies that are a very typical form of housing management in Finland. Most housing companies are small, and manage a limited number of properties. Residents own shares of the housing company, have representation on the board, and pay a monthly fee towards maintenance costs. In year 2008 on average Finnish people spent under 17 % of their disposable income on

housing. In general, tenants spend a higher proportion of their income on housing than homeowners. (Ministry of Environment, Housing facts 2008) But housing costs have risen rapidly in resent years. The main reasons to the high housing costs are the increased renovation and maintenance costs as we can see in table below.

Table 1 Renovations costs of housing companies in Finland (millions of euros)(Official Statistics of Finland)



There is a long history of developing projects of suburban areas in Finland. After Kokkonen (2009) there have been three major national suburban development projects on the years 1995 – 1999, 2000 – 2003 and 2008 – 2011. Besides these large national development project ran by the Ministries there are numerous minor projects organized by larger Finnish cities. Typically these development projects can be divided into inhabitants and theme projects and into research and development projects. Inhabitants and theme projects are usually concentrating to social improvement or to some specific theme like unemployment of the youth. Research and development projects are concentrating to improvement on life cycle costs, physical environment energy efficiency or for example developing the local shopping centre.

Kokkonen (2009) made an assembling research on Finnish development projects in suburbs and after him key elements for successful redevelopment project in suburbs are understanding the needs of the inhabitants, commitment of all the stakeholders, common rules and language, continuity, interaction, trust and of course a common goal and resources to achieve it.

After Heinonen and Ratvio (2007) improving the physical, functional and social environment we can support the identity of the housing area, which is an important element when creating communal feeling. Even it is not possible to solve the social problems by improving the physical environment it is possible to prevent the social segregation by taking care oh the maintenance of housing. Inhabitants may be very much aware of neighbourhood´s social problem but that does not necessary lead to removal if inhabitants are content with the

environment and the services. The quality of housing environment is a crucial competitive edge in the completion between areas.

After Mohammadjavad (2011) in an areal renovation case study situated in Iran concluded that participation is a way to meet social sustainability. They argued based on reviews of renovating project in Iran that four parameters are crucial in order to reach better sustainable environment that arises from the greater participation of the people in reconstruction projects:

1. Participation in all stages from schematic design to operation

2. Design in distressed areas should be for people with people and distance that exist between stakeholders should be eliminated

3. In renovation projects special attention should be regarded in cultural context in the region and building fabric in the site. In distressed areas rehabilitation must be regarded in this point that future residents should be current residents to prevent people immigration.

4. People should be involved in a real participation paradigm to meet social sustainability and it means people should be a part of decision making process and should be involved in all parts of design stages from schematic design till operation phase.

3. Methodology and research design

Research direction in this study is action research and the aim of this experiential case-study design is to benefit from experiential learning cycle described later on in this article. After Pasmore (2001) action research is often mentioned based on American philosopher John Deweys´ ideas on 1930 how practical problems needed practical solutions. He states that reflective thinking has five phases: suggestion, intellectualisation, hypothesising, reasoning and testing hypothesis in action. He emphasises that a solution is viable only if when it was demonstrated to produce desired outcomes on practice. (pp 38-40)

After Riel (2010) action research is a process of deep inquiry into one's practices in service of moving towards an envisioned future, aligned with values. Riel describes that action research is the systematic, reflective study of one's actions, and the effects of these actions, in a workplace context. As such, it involves deep inquiry into one's professional practice. The researchers examine their work and seek opportunities for improvement. As designers and stakeholders, they work with colleagues to propose new courses of action that help their community improve work practices. As researchers, they seek evidence from multiple sources to help them analyse reactions to the action taken.

Riel states (2010) that the researcher uses data collected to characterize the forces in ways that can be shared with practitioners. This leads to a reflective phase in which the designer formulates new plans for action during the next cycle.

Riel and Lepori (2011) describes the goals of action research:

- The improvement of professional practice through continual learning and progressive problem solving;

- A deep understanding of practice and the development of a well specified theory of action;

- An improvement in the community in which one's practice is embedded through participatory research.

Straatemeier et al. (2010) have proposed a new methodology, which they have labelled “experiential case-study analysis”. In their approach they base their method on experiential learning circle. In this learning cycle, the findings on concrete experience leads to the forming of abstract concepts. These concepts are then tested in new concrete situations and when they are successful they will cause chances in existing practices. They state that the experiential learning cycle can also provide a useful framework to characterise planning research, planning practice, and their (potential) relationship. The four activities, observation and reflection, forming abstract concepts, testing in new situation and concrete experience are, of course, already present in current planning research and practice. However after Straatemeier, they are often not linked. He argues that a more direct and systematic link between these different activities would much improve learning processes and thus knowledge development in planning research and practice. This requires change on both sides. In Straatemeier´s approach the most important aspect is to gain insight into the underlying mechanisms. Why does a particular planning innovation work, or not work? In order to understand the mechanisms, the researcher has to reflect upon different aspects in each case.

This study is based on a research and development projects realized in 2001 in a suburb of Helsinki, Finland. The case area is a typical seventies housing area with some architectural values. Houses are two or three floors high without elevators. Inhabitants mainly own themselves their apartments. Houses are in situation that plumbing and façade renovation are indispensable. The maintenance and managing of this area is done by a house managing and maintenance agency owned by the housing companies. A housing company is typically formed of the apartment owners of an apartment building or buildings. Housing company´s shareholders´ meeting is also the primary decision making body when choosing a renovation company. This Siltamäki housing area was originally planned for 3 000 inhabitants with a small shopping centre including a swimming hall, day care facilities and a library. Salastie (2009). Today in this area there are eleven housing companies and four other companies owning garages and some store and business premises. These housing companies have to make in the foreseeable future heavy investments to maintain the condition of the houses. Several different stakeholders involve them selves to renovation project and they all have their own perspective and goals. This picture below illustrates the involved stakeholders.

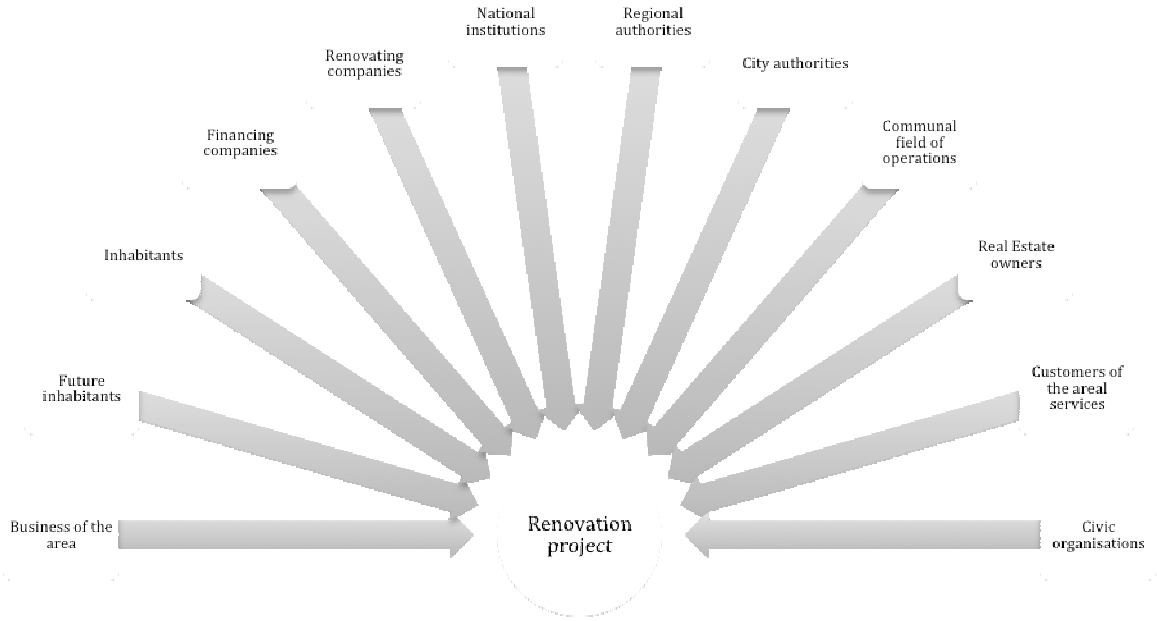


Figure 1: Stakeholders of a renovation project (Junnonen and Karhu, 2012)

3.1 Investigating residents´ preferences and positioning them into a renovation process

This case was a research and development project in order to find methods how inhabitants´ preferences could be taken into account in a large renovation project in a typical seventies suburb. This project is described in Junnonen and Karhu (2012). In many cases in the beginning of renovation project the inhabitants are interviewed and asked on their wishes but seldom this data is included in the planning process of a renovation process. Often these wishes or preferences are not included in the process because they would need some extra agreements and funding between the customer and the renovation company or the construction companies are not the relevant suppliers for these ideas or the ideas are collected too late. Often inhabitants feel themselves frustrated afterwards and contentment to whole renovation project is decreasing while they cannot see any benefit of participating to planning process in first-hand.

Three workshops were organized on this case area together with the inhabitants, researcher, representatives of construction companies and planners. These workshops were following a special method developed by research group Mind at Aalto University. The goal of the two first workshops was to create development ideas with help of co-working among the inhabitants. The participants of the workshops were not selected in any criteria but it was free access to all workshops and the participants were not asked to leave any personal information. In these two first workshops participants started by listing their idealistic housing area and the workshop followed by refining these ideas in groups to be more concrete ideas possible to realise during the renovation project.

The third workshop was a larger but more formal event where there was also official information on future renovation project. In this workshop participant were asked to vote on

the most preferable vision or concrete subject that could be possible to realise during the renovation project. The participants were also asked by which method (questionnaire, oral or written interview, model exhibition, prototyping) they want to communicate their wishes to construction companies and planners.

These workshops were recorded and afterwards the inhabitants´ presentations were analysed in order to find what they think is a obstacle to renovation project and what they would like to achieve as a result of the renovation project. On that same period the researchers and representatives of the construction companies had their own workshops and meetings in order to find what the construction field finds to be obstacles. One of the goals of this project was to describe a theoretical model how and which point in the construction process (owner-) inhabitant needs and wishes should be taken account. After this research we can state that these needs should be investigated early enough that they could be prioritised and taken into preliminary planning. Otherwise they will be neglected for the economical and technical reasons during the process.

4. Results

The practical aim of the research was to recognise obstacles that prevent or delay necessary, desired, planned or profitable improvements in suburban redevelopment projects. Based on research we find four categories of obstacles.

Governance obstacles

The suburban housing areas are usually composed of individual housing companies. These housing companies own usually of one or few apartment houses. The decision makers in the boards of these housing companies are the flat owners. Also all the funding in private housing companies comes from the flat owners. The owners typically differ in life situation and they have varying possibilities to finance improvements. Thus in a decision making situation the share of the more wealthy owners determines the level of renovation and housing companies are unwilling to take costly decisions that would be difficult to less wealthy owners. Some decisions demand qualified majority. Typically decision making in such housing companies is rather conservative and difficult decisions are often delayed because these decisions often mean funding difficulties and temporary housing elsewhere to the owners. Flat owners also are laymen on real estate and construction business and the board members can change randomly. All this makes decision-making unpredictable in housing companies.

Co-Creation obstacles

Successful redevelopment projects often benefit from the user knowledge and co-creation between all stakeholders. These processes create involvement among the inhabitants and the owners. The processes of the construction companies at their present state are not capable to integrate this kind of information in the renovation projects. In these processes there is no adequate place for the user knowledge. This phenomenon creates dissatisfaction

towards to the redevelopment project´s outcome and might create frustration if inhabitants´ expectations were very high that their propositions would become concrete.

Diversity obstacles

Typically inhabitants in a suburban housing area differ in age, education, and professions and in many different ways. Thus their needs and desires are different and often their interests are confronting. This can be remarked in questions like would it be a good occasion to build an elevator in the house or should the playground for children be renovated. These divergent desires of owners can paralyse development projects.

Ownership obstacles

In development projects there are several different stakeholders, owners, construction companies, city planning, business life. All the stakeholders are forced to collaborate but they all have their own targets and point of views. Stakeholders tend to optimise their own share and expenses. Thus no stakeholder is taking the primary responsibility of the final outcome of the projects in the wholeness

Enablers to overcome these obstacles can be discovered by carefully studying successfully cases where all the stakeholders have benefitted. The co-planning, co-working and sharing information are the key elements in order to reach an optimised outcome to all the parties.

5. Conclusions

These obstacles of renovation projects are not solved without strong co-planning and new attitude in managing redevelopment projects. One solution could be an urban manager who could operate as an enabler between inhabitants, city planning and construction companies. Such an urban manager should be chosen by the inhabitants in order to have the position of trust towards all the stakeholders. As a renovation project is a multidisciplinary task should such as urban manager have professional knowledge from different fields.

Developing financing methods such as inverse housing loans should eliminate the instability of the financial situation. Also by developing co-renovating models, inhabitants could achieve more reasonable renovation offers from the companies due larger contracts but also that would support communal feeling end experience. Inhabitants' organisations could be more involved to the renovation project so that inhabitants could by them selves sketch the renovation project and what they want of it.

For further research it would useful to study more enablers to overcome these obstacles. These enablers can be discovered by carefully studying successfully cases where all the stakeholders have benefitted.

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Investments in Innovations in Finnish R&D-functions in Real Estate and Construction

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Finnish R&D-functions in Real Estate and Construction

The roadmap for built environment 2050 indicated the significance of holistic r&d-projects as future success factor for construction and real estate industry in Finland. The research and development activities in Finnish construction and real estate sector are supported by different funding organizations, e.g. by a Finnish funding agency for technology and innovation (Tekes) and Strategic Centre for Science, Technology and Innovation (SCSTI) of built environment in Finland. This paper aims to describe the national innovation system, its focus areas and activities in the field of construction and real estate sector and provide an overview of the successful projects. The methodology is literature review and analysis of variety of evaluations.

Based on the international evaluation conducted in 2012 Tekes has performed well and is among the world's leading innovation agencies. With its activities Tekes has contributed to increasing research intensity, increased cooperation between companies and knowledge infrastructure in for Finland important areas and in this way helped build knowledge and competences to increase the international competitiveness of Finnish enterprise. Especially the activities in public sector and reduction of energy consumption of the buildings were mentioned as an achievement in public sector innovations, which are a specific form of user driven innovations. The results indicate that the construction and real estate industry have traditionally been a disjointed industry. However, joining resources through different initiatives have promoted new collaboration.

Keywords: research and development, innovation policy, construction and real estate sector

1. Introduction

The built environment is constructed and shaped to respond to the social, cultural and economic needs of people; so we can reside, work, worship, move, consume, and enjoy. The number of new building developments depends to a large extent on the social and economic circumstances, following the needs of the economy and the occupants.

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Technologies to produce and operate the built environment are mainly cross-sectorial implementations of the achievements of all sectors of the economy; this technological diffusion depends on socio-economic conditions. The development of the future building stock will vary depending on social and economic scenarios. However, one characteristic of the future built environment already in development is the increase use of embedded sensor and monitoring technologies, which will allow smart technologies to help everyday living.

Generally, construction and the real estate industry pay far too little attention to research and development, and reserve only limited funds for development projects. This is partly due to the business structure and partly due to company conservatism. Additionally, many companies are too small and do not have access to funds for research and development. More important is the fact that allocation of research projects in a company might be less effective to produce tangible outcomes than if the same effort would be put on addressing the issue of how companies can work together and share data for good results and practices.

2. Innovation Policy in Finland

Companies seek competitive success through new products or by renewing their current line – by way of innovations. The innovations are usually based on group of people having different competence areas. Innovations help companies to succeed in business, build up their competitiveness and enhance productivity. This facilitates high wages and new job creation. Innovations boost productivity in the national economy and make a high standard of living and wellbeing possible. Finland has a particularly innovation-driven economy.

Innovations do not always succeed as expected in the markets, thus there is always an economic risk associated to these activities. For this reason, companies do not invest in innovation activities as much as society would wish. Therefore, the public sector tries to motivate the private sector to engage in innovation activities through various measures such as public research funding and other incentives for private research and development activities.

In addition to financing, many factors within the business environment influence the willingness of enterprises to innovate. In Finland, these include legislation, access to international markets, and the functioning of the internal market of the European Union (EU). Such incentive schemes, and the institutions planning and implementing them, constitute the national innovation system. Finland’s innovation system has been ranked among the best in the world (European Union, The Innovation Union Scoreboard, 2011).

In Finland, the Ministry of Employment and the Economy is responsible for most decisions on innovation policy, which forms the base on which the innovation system develops. The development of the innovation system itself is coordinated by the Research and Innovation Council, led by the Prime Minister. In the public sector, a number of measures are in place to encourage engagement in innovation activity. Since the public sector does not produce commercial goods, the goals of its innovation activities differ from those of the private sector.

For example, among other tasks, the public sector seeks to provide citizens with more-useful public services. However, public sector innovation activities also aim to improve productivity.

This paper aims to describe the national innovation system, its focus areas and activities in the construction and real estate sector, and to provide an overview of successful projects. The methodology is literature review and analysis of variety of evaluations of innovation policies.

3. Real Estate and Construction Sector in Finland

The total value of the Finnish national wealth was EUR675 billion (Euro (EUR), in 2011. 75 per cent is tied to the infrastructure of economic activity, housing and leisure pursuits, namely buildings, roads and networks. The infrastructure is maintained, repaired and renovated annually by a sum equivalent to about 6 per cent of its value (reference). In 2011, a total of EUR44 billion was invested in the built environment; 60 per cent in maintenance of existing buildings, constructions, traffic arteries and networks. Investment due to new construction and replacement, which is sensitive to economic fluctuations, represented only 40 per cent.

The ratio of the stable to sensitive production of the real-estate and construction sector changes with the national economy. The entire sector employs more than 500,000 people, which is more than one fifth of the Finnish workforce and accounts for a quarter of the national GDP. Its significance varies according to particular sectors of the national economy. The majority of total housing costs are in one way or another related to all sectors; construction, repair and maintenance of spaces are a significant item of expenditure in the education sector.

The volume of real estate and construction R&D is about €350 million, 70 per cent financed by private sector and 30 per cent by public sector. The most active R&D actor has been building product industry, mainly the building services industry. Recently, the planning sector has also invested in IT application development such as BIM.

The greatest challenge for the industrial society is to adapt its production and economic activities to what nature can sustain. By joining the Kyoto Protocol, Finland has committed to limiting hazardous emissions into the atmosphere. The real estate and construction sector must also take this goal seriously, as it affects over 40 per cent of the consumption of primary energy in Finland and it produces a third of the national CO2 emissions (EU 2008).

The real estate and construction sector can use tools such as energy efficient heating, production and transportation, use of renewable energy sources, and cogeneration systems. In 2012, the new energy regulations for buildings took into force by the Ministry of the Environment. The new regulations aim to reduce 20 per cent of the energy consumption of new buildings and created a demand for renovation activities during 2013 (Finnish Ministry of Environment 2013).

The environmental impact of a building is the sum of the production process of construction materials, the land use related to the building as well as the energy needed for heating, air conditioning, supplying water and running the equipment. The public sector has invested in the reduction of detrimental environmental impacts of construction through programmes such as the Finnish Government Programme for Ecologically Sustainable Construction, approved in 1998 which was among the first of its kind in Europe (Anon, 2001).

A good living environment is healthy, safe, pleasant, stimulating, aesthetic and nature-oriented. Communities must also be competitive in order to serve as bases supporting business and industry. A living environment that meets the needs of its residents should be linked to an eco-efficient community structure with short distances for people to carry out their daily activities and is also pleasant to live in. To this end, the often dispersed community structure of Finnish urban areas can be integrated by small scale complementary building, creating additional benefits through a more independent elder population. Furthermore, the eco-awareness of consumers has increased significantly, creating a demanding client group also in the real estate and construction sector. Eco-efficiency is becoming one criterion for quality construction alongside safety, healthiness, pleasantness and durability.

The ageing gross area of approximately 550 million square metres building stock, 78,000 km of roads, 28,000 km of streets, 100,000 km of fresh water pipes, 45,000 km sewers, and other infrastructure require care and certain technical repairs become timely as a building ages. In fact, the critical age of most structures ranges between 30 (buildings) and 50 years (infrastructure sections). A large number of buildings and infrastructure parts have already reached or are about to reach this point.

The impact of the cyclical nature of new construction investments can be alleviated by timing needed repairs with periods of slow new construction. Currently, the implemented renovations do not meet the repair needs, instead, are delayed and only carried out when the damage is evident, increasing the cost of renovation activities. Pre-emptive repair work and repairs carried out at an earlier phase of the life of infrastructure would improve living conditions and work productivity.

The generalised development of information and communication technology (ICT) has made it as one of the key factors in the construction process. Information networking of projects also networks enterprises into closer co-operation excluding those companies that do not adopt the new technology as part of their business concept. Today, organisations are able to change information on a product model basis. In Finland, a key development in this area was the Vera Technology Programme that has allowed the continued translation of research outputs into practice through an open access model. Future areas of research are the utilisation of design and production information in both infrastructure, and real estate and maintenance management. The focus of the programme is currently shifting from information exchange between design and construction to information utilisation over the entire life cycle.

4. Finnish Public Innovation Investors Real Estate and Construction Sector in Finland

4.1 Tekes, Finnish Funding Agency for Technology and Innovation

Tekes supports high-quality research that generates significant commercial potential for businesses development while also promoting better competitiveness and welfare for society at large. Tekes funding is allocated to individual projects, many of them with global impact through leading research. In practice, this criterion for funding allocation translates into the need for collaboration between research institutions and the private industry. The funded research projects use the construction sector as a source for data as well as wisdom and steering for the research process, so the research outputs are relevant to the academic community and have practical implementation.

Based on the priorities outlined in its strategy, Tekes uses technology programmes to allocate funding, networking efforts and expert services to areas that are important to both business and society. Approximately half of the total funding allocated is granted to companies, universities and research institutes through technology programmes that consist of research projects and services that support business operations, such as shared visions, seminars, training programmes and international visits. (Hyytiäinen et al., 2012)

Based on an international evaluation conducted in 2012 by van der Meen et al. Tekes is among the world's leading innovation agencies, contributing to increasing research intensity, cooperation between companies, and creating new infrastructure knowledge in Finland. These activities have helped build a strong knowledge base and competences that have led to increase the international competitiveness of Finnish enterprises, particularly in building energy consumption reduction technology as a form of user driven innovations. (van der Meen et al., 2012)

The main goal of previous real estate and construction business technology programmes funded by Tekes was to identify Finnish real estate and construction cluster and to initiate a proper technology programme for each sub-cluster. The objective was to launch and reinforce R&D and innovation (R&D&I) activities in these fields, to increase the size of the technology programmes and to promote company-driven R&D&I-activities. The cluster strategy was carried out through five technology programmes during the period of 1997–2007 (Table 1) (Rajakallio et al. 2009).

Table 1. The first Tekes's R&D programmes of real estate and construction sector (Rajakallio et al. 2009).

ProBuild	1997–2001	Developing construction process
Rembrand	1999–2003	User-oriented real estate business
Infra	2001–2005	Civil engineering - construction and services
Cube	2002–2006	Technology program for building services)

Sara	2003–2007	Value-network oriented construction

As a result, the number of new foreign investors in property markets almost quadrupled between 2002 and 2007 (moving from 7 new foreign investors to 26), although this number decreased again in 2008. This fact shows to what degree the markets develop with the support of R&D activities (Steinbock 2009).

According to the evaluation by van der Meen (2012) the R&D&I know-how and vision of the industry has increased through Tekes' programmes, by creating prerequisites for a market-led product development in the industry. The programmes have generated a new, more holistic mindset of business operations, in which value networks are taken into consideration rather than the value chain. Tekes' activities have led to a significant shift in R&D in the Finish construction industry from initiative oriented to target-oriented.

Tekes' cluster programme has also had positives effects on other development areas of the industry business environment, such as the creation of the industry glossary and concepts, and development of procurement practices and network management frameworks. As Rajakallio et al. 2009 showed, international co-operation in R&D projects has also increased due to Tekes' programmes. However, the development of industry trade practices and research culture had as a precondition the creation of a code of conduct for this line of business (Rajakallio et al., 2009). Although the strategy of Tekes included the creation of an end-user-oriented culture, the development of the housing sector and the creation of a competitive advantage through life-cycle expertise, the cluster programme had a less significant effect on these areas.

Tekes published a new strategy in 2011 which includes intelligent and smart environments among the areas of focus. This refers to the development of housing, work and leisure environments into functional, comfortable and energy-efficient entities. Priorities on this area are: Smart energy systems and sustainable material economy, safety and security of the living environment which makes good use of digital systems as well as user-oriented products, services and processes (Saarnivaara, 2011).

The latest programmes are in line with Tekes' strategy and are summarised in Table 2.

Table 2. R&D&I programs of real estate and construction cluster in Tekes in 2000´s.

Name	**Years**	**Goal**
The Built Environment programme	2009-2014	The programme increases the usability and serviceability of the built environment by developing the practices of real estate and construction field. The programme focuses on renovation and refurbishment.

The Spaces and Places programme	2008-2012	The target group of the programme includes service sector players, information and communication technology companies and the construction and real estate industry. The programme encourages the participants to cooperate across sector boundaries. The user of the space is on focus, when developing new business models for developing, producing and maintaining the relevant environments.
The Sustainable community programme	2007-2012	Aims to generate renewable business activities in designing, constructing and maintaining sustainable and energy efficient areas and buildings. One core theme of the programme is a noticeable improvement in the energy efficiency of buildings and communities as well as the promotion of adopting renewable energy sources.

Roadmap of Built Environment was part of the progamme activities in one of the programmes with the emphasis and future prospects of renovation, infrastructure and well-being construction in Finland. The main future challenges of the real estate and construction sector are summarised in the following list:

1. Understanding properties and buildings as service platforms

2. Need for new business models and earnings logics

3. Public sector innovation challenge

4. Urban living and emphasis on public and shared spaces

5. Multipurpose use of facilities

6. Emphasis on local services, local production and telecommuting

7. Adaptability, flexibility and individuality

8. Emphasis on lifestyles, leisure times and well-being

9. Real-time infrastructural monitoring

10. Use of wood in new constructions

11. Energy-efficiency, renovation (e.g. the life cycles of short-term suburbs) and the development of new services are important

12. Export as an important goal for the construction sector

13. Change management in construction

The Roadmap and recommendations for the Built Environment Programme in 2010–2014 are:

1. Turning the real estate and construction sector into a driver for Finnish energy and climate policy

2. Developing cross-departmental cooperation in public administration and legislative reform

3. Innovating new services for housing and combining parallel sectors

4. Increasing participation and creating open innovation platforms

5. Conducting larger projects

The roadmap highlights the need to understand properties and buildings as service platforms. This statement is a relevant guideline not only for traditional technically orientated business but also new possible actors. The role of change management is also emphasised. The vision towards 2020 is to exploit the user perspective as the main driver for businesses development. (Nenonen ed., 2011)

4.2 Strategic Center for Science, Technology and Innovation in Construction sector (RYM Ltd)

RYM Ltd was founded in 2009 as the Strategic Centre for Science, Technology and Innovation (SCSTI) of built environment in Finland. RYM Ltd is a completely new business concept in the Finnish innovation system. We define it as "Venture for Intellectual Capital". The knowledge venture company RYM Ltd. collects financing agreements during the first phase. The second phase marks the start of research programmes as "funds". Finally, the third phase presents the programmes as work packages and tasks as "spin-offs".

RYM Ltd is engaged in the production of forecasting information, acquisition and development of research funding, research programmes in selected spearhead areas, and Living Labs as test platforms for research results. In addition the aim is a networked international operation, close co-operation with other sectors Strategic Centers for Science, Technology and Innovation, as well as open, multichannel communication. The creation of a SCSTI in the real estate and construction sector (RYM Ltd) is a unique undertaking. The RYM Ltd’s research strategy identifies four areas of thematic focus that will initially dominate the research agenda, these are: energy efficiency; processes and frameworks of practice; competitive social infrastructure; and user-oriented spaces Table 3 presents the on-going programmes starting after 2010.

Table 3. The programmes of Strategic Centre for Science, Technology and Innovation in the real estate and construction sector.

Program	Time	Goal	Participants and Volume
Built Environment Process Re-engineering	2010-2013	Goal is to create totally new user centred procedures and business models for the real estate, construction and infra sectors by product model-based data management over the entire life cycle.	43 participants: 37 companies and 6 research institutes, Budget of 21 million euros.
Indoor Environment program	2011-2014	The aim of the Indoor Environment research program is to find solutions that promote productivity, pleasantness and health of space users in an ecologically sustainable manner.	36 participants: 26 companies and 10 research institutes. Budget of 20 million euros.
The Energizing Urban Ecosystems program	2012-2015	Goal is to create an internationally recognized and multidisciplinary hub of excellence for urban development in Finland.	11 participants: 9 companies and 2 research institutes Budget of 20 million euros.

In December 2012, RYM Ltd had 53 shareholders. RYM Ltd directs funds and expertise from both private companies and public financiers of innovation in areas of research that are deemed as most significant for international competitiveness. Joint strategic leading-edge research will generate superior world-class expertise over the entire life span of the built environment. This offers real estate and construction sector companies, research institutes and universities a novel way of engaging in close, well planned and ambitious co-operation to develop and bolster cutting-edge expertise. The evaluation of the Strategic Centers for Science, Technology and Innovation was conducted in 2012. Investigations (Lähteenmäki-Smith, 2013) indicated that RYM programmes enable true company-research cooperation that goes beyond meeting discussion and seminar talks. It also forces companies to make long-term commitment and to introduce long-term actions. Requirement for significant resources and efforts by companies is seen as positive and it has enforced companies strategic role.

4.3 Other actors

The Academy of Finland provides funding for scientific research of the highest quality. The academy now provides funding for housing research. Due to the social significance and impact of living and housing, this sector must be understood to a greater depth than the

building construction and settlement of large communities. Changes in family and age structures, in lifestyles and the workplace as well as energy issues and the challenges of sustainable development have created new areas of focus within the living and housing sector. The multidisciplinary programme approaches housing from the resident's point of view as an entity that comprises environmental issues from sustainable development to land use, logistics and services, as well as consumer issues from cultural needs through to health issues. This research concerns a range of social and physical spaces as well as virtual environments. Requirements of accessibility, sustainability and versatility have gained increasing prominence in relation to living and housing. Further research is also needed in the field of land use, other environmental aspects of housing as well as housing renovation and repairs. However, despite their prominence and relevance, housing issues have received only modest basic research attention in Finland when compared to many other European countries.

Between 1995 and 1998, the Academy of Finland carried out the EKORA Research Programme for Ecological Construction, and, between 1998 and 2001, the Urban Studies Research Programme in a joint effort with other funding bodies. Funding was also directed towards the Spaces of Nature and Culture Research Programme from 2001 to 2004. (Anon., 2011)

Another important actor, which has been active in research activities concerning sustainable development, is Sitra, the Finnish Innovation Fund. This organisation has the duty to promote stable and balanced development in Finland, the growth of its economy and its international competitiveness and co-operation. They have e.g. carried out the Energy Programme with several practical projects that proved that the use of energy by communities and the people, as well as their greenhouse emissions, could be significantly decreased. Through good examples and influencing regulations the programme can help return Finland back to the top in energy efficiency. Energy efficiency of the built environment plays a crucial role in the reduction of emissions. In addition to energy efficiency, people's lifestyle is an important factor. Therefore, the programme aims to create the preconditions and structures that enable people to make low-carbon choices. (Anon., 2012).

5. Conclusion

The research and development in the construction sector has undergone a transformation from a single product and a single research discipline to a wider scope and cross discipline research area. The general trend in the construction sector is to act as integrators of products/services to benefit the industry and its end user. The social/people dimension at a large scale was lagging behind until the year 2000, albeit it has been hidden under many research topics. Nevertheless, the social dimension is currently seen as an essential theme in the construction sector due to the importance of users and their engagement in the process and end-product/service design.

Climate change and lack of resources have been well-known research topics since the 1970's oil crisis; including energy efficiency and energy saving. The new topics of low carbon, low energy and zero energy buildings, highlight a more holistic approach where

buildings are seen as a part of energy systems and sustainable development. The second R&D wave in wood construction is also booming today. Kajander et al. (2011) conducted a study about Challenges for Sustainability Innovations in real estate and construction Industry. Key challenges identified include: the complexity of the industry value network; team building; R&D-intensity; and commercialization management. In addition, their findings suggest that sustainability business innovation in this industry is constrained by project business orientation in REC industry, fundraising and internationalization issues, and lack of regulation and standards.

Interdisciplinary approaches in research have been increasingly acknowledged in the construction and real estate industries. However, methods of interdisciplinary collaboration have not been systematically analysed yet. An interdisciplinary field crosses traditional boundaries between academic disciplines. The investigations in interdisciplinary research in general indicate that the disciplinary boundaries are most thoroughly transcended when members of disparate fields develop a common language that facilitates a shared conceptual framework. This level of collaboration has the greatest potential for originality. However, it is seldom observed due to the challenges associated to the development of a common language. A challenge in interdisciplinary research is to manage both the collaboration within academia and with the industry. Furthermore, the interpretation of the research outcomes might hinder its impact due to the articulation and interpretation of findings from a mono disciplinary perspective by the industry. The research process varies depending on the approach taken. It is always demanding to collaborate with representatives from a variety of disciplines due to the obvious risk of being considered weak or fragmented due to lack of academic rigor. One major challenge is therefore to design the research in such a way that a common language can be found. The common goal has to be shared but the ways to achieve it can be designed differently depending on the relevance of conduct the research in a multi-, inter- or trans disciplinary way (Nenonen and Lindahl, 2012).

Infrastructure research and development in Finland is well established. The challenge is to translate this innovation into the field of practice, which traditionally is not research orientated. New initiatives that support the leading role of companies through innovation policy can create new ways to apply research into practice and to generate collaboration between academia and industry. The construction and real estate industry have traditionally been a disjointed industry. However, joining resources through different initiatives have promoted new collaboration.

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THE IMPACT OF A NEW PLANNING SYSTEM ON CONSTRUCTION IN ENGLAND

Francine Baker[1]

Localism, Planning and Construction

Section 122 of the Localism Act 2011 ("the Act") amended the Town and Country Planning Act 1990 by introducing mandatory pre-consultation requirements for developers to consult local communities before submitting planning applications for certain major developments. This paper outlines these and similar requirements under the Planning Act 2008, and assesses their impact on construction projects in England.

The s.122 pre-consultation requirements for certain types of major developments must be complied with prior to the submission of planning applications, and will involve administrative high costs, time and human resources, if implemented. Early local communities/local councils pre-consultation may influence the quality and suitability of developments, but the process also provides new opportunities for challenges to the planning process. However the government has yet to pass a development order specifying the types of major developments to which the process applies. Instead, it has proposed reforms to reduce the scope of the application of s.122 and expand the range of major developments to be classified as National Infrastructure developments and to be subject to pre-consultation requirements under the Planning Act 2008 as amended by the Localism Act 2011.

This process may prevent challenges to the planning process, and therefore enable more timely completion of much needed developments, e.g., housing and infrastructure. However, the process provides increased avenues for disputes between the local community, the developer and the local authority. The amount of expense and time taken to address such objections may vary, but is likely to considerably delay the planning process and create uncertainty about its viability, funding and completion. The increased risks associated with the project will need to be factored into an assessment of the overall costs of the project. The positive impact of the implementation of s.122 measures in promoting localism may be reduced by recent proposed government reforms.

Keywords: Planning applications, Localism, Construction, Pre-Consultation

1.Introduction

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The United Kingdom government has transferred much decision making and financial powers to local government at the level of local planning authorities, councils and communities (Department for Communities and Local Government, pp.11-7, 2011) with the intention of making the planning system clearer, more democratic, and more effective, and especially to avoid disputes. The vehicle for this transference is the Localism Act 2011 ("the Act"), which received Royal Assent on 15 November 2011. Section 122 of the Localism Act 2011 amended the Town and Country Planning Act 1990 by inserting sections 61W, 61X, 61Y before 62 of the Town and Country Planning Act 1990. It introduces new requirements for developers to consult local communities before submitting planning applications for certain major developments.

The current planning system requires local planning authorities to prepare a Statement of Community Involvement setting out their policy for involving communities in the preparation of local planning documents, and for consulting the public on planning applications (Planning and Compulsory Purchase Act 2004). Local authorities have also required developers on certain projects to prepare a Statement of Community Engagement setting out how they have engaged the community in formulating their planning application (Planning Policy Statement 12: Local Development Frameworks (PPS12)). But pre-consultation has not been a mandatory requirement, and it has been possible for planning applications to be approved and finalised without reference to considerations raised by the local community and interested bodies.

This paper will examine the effect of the s.122 pre-consultation process on the developer and local authorities with reference to a similar process under the Planning Act 2008. It will then consider proposals by the government to address the cost and delay caused to major developments as a result of objections.

Section 62 of the Town and Country Planning Act 1990 concerns how planning applications are made. It has been amended by the Localism Act so that a planning application for certain types of development will be invalid unless it is accompanied by a report detailing certain pre-application consultations which must be carried out in accordance with s. 122 of the Localism Act. Under section 122, 61W subsection (1) states that a person is required to carry out pre-application consultation when *(a) A person proposes to make an application for planning permission for the development of any land in England, and (b) The proposed development is of a description specified in a development order.* Although the proposals to which it applies have yet to be spelt out in a development order, government advice indicates that it is likely that the provision will apply to large scale major applications as defined below:

1. Residential developments of 200 or more new residential units, or (where the number of residential units to be constructed is not specified) with a site area of four hectares or more.

2. Any non-residential developments providing 10,000 square metres or more of new floor space or with a site area of two hectares or more. (Pre-application consultation with communities, p. 2, 2011; Localism Bill: compulsory pre-application consultations between prospective developers and local communities, 2011)

2. The Developer's obligations

2.1 Who should be consulted?

Some guidance is given under s. 122 of the Localism Act as to who should be consulted by a person wanting to make a planning application in order to comply with the s.122 pre-application consultation process. S. 61W (a) states that applicants "must publicise proposals in such manner as the person reasonably considers is likely to bring the application to the attention of the majority of persons who live at or occupy premises in the vicinity". The wording suggests that it is up to the person making the application to decide which measures are likely to bring the proposal to the attention of the relevant majority of persons. It seems therefore that a subjective test is to be applied. But this is surely not what the legislation intended, as It has been usual for councils to advise developers how to carry out adequate pre-consultation, such as arrangements for notification of the proposal on the Council's web-site; placing an advertisement in a local newspaper; positioning notices in and around the site; and holding public meetings or forums (Peterborough City Council, 2012).

There is no 'general principle that it is for the decision-maker alone to decide whom to consult' (R (Milton Keynes Council) v Secretary of State for Communities & Local Government [2011] EWCA Civ 1575, the Court of Appeal (per Pill LJ at [32]). Where there are large numbers of individuals who are affected, it may be appropriate to consult with their representatives such as professional bodies: British Medical Association v. Secretary of State for Health [2008] EWHC 599 (Admin) per Mitting J.

2.2 Contact and timeframe for response

Under section 61W(4) the person is required to set out in the consultation documentation/publicity information about how he may be contacted by persons wishing "(a) to comment on, or collaborate with the person on the design of, the proposed development" and "(b) give such information about the proposed timetable for consultation as is sufficient to ensure that persons wishing to comment on the proposed development may do so in good time".

The phrase 'in good time' does not specify how long the pre-consultation process should take. But it does indicate that those wishing to comment be given an adequate period of time within which to communicate their views to the person proposing to make the planning application. Failure to do so could result in a planning decision being quashed and reviewed. For example, in R (Kelly) v Hounslow London Borough Council [2010] EWHC 1256 (Admin), the local authority's statement of community involvement stated that objectors would be invited to the committee meeting, and that they would have the opportunity to make representations at the meeting. The letter informing the Kellys that they would be invited to the planning committee meeting was sent by second class post four business days before the meeting. The Kellys did not receive it until the night of the meeting. The High Court agreed that the Kelly's had indeed been prejudiced by the local authority's breach of the Kelly's legitimate expectation, and quashed the defendant local authority's grant of planning permission for an extension to a neighbouring property.

The Government Code on Practice Consultation 2008 states at p.8 that the public sector and government departments must provide a minimum of 12 weeks for public consultation exercises. The courts may consider this an appropriate guideline when considering whether or not the 'in good time' element has been satisfied. But the length of consultation will depend on the nature of the development and whether the responses justify a further round of consultation.

2.2.1 Taking responses into account

Under 61X the person has a legal duty to take into account the responses received from those who live at or occupy premises in the vicinity. The planning application must consequently be accompanied by a statement covering the type of the publicity and consultation carried out; who was notified; the location and duration of any event held; a summary of all comments received and issues raised, and a clear explanation of how, if at all, the proposals have been amended as a result of comments received, as well as any criticisms received regarding the public engagement process, and presumably why some responses haven't been taken into account. Communities will therefore be able to raise issues of concern for the developer to consider, and hopefully, make suggestions to improve the development. (IPB Communications, December 2011.)

However it should be noted that it is the responsibility of the local community to provide feedback and comments to the developer applicants. The local councils cannot accept representations or objections to a proposal at this early stage, and communities will not be permitted to veto the submission of a planning application.

3. Benefits of the pre-consultation process

It is only fair that those responsible for the development should be made accountable to those who will be affected by it, before the development begins to affect their local community. The process should assist developers to identify local issues of concern, of which they may have been unaware, and the resolution of which may be important for the viability of the development. The local community may raise concerns about the environmental impact on habitats, or the effect of a commercial development on the volume of traffic in the area, or whether a new private sector housing estate will increase the burden on local amenities, schools and hospitals. Early consultation may avoid later costs and delays to development caused by disputes and litigation. The process provides them with the opportunity to improve their proposal and submit an application that is less likely to be rejected. This process should therefore assist a timely and positive decision from the planning authority.

4. Disadvantages of the pre-consultation process for the developer

4.1 Costs and delay

The government's Impact Report considers that the costs of the complying with the process are likely to be high, but will be relative to the type of development. The Impact Report

estimates that the total cost of undertaking the pre application community consultation alone for large scale major applications is estimated to be £10,000 per application. This involves (a)contacting relevant parties; (b)the preparation of development description and associated explanatory material; (c) Communications (including any public events); and (d) the preparation of Statement of Community Engagement. (Department for Transport, 2012)

These anticipated costs do not include any additional costs, such as the costs of changing the designs for the proposals in response to community views, or addressing objections and ongoing disputes.

4.2 Time

It seems that under s. 122 the extent and impact of the pre-consultation period on the development will vary. It may be extensive due to various reasons, e.g., the scope of the development, or where there is much opposition from the local community. For example, the Toton site development by Peveril Homes has been the subject of significant local opposition because of its plans to build on 103 acres green-belt land. It plans to build 770 homes, a new hotel, primary school and convenience and retail shops. The plans were altered as a result of an extensive public consultation, with education and health sector professionals, community groups and individuals. The plans were submitted to Bruxtowe Borough Council. A decision has not been made yet but residents say they will fight the imposition of the development (BBC News Nottingham, 8 October, 2012).

4.3 When is a second consultation required?

One issue that may arise under s. 122 pre-consultation process is whether a developer has to disclose the changes he has made to his proposal in response to concerns from the local community. S. 122 61X requires that the developer shows what the responses are, and how the responses have been taken into account, when submitting his planning application. It is doubtful that minor changes would require re-advertisement. But does the developer have to consult again where circumstances have changed since consultation began. In R (Smith) v. East Kent Hospital NHS Trust [2002] EWHC 2640 (Admin), Silber J. observed that ‘trivial changes do not require further consideration’ (at [43]) and referred to ‘the dangers and consequence of too readily requiring re-consultation’, and concluded that fresh consultation was only required where there was ‘a fundamental difference between the proposals consulted on and those which the consulting party subsequently wishes to adopt’. What is a ‘fundamental’ change? In R (Elphinstone) v Westminster City Council [2008] EWHC 1287 (Admin) at [62], Kenneth Parker QC (then sitting as a Deputy High Court judge) observed that ‘a fundamental change is a change of such a kind that it would be conspicuously unfair for the decision-maker to proceed without having given consultees a further opportunity to make representations about the proposal as so changed’.

5. Disadvantages of the new process for the local authority

The authority is required to satisfy itself that the pre-application consultation duty of the applicant has been met before it determines the planning application. (Pre-application

Consultation with Communities: a basic guide, 2011). The local authority therefore runs the risk of being challenged on the basis that it failed to consider or satisfy itself that the applicant's pre-consultation duty had been discharged, or that it did not follow internal procedures and policies regarding consideration of the application.

There are many case law examples where claimants have successfully challenged a local authority/Council's decision on a similar basis; for example, in a recent example, R (Vieira) v London Borough of Camden [2012] EWHC 287 (Admin), the High Court found that the local authority had failed to inform the claimants of an amendment to the planning application and had failed to brief councillors about the amendments before determining the application, resulting in a breach of legitimate expectations. The Court decided that the grant of planning permission should be quashed and reconsidered.

6. Pre-Consultation and Nationally Significant Infrastructure Projects- compared to S.122 procedure

If the government has its way, many proposals that would presently come under the s.122 process for major projects will be re-categorised as nationally significant infrastructure projects, and be subject to a more streamlined planning process. This seems to be a move to avoid delays to developments caused by the length of time to reach planning decisions and appeals from planning decisions, which may impact on the economy. (Guidance on the Pre-Application Process, April 2012)

The Planning Act 2008 ('the 2008 Act') established a planning process for dealing with proposals for a nationally significant infrastructure projects (NSIP). It concerns major proposals relating to energy, transport, water, waste and waste water. The process was amended by the Localism Act 2011. It abolished the Infrastructure Planning Commission, moved some of its functions into the Planning Inspectorate and transferred the responsibility for making decisions on applications for development consent orders to the Secretary of State. It includes opportunities for people to have their say before a planning decision is made through pre-consultation. The decision on the planning application is not made by a local planning authority, as under the s.122 process. It is made by the relevant Secretary of State, although, all communication should be directed to the Planning Inspectorate (from 1 April 2012), as it carries out all functions on the Secretary of State's behalf, except for decision-making.

6.1 Effect on Localism

The process the applicant must follow to comply with the amended 2008 process pre-consultation requirement is similar to that under s. 122, but unlike the s. 122 process, there are two separate formal stages of consultation. Firstly, the applicant must also identify and consult statutory consultees, local authorities, landowners and significantly affected persons under s.42; and then, secondly, consult with the local community under s.47. This pre-consultation process therefore includes consultation with both regional and national bodies. Although local authorities are permitted to make representations to the Secretary of State about the adequacy of consultation, they do not have the final say. They can also submit a

Local Impact Report giving details of the likely impact of the proposed development on the authority's area to the Secretary of State, however, again, the local authority has no power over the final planning decision..

Similarly to the s.122 requirement, the appropriate area for consultation must include "people living in the vicinity of the land" (s47(1)). Under s.47(2) the applicant must first produce an SOCC after consultation with relevant local authorities which sets out how it will carry out the public consultation and publicize the application (The Planning Inspectorate, 2012). A similar requirement is not spelt out under s. 122 of the Localism Act, although it states in general terms that applicants should seek local authority advice (S. 122, ss7). Similarly to the process under s122, the developer has a duty under s. 49 to take account of responses to the consultation under s42 and s47 and publicity under s48.

The Planning Act also requires that the applicant must set a minimum deadline of 28 days to receive responses to consultation. More complex applications may need to go beyond the statutory minimum timescales laid down in to provide enough time for consultees to understand a proposal and formulate a response. (Guidance on the Pre-Application Process, pp. 4-5 April 2012). The government guidance states that applicants should consider the degree of change, the effect on the local community and the level of public interest, when considering whether there is the need for an additional consultation round as a result of responses (Ibid., cl. 53, pp. 12.) Neither the explanatory notes nor the guidelines for the s. 122 process provide the level of details as referred above, even though the process also concerns major developments.

The NSIP applicant must finally prepare a consultation report and submit it to the Secretary of State (Ibid). Once the application has been submitted, the Secretary of State has 28 days to decide whether or not to accept it for examination. One of the factors to be considered is whether or not the developer's consultation process has been complied with.

6.1.2 Case Study-HS2

An example where it has been argued that the consultation process has not been complied with, concerns the government proposal to build a high-speed rail line between London and Birmingham by 2026. This rail line referred to colloquially as HS2. HS2 Ltd was set up in 2009 by the Department for Transport to develop plans for a new high speed network and present a proposed route connecting Birmingham and London. It will cut through the Chilterns, an area of outstanding natural beauty, and later be extended to northern England to Manchester and Leeds, including stops in the East Midlands and South Yorkshire (HS2, Investing in Britain's Future). It therefore concerns a nationally significant infrastructure.

The public consultation ran from February until July 2011, apparently in accordance with the Planning Act 2008, and the Aarhus Convention (Convention on Access to Information on Access to Information, 1998). Fifteen borough councils and residents opposed the plans for the rail line, citing environmental reasons and the loss of many homes, businesses and relocations of schools. Resident consultees also argue that they were given insufficient information and that information was withheld during pre-consultation period (Gilligan, Dec.

9, 2012). It is reported that the councils spent £165,000 bringing a judicial review in the High Court, which equates to 9p for every resident who lives in the 15 council areas. It is unclear what costs the Department of Transport will incur (Bucks Herald, 2012).

This is therefore a classic case where all parties have suffered serious costs and delay due to strong opposition and litigation. The government argues that the proposal is in the national interest even though in certain localities, it may cause great inconvenience. Its proposal to put aside up to £1.3bn to reimburse people living close to High Speed Two has not satisfied the complainants (BBC News London, HS2 compensation for Camden 'not enough', 2012).

There have been five judicial reviews over nine days at the High Court in London in December 2012. The fourth case was brought by Aylesbury Park Golf Club. The Club argued that basic rules of fairness were violated, because they had not been told that the proposed route had been changed to take it through the middle of its course, obliterating 12 of its 18 holes, and that 769 alternative route suggestions had been ignored by HS2 Ltd (Op. cit., Gilligan: STOP HS2, 13 Dec. 2012). The judge's decision will be given in early 2013.

6.2 Government responses to planning permission delays

The Growth and Infrastructure Bill currently before Parliament would extend the scope of the Planning Act 2008 so that a wider range of developments can be brought within the streamlined planning regime route for schemes of national significance (Clause 21), rather than under the Town and Country Planning Act 1990 and other existing consent regimes. It would allow developers of nationally significant business or commercial projects to apply to the Secretary of State for the option of using this streamlined planning regime which has a clear statutory timetable. (Department for Communities and Local Government, Nov., 2012)

The list of the types of business and commercial projects which are proposed to be brought under the NSIP process include development, research and development, manufacturing and processing, conference and exhibition centres, where in each case, the gross internal floorspace is over 40,000m2. Projects concerning tourism, leisure and mixed use developments, including a mix of the former uses (but not housing) where the area is over 100 hectares are also involved. This would mean for example, that housing/office schemes in local areas in Reading could be classed as nationally significant infrastructure. (Ibid.) However, the basis for this selection is unclear. The Bill diverts the development's assessment directly away from the local community to central Government. It is a reversion to centralism.

6.2.1 Judicial Review reform

Bringing a claim for a judicial review in the High Court asking is a common means of challenging planning procedure and decisions. The government is concerned at the length of time these proceedings take and the resources they consume ((Ministry of Justice, p.11, para. 33, 2012). The financial viability of developments may be at risk. The government even argues that 'there is some concern that the fear of Judicial Review is leading public authorities to be overly cautious in the way they make decisions. (Ibid, p.11, para.35).

The government intends to introduce reforms to civil procedure rules governing the judicial review procedure to increase charges for applications, shorten the three-month limit on applying for judicial review, and reduce the number of possible planning appeals from four to two. It has been too late to dissuade the HS2 judicial review challenges, but the reforms seem intended to dissuade other 'localism' challenges, when they become law.

7. Conclusion

It is clear that the conduct of any required pre-consultation must be carried out fairly. This requires clearly, fully, and comprehensively informing the local community about the proposal and the consequences of its actualisation, and providing them with a sufficient time of period within which to respond to the proposal.

The pre-consultation process is beneficial in that it will identify the inadequacies of a proposal at an early stage and require their consideration by developers. But if a developer ignores them in his planning application, it is possible that a planning authority could still grant planning permission in which case, communities may have a legitimate case to answer regarding the discharge of the consultation duty, and fairness of the planning process.

It seems that breach of s.122 requirements will provide aggrieved community groups with more tangible opportunities to challenge planning applications and local council decisions through litigation, especially judicial review proceedings. Given increasing concerns about access to environmental justice at a reasonable cost, and the cost of judicial reviews, if the government plans go ahead, claimants may be deterred from challenging the discharge of a pre-application consultation duty. In any case, developers will have added risks and costs to factor into their pre-construction planning, and procurement route.

Whether in the case of an operational s.122 or that of developments categorised as major infrastructure developments, construction companies will need to factor into their budgets, the extra time and preparation for compliance, and for adequately addressing any local community concerns, to avoid costly court challenges to the discharge pre-application duties. Even then, vexatious or ill-informed objections can cause much damage to the viability of a development whether the planning decision is to be made by a local authority, or the Secretary of State. The resulting financial costs and delay are not only issues for the developer, and the decision-maker. They can affect the realisation of infrastructure and other projects crucial to a nation's economic growth.

The government's proposals to speed up the planning process for certain major developments, to increase the types of development subject to it, and to make it more difficult for objectors to bring judicial reviews of planning procedures and decisions in the High Court, recognises the drawbacks of the pre-consultation process and the growing cult of localism. But in doing so, it seems to be throwing out the baby with the bathwater.

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Rethinking the Build Process for BIM Adoption

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Abstract

Collaborative working and integrated project delivery (IPD) are considered to be pivotal for the UK Built Environment Sector to rise up to the important challenges, such as reducing carbon emissions and cost, whilst delivering better value to the client. Considerable work remains to be done after nearly 1.5 decades since Egan listed them among the five key drivers of change. Innovating through integration and advocating change remain amongst the Government's top priorities for the sector to respond to the five-low carbon challenges, and thus to reduce costs by between 10% and 30%.

Building Information Modelling (BIM) is currently hailed as a solution that will eventually make collaborative working a reality. There is a strong push in the UK for the industry to adopt BIM but very limited appreciation of the issues that need to be resolved, e.g. cultural, procedural, contractual and process-related. Technological solutions to this problem exist but they need to be creatively combined to facilitate true collaboration between disparate project stakeholders who are often reluctant to share innovative solutions due to contractual relationships and Intellectual Property.

This paper focuses on improving the processes to design and deliver standardised schools in the UK by developing a novel approach to IPD through collaborative working and learning from project experience (collaborative BIM- cBIM). This is achieved by utilising the power of BIM, and emerging techniques and technologies. First a review of the current processes is undertaken to identify how IPD of standardised designs should be lead, planned and implemented. Second, emerging tools and technologies that can support this novel approach to procurement, design, and delivery are identified. The paper concludes with suggestions to develop an initial framework for cBIM which details the processes and protocols that should be embedded in project teams to make IPD a reality.

Keywords: collaborative BIM, Project, Standardised Schools.

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1. Background

Climate Change and the resultant need to drastically reduce carbon emissions across the Globe, had long been acknowledged as key challenges to industries before the unprecedented global economic crisis started to overwhelm major economies in 2008. As a result, every industry has been forced to re-think its processes and practices to deliver efficiently. The UK Construction Industry, the efficiency of which was identified as being critically important for the UK economy in the Government's Plan for Growth published in March 2011, is no exception.

The UK Built Environment Sector faces a number of important challenges such as reducing carbon emissions and cost, whilst delivering better value to the client. There has been a plethora of initiatives to encourage the industry to take action to rise up to these and other key challenges such as low productivity. Collaborative working & IPD have long been regarded as solutions. However, "lack of progress in implementing the recommendations [of these initiatives], and pessimism about the future outlook for change" were identified as issues in the latest industry review (Wolstenholme, 2009).

BIM is currently hailed as a solution that will eventually make collaborative working a reality. The UK Government has recently announced that BIM will be compulsory on all public sector projects from 2016 (Morrell, 2011). The Ministry of Justice announced in April 2011 that contractors on its framework must use it by the middle of 2013. Therefore, there is a strong push for the industry to adopt BIM but very limited appreciation of the issues that need to be resolved, e.g. cultural, procedural, contractual, process-related, so that BIM becomes the vehicle for collaboration. Technological solutions to this problem exist but they need to be creatively combined to facilitate true collaboration between disparate project stakeholders who are often reluctant to share innovative solutions due to contractual relationships and Intellectual Property. To gain insights about BIM and IPD, it is important understand how other countries have implemented them. The Scandinavian countries have been noted for being technologically advanced with highly educated population and large public sectors (Jensen and Jóhannesson, 2013). Therefore, an overview of BIM and IDP practices Finland and Denmark will be undertaken in the ensuing section.

2. BIM Penetration: Scandinavia vs UK

In 2007, a survey conducted by Kivinemi (2007) revealed that the usage of BIM and Industry Foundation Classes (IFC) compliant applications stood at 33%. The same study revealed that 93% and nearly 60% of architects and engineers respectively, used BIM in some parts of their projects. So, many pilot studies demonstrating the benefits of BIM have been conducted in Finland. Results from these studies have been used in developing mandatory BIM requirements since the end of 2007. A survey by Kiviniemi et al. in 2008 reported that 50% of architects, 29% of clients and 40% of engineers used BIM for some parts of their projects in 2008. In January 2007, Denmark launched an initiative called "Det Digitale Byggeri" meaning Digital Construction for mandatory use of BIM in government projects. While these countries have already established BIM mandatory requirements, the UK's first

BIM mandatory requirements will come into force in 2016 (Morrell, 2011), nearly 9 years later.

Despite immense benefits of BIM already noted in these countries, and others, industry experts have often argued that BIM only becomes a vehicle to delivering better value if parties truly collaborate (Wright, 2012). One of the main challenges is to learn how to lead, plan and implement IPD. It is therefore necessary to review and remodel traditional delivery processes so that using BIM at Level 3 of Bew-Richards' BIM Maturity Model, i.e. intelligent BIM (iBIM), becomes a reality. This paper reports on the initial stages of an R&D project which aims to pave the way to iBIM by developing, testing and validating a novel approach (cBIM) to collaborative working and learning from project experience by utilising the power of BIM and emerging techniques & technologies.

cBIM will be developed, tested and validated in the Education Sector in England and Wales. Education is ripe for an innovative approach of this kind because the Government is under very high pressure to provide more school places in an environment where project funds are dwindling. There is a mismatch between the demand for public services and the funds that are available to provide them. Education is one of sectors in which this mismatch is acute. The education sector in England and Wales requires over £12Bn of funding during the three years between 2013 and 2015 in accordance with the Comprehensive Spending Review. In addition, the population growth in major UK conurbations is creating a Primary Place bulge requirement well-beyond the space available in the current school building stock. Local Authorities, which have a statutory duty to educate children of school age, are having to respond by diverting their resources to primary schools. This strategy will lead to a similar problem at secondary level by 2016-2018. The Government forecasts that there will be 4.39 million primary pupils by 2015 (an increase of about 10% on 2011), and this will increase to 4.8m by 2020. In London, 70,000 new permanent primary school places will be needed by 2015, even after 240 classrooms, built in response to rising demand since 2010, come into use this September. Birmingham faces a shortage of 3,000 reception places between now and 2020.

With an increased focus on both capital cost and long-term cost in use, new ways of working are necessary to meet society's need for school places and to work within the restricted budgets and timescales necessary to enable this major building program. Therefore, a significant opportunity exists to overcome these challenges for innovative providers and for forward thinking procurers to collaboratively create a totally new and unique method of building design and procurement that takes learning from major product manufacturing principles and from projects that are already delivered, and applies this to revolutionise the process of delivering built facilities in order to respond to the James Review which suggested standardised building techniques as one of the best ways to deliver low-cost schools (UK DE 2012; Talbot and Francis 2012).

3. The Novel Approach

The aim of this paper is investigate how best to deliver standardised schools in the UK through innovative IPD processes that harness the power of BIM and emerging technologies

for sensing and automated data collection. First a review of the current processes is undertaken to identify how IPD of standardised designs should be lead, planned and implemented. Second, emerging tools and technologies that can support this novel approach to procurement, design, and delivery are identified. The paper concludes with the principles of a framework for cBIM which details the processes and protocols that should be embedded in project teams to make integrative project delivery a reality.

IPD has been an aspiration for the UK construction industry since the mid-1990s but it remains to be one of the top priorities of the Government. Contrary to traditional construction practices which have made the industry notorious for its fragmentation, IPD is an approach that integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to reduce waste and optimize efficiency through all the phases of construction.

Although it is possible to achieve IPD without BIM, it has actually become the most recommended strategies to enhance IPD. Merging IPD and BIM can lead to greater collaboration in terms of procurement and delivery. It should lead to reductions in time, cost, waste and bring about innovative solutions to persistent problems. The complexities and constraints coupled with the high demand, makes IPD undoubtedly one of the best approaches to deliver schools in the UK.

4. Current Approaches to Project Delivery

Standardisation, off-site manufacturing, prefabrication and similar innovative approaches to delivering buildings is another area which provides opportunities to deliver better built facilities. Finnimore (1989) defines standardisation as an early theory in building technology, borrowed from manufacturing industry's attempts to maximise repetition in methods of manufacture in order to enhance economy and precision. The benefits of standardised construction are fast return on investment, health and safety savings, time savings, quality savings, efficiency savings, material savings, fewer defects and fewer mistakes (Ross 2005). Recently, it has been argued that schools can also gain from these benefits in an environment where demand for school places is increasing whilst funding is decreasing (Watson 2012; UK DE 2012; Talbot and Francis 2012).

In the UK, the provision of standardised schools has an established track record since the end of the Second World War (Phillipson, 2001). However, other than the traditional project lifecycles (CIOB, 2010), details about processes used in the delivery of standardised schools are sketchy despite a rising number of standardised schools being reported in the country. The Hertfordshire schools programme was an outstanding example of a programme which used standardised and prefabrication technology to meet the local pressures from the expansion of London and the establishment of post war new towns (Hatfield, Hemel Hempstead, Welwyn Garden City, etc.) that were driving the need for schools. In the UK, most projects including standardised schools are often required to use construction lifecycles. Some common lifecycles in the UK have been defined by leading institutions such as Chartered Institute of Buildings, British Standards, British Property Foundations and Royal Institute of British Architects (CIOB, 2010). These lifecycles often adopt a stage-gate

approach to project delivery, where professionals are involved only during the stages when their expertise is deemed necessary, dominates. Furthermore, many project partners still pursue these lifecycles in a linear fashion. The BIM approach is non-linear and provides project partners opportunities to collaborate simultaneously on a project. Therefore, the role of BIM can potentially contribute to reducing industry fragmentation, improving efficiency/effectiveness and fostering interoperability thereby reducing cost and time, and thus supporting IPD. It is considered that the use of BIM can greatly enhance the production of standardised buildings by providing integrated information solutions from the factory to the site. Lu and Korman (2010) argue that the use of modular construction techniques may increase as BIM becomes more prevalent in the construction industry.

4.1 BIM tools

The paradigm of collaboration between project partners using Information and Communication Technology (ICT) to share useful information throughout a project's lifecycle is well-encapsulated in BIM. Currently, BIM is at the centre-stage of almost every single country's construction industry including the UK. It is being hailed as a solution to overcome age old difficulties in communications and information management that have plagued the industry for decades. The contribution of BIM in addressing some of these issues that have remained unattended for far too long has already been noted (Jordani, 2008). However, whereas other industries have succeeded in leveraging significant benefits from BIM solutions, the construction industry has struggled to achieve similar productivity benefits for technological, practical and methodological reasons (Olatunji 2011; Arayici et al. 2012).

Hence, it is imperative to understand the technological, practical and methodological challenges impeding the uptake of BIM so as to provide a way forward for its full-scale adoption. In the ensuing section a review of the different BIM tools is undertaken.

The review criteria were identified with the aim of gaining insights of the benefit and challenges involved in the use of BIM. The main criteria considered are the various domain of activities, e.g. architecture, structures, etc.; the various tools used in the different domains; the different professionals involved such as the designers, engineering and cost consultants. Key aspects of exploiting construction information are interoperability, links of BIM with other tools, construction domain and stages in which the tools can be used, and whether the BIM tools are open source or not. With these criteria set, the most widely used tools established by the UK National Building Specification (NBS, 2013) were reviewed. The BIM tools are Revit, Microstation, Allplan, Bentley Building Suite, AutoCAD, Vectorworks, ArchiCAD, Trimble SketchUp. The summary of the review of these tools are presented in Table 1.

Table 1: Comparison of the common BIM tools in the UK construction industry

	Stage	Domain	Users	Links with other software	Interoperability	Open source
Revit Architecture	Planning and Design	Architecture	Architects and drafters	AutoCAD, Google SketchUP, Excel, ODBC, Google Earth	IFC, gbXML, DWG	No
Revit Structure	Planning and Design Construction	Structure	Structural engineers	Ecotect, Green Building Studio	IFC, DWG	No
Revit MEP	Planning and Design	MEP	Mechanical, Electrical and Plumbing Engineers	Ecotect, Green Building Studio	IFC, DWG	No
ArchiCAD	Planning and Design Construction	Architecture	Architects	Revit	IFC	No
Allplan Architecture	Planning and Design	Architecture (3D design)	Architects and drafters	Google SketchUp, Google Earth, Microstation. 3ds-Max, AutoCAD	IFC, DWG, DXF, PDF	No
Allplan Engineering	Planning and Design Construction	Structures (3D design for structural design)	Structural engineers	Google SketchUp, Google Earth, Microstation. 3ds-Max, AutoCAD	IFC, DWG, DXF, PDF	No
Allplan Facility Management	Operations	Facility Management	Facility managers	Google SketchUp, Google Earth, Microstation. 3ds-Max, AutoCAD	IFC, DWG, DXF, PDF	No
MicroStation	Planning and Design Construction Operation	Architectural Design	Architects, engineers, contractors, planners, GIS professionals	AutoCAD, Google SketchUP, Revit, IES, Google Earth	DWG, DXF, PDF	No
Vectorworks	Planning and Design	Landscape design	Planners and Landscape Architects	Google Earth	DWG, DXF	No
Bentley suite	Planning and Design Construction	Architecture, Structures, MEP	Architects, MEP and Structural Engineers	Google SketchUp	DWG, gbXML, IFC, PDF	No
Trimble SketchUp	Planning and Design	Architectural design	Architects	Google Earth	DWG, DXF	Free for limited version, small fee for complete version

4.2 The Barriers to the uptake of BIM tools

Table 1 provides the basis of discussion of factors inhibiting the uptake of BIM. In addition to the technical barriers in Table 1, non-technical barriers will be examined.

Information exchange and interoperability: Information exchange is crucial in fostering integrated process**.** Based on Table 1, it emerged that some of the common BIM tools can output information in at least one standard format, e.g. IFC. However, a recent study revealed that most construction professionals have never used most of the exchange protocols (Redmond et al., 2012). Perhaps that justifies why some tools are still very dominant in the BIM market. Without the knowledge of exchange protocols, the tendencies of buying the most common software will most likely prevail.

At which stage should BIM be integrated in projects? Opinions on the applications of BIM processes and tools on various phases of a construction project vary. These variations are generally based on the level of information available with regards to each construction phase. Current belief is that information about the operational phase of a building is widely abundant and well-researched. Also, there is a shift in investigating the implementation BIM at early design stages (Cheung et al., 2012). In Redmond et al. (2012) more diverse views have been expressed. Some respondents adamantly argued for BIM to be implemented in the whole life cycle while others recommended the early design stage.

Web-based or desk-top applications: Despite an overwhelming support and acknowledgement of cloud-based BIM systems supported by the Web (Redmond et al., 2012), many common BIM tools in the UK construction industry are still localised on desktops. All of the tools in Table 1 are desktop-based systems.

Overcoming the technical barriers alone is not sufficient to trigger the uptake of BIM. Other non-technical barriers such as cost, contractual issues, intellectual property, behavioural, cultural are known to hinder the uptake of BIM (Olatunji 2011; Gu and London 2010; Redmond et al. 2012; Yan and Damian 2008; NBS 2013).

Cost**:** Based on Table 1, most of the BIM tools are not free. In both the UK and the US, cost and human resources are among the major barriers hindering the implementation of BIMs by construction firms (Yan and Damian, 2008). This is particularly worrying given the huge number of SMEs in the construction industry.

Contractual issues with BIM: The openness in sharing construction information in BIM is the fundamental underlying principle of BIM and key in overcoming fragmentation in the industry. However, this “openness” has been considered as a barrier (Redmond et al., 2012). Current construction contracts do not cover information exchange. The lack of Standard BIM contract documents is a barrier to the uptake of BIM (Ashcraft 2008). Thus, issues such as risk allocation, compensation, insurance and dispute resolution common in traditional contract documents cannot be easily dealt with in BIM projects. Ownership and copyright attributions of construction BIM model and/or pieces of a particular aspect of a BIM model still constitute major concerns in BIM managed projects.

The lack of immediate benefits of BIM for designers: The benefits of the adoption of BIM have been acknowledged by academics and construction professionals (Ashcraft 2008; Yan and Damian 2008). However, amongst construction professionals, scepticisms about the level economic benefit in the supply chain exists (Ashcraft ,2008). For the project owner, the benefits are obvious and include design optimisation, fewer construction errors, fewer design coordination issues, increased quality, decrease in cost, shorter delivery times, less coordination and engineering effort and reduced fabrication costs. On the other hand, designers feel less enthusiastic about BIM as they believe its economic benefits are less apparent to them (Ashcraft, 2008). In the conceptual phase of a construction project, the ability to explore various design alternatives using BIM tools leading to greater efficiency and improvement in quality is a major benefit to designers. However, as argued by Ashcraft (2008), unless the designer shares in the economic benefits, the owner, not the designer, reaps the immediate rewards. Yet, it is the designer, not the owner, who must adopt and invest in BIM more than owners (Sebastian, 2010).

Incompatibility of BIM information with Standard Methods of Measurement: A major use of BIM is the measurement of quantities. BIM measurement could potentially change current measurement practices. A classic example is the need to filter quantity measurement output so that it complies with Standard Methods of Measurements. The existence of many different standard methods of measurement further exacerbates this challenge. For example, in the UK building and civil engineering works are managed by the Standard Methods of Measurement (SMM7) or New Rules of Measurements (NRM) and Civil Engineering Standard Method of Measurement (CESMM3) respectively.

The changing roles and responsibilities: The application of BIM to support cross-disciplinary, knowledge-intensive and multi-faceted projects opens new dimensions in the roles and responsibilities of actors in the construction industry. The relationships between the various actors are likely to change. While new roles with special responsibilities and skills (e.g. Model manager, BIM analyst, BIM modeller, BIM facilitator, etc.) will emerge (Sebastian 2011; Barison and Santos 2010), there is an anxiety that some actors (e.g. quantity surveyors) will lose their roles.

Procurement challenges: Current procurement methodologies are ill-suited for the rolling out of BIM in the construction industry. The majority of current procurement methodologies limit the participation of various actors right from the early stages of construction. For BIM integration to be a success there is a need to involve all construction team members including contractors and sub-contractors from the early stages. In addition to the sustainability dimension, BIM and procurement processes constitute the three pillars that will drive the way forward for IPD. These three inter-related issues were strongly echoed in the UK Government Construction Strategy, published in May 2011(GCS, 2011).

5. Preliminary framework for the delivery of standardised schools

In sections 1 and 2 we have argued how IPD and BIM systems can be used in delivering standardised schools. As long as the challenges in deploying BIM persist the benefits from rolling IPD and BIM systems will hardly ever be realised. It is no wonder that experts from

the construction industry have suggested that IT researchers should align with construction practitioners when developing and proposing IT solutions (Gu and London, 2012). This suggests construction industry problems require wider participatory approaches not only from construction professionals but also from other industries working collaboratively in developing innovative solutions. Furthermore, in an industry where almost all projects are handled in multi-disciplinary and multi-organisational terms, the lack of clarity on roles, responsibilities and distribution of benefits in adopting the BIM approach is an important inhibiting factor (Holzer, 2007). Therefore, the challenge in the development of an IPD and BIM solution in delivering standardised schools is multi-dimensional requiring the sourcing, harnessing and using skills of actors both within and without the industry and using them in delivering standardised schools using IPD and BIM approach.

The methodology adopted in this study consists of a literature review, workshops, interviews and case studies. The literature review focuses on different projects that have been delivered through IPD in the UK. This will lead to the establishment of potential factors and decision points to be considered in the development of a framework for the delivery of standardised schools using IPD. We will also conduct a detailed analysis of construction project life cycles (CIOB, 2010) with the view of identifying opportunities and phases where BIM and sustainability can be integrated. Procurement methods are also currently being reviewed for potential recommendations to accommodate IPD and BIM. We are currently exploring BIM Overlay framework developed by RIBA (Sinclair, 2012). Based on these reviews a preliminary framework for delivering standardised schools using IPD has been designed and presented in Figure 1.

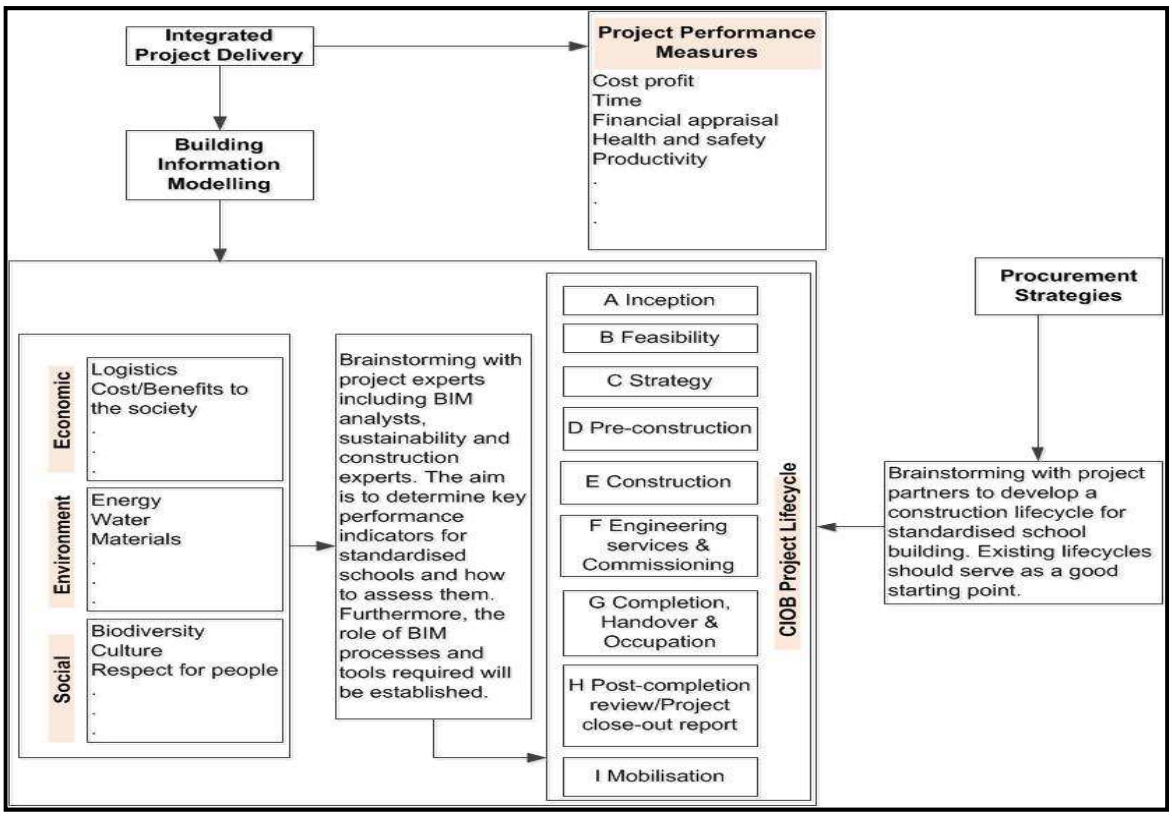

Figure 1: Preliminary IPD/BIM framework for the delivery of standardised schools

Given the novelty of the domain, a series of workshops will be organised and opinion of experts developing standardised buildings in the UK will be sampled and used in developing and validating the preliminary framework. A pilot Sandpit event will be organized for key members of the supply-chain who will use the enhanced BIM for real-time collaborative working in our first live project. A focus group will be held at the end of this event to provide a preliminary evaluation of this new approach, which will be used to further refine the processes.

The project kick-off meeting for our second live project will be a Sandpit. Supply-chain members will attend the event which will provide a “safe play” environment to critically review alternative options and to evaluate the effect of different design and construction alternatives on project performance using the collaborative BIM (cBIM) that will have been developed earlier on in the R&D project. BIM will also give them access to previous project knowledge to improve the product and the process. One example is to generate work packages using the information kept in the recycled BIM in order to evaluate and optimize them according to performance targets such as cost. Attendees will start evaluating this novel approach to collaboratively working so that it can be benchmarked against current approaches to designing and delivering schools using standardised designs.

6. Discussion and conclusion

In this paper we have reviewed the literature on IPD and BIM. We noted that IPD can be achieved without BIM; however BIM can be used to facilitate IPD. Thus, as discussed in most literature, BIM is currently being considered as a vehicle to achieve IPD. To gain an insight of the BIM tools, the most widely used ones in the UK were examined. It emerged from the review that despite the widely popularised benefits of BIM there exist enormous challenges to overcome before many project actors can fully embrace BIM. The challenges were grouped into two main categories. First the technical challenges related to nature of the BIM technologies and secondly non-technical related to the human and industry practices. The challenges constitute part of a wider range of issues that should be overcome for IPD to be implemented in projects. With this in perspective, we proposed an approach to develop a framework for the delivery of standardised schools in the UK. The five components of the proposed framework are BIM technology, sustainability considerations, actors or people, processes (i.e. procurement and project life cycles) and project performance measures.

The BIM technology is about the constituents of BIM technologies and processes that can be used in managing a construction project. In particular in collaboration with our project partners, the most appropriate BIM technologies and processes that can be used in managing standardised school information will be established. The sustainability component will be about the different sustainability issues needed to be included in the development of a standardised school. The set of sustainability indicators will be established through brainstorming with our project partners. The use of BIM in managing construction information requires new roles. These are people related issues. With regards to standardised schools, new roles and relationships within the project teams will be mapped out. New processes, particularly in terms of procurement and construction lifecycles will need to be developed in

order to support IPD. Project performance measure, the last component, will be used to identify the project efficiencies (or otherwise) that can be achieved by using cBIM.

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Methodological discussion and piloting of LCA-based environmental indicators for Brazilian building materials

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Abstract

Brazilian studies on sustainability indicators for the construction sector are considerably variable in criteria and methodology and therefore are not necessarily replicable or allow result aggregation. Worldwide definition and calculation procedures of some indicators also vary substantially. Life cycle assessment (LCA) can scientifically support such calculations, but is still embryonic in the country. This paper proposes the use of life cycle-based indicators to assess ecoefficiency (embodied energy; embodied CO_{2eq}; blue water footprint, abiotic content) and VOC emissions of building materials, normalized per unit of built area (m^2). This discussion is detailed for cement and concrete. The paper also examines the effects that discrepancies between two carbon footprint accounting methods (embodied CO_2 versus CO_{2eq}) have on communication of environmental performance of selected materials. Data for production cycle modeling were collected from national literature or, when considered acceptable, adapted from SimaPro 7.3 built-in Ecoinvent database. For the studied low rise, low window-to-wall ratio, concrete-framed buildings – a core database comprised of 12 materials and components - cement, ceramic blocks, steel rebar, sawn timber planks, PVC tubes, plywood, PVC conduits, roof steel structure, roundwood, ceramic tiles, hydrated lime and adhesive mortar - would provide a very reasonable description of a building's embodied energy (99.7%) and CO_{2eq} (98.1%) profiles. Considering the general lack of LCA studies in Brazil, this could significantly streamline data collection work in the short term. Except for the blue water footprint, all calculated indicators captured the environmental advantages of partial replacement of clinker by ground granulated blast furnace slag (ggbs), a typical practice in Brazil. As granulation of ggbs is a well-known water intensive industrial process, most steelmaking companies have water reuse programs in place. To provide a general picture, such programs were not factored in the calculations shown here, but can be considered on a case-by-case basis. This research contributes to the construction of a Brazilian LCI open access database to enable application of the proposed LCA-based metrics to support design decision-making processes.

Keywords: indicators, LCA, carbon footprint, embodied energy, building sector.

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1. Introduction

The construction sector plays an increasingly important role on regional and global economies, contributing to jobs generation, to the development of new technologies and infrastructures and to quality of life enhancement. However, this social and economic relevance comes at a heavy environmental price: approximately 25% of all raw materials extracted from the lithosphere are consumed for building construction (BRIBRIÁN et al., 2011); about 23% of the energy produced in Brazil is consumed by the residential sector (ANEEL, 2008); and a great part of anthropogenic carbon emissions come from building activities.

Despite its environmental relevance, performance of a given construction project has traditionally been measured in terms of quality, time and money spent (GANGOLLELS et al., 2009). Environmental performance assessment is a relatively new practice and still presents methodological challenges that limit its practical application and accuracy. Silva (2007) points out that Brazilian studies aiming at defining sustainability indicators for the construction sector are considerably variable, with results obtained through criteria and methodologies that not necessarily are replicable or allow aggregation.

Variability within indicators' definition is observed worldwide, and calculations involved sometimes show clear conceptual conflicts, especially regarding accounting of carbon emissions. Wiedmann and Minx (2008) and ETAP (2007) defend that the carbon footprint should measure direct and indirect carbon dioxide emissions accumulated throughout a product's life cycle. On the other hand, Post (2006) states that the indicator should represent the total amount of all greenhouse gases emitted during a product or process' life cycle. Such discrepancy between definitions reveals that the calculation methodology is still quite irregular, and that results from different authors may lead to mistaken conclusions.

A set of indicators should provide a measure of current performance, a clear statement as to what can be achieved in terms of future performance goals and a reference point for progress measurement along the way (JEFFERSON et al., 2007). In other words, environmental indicators are designed to collect, process and use information aiming at making better decisions, at driving smarter political choices, and at measuring progress (WILSON et al., 2007).

Environmental indicators are structured to capture resources usage in terms of production and consumption, and their consequent environmental impacts. Some indicators are shared by many industry sectors such as water consumption, energy consumption and CO_2 emission (UN ST/ESCAP/2561, 2009). In the particular case of the construction industry, building material usage is usually described in terms of regional, renewable, recycled or recyclable content. A less common - but far more relevant indicator - is the non-renewable content, which communicates the depletion intensity of abiotic resources, as demonstrated by Saade et al. (2012). In the current scenario, in which data regarding the operational phase of a building's lifecycle are, many times, inaccurate and subjective, consideration of volatile organic compounds (VOC) emissions during the manufacturing phase might be a

possible alternative to connect materials usage to health-related aspects in overall sustainability performance assessment.

To assure reliability and thoroughness, indicators should provide an entire lifecycle perspective. Life Cycle Assessment (LCA) stands out as a holistic tool to assess the potential environmental impacts throughout a product's lifecycle (ISO, 2006). The wide and comprehensive scope of LCA is useful in order to avoid "problem shifting" from one phase of the life cycle to another, from one region to another, or from one environmental problem to another (FINNVEDEN et al., 2009), and can scientifically support the calculation of more consistent and informative indicators.

This paper proposes the use of a set of life cycle-based indicators to assess ecoefficiency (embodied energy; embodied CO_{2eq}; blue water footprint, abiotic content) and VOC emissions of building materials, normalized per unit of built area (m^2), detailing the discussion for cement and concrete. It also analyses the effects that discrepancies between two carbon footprint accounting methods (embodied CO_2 versus CO_{2eq}) have on communication of environmental performance of selected materials.

2. Methodological approach

A literature review was carried out to cover the concept and applications of environmental indicators and LCA, particularly within the building industry, identifying the state of play and main barriers for their proper insertion in Brazil.

Based upon three case studies, the two main research targets were *(i)* to identify the building materials/components with the largest potential contribution to the building's embodied energy and CO_2; and *(ii)* to further calculate blue water footprint, abiotic (non-renewable) content, and VOC emissions, normalized per m², for the materials/components with the largest contributions, as found in item *i.* The performed cradle-to-gate LCAs followed ISO 14040 (ISO, 2006) methodological guidelines.

2.1 Quantification of materials and components mostly used in three case studies

Total usage of material/components was quantified for three low rise (up to 3 floors), low window-to-wall ratio (WWR), concrete-framed buildings. The case studies comprise one integrated service center (4,975.55 m²); one police-training center (1,511.74 m²); and one school building (4,869.23 m²) and represent typical construction practices in Brazil for their respective functional categories. In the particular cases of concrete, steel rebar and formwork, only the superstructure was considered, in order to isolate the effects of soil's carrying capacity on the sizing – and, consequently, on material consumption - of foundation elements. External and urbanization elements were also disregarded.

For all case studies, consumption of each material/component was totalized (according to the functional unit previously defined), divided by the total built area and corrected by

Brazilian estimates for construction waste (AGOPYAN et al., 1998). Chart 1 indicates functional units and data sources used for production process modeling.

Construction materials and components	Functional unit	Data source
Concrete (fck 30)[1]	1 cubic meter	Silva, 2006
Portland cement (CPI-32, CPII-E-32 e CPIII-32)[1]	1 ton	Silva, 2006
Steel rebar, steel frame, wire, copper wire	1 ton	ELCD, version 2.0
PVC (conduit and tube)	1 ton	Industry Data, version 2.0
Wood (plywood; planed dried; raw dried)	1 cubic meter	Ecoinvent, version 2.2
Sand, Gravel, Acrylic paint, Hydrated lime, Adhesive mortar, Ceramic tile	1 ton	Ecoinvent , version 2.2
Ceramic block	1 ton	Manfredini and Sattler (2005); Hammond and Jones (2006)

[1] Concrete mixes using three types of cement with different amounts of ground granulated blast furnace slag (ggbs) as clinker replacement are presented to best represent the Brazilian practice.

Chart 1 - Inventory data sources and functional unit defined for each material or component considered in the study

2.2 Calculation of the embodied energy and carbon footprint

The embodied energy indicator (EE), normalized by the functional unit previously defined, was calculated using LCI provided by Ecoinvent. The exception was the ceramic block, which used data from Manfredini and Sattler (2005), whose adopted methodological approach was explicit and seemed reasonably close to the one herein adopted. EE calculation considered the total energy from all primary sources indicated in the inventory.

Two scenarios were contrasted: embodied CO_2 emissions only - as defined by the Kyoto Protocol - and embodied CO_{2eq} emissions, which included all greenhouse gases (GHG). For the sake of efficiency and practicality, embodied CO_{2eq} was obtained through *CML 2001 v.2.05* environmental impact analysis, regarding the global warming impact category. The method contains the equivalency factors for all GHGs, and already expresses results in Kg of CO_{2eq} per functional unit.

Embodied CO_2 and embodied $CO_{2eq.}$ per functional unit were calculated from the inventory analysis for each material/component, again except for the ceramic block value, which was obtained from University of Bath's inventory of carbon and energy (HAMMOND; JONES, 2011). Though these authors used an energy mix that differs from the Brazilian case, and such a difference can imply in less accurate results, the methodological thoroughness observed in their research suggest its use as a potential proxy, given the lack of data related to that specific component in national and international LCI databases.

2.3 Calculation of the blue water footprint, abiotic (non-renewable) content and VOC emissions

Embodied energy and embodied CO_{2eq} per built m² were the initial filters applied to select material/components for which the other metrics would be calculated. Blue water footprint

(bWF), abiotic (non-renewable) content (NRc) and volatile organic compound emissions (VOCe) per functional unit were then calculated from the inventory analysis. For the blue water footprint calculation, consumption of different water sources during the extraction and production was totalized. Consumption of mineral resources throughout the product's life cycle fed the abiotic (non-renewable) content calculation, while the VOCe indicator summed both methane and non-methane VOC emissions listed in the inventory.

3. Results presentation and discussion

3.1 Embodied energy (EE) per unit of built area

Figure 1 presents median values of embodied energy of building materials and components per built m². To support discussions made later on this paper, embodied energy of Portland cement and concrete are expressed in terms of three amounts of ground granulated blast furnace slag (ggbs) used as a clinker replacement (CP I-S-32, with 5% ggbs; CP II-E-32, with 30% ggbs; and CP III-32, with 66% ggbs), consistent with Brazilian standards NBR 5732 (ABNT, 1991), NBR 11578 (ABNT, 1991) and NBR 5735 (ABNT, 1991). Portland cement here indicated was not used to manufacture concrete, which was delivered ready mixed, but instead acquired separately for use in other cement-based applications. Figure 1 highlights that – if considered as a composite material delivered to the construction site - concrete would bring in the second highest contribution to EE and its use must therefore be carefully monitored during design and construction.

In Figure 2, concrete was broken down into corresponding cement, sand and gravel quantities, which were added to those, used in other construction applications. Top ten contributors to EE per built m^2 would therefore be cement, ceramic block, steel rebar, sawn timber planks, PVC tubes, plywood, PVC conduits, roof steel structure, sawn roundwood and ceramic tiles. These materials cover 99.2% of the accounted EE value for the case studies median, and seem to provide a very reasonable description of a building's embodied energy profile.

As expected and documented in previous literature data, results show that Portland cement and concrete are the main contributors to the building's embodied energy profile. It is noteworthy, however, that international studies usually investigate performance of ordinary Portland cement (OPC). OPC is composed primarily by clinker, with little or no mineral admixtures and would be equivalent to Brazilian cement type CP I-S-32. In Brazil, however, CP II-E-32 (30% of ggbs) is most widely commercially available type, while CP III-32 (66% of ggbs) is the top selling cement in the region of this study. Results for these cement types were therefore presented for reference purposes and to support discussion presented later in this paper.

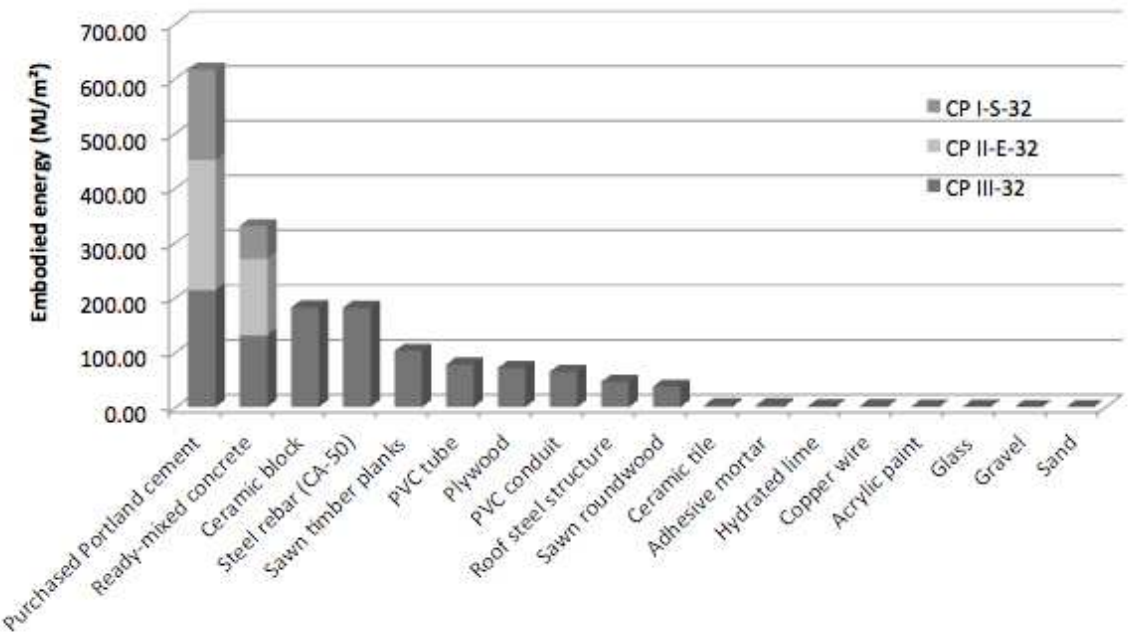

Figure 1 - Embodied energy of materials and components normalized per m^2 of built area

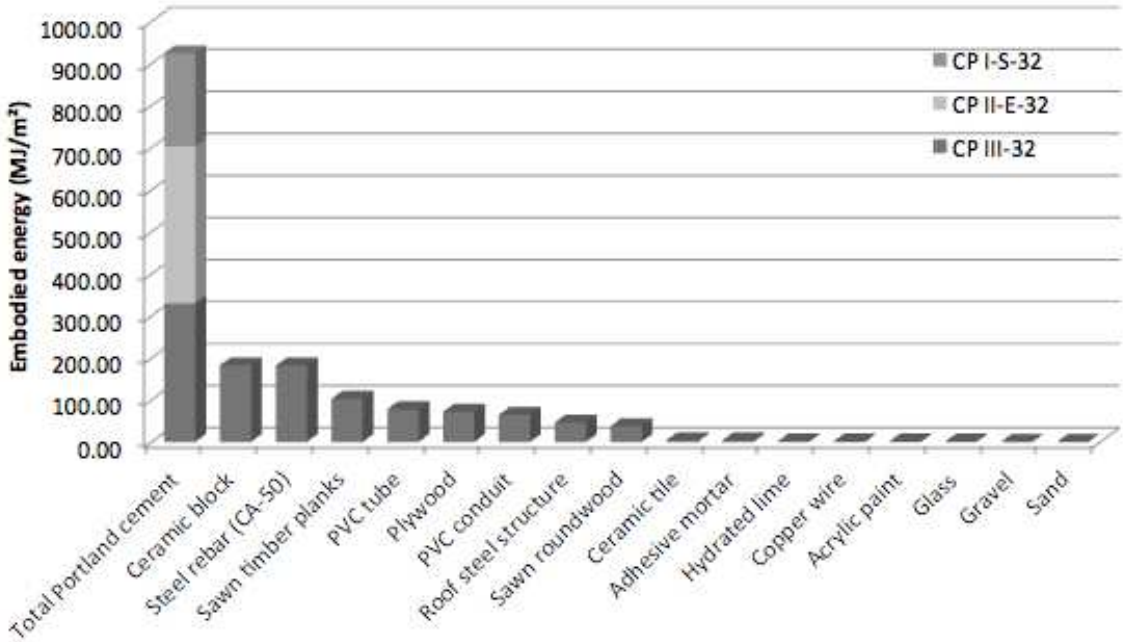

Figure 2 - Embodied energy of materials and components normalized per m^2 of built area, with concrete broken down into corresponding cement, sand and gravel quantities

3.2 Embodied CO_2 (EC) emission and embodied CO_{2eq} (EC_{eq}) per unit of built area

Figure 3 presents median values of embodied CO_2 of materials and components per m^2 of built area. Repeating the pattern obtained for EE, Figure 3 shows that, according with the type of cement used, concrete, taken as a composite, would be the second highest contributor to embodied CO_2.

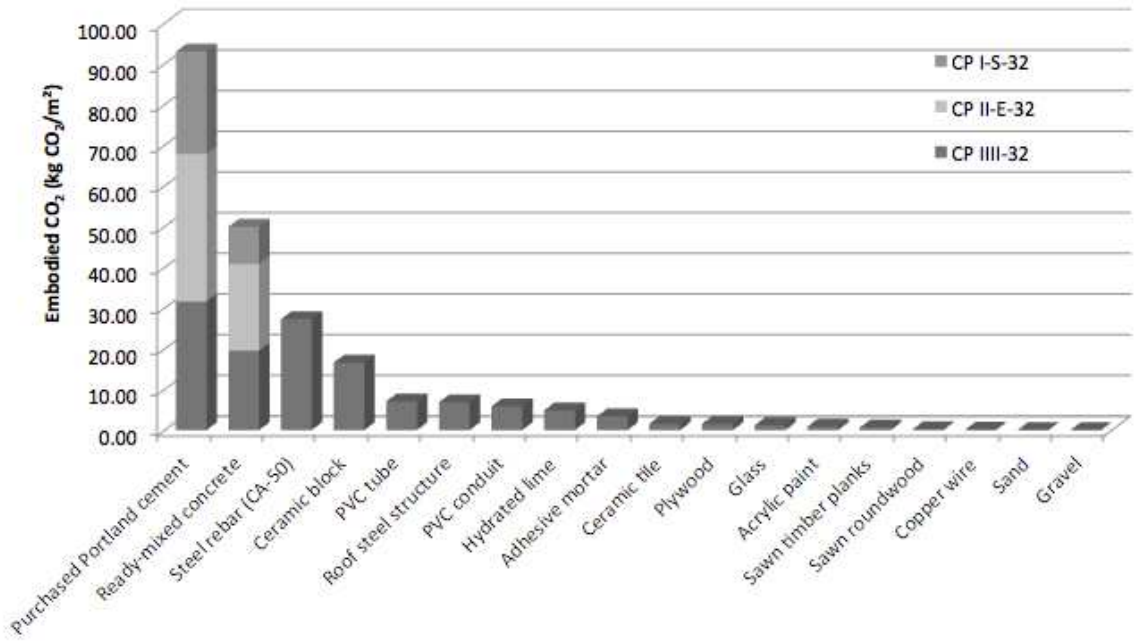

Figure 3 - Embodied CO_2 of materials and components normalized per m^2 of built area

Figure 4 presents median values with concrete broken down into corresponding cement, sand and gravel quantities, which were added to those, used in other construction applications. The top five contributions (cement, steel rebar, ceramic blocks, PVC tubes and roof steel structure) respond for 83.9% of the total embodied CO_2. Enlarging this collection to include PVC conduits, hydrated lime, adhesive mortar, ceramic tiles and plywood increases coverage to 97.4% of the accounted embodied CO_2.

Figure 5 presents the median values of embodied CO_{2eq} for all quantified materials considering concrete as a composite material, while in Figure 6 concrete was broken down into corresponding cement, sand and gravel quantities, which were added to those used in other construction applications.

Apart from some reordering, the top 10 contributors for embodied CO_{2eq} were the same as for embodied CO_2: cement, steel rebar, ceramic blocks, PVC tubes and PVC conduits respond for 82.8% of the total embodied CO_{2eq}, while consideration of the top 10 contributors (roof steel structure, hydrated lime, adhesive mortar, plywood and ceramic tiles) increases coverage to 97.4% of the accounted embodied CO_{2eq}. Most of these materials or components were also among the major contributors to EE.

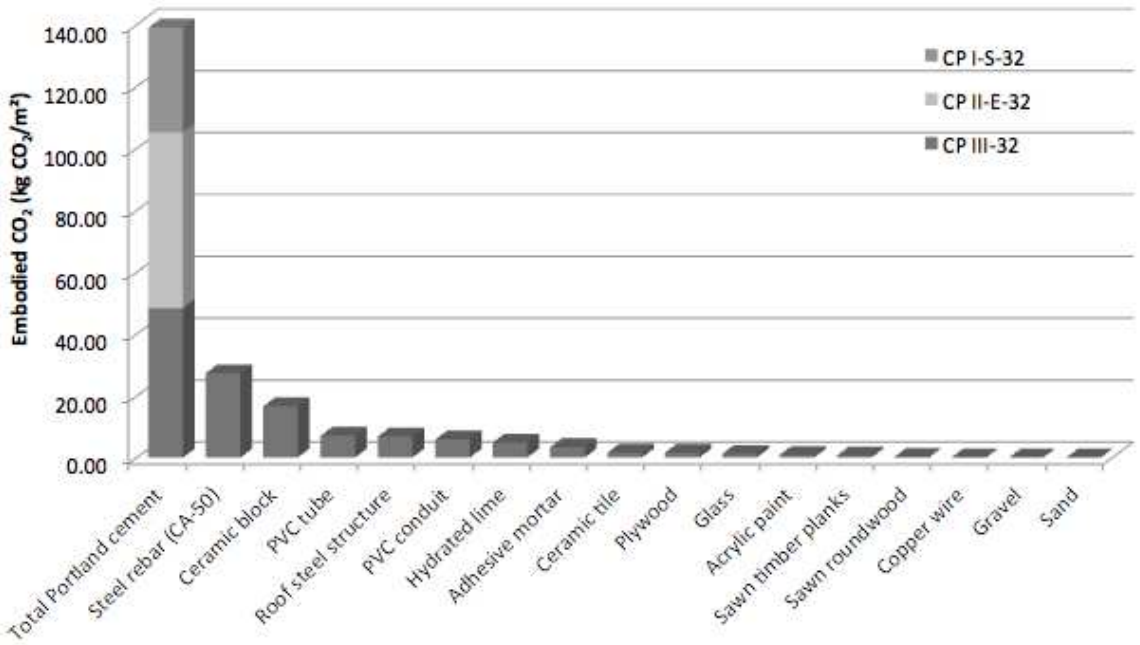

Figure 4 – Embodied CO_2 of materials and components normalized per m^2 of built area, with concrete broken down into corresponding cement, sand and gravel quantities

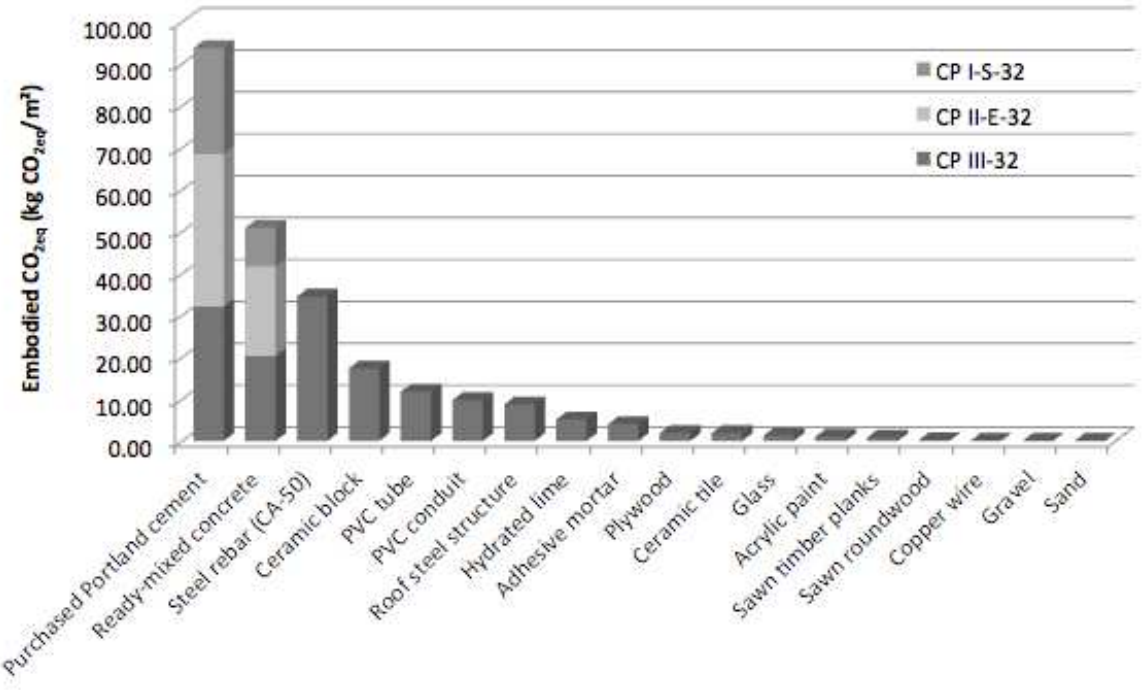

Figure 5 - Embodied CO_{2eq} of materials and components normalized per m^2 of built area

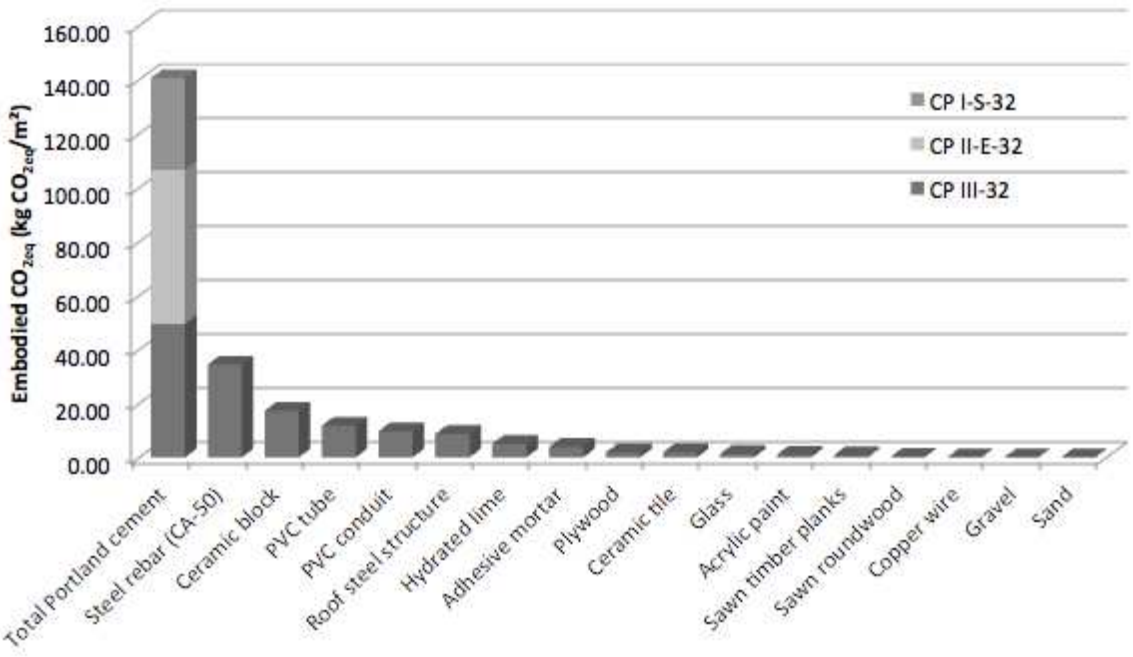

Figure 6 – Embodied CO_{2eq} of materials and components normalized per m^2 of built area, with concrete broken down into corresponding cement, sand and gravel quantities

Combined analysis of accounted embodied energy and GHG emissions therefore suggests that a core database comprised of 12 materials - cement, ceramic blocks, steel rebar, sawn timber planks, PVC tubes, plywood, PVC conduits, roof steel structure, roundwood, ceramic tiles, hydrated lime and adhesive mortar - would provide a very reasonable description of a building's embodied energy (99.7%) and CO_{2eq} (98.1%) profiles. Considering the general lack of LCA studies in Brazil, this could significantly streamline data collection work in the short term.

3.3 Discussion on proposed core set of environmental indicators

In order to advance in the evaluation of the most critical materials, values of embodied energy (EE), embodied CO_2 (EC), embodied CO_{2eq}. ($EC_{eq.}$), blue water footprint (bWF), abiotic (non-renewable) content (NRc) and Volatile Organic Compounds emissions (VOCe) normalized per unit of built area were calculated for cement and concrete (Table 1). Table 2 presents the normalized values found for concrete with cement types CP I-S-32, CP II-E-32 and CP III-32. Figures within parenthesis indicate reductions in relation to cement CP I-S-32 (the most similar to OPC), kept for international reference.

Except for the blue water footprint, all calculated indicators confirm the environmental advantages of using ggbs as clinker replacement in cement (Table 1) and concrete manufacturing (Table 2). The bWF value increased when shifting from CP I-S-32 to CP III-32 and corresponding concrete mixes, as granulation of blast furnace slag is a well-known water intensive industrial process. Most steelmaking companies have water reuse programs in place, which would reduce cement and concrete's blue water footprints. In this paper, however, such programs were not considered, because of the unpredictable differences across steelmaking companies' environmental management programs.

Table 1 - Indicators calculated for cement types CP I-S-32, CP II-E-32 and CP III-32

	EE (MJ/m^2)	EC ($kgCO_{2eq}//m^2$)	EC_{eq} (kg/m^2)	bWF (m^3/m^2)	NRc (kg/m^2)	VOCe (kg/m^2)
CP I-S-32	924.00	139.37	140.54	0.12	470.59	4.85E-4
CP II-E-32	702.49 (-23.97%)	105.57 (-24.25%)	106.59 (-24.16%)	0.70 (+82.26%)	358.15 (-23.89%)	4.21E-4 (-13.15%)
CP III-32	329.79 (-64.31%)	48.81 (-64.98%)	49.53 (-64.76%)	1.50 (+91.77%)	168.88 (-64.11%)	3.00E-4 (-38.13%)

Table 2 - Indicators calculated for concrete with cement types CP I-S-32, CP II-E-32 and CP III-32

	EE (MJ/m^2)	EC ($kgCO_{2eq}/m^2$)	EC_{eq} (kg/m^2)	bWF (m^3/m^2)	NRc (kg/m^2)	VOCe (kg/m^2)
Concrete w/ CP I-S-32	330.41	49.95	50.84	0.82	695.78	1.85E-3
Concrete w/ CP II-E-32	271.02 (-17.97%)	40.85 (-18.22%)	41.68 (-18.01%)	1.00 (+18.36%)	638.94 (-8.17%)	1.74E-3 (-5.57%)
Concrete w/ CP III-32	131.12 (-60.32%)	19.55 (-60.85%)	20.28 (-60.11%)	1.30 (+37.10%)	576.26 (-17.18%)	1.72E-3 (-6.69%)

4. Conclusions and final remarks

Many efforts to describe environmental performance, through establishment of adequate indicators, have been observed throughout the world. However, there are significant disagreements in terms of definitions and calculation methods. Such differences can mislead interpretation, especially when the calculation protocols are not explicit, increasing risk of cumulative errors. Another possible limitation arises from the deficiency of national and international reference for data input in LCA platforms, which might require input from mixed data sources, as in the case of this paper.

Obtained results showed that adoption of different methodologies for carbon accounting had little effect on the values calculated for cement (EC/EC_e ratio between 98.5-99.2%) and concrete (EC/EC_e ratio between 96.4-98.2%). This is not necessarily the case for all relevant building materials, as shown in Figure 3 versus Figure 4 and in Figure 5 versus Figure 6.

Contribution of cement to EE and EC_{eq} per built m^2 increases almost threefold when shifting from Brazilian CP III-32 to CP I-S-32 (two and half times, in the case of concrete). CP I-S-32 is the closest type to the ordinary Portland cement (OPC) used internationally, and is a good example of the adhesion to local practice data needed to deliver meaningful analysis. Except for bWF - increased due to the water-consuming granulation process – all proposed indicators reflected the environmental advantages of ggbs as clinker replacement in cement production. This complements improvement of some technical properties consistently pointed out in literature (CAMARINI, 1995; SILVA, 1998; SILVA, 2006; TANESI, 2010).

Combined analysis of accounted embodied energy and GHG emissions therefore suggests that a core database comprised of 12 materials would provide a very reasonable description of a building's embodied energy and CO_{2eq} profiles. This could significantly streamline work on Brazilian LCI assembly in the short term. Next research steps include investigation of

additional material intensity/dematerialization indicator and database expansion to include other building typologies. Following a coordinated methodological outline, future works will gradually evolve to form an LCI open database comprising the most relevant building materials and components, to enable the use of the proposed LCA-based metrics to support design decision-making processes.

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Stirring sustainable procurement by conceptualizing relationship quality in construction

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Abstract

Appreciating the value of effective and efficient procurement strategies, major construction industry reports and practitioners have either proposed new procurement strategies or improvised the current practice. The relational approach and especially relationship contracting as part of contemporary procurement strategies have been advocated in pursuit of a more sustainable procurement culture as well as a more sustainable built environment. Although different relational contracting methodologies such as partnering, alliancing and joint ventures have been advocated the actual conceptualization and assessment of relationships seems to be weak in the construction industry. Looking at marketing and business research context where a move form transactional to relational has been made the systematic framework of relationship quality is inspired and introduced for construction. This framework comprises of a high order construct involving antecedents, measures and outcomes for the system. Conflict and dispute are considered as the main corresponding antecedents to relationship quality in construction, complemented by performance and relationship status impacting sustainability as the outcomes of the system. It is demonstrated that the changes in contracting circumstances, built environment culture may affect the different layers of the systematic framework for relationship quality in construction projects then modifications are implemented and corresponding constructs are driven for two different construction cases. This illustrates the variations to the relationship quality's systematic construct as the result of the changing contract conditions and built environment. The driven variable systematic construct for relationship quality may provide an assessment tool for evaluating the relationships created by contracting procedures in different built environments. Through examining system reliability theories a fault tree is derived for the systematic framework of relationship quality. Possible combinations of components, causes and events for the two mentioned construction project cases are illustrated through Fault Tree Analysis. The fault tree analysis primarily indicates the combination of events leading to relationship deterioration and also provides a monitoring tool for relationship quality in different circumstances, the ability to have such indications about

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relationship quality may help increase performance alongside stirring sustainable procurement.

Keywords: Sustainable Procurement, Relationship Quality, Conflict, Dispute, Fault Tree Analysis

1. Introduction

The complex, fragmented and adversarial nature of the construction industry which involves different specialized parties is mounting more and more conflicts and tensions between the interests of different parties every day. Several major industry reports have pointed out that the construction industry is filled with many shortcomings which are hindering the realization of the industries full potential, making it a bulky, inefficient and dispute prone industry over-consuming vital and precious resources of nations. Some of these problems are seen partially as the consequence of inadequate, traditional and faulty procurement systems, In fact complications encountered throughout most of the construction projects delivery process has triggered a new collaborative and relational perspectives on procurement of such projects. A report by the Construction Review Committee of Hong Kong (CIRC, 2001) states that construction costs are high and the industry is very fragmented and beset with adversarial culture, this is setting the scene for confrontation instead of collaboration. Another big problem associated with the construction industry is the cost over value approach in tendering, there is a tendency to award contracts to the lowest bidders and delivery programmes are often unrealistically compressed (CIRC, 2001). Cox and Thompson (1997) stated that traditional contracts have been compounded by drives of 'Value for Money' where through competitive tender the works are procured to the lowest-price offered with little or no guarantee (or even incentive) of future work. They regarded the focus on relationships as short-term (for the duration of the project) with both parties attempting to lever what they can out of the existing contract resulting into opportunistic and adversarial arms-length relations rather than working collaboratively together. Wolstenholme (2009) also addressed the fact that most client business models are focused on short-term gains and do not reward suppliers who can deliver long-term sustainable solutions.

High risks and blame culture with unequal risk allocation is also another concerning aspect of the industry(CIRC, 2001; Egan, 1998), hence Wolstenholme (2009) boldly claims “Scratch beneath the surface and you find many so-called partners still seek to avoid or exploit risk to maximise their own profits, rather than find ways to share risk and collaborate genuinely so that all can profit”. Separation of design and construction or poor communication leading to low constructability, undermined accountability by prevalence of non-value adding multi-layered subcontracting and lax supervision, Labour sensitive and inadequately trained workforce, Health and safety issues alongside the dangerous and polluting nature of the construction industry are other problems which have been raised in reports and research works(Construction Industry Review Committee, 2001; Dozzi, Hartman, Tidsbury, & Ashrafi, 1996; Egan, 1998; Latham, 1994; New Zealand Construction Industry Council, 2006; Wolstenholme, 2009).

2. The need for sustainable procurement in construction

The need for change mentioned in many construction industry reports brought about a general realization and consensus that the current code of conduct and traditional procurement strategies accustomed with the construction industry are to a large extent responsible for the existing fragmented and adversarial work environment leading to major unwelcomed conflict, disputes, defects and underperformances in the industry (Love et al., 2002). Wolstenholme (2009) described the industry still as a fragmented industry which could lead to a poor quality product and danger of adversarial relationships within project teams. This adversarial culture and confrontation will almost certainly trigger disputes and conflicts between participants and within project teams. Project dispute is inevitable on construction sites threatening the long-term relationship of project team members (Barnett, 1997), dispute can be regarded as a crisis in every construction project which may damage contracting relations resulting in lengthy program delay and shortage of funding if not handled adequately (Humphreys, Matthews, & Kumaraswamy, 2003).

An important driver of change mentioned in Egan's (1998) report is integrated processes and teams in addition there are suggestions that the best practice guidelines for procurement strategies is to have clients, consultants, contractors and suppliers work together towards improving quality, reduction of costs, decrease disputes and conflict, bringing innovation, sharing the risks and a more effective delivery of project. Accordingly Latham (1994) and Egan (1998) have triggered a partnering movement in the construction industry however the mainstream thinking of the construction industry is believed to be short term and the challenge is to overcome this project focused perception in the industry and enhancing a more valuable relationship model. The increase in construction industrialization is bringing the realization of long-term relationships to significant importance (Bygballe et al., 2010). Despite appreciation of their advantages there is major underperformance in implementing partnering and long-term relationships (Winch, 2000). Even in New Zealand NZCIC (2006) has revealed procurement practice is suffering from short-term focus on cost over value and lowest bid approach with inappropriate risk allocation in the construction industry. Industry reports insist on a change in procurement towards a more sustainable procurement and contracting arrangement.

3. The relational approach and Relationship quality

In order to move towards a more relationship preserving and sustainable procurement construction industry there was a need for observing the relationship status. The monitoring and observation of relationships should provide indications on the state of the relationships throughout the projects or even after projects completion. A good and consistent monitoring tool should be able to spot the weakness of the relationships and also indicate if the relationship is fit for retaining. Monitoring relationships is perhaps the first step of moving towards relational contracting and procurement approaches resulting in more collaboration and long-term relationships striving towards the ultimate goal of sustainable procurement.

Relationship quality is a concept developed for relational marketing purposes for the broad marketing objective of customer retention. This concept was introduced and defined in many different ways, however the general consensus regards relationship quality as a high order construct with antecedents and outcomes.

4. The Systematic layers and timeline of Relationship Quality

Based on the fact that relational contracting and collaboration in construction maybe fundamentally similar to customer retention and keeping healthy business relationships with the customer in the market environment Jelodar & Yiu (2012b) have proposed a systematic framework of layers for relationship quality in construction projects. Figure 1 describes the systematic framework of relationship quality in four different variable layers of triggering layer, antecedent layer, moderation layer and the outcome layer plus a constant layer of relationship quality. Conflict and dispute have been regards as the main antecedents of relationship quality in construction as shown in Figure 1, therefore the study of conflict and dispute should follow a systematic and perhaps deductive approach based on events their precedents and outcomes exhibited on the timeline of project procurement or even after project execution in cases of prolonged and resource consuming dispute episodes exceeding beyond the project lifecycle.

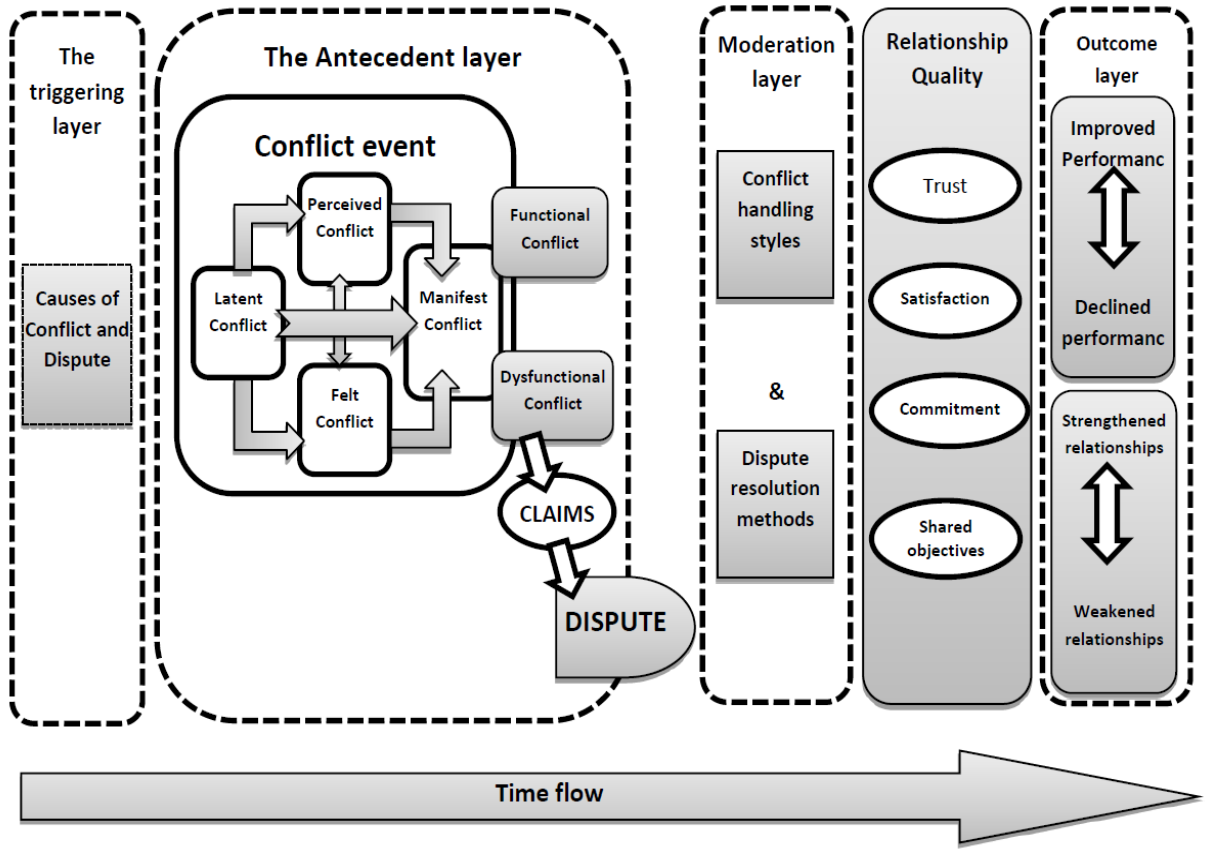

Figure 1: The general systematic framework of relationship quality for construction

Basic events which can trigger changes in relationship quality indicate that the triggering layer may influence both the antecedent layer and also the relationship quality. The antecedent layer is a complex layer containing the conflict process model and dispute. Each component of this process model can affect measures of relationship quality (trust satisfaction, commitment and shared objectives) it is notable that the antecedent layer may have diverse effects on relationship quality. The next layer is the moderation layer which in

this case comprises of components that are used to manage conflicts and disputes. They can cause changes in relationship quality. Contrary to the previous layers the final layer which is the outcome layer is influenced by the relationship quality.

On the other hand Jelodar & Yiu (2012a) have developed a timeline approach in evaluating relationships via the above proposed framework. In this approach the bench mark relationship quality is observed based on its simple derived feature or measures at the start of the project and the variation of these measures are observed after the occurrence of different incidents in each consecutive layer or even in the same layer. For instance the features of relationship quality can be evaluated after events of the triggering layer which are generally the causes of conflict and dispute, bearing in mind that one cause or several causes can happen in the same or different points in time. The same goes for all the other events in the antecedent and the moderation layer. The events of the first three layers may affect the relationship quality and also the outcome layer.

5. Different compositions of Relationship quality

Based on the above elaborated systematic framework different unique relationship quality models can be drawn for each different construction project. The events of the first three layers of the framework are variable and a function of the project conditions and incidents, whereas the relationship quality layer is constant throughout different projects and explains the features and measures of relationship quality. In this section two cases are used to illustrate the different compositions of the relationship quality and the associated models.

Case one; in this case project type is expansion of a countryside road to a national highway going through privately owned lands. Contract condition design bid built lump sum and follows the FIDIC conditions of contract (red book). In these contracts dispute resolution procedure starts with Dispute Adjudication Board (DAB) then amicable settlement and the last resort is arbitration.

For this project any cause can occur and trigger conflict or dispute; however some causes according to the conditions of the project may be more probable to occur. For instance part of the governments and the client organization's responsibility is to free all the lands for the course of the high way and also control the existing traffic on the countryside road, if the client or the government fails to do so this may mean late availability of site and limitations in access which are project and uncertainty related causes. Other causes may also happen for instance from time constraints under the FIDIC contract, disputes may arise which are more contract and process related or even poor communication could trigger conflict because the contract is rather fragmented into design-bid-built procedures. Thus some causes are more probable then others as illustrated in the layered system drawn for case one (Figure 2).

For the antecedent layer there is a probability of occurrence for functional and dysfunctional conflicts as well as claims and disputes. But as far as the moderation layer is concerned the contract has previously defined means of conflict management and dispute resolution. The events of this layer are either in the form of Dispute Adjudication Board (DAB), amicable settlement or arbitration. However amicable settlement itself may be obtained through a

variety of different methods (direct negotiation, the engineers recommendation, mediation and conciliation)(Totterdill, 2006); which may impact the relationship quality differently. In this model the first three layers are able to first affect the relationship quality and also their consecutive layer. The events in each layer may or may not occur or on the other hand even several loops of the these events may occur each time triggering different conflicts or dispute simply meaning that different causes may trigger different conflict and dispute events at the same time or in different points of time for the projects. The relationship quality layer consists of the measures drawn from previous studies that will best describe relationship quality (Jelodar & Yiu, 2012b).

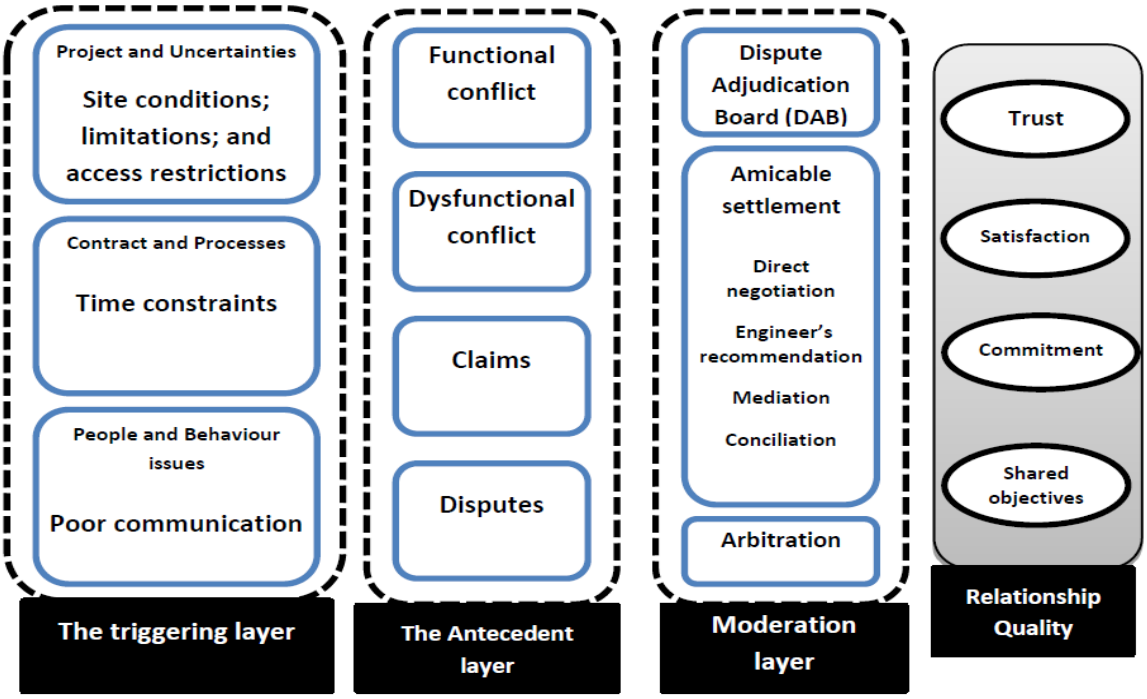

Figure 2: systematic framework for case one

Case two; the project type is the construction of a multi-storey commercial and shopping centre with contemporary architectural design in New Zealand. Contract conditions are design built measurement by bills of quantity, the contract is based on the NZS 3910:2003 domestic contract. The proposed dispute resolution procedure of this contract starts with engineer review, then mediation if not settled, through dispute tribunal or arbitration.

Although like the previous case any cause of conflict and dispute may occur some causes are more likely to occur according to the nature of the project, such as technical problems due to complexity of design and construction, design errors, ambiguities and change orders, lack of experience with the type of work performed. Again for the antecedent layer the probability of occurrence for functional and dysfunctional conflicts as well as claims and disputes exists. However the contract condition determines the dispute resolution process by the previously mentioned four steps which is completely different with the conditions mentioned in the previous contract. A similar systematic illustration is drawn for this case which is quite different with case one's systematic illustration (Figure 3). The systematic

approach allows the practitioners to draw their unique system based on the events that are most likely to happen in their unique projects. This allows the evaluation of relationship quality easier through each step of the project because most the events that may influence relationship quality are indicated in the corresponding layer.

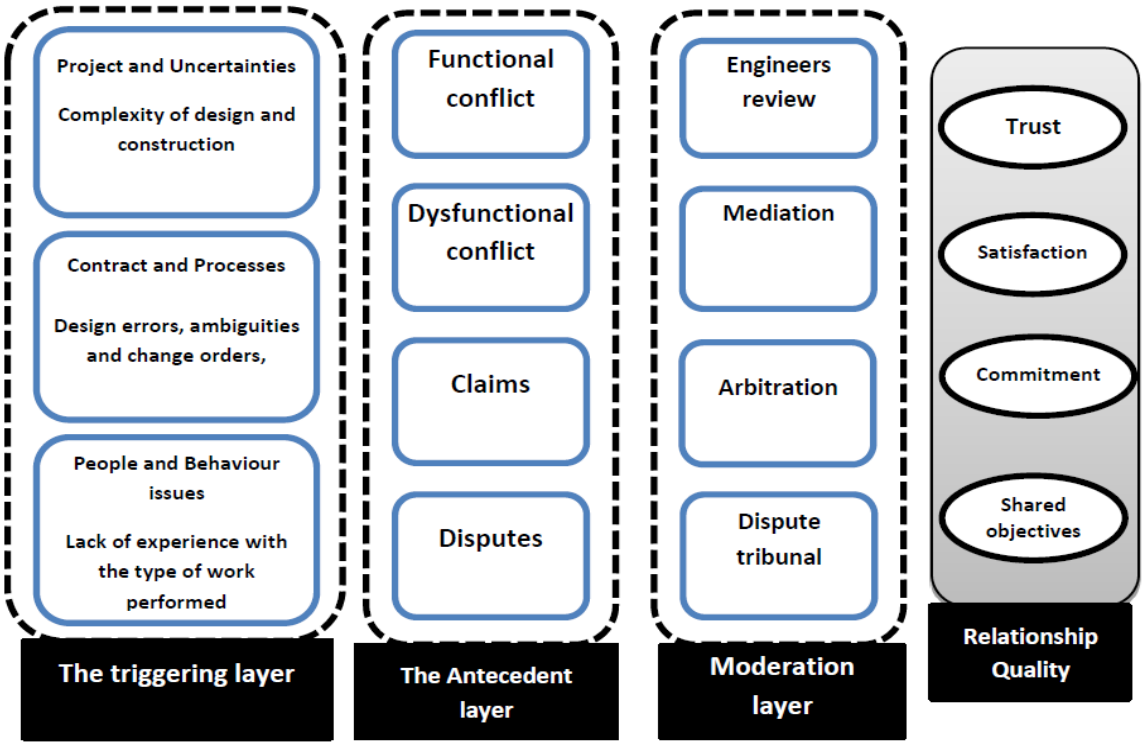

Figure 3: systematic framework for case two

6. Failure models of relationship quality via applying system Reliability theories

After establishing the systematic framework of relationship quality for each project the relationship quality of construction parties are regarded as a dynamic system which may be influenced by a number of layer and their incorporated events. The failure of this system simply means the failure of the system components such as conflict management and dispute resolution strategies in balancing out causes of conflict and dispute consequently diminished relationship quality of the parties. System failure models such as Fault Tree Analysis can be used to evaluate the possible failure of the system according to the components derived for each project discussed in the previous section. Rausand & Høyland (1994) defined the fault tree as “a logic diagram that displays the interrelationships between a potential critical event (accident) in a system and the causes for this event”. The fault tree can be either qualitative or quantitative and normally aims to; list the possible combinations of factors, errors, events, and component failures that may result in a critical event in the system. The Fault Tree Analysis (FTA) also helps to identify the probability that a critical event will occur during a specified time interval. In drawing the fault tree the top event is normally the system failure notion. Because the aim is to use FTA to evaluate the

relationship failure as a system fault in construction projects the top event is deterioration of relationship quality. Based on this top event and the systematic framework derived for each case the fault tree of each project is extracted. In this section the fault trees related to the previous mentioned cases are derived and illustrated in Figure 4.

In both cases conflict and dispute systematically will contribute to the deterioration of relationship quality, therefore all the possible causes of conflict and dispute should be included in the fault tree. The first step in developing the tree is to understand how relationships my fail, as illustrated in the systematic framework the triggering layer will start conflict and disputes which in most cases will adversely affect the relationship quality except for cases where they lead to functional conflict. On the other hand the moderation layer will try to moderate this negative effect by applying conflict management and dispute resolution strategies, if this endeavour is unsuccessful then failure of relationship may occur. Consequently for the relationship to deteriorate a dispute or adversarial event is needed and the problem must go unresolved that is why these events are linked and demonstrated in Figure 4 via an “and” gate to the top event. Figure 4 also shows that conflicts either directly arise from causes or from contract provisions, in addition disputes are linked with conflicts or unaccepted claims. The conditions of contract will dictate how the adversarial event, dispute or problem should be resolved as demonstrated in Figure 4 the two cases have a totally different conflict management and dispute resolution strategy. In case one the focused is basically on more informal and more effective dispute resolution methods whereas in case two although mediation is mentioned but ultimately the dispute tribunal may get involved which is devastating for relationships among the parties.

Another issue with the fault tree model in figure 4 is that some events and especially causes of conflict and dispute are more likely to occur in different conditions of contract. As discussed before for case one late availability of site, limitations in access, time constraints, and poor communication are more probable to occur based on the nature of the contract. The FTA model illustrates the possible combination of causes and events that may lead to relationship deterioration in construction projects. Furthermore if the probabilities associated with each cause and event of the fault tree is obtained the ultimate probability of the system failure in this case relationship quality deterioration for different types of projects and various contract conditions could be obtained.

7. Conclusion

Moving towards a more relational contracting and working environment seems to have become the main theme of a lot of industry reports. The construction industry needs to make amends and move towards a more sustainable procurement procedure this is to prohibit the extensive loss of money and resources. A systematic framework for relationship quality has been developed in order to evaluate and provide indications on the working relationships of contracting parties in construction. It was shown that the current systematic frame work is an indication of the relationship quality system not a generalized structure which could fit all project types nonetheless a construct unique to each structure can be drawn which was demonstrated by two construction project cases. In these cases the probability for the occurrence of certain causes of conflict and dispute as part of the triggering layer will change

due to the project type. It was also demonstrated that the conditions of contract can have a defining effect on the moderation layer of the systematic framework by identifying the procedures of conflict management and dispute resolution in their content. Consequently it can be said that the type of project, contracting arrangement and build environment culture usually determines the systematic framework of relationship quality for different projects.

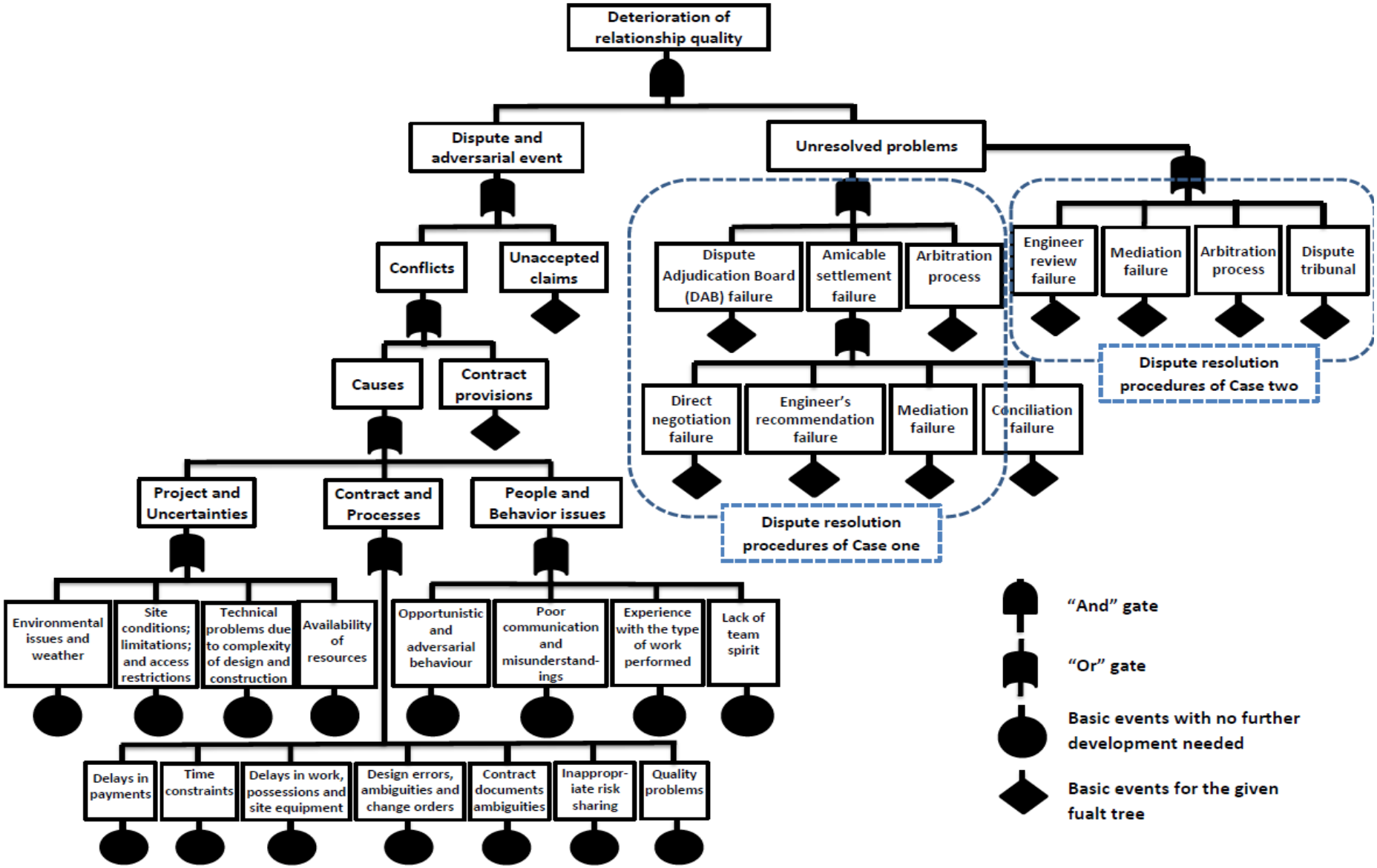

Figure 4: Fault Tree Analysis of the relationship quality system in construction

Based on the identified systematic framework for relationship quality a Fault Tree Analysis can be performed to shows all the possible combinations of components, causes and events for any construction project. This was illustrated by developing the fault tree of the previous mentioned cases. This Fault Tree Analysis first of all may indicate the combination of events leading to relationship deterioration and also a monitoring tool for relationship quality in different circumstances, the ability to have such indications about relationship quality failure may help increase performance alongside stirring sustainable procurement. The basic idea is to find out what possible circumstances and events may lead to relationship failure or deterioration and either take preventive actions or amendments to keep and maintain relationships in favour of sustainability in contracting and procurement. In cases were the relationship is deteriorating or not beneficial it can be cut saving both sides a lot money resources and hassle.

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The Challenge: Teaching Accounting Concepts to Students of the Built Environment

Hera Antoniades[1]

Abstract

Accounting Concepts are considered crucial for the successful operation of any business or profession. Therefore, many undergraduate degrees include an individual subject for accounting. Consequently, lecturers are faced with the daunting task to teach accounting to non-accounting students, usually within a short space of time, and yet with the expectation that the students will immediately grasp all the key concepts and adequately maintain books and records to comply with relevant Accounting Standards.

The purpose of the research paper is to ascertain the effectiveness of different teaching styles for students in the built environment. The research methodology in this paper analyses results from four groups of students, over two years, who were enrolled in property and or construction undergraduate degrees. The undergraduate degrees comprised of one shared accounting subject which was taught over one semester. Two groups of students (Groups A and D) were taught with a "modified" approach towards accounting "language", with integrated examples relating purely to the built environment, and the other two groups (Groups B and C) were taught with the traditional accounting language found in an accounting degree and with the use of examples relating to a variety of industries, but not including the built environment.

The results indicate a superior learning outcome, outstanding results, and a higher pass rate for groups A and D.

KEYWORDS: Accounting, Built Environment, Case Studies, Education

1. Introduction

Accounting concepts are considered a critical aspect of the knowledge fields which complement good management and business skills, and are also considered crucial for the successful operation of any business or profession. Consequently, the Built Environment has experienced a demand for business subjects, with many undergraduate degrees including a subject for accounting. As a result, lecturers are faced with the daunting task to teach accounting to non-accounting students, usually within a short space of time, and yet

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with the expectation that the students will immediately grasp all the key concepts and adequately maintain books and records to comply with relevant Accounting Standards.

Traditionally, accounting subjects are assessed via an assortment of quizzes, class tests and formal exams. This method of assessment can be viewed as being inflexible and does not offer the student the opportunity to develop "problem solving skills". Similarly the lecture style of teaching followed by tutorial classes might be considered too rigid with an emphasis on the mathematical calculations as a key component of the learning objectives, rather than embedding theoretical structures as a desired knowledge field. In addition, the traditional accounting language found in an accounting degree with mathematical examples relating to various industries such as retail and manufacturing, are not relevant to the property and construction disciplines. Ideally, accounting language and examples applied to the Built Environment would offer a practical and meaningful application for students to grasp the core elements and application of accounting and good business management skills.

The purpose of the research paper is to ascertain the effectiveness of different teaching styles for students in the built environment. The first section of the paper commences with a discussion on the literature for teaching accounting in the accounting and non-accounting disciplines, and the various best practice approaches applied within these disciplines. The discussion is complemented with data and an analysis of the assessment results relevant to the selected groups of students enrolled in property and undergraduate degrees. The pass rate results from these four groups are compared, and the paper concludes with an overview of the effectiveness of the different teaching styles.

2. Literature Review

There is vast literature in accounting education journals, which acknowledges the need to improve student interaction and learning outcomes within the disciplines of accounting. In contrast there is minimal literature published with regards to teaching accounting to non-accounting students. Research undertaken in this field, has acknowledged the difficulty and restrictions in teaching accounting subjects and Lloyd and Abbey (2009) were of the opinion that a "central recurring theme in business education is the optimal strategy for improving introductory accounting" (pp23) followed by a desire to engage in active learning processes to maintain the students interest.

During the 1990s, faculty members who taught accounting to accounting students were surveyed, and the results indicated that lectures were the most favoured style of teaching followed by the seminar/tutorial format (Brown and Guilding, 1993). A criticism of this trend was the observation that students "are not being encouraged to exercise and express independant thought". This notion was also earlier reiterated by Dent 1986, Richardson 1988, Subotnik 1991. In addition, the importance of communication skills was highlighted by Zaid, Abraham (1994), where it was observed that accounting graduates were lacking in the written report style required to disseminate information to their clients.

Other suggestions during the following years included the need to set goals and objectives for the students to master, and for the lecturer to provide immediate feedback of

assessments to the students. (Borja 2003). The specific accounting language was also highlighted as an issue, and sometimes viewed by students as a "foreign" language. Borja (2003) also recommended that at the beginning of each class, a review be undertaken of the accounting vocabulary discussed previously to assist the students with increasing their comprehension level. Other considerations included the introduction of role play simulation to engage students interest and learning (Beardean 2004), and the development of "analytical thinking, decision making, and communication" skills (Francisco et.al. 2003). A comparison of teaching styles by Leveson (2004) concluded that the quality of teaching could be improved with technical and procedural information, with the addition of providing the student with a conceptual process of accounting which contained clearly specified learning objectives. A similar observation was noted by Buckhaults and Fisher (2011), who identified students learning and interest could increase if the lecturers were more familiar with the course material!

The introduction of technology has also seen a new approach to teaching many subjects and accounting is no exception. Can et al (2012) evaluated the effectiveness of conducting accounting lectures with the use of power point presentations and concluded that students who were taught via the blackboard gained a deeper understanding of the subject if this was integrated with the use of the application of the subject. However, Holtzblatt and Tschakert (2011) favoured the use of digital technology for accounting students to increase student motivation and fully engage student learning. Potter and Johnston (2006) explored the application of interactive on-line learning systems and noted a positive association with exam performance. Therefore, over the years, research indicates a need to improve the teaching style of lecturers, who teach accounting within the business discipline; for that reason, of tremendous challenge is the concept of teaching an accounting subject to students of the built environment, i.e. teaching accounting to non-accounting students.

So the question arises on how we can improve the teaching delivery to maintain adequate interest and engagement with the built environment students, and simultaneously achieve the desired learning outcomes and pass class tests and exams. As mentioned earlier in the literature review, research has focused on teaching accounting to the business accounting discipline, with very little research undertaken for teaching accounting to non-accountants, and in particular within the Built Environment.

In the wider context, it is generally accepted that accounting has numerous capabilities and end results. For instance, a criticism of the accounting discipline is the perception of the "rules-based procedural approach" (Lucas 2002), with little emphasis on the macro issues which underpin the conceptual understanding of the accounting principles. This imbalance of micro and macro accounting was also noted by Boyce (2004) who observed students were readily able to perform the technical calculations only. Therefore, it could be assumed, that students from the Built Environment, would benefit from selective examples inclusive of property and construction themes, instead of retail and manufacturing. This suggestion of applying accounting skills to related topics in their undergraduate degree, would greatly enhance the students' practical application of accounting and position the subject in the context of real-life examples, and provide a more meaningful outcome for the students.

The enhancement of student learning can be analysed with different approaches. For instance, Curtis (2011) suggested the introduction of formative assessment, whilst Frakes and Lathen (1985) analysed the difference in the exam mark when students were tested with the use of multiple choice-equations or problem based questions, and concluded that there were no significant differences with the score but did note however there would be limited grade variation with multiple choice questions. This observation could suggest that multiple choice assessments can provide the student with a higher opportunity of selecting/guessing the correct response to the question!

Historically, accounting education research favours a variety of teaching styles, such as innovative problem solving (Howieson 2003, Stanley & Marsden 2012) and integrated case studies (Kolb et al 1986). Case studies can improve a student's ability to identify problems and develop a rational constructive approach to aid the research of the relevant issues. The student needs to be engaged and stimulated and particularly with accounting, this can be very challenging for the lecturer! It is also important to align the student with a connection of the accounting topics to their field of discipline, such as the Built Environment. As mentioned in the earlier section of the literature review this approach is also favoured by Lloyd and Abbey (2009)

Other considerations which are noteworthy, includes student preferences for class handouts to supplement information (Farrelly & Hudson 1985); and problem solving, lecture/discussion format for classes (Smith & Usry 1989) which were relatively unchanged during the preceding 25 years. Additionally, Inglis et al (1993) compared an intensive summer-school in seminar format, with the traditional weekly lecture and tutorial format and concluded students in the intensive format had higher grades and a greater knowledge of retention of the information, even 2 years after the subject had been taught. Also, Lucas (2000) identified the importance for students to "recognise the different contexts in which accounting is used and the different terminologies". Furthermore, Thomas and Bebbington (2004) noted that it was important to consider "what" we teach and "how" we teach, and Kowalcz (2001), concluded that students were provided with a "richer contextual environment" by the introduction of case studies relevant to the students' field of study.

Therefore, It is interesting to note that the detail and contents of the case study plays an important role with the student's involvement and enthusiasm. In conclusion, if the accounting examples and the accounting terminology were adapted to the Built Environment, this would have a more meaningful learning outcome for the students, as opposed to learning how to manage a pharmaceutical retail business.

Ideally, short answer problems and questions, to demonstrate the application of accounting concepts in the initial stages of the subject, lays the conceptual foundation of knowledge for the students (Dockter 2010). The student would then progress to more complex problems with the assistance and guidance of their lecturer through on-going interaction and online support. At this stage the lecturer could attempt to engage the student in case studies which were more relevant to their discipline. This was further reiterated by Lehman (2001), who also considered it was necessary to "make the learning process challenging" and suggested

the use of the role play approach, with a case study, as an activity to stimulate and engage the student's interest and learning.

So whilst literature acknowledges the introduction of case studies, and integrated examples relevant to the discipline of study, which provides the student with the opportunity to engage in complex problem solving skills, the question arises as to why this mode of teaching is not more widely adopted when teaching accounting to non-accountants? There are a number of possible answers, such as the specialised knowledge of the lecturers in that subject, the lecturer's level of experience in teaching, their ability to modify the students learning experience, different learning styles and students' special requirements can all contribute to the final decision of how a subject will be delivered and taught. Interestingly, Buckhaults and Fisher (2011), stated that it was necessary for the lecturer to have a complete understanding of the material relevant to the subject and to keep introducing new methods of teaching to make the subject interesting. Therefore, this is an important link between the lecturer's depth of knowledge and the ability to prepare a challenging case study for the students to research.

In conclusion, the literature reviewed in this research paper has identified the need to modify accounting subjects taught to accounting and non-accounting students, so as to demonstrate the relevance of the accounting theories and concepts, to the discipline selected by the student.

3. Research Method and Limitations

The research methodology in this paper analyses results from four groups of students, over two years, who were enrolled in property and or construction undergraduate degrees. The undergraduate degree comprised of one shared accounting subject which was taught over one semester. Two groups of students (Groups A and D) were taught with integrated examples relating purely to the built environment, and with a modified approach to accounting "language". For example, the accounting term *"inventory"* was substituted with the equivalent term commonly known in construction as *"materials".*

The other two groups (Groups B and C) were taught with the traditional accounting language found in an accounting degree and with the inclusion of examples relating to a variety of industries, such as retail and manufacturing, but did not include the Built Environment.

The purpose of the research paper was to ascertain the effectiveness of different teaching styles for students in the built environment. These teaching styles included problem solving skills relating to case studies, modification of accounting language and the integrated examples which related to the built environment and other unassociated industries. All four groups of students were assessed using an identical mix method of quizzes, class tests and a formal exam. All assessments had similar weighting for each topic in the accounting subject. A matrix which identifies the assessment criteria, plus data relating to class sizes and exam results is also provided to support the conclusions in this research. All groups participated in workshop/tutorial classes; additionally, all four groups were provided with on-line tutorial questions and answers.

4. Discussion and Analysis

As discussed earlier in the paper, teaching accounting principles to non-accounting students can be very challenging. Particularly when the elementary concepts must be grasped first before more complex problems are considered. However, it is crucial that learning outcomes and the delivery of these topics are within an acceptable learning environment framework, with academic rigour maintained.

The four groups of students discussed in this research, were from either the Property or Construction Project Management undergraduate degrees within the discipline of the Built Environment. The accounting subject was a compulsory shared subject for both undergraduate degrees with a couple of students from either Architecture or Design selecting the subject as an elective.

Table 1 below, identifies the group of students analysed. Each cohort is listed with the relevant method of assessment and teaching delivery. In particular Groups A and D were primarily taught with the use of a white board, as opposed to Groups B and C who were taught with the aid of power point presentations.

TABLE 1: COHORT GROUPS – IDENTIFIED AS GROUPS A, B, C, D,

GROUP A – Application to the Built Environment	GROUP B – Application as an accounting discipline	GROUP C – Application as an accounting discipline	GROUP D – Application to the Built Environment
Quizzes	Quizzes	Quizzes	Quizzes
Class Test	Class Test	Class Test	Class Test
Formal Exam	Formal Exam	Formal Exam	Formal Exam
Weekly Lecture/Tutorial	Weekly Lecture/Tutorial	Weekly Lecture/Tutorial	Weekly Lecture/Tutorial
On Line Tutorials	On Line Tutorials	On Line Tutorials	On Line Tutorials
Built Environment examples	No Built Environment examples	No Built Environment examples	Built Environment examples
Modified language	Accounting language	Accounting language	Modified language
No Power Point	Power Point	Power Point	No Power Point
Weekly Lesson Overview	None	None	Weekly Lesson Overview

The analysis above in Table 1, provides a snap shot of the assessment and teaching delivery for the four groups of students. Furthermore, all groups of students were assessed using the identical assessment matrix which appears below in table 2:

TABLE 2: MARKING CRITERIA FOR THE ACCOUNTING SUBJECT

CRITERIA FOR ASSESSMENT	WEIGHTING
Application of accounting theory	25%
Application of business decisions skills	25%

Mathematical calculations - process	40%
Creative thinking - alternative solutions	10%
	100%

The marking criteria deliberately removed the focus from the mathematical aspect, in an attempt to draw out the students' ability to use theoretical concepts to solve problems and to develop high-quality business making decision skills. Whilst the accuracy of the mathematical component is important, there is also the acknowledgement that computer programs and software such as excel can provide support for the student in the area of mathematical knowledge; hence, in Table 2 above, the allocation of 40% marks were primarily driven towards the accuracy of the "correct technical process" for the calculation.

The examples and problems selected for groups A and D, were specifically relevant to the Built Environment industry and inter-related with their other core subjects in their discipline. Additionally the students were introduced to the accounting language systematically with weekly review and examples of the application of the terminology relevant to the Built Environment. During class time, all groups of students practiced their accounting and decision making skills with small case studies, and were taught to break down the various key components and to consider the application of various possible solutions to solve the case studies presented in the class exercises. This required the students to use both analytical and critical thinking skills. The students were given the option to work individually or with another student, and were able to practice small style case studies as a follow-up with the online tutorial questions made available throughout the semester.

After the first half of the semester, the students were encouraged to develop their research skills in combination with their accounting and decision making skills. This approach allowed the student to individually develop answers to intricate case studies and check their answers progressively against the on-line tutorial sessions, which provided a suggested solution. However, as mentioned earlier in the paper, only Groups A and D were using specific examples relating to the Built Environment, and furthermore Groups A and D, were provided with a modified approach to accounting language and during each lecture/workshop, these two groups, were given the opportunity to assimilate the accounting language in context with the Built Environment. In contrast Groups B and C, used primarily non Built Environment examples, and were taught in the mode of teaching accounting within the accounting discipline. All assessments for the four groups, contained a similar weighting for each topic in the accounting subject.

This diversity of case studies, lectures and workshops, and online tutorials, gave students the opportunity to develop and learn at their own pace and seek assistance as required. This forced the students to participate in active learning and take responsibility for their progress with their studies for this subject. By providing the solution to each of the exercises and case studies progressively, the students were able to evaluate their own answers, critically reflect and finally compare their written answers with the final solution. This also improved the students' critical thinking skills and written communication which was measured by using the same matrix for all groups of students. For example, in some cases there were different possible solutions to the complex problems and the students were

assessed on their ability to think outside the “square box”. It was important to integrate their skills though out this subject so there could be a meaningful outcome.

Below, in Table 3, are the final results achieved within the different groups. These groups were assessed using the same assessment matrix as identified in Table 2, earlier in this paper. Students who did not attempt any assessments for this subject, and discontinued attendance were removed from the analysis. There could be varying reasons for not continuing with the subject, ranging from work commitments which caused the student to have no time to attend class, or perhaps a heavy study load and not being able to keep up with the class work.

Table 3: RESULTS FOR ALL GROUPS

GROUPS	DETAILS	NO. OF STUDENTS	Students not continuing	Mark under 50	Mark over 50	Percentage Failed	Percentage Passed
GROUP A	Undergraduate Autumn 2010	83	7	14	69	9.21%	90.79%
GROUP B	Undergraduate Autumn 2011	69	5	16	53	17.19%	82.81%
GROUP C	Undergraduate Spring 2011	63	1	21	42	32.26%	67.74%
GROUP D	Undergraduate Autumn 2012	44	0	2	42	4.55%	95.45%

The identical assessment matrix listed in Table 2 was used to assess the results for all 4 groups. Therefore, Table 3 analysis indicates that Groups A and D had a higher pass rate in comparison to Groups B and C. For instance, the pass rate for Groups A and D was 90.79% and 95.45% respectively, whilst Groups B and C recorded 82.81% and 67.74% respectively. Further analysis of the results indicated that Groups A and D achieved a better learning outcome experience with 39.47% and 47.73% of the class achieving a score of 75 and above, whilst with Groups B and C, 21.88% and 9.68% of the class achieved a score of 75 and above.

In conclusion, the results from the analysis indicates that teaching accounting concepts with Built Environment examples, and a modification of the accounting language, provides the student with an opportunity to improve their performance and enhance their learning outcome.

5. Conclusion

Teaching an accounting subject, within the discipline of the Built Environment, does not provide the student with sufficient exposure to comprehend the accounting concepts and their relevance within the organisational aspects of various industries. However, the integration of specific examples in the appropriate context, and the application of modified accounting language, gives the students the opportunity to understand and comprehend the accounting concepts as applied to the students’ core discipline.

This is evidenced with the analysis discussed earlier in the paper, where Table 3 indicated a superior learning outcome and a higher pass rate for Groups A and D who were taught within these prescribed methods. The discussion within the literature review also highlighted

the issues faced by the accounting disciplines, in particular the technical and procedural processes were equally important as the application of the conceptual theories. This is evidenced with the disparity of results between Groups A and D who had superior learning outcomes in comparison to Groups B and C who did not apply accounting concepts to their discipline and therefore were unable to conceptualise many of the core accounting concepts.

In conclusion, the selected students of the Built Environment achieved a superior learning outcome, with outstanding results, and a higher pass rate when the accounting theories and concepts were integrated with examples from their core discipline.

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Strategy workshops: The fusing of the past and the future in the present

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Abstract

This paper draws on empirical data from a longitudinal study of strategy management in a large Swedish construction company. We examine strategy-in-the-making at the micro level of discursive practice during a two-day strategy workshop with middle managers. We show how strategic sense-making is achieved through creating a coherent link between past and future, staged as a rehearsal in the present. This collective, informal strategising rehearsal provides middle managers with a liminal space, time and mediating tools to make sense of and appropriate the information and knowledge embedded in new strategies. We suggest that by conceptualising strategy workshops as ritual backstage rehearsals of future actions, managers may enhance the success of the intended strategy outcomes. Studying strategy-in-the-making at the micro-level contributes understanding of how actors avail themselves of institutional practices and mediating tools to construct meaning.

Keywords: liminal space, rehearsal, ritual, strategy workshop, time

1. Introduction

Studying processes and practices at the micro-level provides insight into how people use institutionally established practices to construct meaning and relate to each other over time (e.g. Bakhtin 1986; Harré and van Langenhove 1999; Pearce 2007; Räisänen 2002; Räisänen & Linde 2004). Studying the unfolding of an institutional practice such as a strategic workshop at the micro-level can help us understand how an organisation's "forelife" (Räisänen et al 2011) and the anticipated outcomes or "afterlife" (Pearce 2007) of the practice influence the enactment of that practice. In other words, what impacts do an organisation's past history and its strategic vision and goals have on the present planning and implementation of an event such as a strategy workshop. Paying attention to strategy-in-the-making at the micro level can provide us with a possibility of tracing acts that may or may not result in strategic actions in the future.

The perspective adopted in this paper draws on the broad and philosophical views of Bahktin (1984, 1986), who sees discursive practices as composed of utterances in continuous interplay, responding to past utterances and anticipating future ones. In this interplay, individuals construct their tacit knowledge of the "multifaceted and multi-voiced

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realities situated in culture" (Markova et al 2005), and in time. Thus discursive practices are sense-making practices in a socio-cultural space which have various temporal relations to other practices in other times – past and future, and where coordination of perspectives and voices are crucial dimensions for their uptake.

Insufficient attention in the strategy literature has so far been paid to the dialogic unfolding of organisational meaning making and its dialectic relationships to past discourses and actions and to potential future ones. Chia and Rasche (2010: 35) have recently critiqued much of the current strategy research as belonging to a "means-ends logic" where action is seen as a result of the meanings and intentions of individual actors i.e. top managers in the present. They advocate a "dwelling worldview" that accounts for the tacit dimensions of knowledge, i.e. the deployment of *phronetic (practical wisdom)* and *mëtic (know-how)* intelligences in day-to-day strategy practices over a longer duration. Such a worldview needs to consider the immanent, shifting and transient episodes, which, although ephemeral, remain as unconscious impressions wielding influence on ongoing practices. We argue that impressions are dependent on various aspects of time, e.g. timeliness and duration, and dwell in "what is not said", bridging the forelife of a practice to its afterlife. Taking our point of departure in a specific strategy practice, namely a strategy workshop in a construction company, we examine how strategic sense making is mediated through action-based, interactional and contextually interdependent discursive practices that fuse past and future in present interaction.

2. Theory

In our analysis of a strategic workshop, we use the theoretical framing of "strategic episode" (*initiation, termination and conduct*), which enables a systematic and specific analysis of salient organisational phenomena (Henry and Seidl 2003). We also draw on Johnson et al's (2010) model of strategic workshop dynamics, which is based on theories of "ritualisation" (*liminality, communitas and anti-structure*), to describe the performative dynamics of the strategic workshop. Bucher and Ruegg-Sturm (2008), drawing on Henry and Seidl, depict strategic episodes as "protected interruptions" from the day-to-day processes and practices of organising. The protection is provided through the CEO's sanction of the interruption, by the design of participative activities that momentarily suspend hierarchical status, and by fostering collective and open reflection on the organisation's strategic organising. Johnson et al (2010) compare strategic workshops to rituals, where a change of location in combination with a predefined liturgy or script produces a state of *liminality*. The suspension of time and space generates a temporary *anti-structure,* which for the duration of the workshop "flattens" status inequalities. These two affective states create *communitas* or communal commitment, which if strong enough, may work as drivers to carry the insights from the workshop into the daily practices of the organisation.

Another feature closely connected to the conceptualisation of strategy workshops as a ritual performance is Goffman' (1990) conception of impression management. Individuals during rituals perform different identities to manage and/or control the impressions they make on the participants or audience such that, if the performers are successful they exert influence

on the way in which the participants or audience view themselves within the enacted context. Goffman's (1959) analogy of social interaction with dramaturgical performance has been used here to explore the interaction between strategists and strategy followers as they, together, perform the strategy workshop. In social settings, actors, i.e. the strategists, attempt to manage the impressions of organisational members, by enacting the plot and roles expected of or ascribed to the situation and to the intended impression. Through this social interaction, according to Goffman, the audience will usually conspire with the actors thus helping them uphold the interaction and consequently also enable the actors to control the audience's impressions and affective states.

According to the strategy-as-practice literature, intended affective states are easier to create in small homogeneous groups consisting of top managers (e.g. Bucher and Ruegg-Sturm 2008; Johnson et al 2010; Macintosh et al 2010). Creating a meaningful strategic episode capable of generating positive and lasting affect in a large group of employees has, to our knowledge, yet to be reported. This paper contributes rich empirical data and some preliminary findings from the analysis of a two-day strategy workshop for a large and mixed group of middle managers of a construction company.

Data collection and case

The empirical data is part of an on-going longitudinal case study at one of the largest construction companies in Sweden, referred to here as ConstCorp. A case study approach was chosen since the aim was to increase understanding of the unfolding of complex phenomena at the micro level. The data was collected through participative observation of a strategy workshop in November 2007, in which extensive field notes were taken. Interviews were carried out pre and post workshop with several members of the strategic executive staff and with participating middle managers. This is an on-going longitudinal study, and positive allusions to the 2007 strategy workshop are still being voiced in current interviews.

ConstCorp is a well-known large constructor in the Swedish market. Following a period of turbulence, change of CEO and of strategic priorities, the CEO chose an off-site event to communicate the new strategies downstream in the organization. The event was planned by the strategic executive unit, consisting of five closely knit organisation-development experts, and facilitated by the CEO in collaboration with top-management.

The off-site strategy workshop targeted the organisation's middle management, including approx 190 participants, which means that this workshop was much larger than any of the off-site events hitherto reported in the literature. Middle management in this context consisted of managers reponsible for districts, geographically spread throughout the country. Project managers were not included in this group. Answering the call for empirical research concerning the process and practice of off-site events, we found the case a viable point of departure to try and "distinguish the more effective from the less so" (Hendry and Seidl 2003: 192) and to try and identify the factors that implicated success or failure.

3. The unfolding of a strategy workshop practice

3.1. The workshop's forelife

An event does not take place in a vacuum. In order to make sense of what is going on, practitioners and researcher need to tap into other contexts and bring these to bear on their understanding in and of the moment. For us as researchers, it was therefore important to acquire a sense of past events through document analysis and elicited retrospective narratives. To frame the strategy workshop analysis, the forelife spans the five-year period prior to the workshop, when a new CEO made his entry.

This CEO was deeply engaged in fundamental strategic re-organisation, consisting in the centralization of hitherto highly distributed and relatively independent units. His rationale for this change was to enable better use of economies of scale and standardized work processes. A feature of this "new" organization was the development and implementation of a framework for measuring and assessing performance, which included systematic and frequent evaluations of tangible as well as intangible assets. The novelty of the new framework was the importance ascribed to intangible assets such as customer and employee satisfaction. The in-house performance assessment framework and tool had been tailored to align with the existing culture, becoming a part of the repertoire of discursive practices (Orlikowski 2002; Orlikowski and Yates 1994) and values of the organisation, while at the same time generating a "new" integrated performance self-assessment framework (Samuelsson 2006). Thus, although focus on profit prevailed, the way to profit was re-drawn.

One of the prerequisites of the assessment framework was that it would create a virtual representation of the organisation's reality. Thus the organization's performance would be visible and transparent to everyone, triggering motivation for improvement and alignment of the numerous units with the organization's strategies. Another prerequisite was that the framework be simple and constitute an on-going means of "conversation" between the units and top-management.

The CEO's strategic direction was summarised as a motto in the form of a simple linear image depicting a causal chain shaped by four successive arrows directed toward a circle. The motto was that "Sound Leadership" (arrow 1) leads to "Engaged Co-Workers" (arrow 2) leads to "Quality and Efficiency" (arrow 3) leads to "Satisfied Customers" (arrow 4), which culminate in "Predictable Profit" (circle). This image was widely communicated by the CEO personally and by his executive development team and became an internal iconic symbol for the organization: it was used as a starting point for strategy meetings; it figured in the strategic documents; it was used in internal training courses. The arrow image came to function as a boundary object in the organization: specific enough to indicate top management's strategic direction, but plastic enough to allow for local interpretations of actions. The arrow can be seen as a future perfect, linking past and present to emergent future benefits for the organisations (Weick 1996; Pitsis et al 2003).

However, the large number of strategies in place (30) and their abstract formulations made it difficult for managers and operatives to align the performance indicators of the framework with the strategies. Moreover, the operative level, from the district managers and down, were largely excluded from strategic planning and formulation, which resulted in their marginalisation and lack of engagement in strategizing activities. This separation caused numerous mismatches between the intentions of top-level strategists and the strategic outcomes in the projects. As one of the strategists declared: *"The strategies are not formulated for the middle managers, only for top manager".* The rationale for this decision was that top management should filter the strategies down to (their) middle managers, who in turn should do the same to (their) project managers (Samuelsson 2006). It is not so strange that meanings get lost or shift as the strategies pass through the various translation loops on their way from the top to the bottom.

A few years after the advent of the new CEO, he initiated a fundamental review of the strategies, reducing them from 30 to 8 strategies. In addition, awareness of the need to include middle managers in the strategising endeavours to enhance uptake and improve productivity was increasing. This recognition resulted in a two-day off-site workshop to introduce the eight strategies for 2008 to all the middle managers in the organisation and to create engagement and commitment.

3.2 Initiation – planning

The off-site strategy workshop was a familiar practice to all the middle managers, many of whom had attended or carried out similar events with their project managers. The 2007 strategy workshop, however, was intentionally planned as an event that would make a difference; as an event that would be remembered. To achieve such an impression the workshop had to be carefully orchestrated and enacted. For example, the middle managers received an invitation in which the purpose was stated as:

> *Welcome to [event]*
> *Days during which we hope to engage and inspire you.*
> *Get you to contribute with your thoughts and perspectives so that we together more clearly see the picture of the ConstCorp we want to become. [*mentions some of the strategies*]*
> *We are moving in this direction, but are not there as yet. We have a collective job to do, a team effort, and we need your active contribution! When these [*two*] days are over I hope that you will not be able to wait until you are back home to start doing your part in our teamwork.*

This short, receiver-oriented text addressed the middle managers directly and personally (*you)*, highlighting their role as important contributors in a collective (*we*) strategic effort. The signature of the message consisted simply of the CEO's first name in an attempt to decrease the distance between their respective organisational place thus creating an impression of anti-structure, as well as to frame the setting. The tone and format of the invitation was the first distinctive feature that signalled that this workshop event would be different.

Another difference was the duration of the workshop; rather than the usual half to a full day, it would run over two full days. The chosen site was a large modern conference hotel located in a city about mid-distance between the three main company headquarters. The choice of location enacted one of the eight strategies: “To be an environmental builder of society”, since the majority of participants could reach the venue by train, and were encouraged to do so.

Attendance was very high (over 90%), probably because the workshop was counted as work days, and even though it was not explicitly compulsory, participants would have needed to account for non-attendance, e.g. illness, holiday or work trip.

Over the previous four years at ConstCorp, concentration on strategic change using the discursive practices of the performance assessment framework and the regular reviews of client and employee satisfaction, has clearly signalled top management’s intentions and expectations; however, actual use of the framework and tools differed among middle-managers. The current workshop was presented as a rally around a common strategic renewal: a kick-off to a “bright future”. So although the practice of the workshop was a familiar discursive practice, the effort, planning, preparation and execution time and cost spent, and the “mystery” surrounding its preparations raised middle managers’ curiosity and expectations.

The planning of the workshop was done in-house by the CEO and his executive team rather than commissioned to consultants. The CEO himself acted as the main facilitator throughout the workshop aided by the executive team and by top managers. The only outsider was a well-known sports coach who acted as the “comic relief”, facilitating collective reflection and dialogue among participants. The invitation letter sent out prior to the workshop was printed on the first page of a booklet that each participant received in a welcome package.

In the booklet, the organisation’s strategic concerns, its values, business idea, visions and goals were summarised with company-specific familiar cartoons. In addition, each of the eight strategies was elaborated by a one-page explanations: strategy in blue, action points in green. For each strategy, there was a blank page for the participants’ own notes and reflections. The booklet served both as a symbolic and a functional tool signifying that the participants thoughts and contributions were valuable, and more importantly that the inscriptions would travel in time and through space to be at hand for take-up. This of course in the best of worlds; here what is of note is that the notebook, a fairly simple workshop tool, was personalised.

The significant difference between this strategic workshop and similar past workshops was that it was designed and labelled “a journey”. This journey consisted of visits to nine very different “stations”, each representing one of the eight strategies, and one representing global industrialisation within the construction sector.

3.3 Conduct – execution

The workshop was bounded by two plenum sessions of about three hours each: before lunch the first day and after lunch on the second day. The participants were divided into nine groups of about 20 participants according to their area of specialisation, e.g. housing or infrastructure. The nine stations of the journey were each facilitated by top managers relevant to the particular strategy, e.g. for the strategy concerning satisfied employees, the HR top-management team facilitated. Note: The first author, who observed the strategy workshop, joined one of the groups for the duration of the journey. During the plenum sessions, breaks and meals, she mingled with a large number of participants, and the field notes cover the whole workshop.

In the plenum session, participants sat at round tables in front of a large stage. The CEO with his strategic executive team and the sports coach remained on stage for the duration of the sessions. They were dressed casually and used an informal style of address. The CEO started by giving his own, very personal, view of the organisation's trajectory since he took over as CEO; he talked in "I" and "we" terms, always starting with the positive and giving credit to the efforts of the employees. The coach intermittently took over to engage the audience in the conversation by asking them to formulate and share their expectations for the two days.

Presentations by certain top managers concerning critical strategic issues were mixed with the audience reflections on their experiences. Key words were written on a whiteboard, which digitally transferred the text to a computer. Some of the issues middle managers were asked to reflect on collectively were: What has happened in the organisation over the last 60 years? What strategic changes have we managed to successfully implement? What three factors are most important for reaching our goal and vision (after the CEO had presented the eight new strategies)? These reflections evoked the company's long history and set sights for future achievements.

After the plenum and communal lunch, the groups started their journeys through the stations, each station being allotted approx. 45 minutes. The stations had different designs to suit the content as well as proclivities of the facilitators. The executive team and CEO saw the stations as enablers of collective meaning making of the strategies through hands-on demonstrations of the "what", the "why" and the "how". Each station provided middle managers with a platform and tools for querying the strategy and providing feedback to top-management. In a sense, they were able to "see", "feel", "sense" and "hear" the strategy in context. A few had a traditional format of power-point presentation and question-answer session; others used films, computer or paper quizzes, small case studies and demonstrations.

A novelty for this strategy workshop was a strong emphasis on affect, feelings and empathy. One of the eight strategies concerned professional behaviour: employees shall behave professionally in all their endeavours proclaimed the strategy text. The station that took up this strategy focused on inculcating a new construct, namely *empathetic professionalism,* abbreviated and talked about as EP. None of the 19 middle managers in the observed group were familiar with the construct, but after leaving the station, we doubt that the construct

would be forgotten in the first instance. It was presented, defined and described using examples, then the participants worked with three cases. The moderators were careful to emphasise that EP already existed in the organisation; the issue that the participants had to work with was how to make it visible and a part of the organisation's brand.

At all the stations participants were encouraged and given time to make notes in their workshop booklet. They also had to fill in an evaluation form and grade each station on a scale of 1 to 5. The EP station was rated 4.5 by the observed group. The only station that received a 5 was the one on managing projects, which was not only that of most practical relevance to the groups' every-day activities, but also the most dialogic station, where the participants had to solve a problem concerning waste in a real project. At this station an internal development project to enhance project communication was also presented and the middle managers were offered the possibility to participate.

3.4 Termination

The workshop ended with a long plenum session on the second day. The sports coach, who had not been active during the journey part of the workshop, initiated the session with a a metaphor that he carried over from the first plenum. The CEO then recapitulated briefly the participants' reflections and key words from the plenum. Participants were now asked to further reflect individually and in their groups on their experiences from their journey. The CEO surveyed the statistics for 2007, pointing out indicators that needed to improve, e.g. health and safety and employee satisfaction interspersed with the coach's pep talk. The last task of the workshop was to reflect, using words and images, on how to improve their units. The CEO ended the workshop sending the participants on their way to implement the strategies using their new insight from the workshop.

3.5.Afterlife

A year later while interviewing a number (about 20) of top and middle managers in a follow-up study, one of the topics addressed was the 2007 workshop. All of the interviewed managers could still one year later provide detailed descriptions of the strategy workshop, and talked of it as a "divide" or a "turning point" for the organisation in general and for middle managers in particular. One of the top managers we interviewed toward the end of 2008, who had just before the workshop returned from two years abroad, described it like this:

> *It was the simple set-up that made it creative, you met people you respected; there was variation and a fundamental pedagogy. It was concrete with many examples. The groups were involved. No rocket science, but it was timely: Create awareness, make it interesting, encourage evaluation and the result will be to adopt!*

According to him, the long-lasting and difficult strategy-communication bottleneck at middle-management level "disappeared" after the 2007 strategy workshop. It is interesting to note here that the organisation is now working toward eliminating the bottleneck at project-management level by including this level in the strategizing discourses and activities. In 2010 we initiated a new study in the organisation and found that many of our respondents still

referred to the workshop as an important milestone for strategic change, even though there has been a change in CEO since. This seems to indicate that the middle managers have inculcated the strategic discourse of the organisation and feel more involved in the strategising process.

4. Closing remarks

We have tried to maintain a "dwelling worldview" in our analysis of the strategic workshop by paying attention to how *phronetic (practical wisdom)* and *mëtic (know-how)* were deployed in practice in its design and implementation (Chia and Rache 2010). Studying strategy processes and practices at the micro-level provides insight into how strategists use institutionally established practices and tools pragmatically as well as creatively to manage impressions and construct meaning. Drawing on the strategy-as-practice literature, we have used Hendry and Seidl's (2003) systemic framework and Johnson et al's (2010) ritualisation model to analyse and structure the performative dynamics of the strategy workshop. Our focus in this study has been to show how the workshop event through careful design, preparation and use of material props managed to stage a "strategy rehearsal" that fused the company's past with its prospective future in a coherent present.

Strategy workshops that are a part of a sequential set of workshops are more likely to result in change (MacIntoch et al 2010). However, it is not the frequency of the repetition that generates the change, but rather the ability to create a present that explicitly evokes a past and connects it to an anticipated future. A workshop thus becomes a part of an ongoing conversation held through many different established discursive practices in an organisation over time.

In agreement with e.g. Hodgkinson et al (2006), we found that the strategy workshop is an important practice for strategic planning and sense-making that is frequently used at top management level in this construction firm. However, as Hodgkinson et al also found, it can underpin the power at the top by excluding middle-management from participating. We have shown how ConstCorp created a space in which top *and* middle managers could engage together in future-perfect thinking (Weik 1995; Pitsis et al 2003). Through the mediation of human and non-human entities, the middle managers were able to visualise the means by which they could/would be able to successfully implement the strategies in the future. Future-perfect thinking during the duration of the workshop enabled the possibility to critique and co-construct cognitive and emotional perceptions, which facilitated understanding and decreased the abstraction of the strategy formulations (see also Eppler and Platts 2009). However, there is an important caveat to keep in mind; the middle managers' impressions have been managed by the carefully crafted staging and performance of the top managers. That their impression management was successful could be due to the strong sense of adherence to a "construction worker" habitus among managers at all levels in construction firms (Löwstedt et al 2012).

For example, we found that the top-management team tapped into their own individual past experiences, both successes and failures, scrutinised results from past employee

questionnaires, discussed various pedagogical approaches to use before they started planning the workshop. Their concerns were that the workshop be timely, relevant and situated in the practices of the middle managers, and that it result in their appropriation of the new strategies, i.e. that middle managers make the new strategies their own. The literature on strategising promotes communication as a means of successful strategy implementation; however, what is usually meant by the term *communication* in the context of the literature is a top-down transfer of information rather than enabling understanding and collective sense making as shown here and argued for in e.g. Räisänen and Björnström (2006), Björnström et al (2007), Hodkinson et al (2006) and Eppler and Platts (2009). In this case, ConstCorp managed impressions through a *backstage* performance (Goffman 1982), providing a space in which the middle managers could rehearse each strategy (its reason and implications) before they had to start implementing it *frontstage* within their own units

To sum up, the observed workshop was a strategic episode bounded both in time and in space; the participants were enclosed within the confines of the hotel premises, having symbolically surrendered control over their time and actions for a contracted duration. This two-day surrender was physically enacted through first *checking in* to the premises, and at termination *checking out*. The participants were thus removed from their habitual space and time pattern and relocated in a liminal space. However, as argued in Johnson et al (2010), to create a liminal state the forms and interaction have to be sufficiently different from those experienced in day-to-day practice. The CEO and his support team used the affordances of a variety of discursive practices and tools which maintained a sense of anticipation and surprise among the participants.

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Improving the environmental performance of the construction supply chain

Robert H. Crawford[1]

Abstract

Improving the environmental performance of the construction industry has typically focused on reducing energy and water consumption and the production of waste on the construction site. Studies have shown that this direct requirement for resources and waste is responsible for only a small proportion of the total environmental impacts of construction. Indirect requirements represent a much greater proportion of the energy and water demand of construction and are typically associated with the manufacture of materials upstream in the supply chain. Previous attempts to quantify these requirements in order to prioritise environmental improvement efforts have failed to adequately cover the multitude of processes involved in the supply chain. The complexity of this supply chain makes it virtually impossible to use traditional techniques to quantify the environmental impacts associated with every individual process necessary to support construction. Input-output analysis, with its systemically complete framework, provides an ideal solution to this problem.

This study uses input-output analysis to model the energy and water consumption associated with each individual process within the entire Australian residential construction supply chain. It was found that the indirect requirements account for at least 96% of the total energy and water consumption associated with construction. The remaining proportion represents the direct energy or water consumed on-site. The findings from this study also provide a greater understanding of the significance of the resource demands for each individual process across the construction supply chain, that has until now been lacking. This indicates that further improvement to the environmental performance of the construction industry requires greater emphasis on the processes located further up the supply chain. Only with this detailed level of information can the construction industry make considerable improvements to its environmental performance.

Keywords: construction, supply chain, input-output analysis, energy, water.

1. Introduction

Buildings are responsible for a significant proportion of total energy demand, greenhouse gas emissions and other environmental loadings in most industrialised countries around the world. Existing efforts to reduce the environmental impact of buildings tend to focus on minimising energy and water consumption and greenhouse gas emissions associated with building operation and on-site construction. Indirect or embodied resource requirements and

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emissions are often overlooked and previous research shows that these can be just as significant, and increasingly so as building operational efficiencies improve.

An understanding of where the greatest impacts occur within the supply chain is essential for improving the environmental performance of the construction industry. Traditional approaches for identifying indirect resource demands and emissions suffer from considerable flaws. The most notable being the truncation of the system boundary, resulting in a large proportion of processes being excluded from the analysis. More recent methods involve the use of economic input-output (I-O) data. However, this is most often used as a black box, which does not facilitate the easy identification of the most significant processes within the supply chain, so that these can be prioritised for environmental improvement. More recent assessment models that further disaggregate this I-O data allow it to be much more transparent and useful for targeting environmental improvement efforts.

The aim of this paper is to demonstrate how I-O data can be used to provide a more comprehensive understanding of the environmental loadings associated with the construction industry and identify strategies for environmental improvement.

2. Background

Our current understanding of how best to improve the environmental performance of the construction industry is based on information developed using incomplete assessment techniques and a limited knowledge of the processes occurring across the entire construction supply chain. This has the potential to result in a focus on processes that are much less important than others that are often much higher up in the supply chain. For example, a focus on reducing the waste produced and energy and water consumed during the construction process itself stems, in part, from a belief that these areas are significant in terms of the overall impacts related to construction. However, a number of studies have shown that the on-site requirement for energy and water accounts for less than 5% of total demand for these resources (Crawford and Treloar 2005; McCormack *et al.* 2007; Crawford 2012). An understanding and knowledge of the indirect resource demands and pollutant releases occurring across the entire construction supply chain is thus vitally important.

Process analysis, based on physical quantities of materials and fuel, is the approach typically used to quantify the inputs required across a supply chain. This approach usually quantifies the inputs to the supply chain to two or three tiers upstream of the main product (such as a building). This may include the energy associated with steel production and fuel required for transporting iron ore to the steel manufacturer, for example. A significant number of these inputs can occur further upstream. However, tracing an entire supply chain using a process analysis approach is virtually impossible due to the time, cost and complexity involved in physically analysing each transaction within the supply chain (Treloar 2007). Because of this, a considerable proportion of the inputs within the supply chain of any product are often excluded. Previous research by Lenzen (2000), Lenzen and Dey (2000) and Crawford (2008) indicate that this may be as high as 87%. I-O analysis provides a solution to this truncation issue as it is based on a systemically complete framework and can thus be used to quantify a much larger number of the inputs associated with construction.

2.1 Input-output analysis

I-O analysis is a top-down economic technique, which uses matrices of sector-based monetary transactions (I-O tables) describing complex interdependencies of industries in order to trace resource requirements and pollutant releases throughout a whole economy. These I-O tables describe, in economic terms, the inputs required by each industry sector from each and every other sector in order to produce a certain quantity of output. The system boundary of I-O analysis is economic, such that if a sector pays for any product or service, the inputs to that product or service are included. This results in an almost limitless number of potential transactions upstream through the supply chain.

Total requirements coefficients for each sector provide the sum of direct requirements and indirect (or upstream) requirements of inputs to a sector. The sum of the indirect requirements can be deduced by subtracting the direct requirements from the total requirements; however, modelling individual indirect requirements (such as the inputs required in mining the iron ore needed to produce steel) is much more complex and time-consuming due to the shear number of processes involved. This is the reason why I-O analysis is often used as a black box. A disaggregated I-O model is needed to identify the significance of individual inputs occurring throughout the supply chain.

3. Identifying and prioritising strategies for improving the environmental performance of construction

A disaggregated I-O model of the construction sector includes every flow or relationship associated with the entire construction supply chain. This model, when combined with environmental data, can then be used to identify where the most significant environmental loadings occur across the supply chain. These loadings may be related to specific material manufacturing processes (e.g. mining and production), the provision of services to construction processes (e.g. finance, communications and advertising) or the provision of capital equipment and machinery to any of these processes (e.g. for factory buildings or the equipment and machinery required for extracting, transporting and processing iron ore).

The number of sectors into which an entire economy is disaggregated varies by country and even over time. I-O models depicting the flows within the Australian economy are typically disaggregated into around 100 sectors. For a product produced by any one of these sectors (e.g. a building), there is a requirement for goods or services from potentially all of these 100 sectors at the first tier in the supply chain (Tier 1). For a building, this would typically include the main construction materials (steel, glass, concrete etc.). The potential number of goods and services requirements increases exponentially at an alarming rate at each further tier upstream in the supply chain. At Tier 2, the number of potential inputs is 100^2 as each of the 100 sectors may require inputs from every other sector to produce the main output of that sector (e.g. the purchase of cement used in concrete production). At Tier 3 of the supply chain there is potentially 100^3 additional inputs at the sector level (e.g. limestone used for making cement). At Tier 4 there are 100^4 potential inputs, which might include the provision of capital equipment to mine the limestone, amortised over its life (i.e. just the share of that equipment's value used to mine that limestone). At Tier 5 there are 100^5 potential inputs at

the sector level (e.g. sheet steel used to make the machinery used for mining the limestone). This would result in a total number of inputs at the sector level, at only 5 tiers upstream in the supply chain, according to these simplified calculations, of 10,101,010,100. Figure 1 depicts the individual flow of goods and services between sectors for residential building construction. This shows just the top 1,500 most significant inputs, representing 46% of the total energy requirement of the Australian *Residential building* sector.

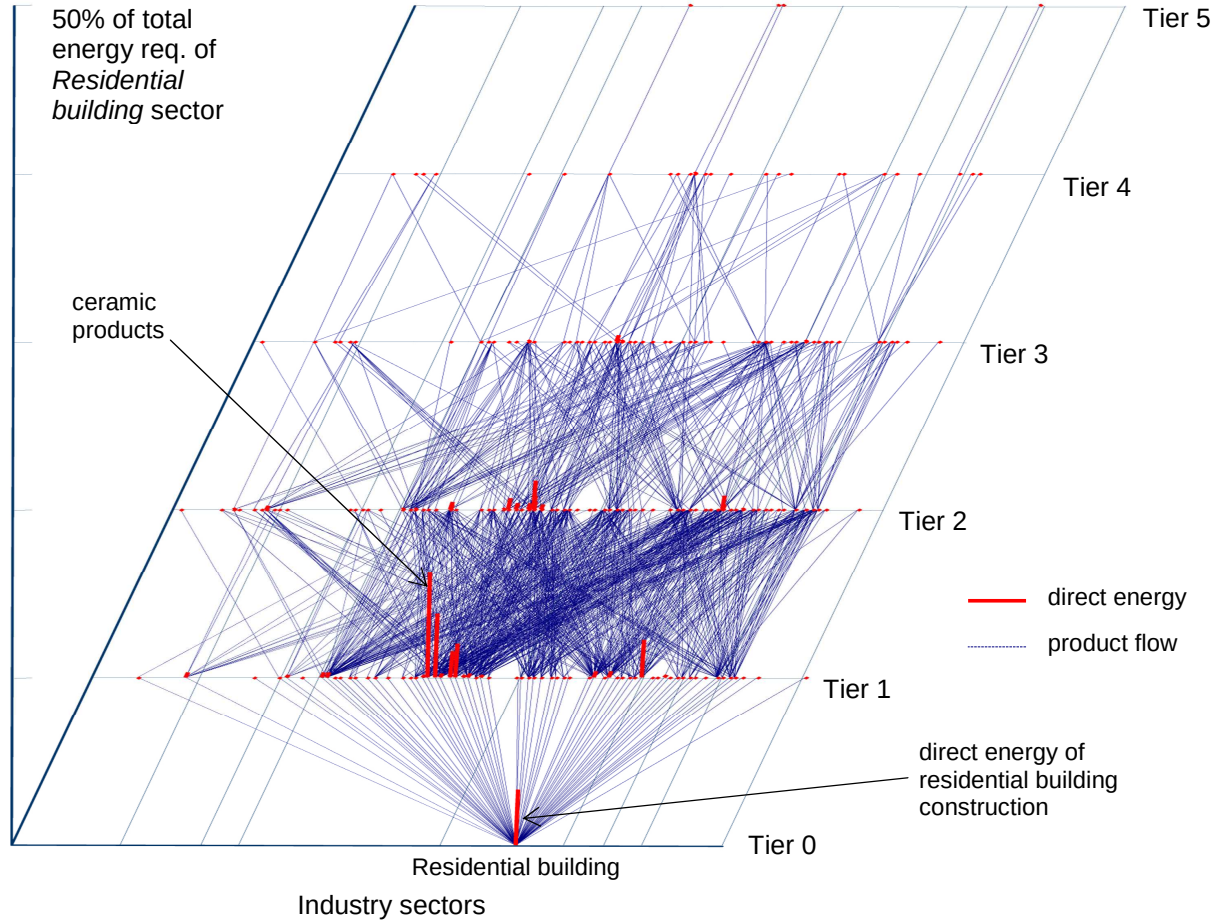

Figure 1: Diagram showing flows of goods and services within the Residential building supply chain, by sector

For the construction industry, some of the most important environmental concerns are energy and water resource depletion and the release of greenhouse gas emissions. I-O models that model energy and water flows and the greenhouse gas emissions resulting from particular processes across the supply chain are thus the most common types of I-O models used to assess the environmental performance of construction products.

Almost any type of environment-related data can be integrated into an I-O table, including energy, water and raw material consumption, as well as waste and emissions, such as carbon dioxide. To enable the integration process to occur, the environmental data must be in the correct format, giving values for inputs of resources or outputs of waste or emissions per economic sector. Based on the total resource requirements or emissions associated with a particular sector as well as the total monetary value of all outputs from that sector, it is then possible to determine the quantity of resources required or emissions released per monetary

unit of output for each sector. In simple terms, this is done by dividing the total resource requirements or emissions by the total monetary value of sector outputs, which results in a sector-level *total requirements coefficient* in units per monetary unit of output (e.g. GJ of energy per dollar). The quantity of resources or emissions associated with a particular quantity of output from any sector of the economy, including the indirect inputs of goods and services required to support the production or supply of that output, can then be determined.

Generalised I-O models have been applied extensively to environmental analysis since the late 1960s (see for example Isard *et al.* 1967; Leontief and Ford 1970; Bicknell *et al.* 1998). A detailed introduction to I-O analysis and its application to environmental problems can be found in studies by Leontief and Ford (1970), Proops (1977) and Dixon (1996).

3.1 Approach

The following sections provide an I-O-based analysis of the Australian residential construction supply chain for two common environmental parameters – energy use and water use. This analysis is based on an I-O model of the Australian economy using 1996-97 I-O data, combined with energy and water consumption data from Australia's National Accounts. The resultant model provides not only an indication of the specific flows of goods and services occurring between each of the sectors involved in the construction supply chain, but also the quantity of energy and water associated with each one of these flows, in GJ and kL, respectively. The initial use of this model is an analysis of the total resource requirements associated with the construction of a building. The total monetary value of the building is simply multiplied by the total energy or water requirement of the *Residential building* sector to determine the total I-O-based resource requirement for the building. This process is demonstrated in Crawford (2011: 93) and is beyond the scope of this study.

An innovative tool developed by Treloar (1998) has been used to disaggregate the energy- and water-based I-O models at the individual process level. For example, this includes the process of iron ore mining, transporting iron ore for processing as well as the process of manufacturing steel from the iron ore, as separate items. With this information, environmental improvement strategies can then be prioritised based on the areas of greatest potential environmental improvement.

3.2 Analysing energy use across the construction supply chain

This section presents an analysis of the energy demand associated with the Australian residential construction supply chain using a disaggregated I-O model of Australian direct and indirect energy use based on Australian Bureau of Statistics National Accounts (ABS 2001a) and National Energy Accounts (ABS 2001b). The total energy requirement of the *Residential building* sector, based on 1996-7 I-O data is 10.3 GJ/$1000 of sector output (construction and maintenance of residential buildings). Figure 2 shows the distribution of energy demand associated with residential building construction by supply chain tier. From this it is evident that direct energy consumed during the construction process (Direct - Tier 0) is insignificant in relation to the total energy requirement of the sector (3.3%). A total of 86% of the total energy requirements occur within the first 5 tiers of the supply chain.

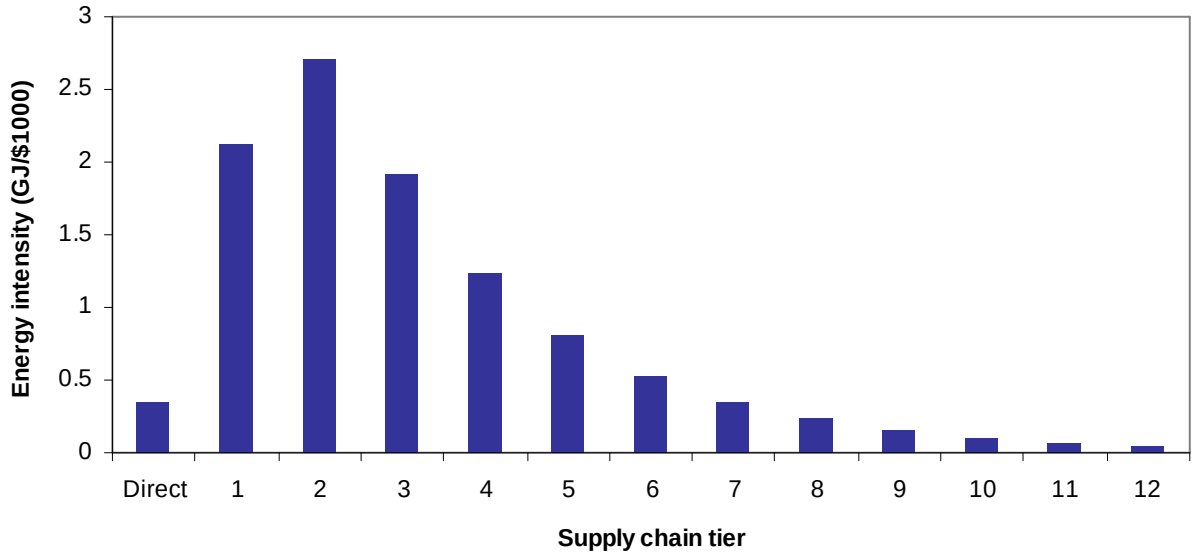

Figure 2: Total energy requirement of the Australian Residential building sector, by supply chain tier

Figure 3 shows the total energy requirement for each of the top 25 most significant Tier 1 inputs into the *Residential building* sector. Each column includes the energy associated with the main process (e.g. for *Road transport* this will be the fuel required to operate transport vehicles) as well as all indirect requirements for energy upstream of this Tier 1 process (covering all minor goods and services required to support the provision of road transport).

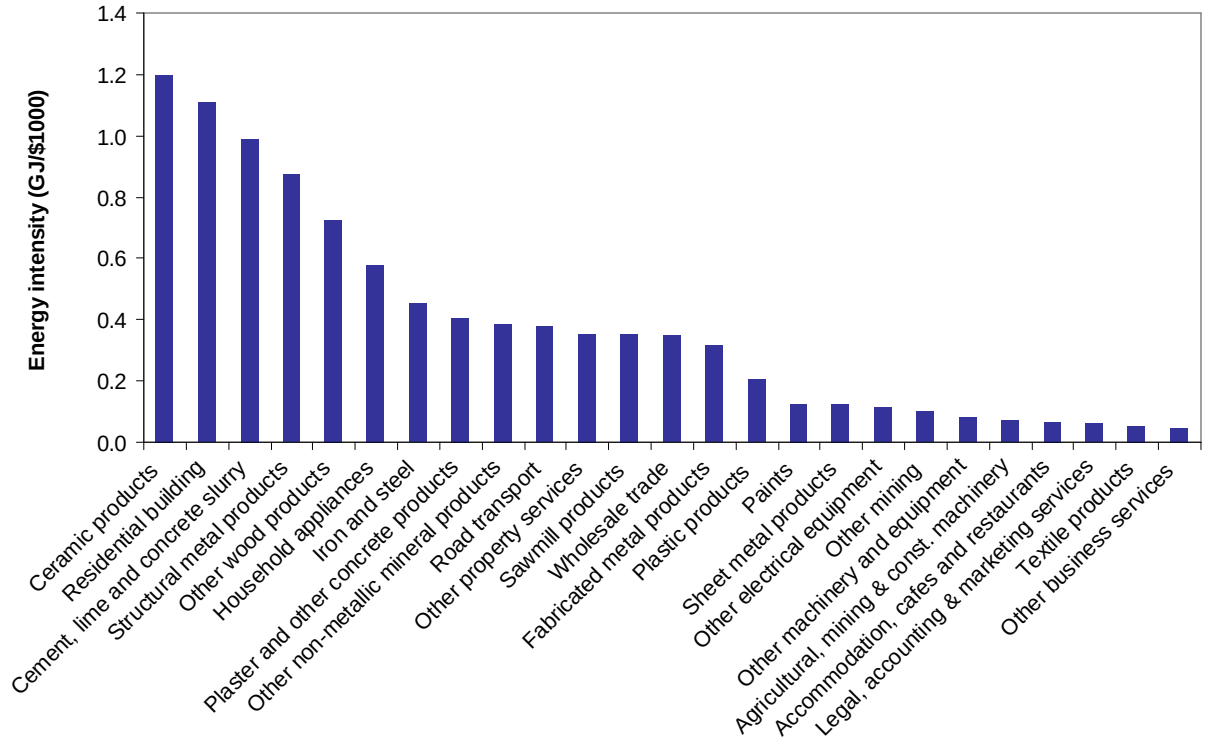

Figure 3: Total energy requirement of the top 25 Tier 1 inputs into residential building construction, by sector

Figure 3 shows that at the sector level, ceramic products represent the largest proportion of energy demand for residential building construction (11.3%). This includes the production of clay bricks, ceramic tiles and sanitary ware. The energy associated with the production of concrete (9.3%) (for floor slabs, driveways and paths), structural metal products (8.2%) (for steel reinforcement, structural steel members and aluminium window frames) and wood products (6.8%) (for structural framing, window frames, doors and joinery) is also significant.

3.2.1 Identifying the most significant energy demands

A further disaggregation of the I-O model can help to identify the individual processes that are most energy intensive within each of the most significant sectors identified in Figure 3. Table 1 shows the direct energy requirements (DER) for the 10 most significant inputs associated with the production of goods (bricks, tiles etc.) from the ceramic products sector required in residential building construction. This list is only a small fraction of the millions of individual processes associated with residential building construction, of which, individually, the vast majority represent an insignificant proportion of the total energy requirement (TER).

Table 1: The direct energy requirement of the top 10 most significant inputs for ceramic products production into the Residential building sector

	DER (GJ/$1000)	Tier 2 of *Residential building* sector	Tier 3 of *Residential building* sector
1	0.6629	Direct energy for ceramics production	
2	0.0411	Other non-metallic mineral products	
3	0.0326	Road transport	
4	0.0063	Ceramic products	
5	0.0057	Cement, lime and concrete slurry	
6	0.0050	Other mining	
7	0.0049	Other chemical products	Basic chemicals
8	0.0042	Other non-metallic mineral products	Road transport
9	0.0036	Road transport	Road transport
10	0.0035	Rail, pipeline and other transport	
Total	0.7700	% of TER of Ceramic products into Residential building construction: 64%	

NB. Tier 1 is *Ceramic products*

One of the limitations of I-O analysis is the inability to identify the exact process that is responsible for consuming energy, especially for the more aggregated sectors where multiple products are produced within the one sector. In this case, assumptions can be made, based on knowledge of the goods and services that are most likely to be purchased from these sectors for the construction of a residential building and knowledge of the processes that are most likely to be the most energy intensive in the manufacture or provision of these goods or services. For example, Table 1 indicates that the most significant energy requirement for ceramic products is the direct energy required for production (6.2% of the total energy required for residential building construction). It can be assumed that a large proportion of this relates to the production of clay bricks due to the considerable quantity typically required in the average residential building and the energy-intensive nature of their production (for kiln firing). The next most significant energy requirements associated with the use of ceramic products are for the production of lime (from the *Other non-metallic*

mineral products sector) and the transport of ceramic products to the construction site (*Road transport*). These two processes represent 0.4% and 0.3% of the total energy requirement associated with residential construction, respectively. Individually, the remaining processes account for less than 0.1% of the total energy required for residential building construction. A similar analysis can be performed for each of the other Tier 1 inputs into residential construction using the disaggregated I-O model.

3.2.2 Potential improvement strategies

The above analysis suggests that a number of strategies for reducing the energy demands of construction are possible. The first of these is either to look for alternatives to the use of clay bricks or to source bricks from manufacturers with the highest operational energy efficiencies in production (using modern firing technologies or fuelled by renewable energy sources). The input from the *Residential building* sector (Figure 3) refers to the materials required in building repair and maintenance. As such, utilising more durable materials may also result in significant environmental benefits. These strategies do not consider the potential impact that might result from any alternatives, but merely suggest areas where considerable savings in energy requirements may be possible.

3.3 Analysing water use across the construction supply chain

The analysis of water requirements associated with the Australian residential construction supply chain used a disaggregated I-O model of Australian direct and indirect water requirements based on Australian Bureau of Statistics National Accounts (ABS 2001a) and National Water Accounts (ABS 2000). The later are generated from water supply-and-use tables based on financial and physical data which describe the economic consumption of water and show linkages between the economy and the environment.

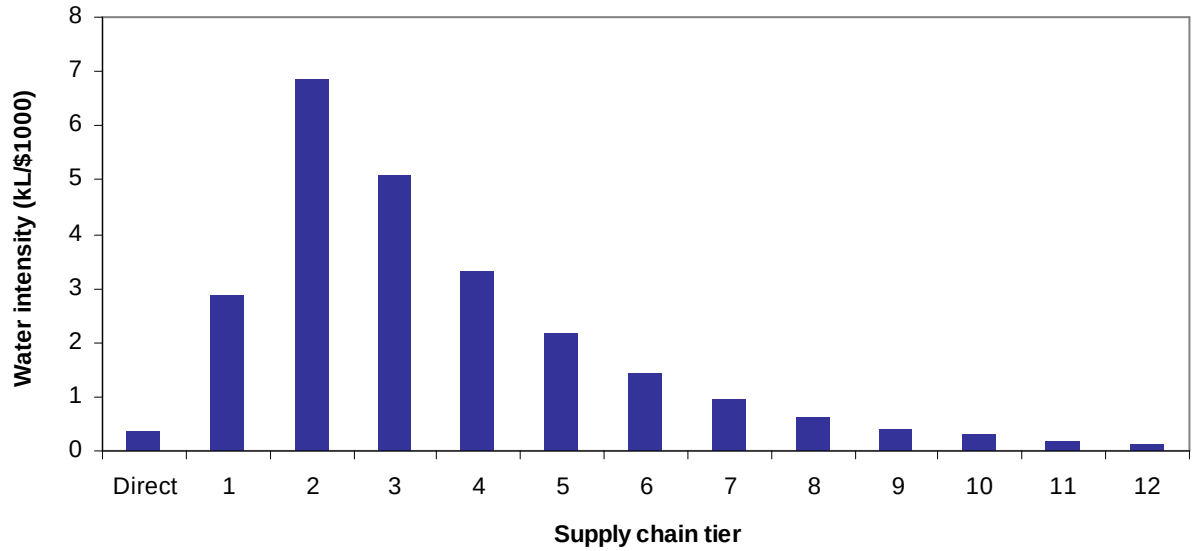

Figure 4: Total water requirement of the Australian Residential building sector, by supply chain tier

The total water requirement of the *Residential building* sector, based on 1996-7 I-O data is 24.73 kL/$1000 of sector output. Figure 4 shows the distribution of water demand associated with residential building construction by supply chain tier. As for energy, it is evident that direct water consumed during the construction process (Direct - Tier 0) is insignificant in relation to the total water requirement of the sector (1.5%). A total of 84% of the total water requirements occur within the first 5 tiers of the supply chain.

Figure 5 shows the total water requirement for each of the top 25 most significant Tier 1 inputs into the *Residential building* sector. Each column includes the water associated with the main process as well as all indirect requirements for water upstream of this Tier 1 process.

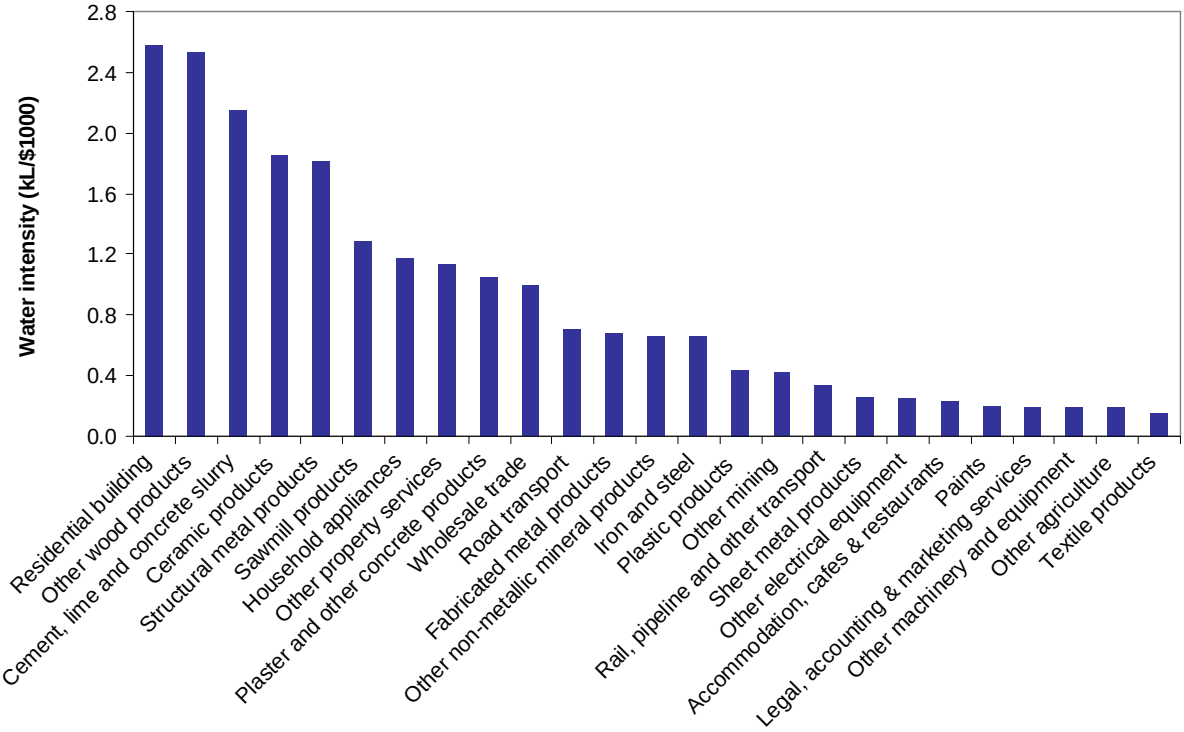

Figure 5: Total water requirement of the top 25 Tier 1 inputs into residential building construction, by sector

Figure 5 shows that at the sector level, goods or services provided by the *Residential building* sector are responsible for the largest proportion of water demand for residential building construction (10.4%). Current I-O models do not allow for a more detailed understanding of the actual source of demand for this water, but it is likely to be related to the repair and maintenance of residential buildings (the only other output of the *Residential building* sector other than residential building construction). The water demand associated with the production of wood products (10.2%) and concrete (8.7%) are also significant. This is followed by ceramic products (7.5%) and structural metal products (7.4%), which are also significant in terms of total water demand.

3.3.1 Identifying the most significant water demands

Further disaggregation of the *Other wood products* sector into the processes associated with the production of wood products (structural framing, window frames, doors and joinery) required in residential building construction shows that the direct water required for production is the most significant water requirement for wood products (2.2% of the total water required for residential building construction and 22% of the total water required in the production of wood products). The next most significant water requirement associated with the use of wood products is for the production of sawmill products (i.e. sawn and dressed timber) at 3.7% of the total water required for the production of wood products. Individually, the remaining processes account for less than 0.2% of the total water required for residential building construction.

3.3.2 Potential improvement strategies

As for the energy parameter, the significance of building repair and maintenance (*Residential building* input) on total water demand is likely to mean that more durable materials will result in considerable indirect water savings associated with construction. Specifying more durable materials that require less ongoing maintenance and lower frequency of replacement reduces the demand for water in their production.

In addition, the analysis has highlighted the significance of water demand associated with the production of wood products and concrete. For wood products, considerable water savings may be achieved by selecting products from manufacturers with higher water efficiencies in production. Avoiding the use of wood products altogether may not be an ideal solution as these products bring other environmental benefits such as carbon storage.

4. Discussion

The list of discrete inputs, ranked from most to least significant in terms of resource requirements, represents an ideal starting point for the construction industry to prioritise environmental improvement efforts. These efforts may focus on a range of strategies from materials substitution or development to process efficiencies and specific design interventions. This initial analysis shows that structural metal products, ceramic products, concrete and wood products appear in the top five inputs for both environmental parameters. This suggests that the production of these materials provides the greatest opportunities for improving the environmental performance of residential construction.

I-O analysis has its strengths, as discussed earlier, however the aggregation of commodities and establishments into sectors reduces the relevance of these findings to any particular product or region. The economic system boundary that gives I-O analysis its depth and breadth results in errors when these financial flows are attributed to physical quantities of materials or environmental loadings. For this reason, physical material and process specific data is needed in order to provide a detailed understanding of the environmental loadings associated with specific materials and products. Also, this analysis and the conclusions that can be drawn from it, relate only to the average product of the residential building sector and

not to any one specific residential building. This may be acceptable for houses that are similar to the national average house, but is much less relevant to houses that aren't constructed from conventional building materials or by traditional construction methods. For example, a house clad externally with timber weatherboards is not likely to rely as heavily on products from the *Ceramic products* sector as the national average I-O model suggests.

Another limitation of this study is the use of I-O data that relates to production that occurred over a decade ago. Over time manufacturing technologies and efficiencies of production can change and this can alter the environmental profile of particular products. However, in general, *total requirements coefficients* change only marginally from one year to the next and any efficiency improvements are often offset by an increase in the cost of products. Also, there is a time lag of at least 2-3 years in the release of I-O tables and so even the most recently released data may not necessarily reflect the current-day situation.

In addressing the environmental impacts of the construction industry it is also important to consider other types of construction such as commercial buildings, infrastructure and prefabricated buildings, which may or may not result in a range of different impacts on the environment. Also, the inputs that represent the greatest resource demands and environmental impacts may differ from those identified for residential construction.

5. Conclusion

The aim of this paper was to demonstrate how I-O data can be used to provide a more comprehensive understanding of the environmental loadings associated with the construction industry and help to identify strategies for further environmental improvement.

Through the use of disaggregated I-O models, this paper has demonstrated the significance of indirect inputs on the environmental loadings associated with construction. The I-O models used provide an ideal approach for identifying these loadings and prioritising environmental improvement efforts within the industry. Only with this broad view of the entire supply chain is it possible to know whether existing and future environmental improvement efforts are addressing the most critical environmental impacts associated with construction.

This study shows that the greatest scope for improvement to the environmental performance of residential construction across the two environmental parameters considered is in the manufacture of ceramic products, structural metal products, wood products and concrete. Once this initial scoping process has been completed, more detailed environmental information specific to particular materials, products and processes can then be obtained.

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Reforming as remembering: exploring the continuities of industry reform in the case of British Rail

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Abstract

Industry reforms, embodied in various governmental inquiries into the affairs of the construction industry, have become a regular feature in Britain. Underpinning these reforms is a common agenda of performance improvement, where the industry is continuously urged to deliver a better built environment more quickly and in line with technological change. Each reform appears to be motivated by a desire to disrupt the status quo as the industry moves forward into an often-positive future triggered by episodes of change. However, treating each reform as episodic change implies that change is an event that is 'out there' to be made sense of *over* time, rather than experienced 'in here' as the industry metamorphoses and changes *in* time. Inspired by Henri Bergson's ideas of duration and the multiplicity of time, an alternative interpretation of industry reforms is one of continuous *changing* rather than discontinuous *change*. This article draws upon archival research into the reforms of the British railway industry, as we scrutinise the minutiae behind the many inquiry reports since the 1960s. The findings reveal that, far from looking ahead into a better future, there is more of a continuity of remembering the past when undertaking industry reforms. This ever-extending past is situated in the intensification of current debates into public-private-partnerships, where the rhetoric of collaboration is more about returning to the glorious past of coordination rather than blind faith in the profits of privatisation.

Keywords: archival research, changing, industry reform.

1. Introduction

Given that the construction industry plays a pivotal role as an underpinning sector in any national economy (see e.g. UK Contractors Group, 2009), it is unsurprising to find a great deal of government interest into the affairs of the sector. In the UK, the construction industry has, over the past two decades, engaged in a series of government-led initiatives aimed at improving the performance of the industry starting with the often-cited Latham (1994) and

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Egan (1998) reports (see e.g. Adamson and Pollington, 2006; Smyth, 2010, and; Green, 2011). These inquiries tend to tell of a similar tale; that is, the industry is underperforming, especially when compared with manufacturing, and that reforms are necessary to bring about better performance (see e.g. Green, 2011). Typically, recommendations are made for the industry to adopt new working practices such as integrated team-working and better collaboration to drive improvements. Supporters of such reforms have often been inspired by popular ideas in the 1990s of business process reengineering and lean production techniques (see e.g. Womack *et al.*, 1990, and; Hammer and Champy, 1993). Consequently, efforts have tended to centre on advancing performance measurement frameworks for the industry (see e.g. Cooke-Davies, 2002; Beatham *et al.*, 2004, and; Chan *et al.*, 2004).

Critics have, however, observed that the continuous improvement agenda is far from being a contemporary feature in the UK construction industry. Murray and Langford (2003), for instance, traced the various inquiries about UK construction since the post-War period and discovered a number of themes that keep recurring over time. Ostensibly, calls for better communication and coordination between design and construction and a move away from the 'adversarial culture' of the industry in order to drive efficiency gains have all been longstanding, well-trodden aspects of industry reform. Thus, it can be seen that little has changed of reforms in the UK construction industry. Industry reforms have certainly been argued to have limited impact in the construction industry. Bresnen and Marshall (2001) noted the difficulties of changing working practices because the diffusion of new ideas, especially those imported from other industries like manufacturing, often fails to account for the contextual specificities of construction. Furthermore, Green (2011) found the efficiency agenda somewhat tiresome; he argued that the exhortations of continuous improvement and industry reforms seem meaningless, and that the only thing that appears to have changed is the circumstance within which construction operates.

Indeed, as Green (2011) asserted, reforms of the construction industry have often focussed myopically on rational processes of managing performance as if the industry existed in a vacuum devoid of its institutional context (see also Winch, 2003, and; Adamson and Pollington, 2006). By downplaying the institutional context of industry reforms, there is often a sense that continuous improvement is simply a managerial process where firms in the industry have control over their own destinies. So, reforms tend to be conceptualised as discrete change programmes where rhetorical moves are made in the present to dismiss the ills of the past and promise a brighter future. It is our contention, in this article, that such interpretations of industry reforms are inadequate on two counts. Firstly, working practices in the industry are shaped by, and constantly shaping, broader institutions that govern the sector (e.g. the state, markets etc.). Therefore, the analysis of industry reforms cannot simply be reduced to managerial ideas of change and continuous improvement. Rather, there is a need for closer scrutiny of the complementary and contesting institutional agendas that transcend the boundaries of construction companies. Secondly, the tendency to view industry reform as change moving forward towards a perfect future (e.g. Pitsis *et al.*, 2003) raises questions about the assumptions of time. As Chan (2012) suggested, drawing on Henri Bergson's (1913) ideas about social change, time is often misconstrued as merely a linear entity embodied in clock-time. Consequently, the focus has largely been on time moving forward into the future, rather than a deeper appreciation of the ever-extending past

and the pace of present life. Thus, in examining industry reform as a change process, there is a need to draw on memories of the past to supplement current emphasis on the future.

In this article, we turn our attention to the analysis of public-private-partnerships as the centrepiece of reform of the UK construction industry over the last twenty years. Much has been written about the prospects of how more effective ways of collaboration between the public and private sectors can yield better performance in the construction industry. Yet, we draw on an ongoing archival analysis of the British railway industry to demonstrate how the seeds of public-private-partnerships had been sown during the 1960s, and how reform tends to have less of a performative rationale and more of an ideological, often-emotional imperative that is mostly ignored in the analysis of collaborations in construction. This article is organised as follows. In the next section, we draw upon Henri Bergson's ideas about time and social change to offer a critique of the way change is perceived in the study of industry reforms in the construction industry. The central argument is that one needs to move beyond the duality of change over time – change as a thing or change as a process – towards understanding the situated experiences of industry reform in time. The archival research method of analysing the case of the British railway industry in the 1960s is then outlined before a discussion of preliminary findings is presented. The findings point critically to the limits of viewing industry reform as change moving positively forward into the future, and suggest a need to conceptualise change as an integral process of remembering the past in the ever-moving present.

2. Time and continuous improvement: moving beyond the duality of change

Scholars analysing industry reforms can be broadly split into two main camps. On the one hand, proponents of reforms emphasise change as a prescriptive, managerial process where the measurement and improvement of performance is a key object to be attained. On the other hand, critics of the reform agenda in the construction industry often highlight the challenges that prevent the transference of acontextual prescriptions of interventions that promises a better future. Yet, both proponents and critics of industry reform in construction share a common vantage point. That is, both camps tend to view change and their effects as a linear, episodic phenomenon that is "out there" waiting to be analysed, rather than experienced "in here" (Pettigrew *et al.*, 2001). Even in Green's (2011) very rich institutional analysis of industrial change in the UK construction industry, the various episodes tend to be carved up in to episodes of decades moving forward. Therefore, reforms are often analysed as discrete phases of change that starts with a (bad) past, (challenging) present, and (promising) future, with proponents focussing rationally on the cause and effects of positive change and critics emphasising the problems of the change process.

However, there has been, at least in wider organisational and management studies, growing dissatisfaction with the ontological and epistemological standpoints taken in the production of knowledge about organisational change (Van de Ven and Poole, 2005). Pettigrew *et al.* (2001) claimed that much research on organisational change have, in the main, accounted for static states and urged for more fine-grained analyses of the experiences of change as a discontinuous process to be undertaken. Weick and Quinn (1999) argued that the focus

should be diverted to ongoing change, or *changing*, in organisations. Chia (2002), inspired by Henri Bergson's thinking about time, argued against the way knowledge about change has become a "commodified 'product'; a thing that can be 'assembled', 'rearranged', 'packaged', 'transferred' and 'consumed' (p. 865)." Thus, change can not only be understood through its visible effects over time, but also by the everyday lived experiences of all those concerned. According to Barley (2008), organisational theorists have largely ignored "the throws of everyday life (p. 510)."

To transcend episodic moments of change and account more fully for the experiences of ongoing change, there is a need to see beyond the duality of prescription and process and embrace broader understandings of time. As Chan (2012) drawing on Henri Bergson's (1913) ideas about social change stressed that scholars in the field of construction management have mainly limited the understanding of time to chronological, linear notion of clock-time where time is usually separated in to discrete episodic moments moving forward. According to Bergson (1913), time is much more multiplex than clock-time suggests; there is oftentimes a heterogeneous array of temporal perspectives in (organisational) life, and that time is not only moving forward, but extending backwards to the past and embracing the ever-moving (and emotional responses to the) present. Arguably, in studying industry reforms in the construction industry, the extensive past as each reform is introduced and the emotional responses to the present day are aspects that often get downplayed in the analysis of change. It is with this in mind that this ongoing study seeks to account for through an archival analysis of reform in the British railway industry.

3. Research method

As argued above, the analysis of reforms in the construction industry has hitherto ignored the role of the ever-growing past and emotions of ever-moving presence of ongoing change. Thus, a conscious effort was made to ensure that the study focuses less on the rhetoric of continuous improvement and performance management that has indoctrinated current understanding of industry reforms. Rather, an attempt is made to return back to history to re-examine the institutional dynamics of the reform agendas of the past. The choice of studying the case of British Rail is two-fold. Firstly, there is contemporary interest in railway infrastructure in the UK, given debates surrounding the viability of High-Speed Rail. Yet, as the story unfolds, the railway sector in the UK sets a useful scene for unveiling the chequered past of a public service that has been through a series of reforms dating back to the 1960s that saw the encouragement of private sector involvement. Secondly, as discussed earlier, there is a need for more fine-grained analyses of institutional dynamics of industrial change that goes beyond the boundaries of the construction sector. Thus, the choice of British Rail as an archival case study is considered appropriate because rail transport projects are often fraught with the complexities of socio-economic and political interactions (see e.g. Galilea and Medda, 2010, and; Chi and Javernick-Will, 2011).

Archival research is rarely used as a method to analyse the intricacies of industry reform, even though it offers the possibilities for researchers to detect the minutiae of what went on in the reform process. At the same time, the archival research method can be extremely time-consuming and unwieldy, resulting in the researcher feeling lost in the masses of

potentially relevant data. To help develop the narrative for the archival study, we identified the Beeching (1963) report into the reorganisation of British Rail as the starting point for the data collection and analysis. The Beeching (1963) report represented a key moment in the history of British Rail, and one of the early examples of reform of public services that resulted in the closure of one-third of the railway infrastructure in the UK. To help piece together the institutional dynamics of this reform, and to explore the emotional responses as the reform was undertaken, the team amassed a range of data sources from various archives (including the British Library, the Railway Museum and Kew Gardens), including de-classified notes, articles from national, regional and local press, draft notes to inquiry reports and White papers etc. to examine the 5Ws (Who were involved, What went on, Where it all happened, Why it happened, and When events took place) and 1H (How did the reform take place) of this momentous milestone in the history of the British Rail. The purpose of the archival data collection analysis was to help provide a snapshot of the socio-political and economic context of the time (see Hill, 1993). The findings will be discussed in the next section.

4. Some early findings

In this section, the analysis of the triggers for, and consequences of, the Beeching (1963) report will be presented with a view to trace the dynamics and emotional responses to change.

Triggers for reform of British Rail in the 1960s: At first glance, reform of the British Rail appears to follow the convention of rational calls for performance improvement. Consider the following quote extracted from the introduction to the White Paper by the Ministry of Transport (1960), which sets the scene for the reorganisation of the railway infrastructure and the inquiry led by Beeching (1963).

> *"The heart of the problem is in the railways. They are a great national enterprise and a vital basic industry. They employ half a million people and represent an investment of nearly £1,600m, which is growing by more than £100m each year […] The railways are now in a grave financial plight. They are a long way short (by about £60m a year) of covering even their running costs (Ministry of Transport, 1960: 3)."*

Thus, the reader is drawn to the 'fact' that the railways is the central problem. Despite the inherent contradiction found in this quote, where compliments were paid to the economic significance of the railway infrastructure, the focus is nevertheless placed firmly on reining in the growing costs of running the railway system. A rather strong message is then asserted in the report, stressing that:

> *"Sweeping changes will be needed (Ministry of transport, 1960: 3)."*

The tone of this statement gives some sense of the rhythm and pace of change at that time. Reform was not only inevitable but also urgent. Of course, the concern underlying this urgency was not simply about improving the efficiency of this nationalised undertaking. The efficiency claim was arguably a rhetorical device aimed at justifying the means to the reform,

masking a growing political ideology that was in favour of reducing government expenditure and increasing private enterprise. Indeed, the following quote illustrates just how, in these early days of seeking private-sector efficiencies, tensions existed between the desire to seek alternative, non-public-sector ways of organising public services and the recognition of the role British Railway plays in terms of a social good:

> *"The activities of the British Transport Commission as at present constituted are so large and so diverse that it is virtually impossible to run them effectively as a single undertaking […] There has also been […] confusion in judging between what is economically right and what is socially desirable (Ministry of Transport, 1960: 4)."*

As the reorganisation moves forward, the Beeching (1963) report recommended for a rational carving up of the railway infrastructure. It became clear that official review of British Rail followed a typical process of managerial change, where a troubled past is framed as the point of origin and the promises of a better, bolder, more competitive future logically laid out.

> *"The thought underlying the whole Report is that the railways should be used to meet that part of the total transport requirement of the country for which they offer the best available means, and that they should cease to do things for which they are ill suited […] The proposals for reshaping the railways are all directed towards giving them a route system, a pattern of traffics, and a mode of operation such as to make the field which they cover one in which their merits predominate and in which they can be competitive (The Beeching Report, March 1963; p. 57-58)."*

Reactions to the Beeching (1963) report and emotions in that time: Whereas the reorganisation of the British Rail was meant to reap economic benefits of cost savings and increased 'profitability', the responses from the travelling public and local businesses relying on the railway infrastructure spoke of a different story. So, whilst the Beeching (1963) considered the economic effects of reshaping the railway infrastructure for British Rail, the reorganisation did not anticipate the unintended effects on the contraction of local businesses. Consider the two quotes extracted from a research report into the perceptions of members of the public in Norwich to the Beeching (1963) report.

> *"Some people, especially famers, have suffered financial loss because of the closing of a branch line. Not surprisingly, they are very resentful. Other people bear a grudge against the Railways because their branch lines, though still open at least for the immediate present, are so inconvenient (Research Projects Limited, 1963: 10)."*

> *"People deduce what British Railways think of the passengers by the way the employees are dressed, the way they do their job, the way the trains are cared for, the sort of amenities provided on the train. It all adds up to the fact that the Railways don't care much about the passengers – certainly not as much as they used to years ago (Research Projects Limited, 1963: 3)."*

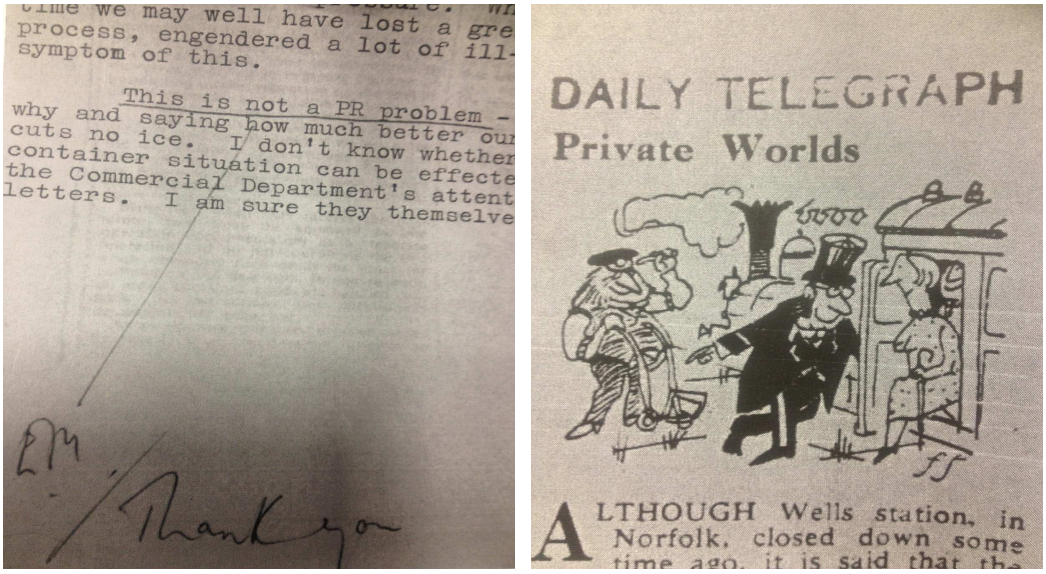
Reactions were also rife in the national press with caricatures of the privatisation of the railway industry commonplace in broadsheet newspapers (see Figure 1 below). Letters were

also sent in by members of the public to voice concerns over the shrinkage of the railway provision. Anger and resentment appear to characterise the mood of the times. Consider this letter from the Managing Director of a logistics company published in the *Times* newspaper in November 1964:

> *"At the time of the railway reorganization, the new highest Railway Executive issued instructions, limiting the number of containers in various railway stations so that each container was to be kept in constant use – in theory sound, but in practice unworkable for the daily fluctuation in trade." Letter by Robert Fisher, Managing Director of Robert Fisher (Packing and Shipping) Times: 3 November 1964*

This subsequently led to an internal response by Eric Merrill, Public Relations Manager at British Rail. Note especially the gravity of the situation demonstrated by the message 'This is not a PR problem' underscored by Eric as depicted in Figure 1 below.

> *"I am particularly worried about containers. The demand for them is greater than the supply – and we have surely contributed knowingly to this demand by what we have said and published and are still saying and publishing about railway services to-day and in the future […] As the Board's policy is not to build any more conventional containers the shortage will presumably continue until Liner Trains relieve the pressure. What worries me is that by that time we may well have lost a great deal of business and, in the process, engendered a lot of ill-will. Mr. Fisher's letter is a symptom of this. This is not a PR problem" Letter from Eric Merrill, public relations manager to the British Railways Board – 6 November 1964.*


time we may well have lost a gre
process, engendered a lot of ill-
symptom of this.

This is not a PR problem -
why and saying how much better ou
cuts no ice. I don't know whether
container situation can be effecte
the Commercial Department's attent
letters. I am sure they themselve

DAILY TELEGRAPH
Private Worlds

ALTHOUGH Wells station, in Norfolk, closed down some time ago, it is said that the

Figure 1. Reactions to railway closures following the Beeching (1963) report. (Left: Extract of memorandum sent by Eric Merrill to the British Railways Board, 6 November 1964; Right: Graphic published in the Daily Telegraph, 31 October 1964).

Yet, it would be naive to think that such problems were not anticipated during the review process. Indeed, we uncovered numerous letters sent in by various business representatives warning against the proposed recommendations contained in the draft Beeching (1963) report, including the two quotes below on how closure of railway lines could lead to detrimental effects on a growing tourist market:

> *"The seaside resorts such as Bridlington and Scarborough will close down. Anyone who wants to go from Hull to Scarborough will have to go via Selby" Yorkshire Post – 16th March 1963*

> *"Against what has been called the realities of railway finance, it must place, with such force as it can convey, other realities which are equally important to the national interest. […] In particular the Board would urge second thought on the cutting of the links between Girvan and Stranraer, and Stranraer and Dumfries. These closures would have a disastrous effect not only on the fast growing holiday trade of the south-western counties but on the tourist traffic to the north of Ireland by the short Stranraer to Larne route." Response by the Scottish Tourist Board to the draft Beeching Report.*

Yet, it would seem from the following quote that the government of the day had already committed a decision on de-nationalising the railways whether there was a business case to be made outside the confines of British Rail to account more fully the consequences on the wider economy. Thus, reforms are not always about upholding the values of economic efficiency and continuous improvement, but rather driven by ideological concerns.

> *"The Holding Company had been going into this to see how far they could replace the services […] Sir Philip Warter added that it was vital not to allow local authorities to run subsidised bus services in substitution for the closed railway lines. If there was done they would do it where they thought fit and it would ruin the chance of the Holding Company and their associates providing comprehensive coverage." Extract from the note of the Minister's meeting with Sir Philips Warter and Sir Reginal Wilson (Chairman and Managing Director of the Transport Holding Company) on Wednesday, 13th March, 1963.*

Opposition also came from within government, as shown in the following quote taken from a response by a regional county council expressing concerns over the reorganisation of railway infrastructure and spillover effects on other modes of transportation.

> *"[…] unless major road scheme in this area are expedited, the road situation will become chaotic and desperate, a situation which can only lead to more congestion and more accidents, and would seriously jeopardise Lancashire's industrial future by constricting goods and business traffic." Response by Lancashire County Council in a letter to the British Railways Board, 6 August 1963.*

The consequences of Beeching (1963) and the precursor to the next reform: As can be seen from the variety of responses to change ignited by the Beeching (1963) report, the emotional journeys in the time of the Beeching reform certainly seemed tumultuous. There was a great deal of resistance before and during the reshaping of the railway infrastructure in the early

1960s. Yet, it would appear that resistance was downplayed in the policy-makers' pursuit of the rhetoric of economic efficiencies for British Rail… although not for long! Still, the immensely negative reception to the Beeching reform meant that the pace of change intended by the Ministry of Transport (1960) had to be somewhat arrested. Notice, for example, the change of tone in the following White Paper published in 1967. Here again, the importance of commercial needs is still underlined. However, note that social needs start playing a more prominent position in the revised government intent. Such conciliatory tone provides evidence that reform is not simply a stand-alone episodic moment of change as times move towards a better future. Rather, there is often an emotive element of remembering the pitfalls of the immediate past. Thus, it is equally about avoidance of the troubled past as it is about rationally trekking into the future.

> *"The Government believes that, if our transport system is to **meet the social** as well as the economic needs of the country, we shall need a substantial railway system for some time to come […] The Government's first problem, therefore, was to determine the size and shape of the basic route system to meet both commercial and social needs. This was essential so that management could concentrate on the **improvement rather than the contraction** of the system, and provide a **first class service to the public**, as well as an **assured and worthwhile future for railwaymen** […] It reflects the necessary running of lines which no longer meet modern traffic needs but calls a halt to the drastic reductions which would have been necessary under the terms of the 1962 Transport Act. (Ministry of Transport, 1967: 1-2; **emphasis** added)."*

Further evidence of how social issues become more significant is demonstrated in the extracts below, taken from HM Treasury's (1967) review of the state of nationalisation:

> *"4. In the six years since 1961 much has happened […] Despite contractions in one or two industries, the overall capacity of the nationalised sector has been growing fast to meet increased demand […] In consequence, calls upon scarce resources of manpower and capital are now very heavy […] the need to measure these calls, to assess priorities, and to allocate resources upon an economically and socially rational basis has become even more important (HM Treasury, 1967)."*

> *"7. Investment projects must normally show a satisfactory return in commercial terms unless they are justifiable on wider criteria involving an assessment of the social costs and benefits involved, or are provided to meet a statutory obligation (HM Treasury, 1967)."*

5. Implications and conclusions

In this article, we have attempted to reconceptualise industry reforms through the archival case study of the British Railway Industry. We argued that reforms are often less about rational processes of change moving forward. Rather, reforms are often entangled by ideological concerns hidden away by rhetorical projection of a seemingly better future. We considered how, in the case of the Beeching reforms of the British Railway Industry, that reforms are much more continuous than episodic. Thus, given how one reform often leads on to another reform, change can sometimes be more about remembering the ever-

extending past than it is about moving positively into the future. Although the process of change – carved up in episodic moments of a chequered past, moving present, and an optimistic future – was detected in this archival narrative, we also saw how time embodied in temporally lived experiences of those involved (and affected) can serve to accelerate or arrest the pace of change. These different interpretations enrich our accounts of how institutional change happens (see e.g. Löwstedt and Räisänen, 2012). Our conclusions here suggest that reforms are not only (and often less about) rational economic performance bounded narrowly by a particular interest group within a sector. Rather, reforms are emotional as demonstrated by the responses of anger and resentment directed at the changing railway infrastructure in the 1960s, and that resistance matters a great deal.

So, what relevance does this historical case of the British Railway Industry have for our understanding of construction reforms? Clearly, the seeds of privatisation and the dismantling of public-sector provision of infrastructure were sown at the turn of the 1960s. It is interesting to note that Green (2011) appeared not to have placed much emphasis on the 1960s in his account of industry reforms. Indeed, he suggested a relatively calm decade for British construction, as he described,

> *"Expectations in the 1960s were indeed very different from those of today and it is perhaps in the area of employment stability where the greatest contrast lies. (Green, 2011: 12)."*

The analysis of the reforms of the British Railway Industry presented in this article suggests an earlier account of institutional change that took place in Harold Macmillan's administration in the late 1950s/early 1960s. The reality was certainly not one of stability. And so, the understanding of the relationship between the public and private as applied in the construction industry cannot really be understood fully without tracing the broader past that led us to the moving present. It is contended that the study of reforms from the standpoint of a particular industry or sector at a moment in time is not entirely adequate. Instead, there needs to be much wider consideration of the institutional context within which a particular industry operates. This necessitates an appreciation of the socio-economic and political changes surrounding the reforms, both in time (temporally) and over time (episodically).

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Student and supervisor perspectives on publishing during PhD candidature: towards developing a capacity building model in academia

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Abstract

There is increasing pressure for academic institutions to solve societal problems, engage more deeply in industry-academic linkages and produce PhD graduates who are ready for an industry or academic career pathway. The training of doctoral students is becoming much more focussed on outputs. The academic workplace where new academics are employed is arguably different from that which characterised graduate education in the past. PhD graduates enter an academic workplace where they are expected to demonstrate multiple skills and abilities as they engage in a full range of academic activities that support various institutional missions. An academic's understanding of the institutional expectations and the development of their capacity to contribute to the institution's performance begins with the graduate school experience. Publications are an important way for universities to measure personal and institutional performance. However the academic workplace places demands on academics to give priority to other achievements. Consequently writing for publication appears to be an ad-hoc activity for many PhD students. Underpinning this is the capacity of supervisors to support and steer students to publish effectively. This article represents the authors' experiences of publishing during their PhD candidature from a student and supervisor perspective. The advantages and disadvantages of the publication process are presented as well as the inhibitors and enablers for successful outcomes. The discussion is contextualized within the Australian graduate research education sector. The growing body of literature reimagining doctorate education and in particular the publishing process is considered. We conclude with suggestions on how the authors' experiences can contribute towards the development of a capacity building model for both PhD students and supervisors in fostering publications by PhD students. The *art* of publishing is pursued with the philosophy that it is the space dually occupied by the supervisor as academic mentor and the doctoral student as emerging trainee scholar.

Keywords: doctoral education, supervising PhDs, academic capacity-building, academic publications

1. Introduction

Past work into graduate research education has identified that current training tends to focus on the "how to" instead of the actual "doing" of a higher degree research program (Rugg and Petre, 2004; Churchill and Sanders, 2007). Whilst achieving the final research dissertation is often seen as the ultimate outcome of a postgraduate degree it is not the only outcome. The softer side of graduate education – with an emphasis on the experiential role of the student –

in the development of their training to become future leaders in academia, government or industry and the social interactions which take place in the process are equally important if we are to develop well-rounded high performing academics. Increasingly questions are raised about the appropriateness, quality and adequacy of existing graduate education programs in preparing PhD students for the competitive and demanding workplace they will face (Austin, 2002; Evans et al, 2003). Publishing skills are often considered as one of the main tools of the academic *trade* whereby writing for publications is an important activity for established academics and PhD students alike (Cuthbert and Spark, 2008). The capacity of students to publish during their PhD candidature is increasingly being recognised as an important way to prepare students for the competitive real world of science (Giegerich et al, 2007). Success in publication of PhD work is well correlated with subsequent scholarly activity (Robins and Kanowski, 2008). Newly employed academics who learnt to balance writing, teaching and collegiality early in their academic careers generally have high levels of publication productivity (Page-Adams, 1995). Within this context formal structures, pedagogic practices and supervisor capacity can play a critical role in building PhD student capacity and exposing them to the values and practices that they are likely to confront upon entry into academia. The majority of PhD students do not receive adequate mentoring or structural support to publish from their research.

There is a small but growing body of literature on the advantages of publishing during PhD studies. However very little attention has been placed on the complexities of the publication process during PhD candidature. The conditions or enablers which foster PhD publications are also not often considered. There is a need to develop a greater understanding of the enablers and inhibitors for success. This paper explores the authors' experiences of publishing during PhD candidature from a student and a supervisor perspective. The advantages and disadvantages of the publication process are presented as well as the inhibitors and enablers for success. The discussion is contextualized within the Australian graduate research education sector. The growing body of literature that is evaluating and reimagining doctorate education and practices and in particular the publishing process is considered. We conclude with suggestions on the development of a capacity building model for both PhD students and supervisors in fostering publications by PhD students.

2. Graduate research education in Australia

The PhD was first introduced in Australia in 1948. The approach to graduate research education in Australia was similar to that which emerged in the United Kingdom (UK) in the early twentieth century where individual students have been closely associated with individual supervisors as well as individual institutions (Evans et al, 2003) with a research program that has been characterised as an "extension of the BAHons with some research" (Clarke, 1995, p. 79). This is unlike the American system which adapted the German practice combining graduate coursework with research in a PhD program (Gellert, 1993). Since the award of the first PhDs in 1948 in Australia there has been a significant growth in numbers of research students and PhD students in particular. The approach to doctoral education in Australia has, however, remained largely research-based and is generally completed in 3-4 years full time or part-time equivalent. The definition of a PhD degree offered by the University of Melbourne's Graduate School of Research (GSR) largely sums

up the general approach to doctoral education in Australia: *A PhD degree "signifies that the holder has undertaken a substantial piece of original research which has been conducted and reported by the holder under proper academic supervision and in a research environment for a prescribed period…Its contribution to knowledge rests on originality of approach and/or interpretation of the findings and, in some cases, the discovery of new facts. It demonstrates an ability to communicate research findings effectively in the professional arena and in an international context. It is a careful, rigorous and sustained piece of work demonstrating that a research "apprenticeship" is complete and the holder is admitted to the community of scholars in the discipline" (University of Melbourne, 2012).*

Increasingly PhD graduates have varying employment outcomes and as a result the PhD may no longer be seen as an "apprenticeship" for being a university academic (Thomson et al, 2001). The emergence of professional doctorates in Australia in the early 1990s represents one of the key responses towards the changing expectations of graduate education (Kemp, 2004). Another response has been a liberalization of rules governing PhD programs to accommodate new specialties as well as different ways in which research can be carried out and theses presented (Pearson and Ford, 1997; Evans et al, 2003). In 2008 there was an increase of 41 per cent in number of students who completed a higher degree by research (HDR) in Australia since 1998 with international students contributing significantly to this growth (Australian Government, 2011). Research training in Australia is funded by the Australian government through the Research Training Scheme (RTS), Australian Postgraduate Award (APA), International Postgraduate Research Scholarships (IPRS) and Commercialisation Training Scheme (CTS). The Australian Research Council (ARC) and the National Health and Medical Research Council also provide a number of research training places. Additionally, universities, private research institutes, industry bodies and employers also contribute towards funding research training (Aust Govt, 2011).

2.1 Publishing productivity of graduate research students

In Australia there has been no widespread move to develop the publishing potential of graduate research students (Cuthbert and Spark, 2003). One of the key factors contributing to the lack of attention paid towards fostering publications by graduate research students is the policy and management of higher degree by research education in Australia which significantly downplays the importance of the publication process (Cuthbert and Spark, 2003). The Research Training Scheme (RTS), which is the country's largest source of funding to higher education providers, provides support for research training to domestic (including New Zealand) students undertaking doctorate or masters degrees. The RTS is paid, on a calendar year basis, as a block grant to eligible universities according to a performance index (DIISRTE, 2012). A weighted performance index determines the allocation of the RTS block grant to universities based on the following breakdown: HDR student completions: 50 per cent, research income: 40 per cent and research publications: 10 per cent. Underpinning the formula for the performance index is an assumption that student completions within the required timeframe equates to students receiving high quality research training supervision. Whether or not high quality research and research training supervision is achieved, however, remains questionable as pointed out by a recent consultation paper by the Australian Government (2011) on defining quality for research training in Australia: *"The original policy intent for including HDR completions in the RTS funding formula was*

to reduce completion times when these were becoming unsustainable, and to reduce attrition…Whilst the inclusion of completions in the RTS formula has been effective in reducing completion times, there have been some concerns that in some cases higher completion rates might have been achieved at the cost of quality" (p. 11-12). As can be seen through the RTS' weighted performance index, extreme pressure is placed on academics to perform in the two areas of student completions and research income. Arguably the focus on achieving timely completions and obtaining research income has been undertaken in expense of other areas in the delivery of graduate research education including nurturing students into the publication and research cultures of their disciplines (Cuthbert and Spark, 2003).

Publications are an important way for universities to measure personal and institutional performance. It is widely recognised that PhD research is a major source of new knowledge production in universities. PhD students play a critical role in establishing international collaborative links (Kamler, 2008). Yet writing for publication appears to be an ad-hoc activity for many PhD students whereby publication performance varies considerably from one student to the next. Mentoring towards publication is also not often a routine part of the process of graduate education whereby PhD students appear to be "left to their own devices to sort out how to publish from their research" (Kamler, 2008, p. 283). Work conducted in the United States of America uncovered that publishing productivity could be stimulated during graduate education (Green et al, 1992). Amongst some of the key factors that could facilitate PhD students' publishing productivity are: encouragement from supervisors (Dinham and Scott, 2001), institutional support (Kamler, 2008) and critical feedback and attention to writing-in-progress for eg through writing groups (Lee and Boud, 2003; Cuthbert and Spark, 2003). In summarising these studies, Kamler (2008) aptly points out that "doctoral publication is not a given" and that "it flourishes when it receives serious attention and skilled support from knowledgeable supervisors and others who understand academic writing as complex disciplinary and identity work" (p. 284). Kamler (2008) further argues that greater pedagogical attention needs to be provided to writing for publication through a more sustainable and long-term approach to re-envision and rethink doctoral pedagogies.

3. Reflections on publishing during PhD candidature

This section outlines the reflections of the authors' experiences of publishing during their PhD candidature from a student and a supervisor perspective. The advantages and disadvantages of the publication process are presented as well as the inhibitors and enablers for successful outcomes. The two PhD student authors are currently doctoral scholars in the School of Property, Construction and Project Management at RMIT University, Australia and are both supervised by the same principal supervisor (author 3). The first student commenced her PhD program in August 2009 at a different Australian university and transferred to her current university in February 2011 to remain under the supervision of her supervisor who had taken up a position at the university. Since commencing her PhD program, the first student has produced 26 publications which include 1 book, 17 conference papers, 5 journal papers and 2 book chapters. Similarly, the second student commenced his PhD program in June 2009 at a different university and transferred to his current university to remain under the supervision of the same supervisor. Since commencing his PhD program, the second student has produced 16 publications which

include 12 conference papers, 3 journal papers and 1 book chapter. The third author is a senior academic in the same school who supervises a number of doctoral students including the two PhD student authors of this paper. The supervisor has jointly produced 41 publications with her research students since 2009. The average annual publication rates of the authors are 8.7, 5.3 and 19 respectively for a three-year period between 2009 and 2012. The publication output of the authors far exceeds the discipline average of 1.3. The authors can thus be considered as successful cases of students publishing during their PhD candidature. The authors have also received several awards for their publications: 2009 Emerald Best paper award, student 1 and supervisor; 2011 Emerald best paper award, student 1 and supervisor; 2011 UITM Innovative paper award, student 2 and supervisor and 2012 Best paper award, student 1 and supervisor. More recently the three authors signed a book contract with a renowned publisher. The book is a collaboration between the authors and includes the PhD work of students 1 and 2 as well as previous research projects lead by the supervisor and for which PhD student 1 was employed as a researcher.

3.1 Case 1: PhD Student 1

The first student author is a recipient of an Australian Postgraduate Award, which is a scholarship awarded to "students of exceptional research potential undertaking a HDR in Australia" (DIISRTE, 2012). Her PhD study explores the client governance context of megaprojects using the theories of governmentality and cultural political economy. The research involves two case study megaprojects in Malaysia and Singapore and the student has visited both countries on several occasions to conduct fieldwork. During her PhD studies she also spent two weeks at Hosei University, Tokyo, participating in an intensive Young Researchers' School through a scholarship awarded by the Promotion of Sustainability in Postgraduate Education and Research alliance at the United Nations University. Throughout her PhD studies she has worked on a number of research projects on an average of 2 days per week. It is relevant to note that Student 1 completed a Masters of Philosophy under the supervision of the third author-supervisor at a university in NSW, Australia. She has also worked as a Research Assistant (RA) and Research Fellow on research projects since 2004 in both full time and part time positions. Her experiences of the publication process thus began prior to commencement of her PhD program. Student 1 has also tutored in an Honours Research Methods course which has provided her another dimension to the research process. The student has found that through explaining the process of research to others she is able to increase clarity in her own ideas. Student 1 was offered her first RA job by her supervisor to work on a Cooperative Research Centre (CRC) for Construction Innovation research project in 2004. The student worked closely with her supervisor on various activities: reviewing literature, developing ethics application, collecting and analysing data. It was while working on this project that the student was first introduced to the world of academic publishing. The student co-authored a conference paper with her supervisor who guided her through the publication process from abstract to paper submission to conference attendance. The paper explored one component of the study and the student found the writing process both enjoyable and useful as it enabled her to sharpen her thinking around a concept. It was also important that she was able to simply attend the conference without the stress of having to present as her supervisor presented the paper, which allowed her to observe and experience the process in a relaxed manner. At the conference the student

began to appreciate the value of publishing where she could see that it was an opportunity to present early findings to an intelligent audience for critical feedback. The student was introduced to various academics and HDR students and started to feel like she was a part of a larger community of researchers.

Since then, she continued to work on five other CRC-CI research projects with her supervisor. Being involved with the CRC environment provided her with an excellent opportunity to engage with industry and government as well as other academic institutions. The CRC projects provided an environment for intellectual debate and discussion to take place as projects often involved more than one RA and the research team tended to be multidisciplinary. The student was introduced to theories from sociology and business which she could see were applicable for understanding built environment industry problems. She was consistently entrusted with a high level of autonomy and responsibility on the projects by her supervisor. When she had developed her confidence and skills she assisted her supervisor in overseeing junior research assistants on projects in selected tasks During this time she was a foundation member of a research centre of which her supervisor was the director. She was a member of the organizing committee of a conference hosted by the centre and experienced conference organisation. The CRC projects had project deliverables including administrative milestones and research outputs. Research teams were not only encouraged to publish but it was often a part of the project requirements. Specific funds were often sought by project leaders to present findings at academic conferences. Through her involvement on the CRC projects student 1 was able to attend conferences each year. One of the highlights was her first presentation at a conference in London. The student gave a joint presentation with her supervisor. The student prepared the presentation with her supervisor and was given advice on key points to discuss when they were preparing the presentation. The supervisor ensured that the student was comfortable with presenting and physically stood next to the student throughout the presentation. This was an important experience for the student because this was the first time she was presenting and engaging with an international research community. The experience enabled the student to build her confidence. It also further demonstrated to her the merits associated with the publication process. Following the conference they received an invitation to develop their paper into a book chapter. Whilst this seemed like an exciting opportunity the student found parts of publishing process quite challenging. Reflecting on her experiences she recalls feeling overwhelmed and inadequate as the reviewers had recommended extensive changes to the chapter. The student and supervisor went through a series of intensive sessions to address the reviewers' comments which eventually resulted in a most positive outcome. Despite the sessions being extremely productive the student felt that she was incompetent in writing an adequate literature review and communicating ideas and findings poignantly. Looking back she can now see the invaluable learning achieved through the experience but it was not easy and did at one point discourage her from wanting to publish. During this time she shared her feelings of disheartenment with her supervisor who then shared her own personal experiences in relation to the publication process and in particular in addressing reviewers comments. The supervisor said something which stayed with the student, "it happens to everyone" and very importantly the supervisor let the student know that she respected and valued her work as a researcher. This was important because the student had lost confidence in writing and being told by a respected senior academic that her work

was valued and knowing that others also had similar experiences kept her motivated. Eventually she could see that the process led to a much more enhanced and refined chapter with richer work presented. It was through this experience that the student realized the importance of publishing as it forced her to not only commit to a position when writing but to also justify and provide a rationale for the position.

Student 1 has received funding through a variety of sources to participate at conferences since 2004 including research projects and CRC projects. Another key source of funding has been HDR funds provided by universities. For example the student has been provided $4000 for the duration of her candidature which can be used for various activities such as fieldwork, traveling to conferences, etc. Whilst the HDR funds were very useful the student found that the funds were inadequate to support a high level of publication activity. Given that the funds were expended after only one international trip the student has missed out on opportunities to publish at specific conferences even though the conferences were well aligned with her area of research due to a lack of funding. Unfortunately PhD students are not provided the same opportunity to apply for travel funding as staff members and therefore there is little incentive for students to want to write more than one publication throughout their candidature. Student 1 is currently the President of the RMIT CIB Student Chapter which is an organisation of research students in the built environment disciplines aimed at providing students with opportunities to network with the international research community, provide peer support, build their identity and provide a framework for career development. Regular meetings are held which are chaired by Student 1, under the guidance of at least one of three academic advisors. The third author-supervisor of this paper is the senior academic advisor of the Chapter. The Student Chapter provides students with a 'taste' of the academic environment. Student 1 is also actively involved with the Chartered Institute of Building (CIOB) Australasia and is the editor of the professional magazine "Contact Australasia" with readership of over 750 members. Her supervisor, who is the president of the CIOBA invited her to become a member of the CIOB and take on the role of Publications officer. Her role as the editor has provided her with yet another interesting perspective of the publication process. The audience of the magazine comprises largely industry professionals and so the student has had to think of ways to present quality research and keep the audience engaged

Since 2004 she has been exposed to various activities academics are required to engage with and the capabilities they must develop to become high performing academics. The student learnt academic research skills and research management skills for eg. developing grant proposals, collaborating with other academics and/or researchers and managing budgets. The student learnt quite early that people issues often required attention and appropriate management. The student also realized that in order to teach well and develop high quality curriculum design this needed to be supported by leading edge practice and innovative research. Such softer skills and capabilities are largely "passed on" to students by their supervisors and not found in university policies or guidelines. There is often no clear guidance provided on how students can be taught these essential skills on becoming a high performing academic. Student 1 has been fortunate to have been nurtured and mentored with much care by her supervisor who has taught her much more than research skills alone. Through her variety of experiences the student has started to understand the importance of

achieving a balance between research, teaching and leadership/governance in academia and the importance of the publication process within this context.

Case 2: PhD Student 2

The second student's PhD topic is "Comparative analysis of China and developed countries' construction industry based on productivity and industrial competitiveness under the context of globalization and internationalization". Both qualitative and quantitative approaches in data collection and analysis are employed in this study. Chinese and Australian construction industries are studied as cases. He is currently the secretary of the RMIT CIB Student Chapter. He has been supervised by the third author since 2009. He has worked as a Research Assistant on several research projects since 2011. He usually works 2 days a week on research projects and dedicates 3 days a week to his studies. Throughout student 2's PhD candidature, his supervisor has always encouraged him to develop his ideas through publications. He has found this very helpful for him to generate his PhD dissertation. Following the publication of his papers, the student 2 would reorganize the material in the papers and revise its content based on the feedback received from the reviewers and/or conference audiences' feedback to further develop his PhD thesis.

In 2010 student 2 attended and presented at his first international conference in Brisbane. This was his first experience of the publishing world. Through this experience he learnt the whole process of publishing a conference paper and the process of writing up an academic paper. The supervisor greatly helped him by explaining to him the key issues associated with the publication process. Before his presentation at the conference, the supervisor explained to the student a number of important and useful skills, such as how to do a presentation, how to control his nervousness, how to answer the audiences' questions and how to build up his network. Student 2's first journal paper was published in 2011. What the student found most important about his learning from his supervisor was the process of responding to the reviewers and revising the publication based on their comments. Student 2 is currently working as a research assistant on an international project where he is working closely with his supervisor on various phases of the project. His work on this project has provided him with an exposure to some of the realities of the research and academic world. He has learnt about various aspects of working on research projects including identifying and preparing relevant material for developing a literature review, organising data collection, generating interview questions and conducting interviews overseas. The student has also been able to further develop his skills and abilities in solving new problems, communication skills, team work and time management. In addition, the School of Graduate Research provides a series of seminars and workshops for HDR students to develop their research skills. Some very useful seminars are provided, for example "Finding Theses and learning from them", "Citations: tracking the development and impact of research", "Searching Library databases", "Introducing Library resources and services", "How to pass confirmation", "How to make a beautiful thesis", "Writing for and presenting at Conferences", "Peer reviewing: tips and techniques", "The literature review: writing and structuring", "Managing (up) your supervisor", "What do examiners really want", etc. A series of research seminars is also organized by the student's school. Through the weekly seminars students could not only learn from the presenters, but also they can present to academics and staff in the school to get feedback

as well as improve their presentation skills by using it as a good practice environment prior to presenting at an international conference. Recently student 2 gave a joint presentation with authors 1 and 3 in the school's research seminar on the topic of publishing during PhD studies. All HDR students can apply for funding from their school and university to support their publication activities. Every PhD student is provided a total of $4,000 by the school. Additionally they can apply up to twice for funding from the university through the Deputy Vice Chancellor's (DVC) Research and Innovation HDR Student International Conference Grant. Student 2 has used funding from both the School and DVC R&I sources to attend various international conferences, which has been good opportunity for him to share ideas, learn from others, receive feedback and get recognized in the academic world. Student 2 is very appreciative of the support of his school and university in helping him publish.

Case 3: Supervisor

The supervisor had experiences to share from being a Masters and doctoral publishing scholar as well as a supervisor. There were seven key advantages of publishing during the student projects as perceived by the supervisor including; 1) developing skills in publishing 2) improving rigour of the research through the international peer review process 3) creating a name for yourself 4) developing a robust CV for an academic career 5) the enjoyment of learning from others in a collaborative research group 6) developing collaborative research skills in writing with others and 7) a sense of achievement with smaller milestones. There were four key disadvantages of publishing including; 1) getting 'side tracked' 2) writing and not getting credit for your efforts 3) writing and exposing your IP on your PhD too early to 'preying' academics (other than your supervisors) and 4) doing too much publishing in low quality places and thus diminishing your credibility. The inhibitors can be 1) lack of mentoring by supervisor 2) lack of interest by supervisor 3) demotivation caused by negativity of the peer review process and 4) lack of skills in dealing with the publishing process. The key enabler is a supervisor who understands mentoring; that their role is fundamentally about building and nurturing careers and that the writing process is one of the key learning spaces for this close mentoring to occur. As a Masters student she was introduced early on into academic publishing as she was employed on an ARC Linkage federally funded grant. She was a full time research assistant and she completed her Masters part time. The study duration was 3 years and for the final year the supervisor was employed outside the University environment as a full time project manager for capital works projects within a government agency. The research study was supported by two research assistants and three Chief Investigators (CIs). Two of the CIs were completing their PhDs at the same time. The culture of this group was characterised by high performing people who were very competitive. Interestingly they were largely competitive with themselves; although peer competitiveness was also a feature of the group and they were all high achievers. Three of the four in the group have subsequently become Professors. The lead CI was a Professor and mentor to all in the research group. Publication of conference and journal papers was the norm. It wasn't the most productive group that the supervisor has experienced to date and there could have been many more outputs, however given other experiences that other students have had this appeared to the supervisor as an excellent grounding and introduction into what it *means* to be an academic.

As a PhD student she was enrolled at a G08 University in Australia and the experience was very different. The attention to publishing was much deeper and more focussed. The career development and the *'entre'* into the life of an academic was profound. The expectations were much clearer and it was almost like the supervisor had entered an academic professionalization phase of her life. Career pathways were clear and well communicated and the conventions and norms were well established. Corridor discussions on the 'right journal', the 'right company to keep' and who was in whose research networks were commonly held. She recounted a story whereby she had drafted an abstract for a World Congress within 8 weeks of arriving because as her supervisor told her this event was only held every three years and 'she must get to it and begin to expose her research to the international community'. It was an unwritten rule in the Faculty that you would have published at least one journal paper in 'the best journal in your discipline'. The convention was that the paper idea was to originate from the PhD student however the supervisors would be co-authors on all papers published during the candidature. The primary supervisor would discuss the idea of the paper and the overall structure of the argument in the early days and then the student would subsequently develop the paper. The level of detail and attention to argument structure and writing style overwhelmed the supervisor on the first paper but then for some reason she let go and attended to the critique one step at a time and could literally feel the quality and argument emerging from the paper. She recounted that she would be forever grateful as her PhD supervisor developed and honed her resilience to critique. This is one of the attributes she tries to instil in her students now. The way she supervises is a development of the way she was supervised. She pays attention to the publishing process and attempts to build student confidence levels. She also tries to think more holistically about their experience as a scholar and their future. She tries to expose them to grant writing, conference organisation, event organisation and the international network of researchers which is 'their individual home'. She attempts to attend conferences with the students writing a paper from her own work as well as attending their publication presentation. This time away together is about discussing the conference, the other participants and the audience response to their paper. The supervisor published quite extensively with her supervisor during her PhD and found it a most rewarding experience. Finally the attendance at conferences is not without a financial burden which must be borne by the institution or the supervisor. When the supervisor was completing her PhD she was well supported by her scholarship as the industry partners had provided an additional grant towards conference attendance above and beyond her scholarship. Her supervisor explicitly allowed her to use that funding and plan it herself with discussion and some guidance. The supervisor then understood the importance of institutional support and the role that grant income can play in supporting students to attend conferences and participate in these networking activities. This guided her in her own methods for supervisor whereby she developed the philosophy that grants provided infrastructure to support research activity for both the student, the research assistants and the supervisor. This additional income often supplemented University or School level financial support for travel to conferences.

4. A capacity-building model in academia

The authors' experiences support findings of past research in that there are various benefits associated with the publication process. A key part of the graduate education process is

about the PhD student feeling empowered and being able to take control of their research and personal development (Mercer et al, 2011). The reflections of the three authors highlighted that they were provided various opportunities for personal and professional development through non-technical skills training including; practice in communicating their ideas, writing and reviewing scholarly publications and networking with the wider academic community and industry. The authors' experiences demonstrate that there is value in PhD students learning with and from other researchers through these exchanges. For a large majority of PhD students there is a tendency to assume that writing is an activity that is undertaken at the end of the research process. A more useful approach evidenced here has been to consider the activities of writing, reviewing and analyzing as part of the daily academic work practices. The authors received much support from their supervisor to write for publications, however, this largely was left up to the supervisor and students to manage themselves. Perhaps greater attention can be given to thinking about how to better support and achieve more sustainable ways of fostering publications during PhD candidature. This section identifies some of the common themes highlighted by the authors as inhibitors and enablers for successful outcomes in relation to publishing during PhD candidature.

4.1 Enablers and Inhibitors

Two main themes can be identified as enablers and inhibitors for successful publication outcomes of PhD students; 1) encouragement and mentoring from supervisor and 2) institutional support. Perhaps the most important theme which has arisen is that the practice of supervision shapes the writing and publication activity of students. For the authors writing for publications has become very much *part and parcel* of completing their research degree. Their supervisors instilled in the authors a culture of writing for publications and published extensively with the authors. Ultimately this had led to a high level of performance by the authors in terms of publication output. However it is important to note that the encouragement and mentoring received by the students was heavily reliant upon the capacity of the supervisor to be able to carry out the supervisory role appropriately. Little attention currently goes into ensuring that supervisors have the right skills and experiences to mentor students towards publishing. As cautioned by the third author, there are a number of potential disadvantages to publishing during PhD candidature if not undertaken appropriately. For novice researchers much guidance and mentoring is required to ensure that they are not disadvantaged by the publication process for example getting side-tracked in their studies or publishing consistently in low quality places. For the authors the mentoring received from their supervisors was crucial in training them towards understanding the 'right' approach to writing and publishing in the 'right' places. It is also important to note that the role of the supervisor encompasses the softer side of providing encouragement during times when students get demotivated by the negativity of the peer review process. There often comes a time in an academic's publication experiences where they will encounter challenges when dealing with the peer review process. Often one's confidence will be questioned and it is during this critical time of crisis that students feel most fragile and need to be treated with much care and sensitivity as they can easily be dissuaded from being involved with the publication process altogether.

The second theme relates to institutional support towards fostering publications by PhD students. Funding provided by the university greatly assisted the students' ability to attend and present at conferences. However the experiences of the students also demonstrated that the current level of funding provided to PhD students does not appear to be particularly supportive of high performing students who seek to publish at more than one international conference throughout their candidature. Underpinning this is perhaps a general lack of valuing the importance of writing for publications which can be attributed to the RTS weighted performance index which places far higher importance on student completions and research income compared to research publications. Whilst this relates to broader issues of government funding and policy which perhaps may be difficult to change it is important that the manner in which students tend to deal with issues arising from the lack of funding is again to seek assistance and guidance from their supervisors. Experiences of the authors show that the students' first 'port of call' whenever there was an issue related to their PhD studies was their supervisor who would then provide relevant advice to help the situation.

4.2 Building capacity of supervisors

The graduate education experience is the beginning of the development of an academic's understanding of the full range of academic activities that support various institutional missions. A PhD student's academic performance and learning takes place within a network of relationships with peers, academic supervisors and the broader intellectual and social domains of university life. HDR success and well being is reliant upon the support of diverse professional staff from across the university. For example, at RMIT University research support is delivered by staff from Schools, Colleges, Research and Innovation Portfolio, Financial Services Group, Legal Services Group, RMIT Library, Marketing Group and International Services Group. They each play a critical role in contributing towards a positive graduate education experience for PhD students. However for many students the graduate education experience is closely linked to their relationship with their supervisor and how the supervisor "brings them into the fold of things". The reflections of the authors show that the supervisor is often the 'lynchpin'; the person who introduces and mentors students towards understanding the academic world. A high level of care needs to be given to crafting the publication pathways of PhD students alongside their career pathways. The realities of the academic workplace places demands on academics to give priority to other achievements such as grant income and PhD completions. Publication writing appears to be an ad-hoc activity for many PhD students and performance varies considerably from one student to the next. Underpinning performance is the supervisor capacity to support students to publish effectively and to develop various other skills related to academic and research activities. As shown by the third author, the manner in which she now supervises has very much been shaped by the way she was supervised as a student. Therefore it is critical for students to be provided the 'right' training during their PhD candidature as this will inevitably influence the way they supervise in the future. At present the institutional policies for student supervision generally define the minimum responsibilities for supervision. Whilst most of the policies are aimed at providing students an appropriate intellectual and academic environment and ensuring that students receive high quality supervision there is little explicit recognition that supervisors require adequate training to learn good practices in supervision. There is even less guidance or support provided to supervisors to develop the intangible skills required to

supervise effectively for eg sensitivity, etc. The unspoken or unwritten skills appear to be critical skills that supervisors need to possess in order to provide appropriate mentoring to their students. In summary there is little spoken about what it means to achieve excellence in a research group within the context of higher degree students publishing.

5. Summary and concluding remarks

The authors' experiences of publishing during their PhD candidature from a student and a supervisor perspective have been presented in this article. We identified enablers for successful outcomes based on how the authors' experiences can contribute towards the development of a capacity building model for both PhD students and supervisors in fostering publications by PhD students. In summary the supervisor plays a critical role in facilitating the publication productivity of PhD students and more attention needs to be given towards building supervisor capacity. This paper explored cases where students have achieved a level of success in their publication performance during their candidature and so did not identify specific inhibitors to successful outcomes. The findings are limited in that only the personal experiences of the authors have been discussed. Further work is required in order to explicitly develop a capacity building model for academics based upon more case studies of both successful and unsuccessful PhD publication performance. This should be carried out with a larger pool of doctoral candidates and supervisors to validate the findings.

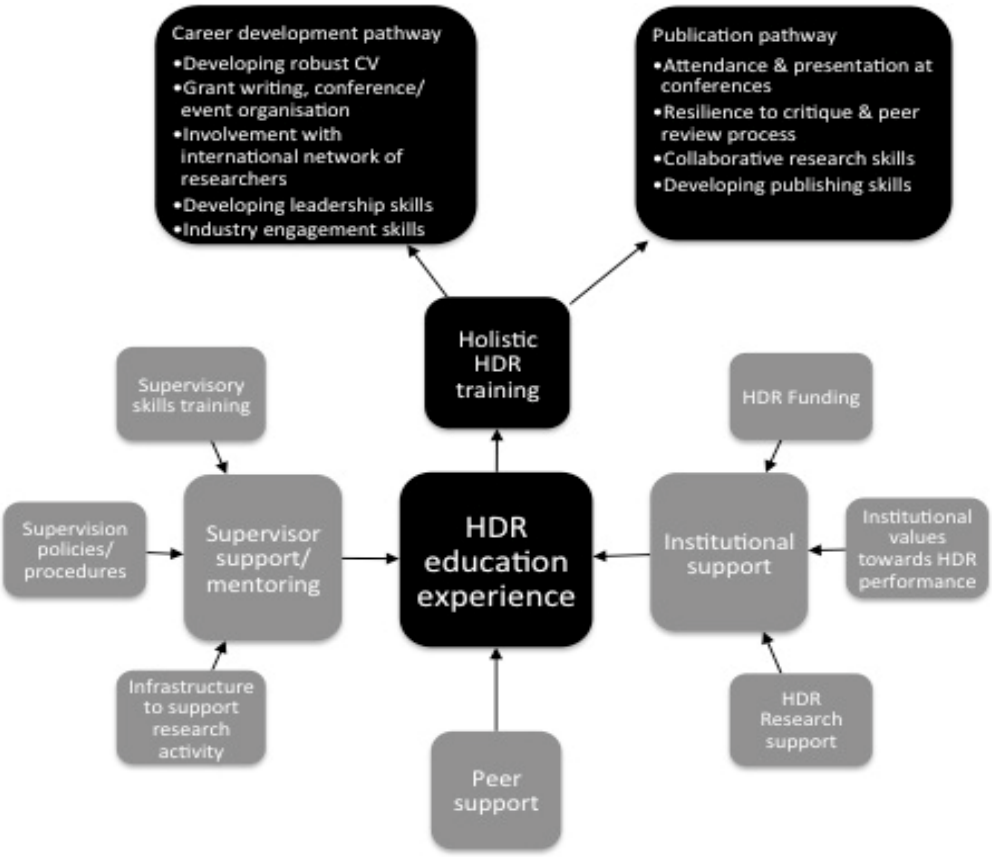

Figure 1: A capacity building model in academia (developed for this research)

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The Need for Improvement of the Productivity Understanding in Highway Asphalt Pavements in Brazil

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Abstract

Introduction: The importance of heavy construction, in Brazil, is demonstrated by the latest interest in the topic of infrastructure development, motivated by three factors: the need for infrastructure investments; the sector was opened to private enterprise; and the infrastructure has permanent effects on the income level and in the attraction of foreign investments, with direct results on human development. The interest in the infrastructure development, leads us to the urgent need to improve the quality of road pavements. Therefore, investments, organized in various sectors: research, consulting engineering, construction and quality control, become necessary. **Study objectives:** This work studies the productivity variation in the highway asphalt pavement construction in Brazil and discusses the differences among the opinions of budget manuals. **Methods:** Based on the Model of Factors (this approach entails the prediction based on aspects observation related to a greater or lower expectation of efficiency of equipment in a certain service), the selection of research methods covers the objectives outlined, including literature review, exploratory studies and field surveys. **Conclusions:** Regarding services of asphalt pavement, there are many manuals, however each one deals with the execution steps differently and the productivity indicators presented are extremely variable. Furthermore, it is not possible to know (reading the manual) which factors were considered when the manual indicates a specific value for a certain service. Accordingly, its usage (the manuals) as a tool for budgeting and management is inefficient. The result of budget manuals study is presented and new methodology is proposed.

Keywords: productivity, pavement, highway infrastructure.

1. Introduction

In Brazil, in recent decades, investment in road infrastructure is far below the needs of the country, with a growing dissatisfaction of the productive sector with this level of investment. The IPEA survey, from 2010, showed that of $ 89.8 billion needed for the Brazilian federal

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highways, the Programa de Aceleração do Crescimento – PAC (Program of Acceleration of Growth) only predicts investments equivalent to 13% demand.

1.1 The highway as a response to demand for infrastructure

Providing infrastructure represents major public investments and a long-term planning. It is essential that the functionality is in line with the useful life of the enterprise (Fehrl 2008). Aware of this reality and the social importance and needs of the sector, between 2007 and 2010 several works were completed in Brazil: 1.306 kilometers of roads were doubled, 1.789 kilometers were paved and 3.282 kilometers were granted to private companies, which manage 15.000 kilometers - less than 1% of the paved mesh. There are duplication works on 1.592 kilometers and 3.524 kilometers of pavement in execution, besides signposting and maintenance services hired for more than 50.000 kilometers of network. For the private sector, there is immediate potential to grant, at least, over 12.000 kilometers (Abdib, 2011).

1.2 Available pointers of productivity

For the forecast of the productivity in Brazil the cost data manual use is common. However, it is perceived in practice, that the productivity pointers can have a great variability requiring knowledge of the factors that make them vary.

In the revision / perfection work developed for the Polytechnic School of São Paulo, USP (EPUSP, 2008) of the prognostic costs effected by the Brazilian Federal Government for the airport construction it was found a great variability of relative efficiencies to the pavement service (according to study in construction and consults to specialists, manuals and technical documents). Examples of variability are presented in Figure 1.

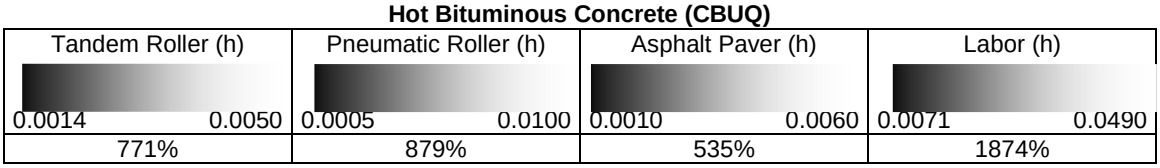

Figure 1 – Change (%) among the yields for the service CBUQ (number of equipment hours to launch a ton of material)

This example, which varies from 535% to 1874%, is a warning about not being able to make reliable decisions based on imprecise indicators.

1.3 Study objectives

This paper proposes studies of productivity variation in the highway asphalt pavement in Brazil and discusses the differences among Brazilian budget manuals. Built on the concept of productivity variable (unprecedented in the subsector of heavy construction) and it uses the approach of Model Factor. This approach entails a prediction based on careful observation of various aspects related to a greater or lesser expectation of labor productivity and the efficiency of equipment in a particular service.

2. Material and methods

The improvement of understanding the productivity of highway asphalt pavement started from the finding that many available methods assume postures that prevent them from making different decisions: those related to budgeting to those associated with production management.

Thus, the following steps were developed: a) expert opinion survey; b) use of theoretical and empirical methods; c) review the different executive phases of each type of service; d) present the indicators of these services through ranges of values (representing the variable productivity), e) and allies to the tracks are the guiding factors for the decision on what value to adopt. Therefore, based on ranges of values (productivity variable), and abnormalities of the factors that affect the productivity of paving, data obtained from eight sources studied (five books and two case constructions), and grounded in bibliographical studies, presents the following is the proposal to improve the understanding of productivity. This proposal aims to apply the concepts of variable productivity in Asphalt Paving of Highways.

The following criteria were used to choose the Brazilians manuals adopted in this work: technical recognition; degree of detail as the description of the cases examined, avoided use of manuals with the same sources of information.

The manuals used in this study are derived from the following sources:

a) National Department of Transport Infrastructure – DNIT (Brasil, 2007);

b) Company of Public Works of the State of Rio de Janeiro – EMOP (EMOP, 1999);

c) Municipal and Urban Infrastructure Works – SIURB (Sao Paulo, 2010);

d) Composition Table Prices Budgets – TCPO (TCPO, 2008);

e) Department of Civil Engineering at the Polytechnic School of the University of São Paulo (EPUSP, 2008).

The results of data collection processing and the posterior analysis are originated from the system presented in Figure 2.

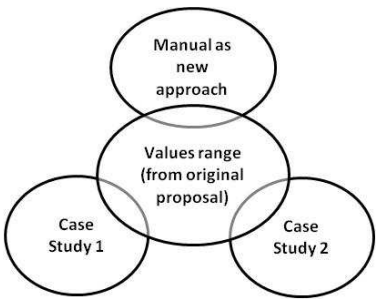

Figure 2 – Range of values: build system

3. Divergence between the Brazilian budget manuals

Amongst the services related to the highway asphalt pavement construction, aiming at illustrating the application of the productivity improvement, the service of the Hot Bituminous Concrete (CBUQ) will be presented as follows.

In the study effected in some cost data manuals the variety of equipment teams met a great difference and the same enters the productivity adopted for service. The variations found were: a) Asphalt Paver was 643%; b) Pneumatic Tire Compactor was 1042%, c) and Tandem Vibratory Roller was 918%. Table 1 illustrates this situation.

Table 1 – Hot bituminous concrete machined (ton/h)

Discrimination	DNIT	EMOP	SIURB	EPUSP
Asphalt Paver	90.7	14.1	13.1	37.0
Pneumatic Tire Compactor	126.1	14.1	13.1	12.1
Tandem Vibratory Roller	129.5	14.1		31.9
Farm Tractor	303.4			

4. New approach for productivity prediction (theory)

The method of prediction of productivity of asphalt paving services, proposed here, is divided into five parts, as the matters described below:

a) Unitary Production Ratio;

b) Unitary Production;

c) Model of factors;

d) Use of Quartile;

e) Details of equipment hours.

According to Souza (1996), although in most cases, the definitions on how to measure productivity represent a ratio between inputs and outputs of the process you want to evaluate, there may be variations in its scope, it is measured as inputs and outputs and the establishment of the ratio between inputs and outputs, among others. From the physical point of view, productivity could be defined as the efficiency (and, to the extent possible, the effectiveness) in the transformation effort by workers or equipment on construction products (the work or its parts), see Figure 3.

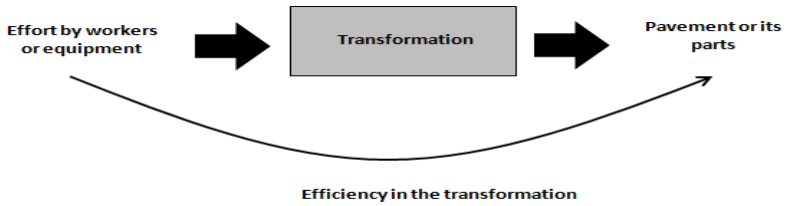

Figure 3 – Definition of productivity

4.1 Unitary Production Ratio

The accepted definition of productivity shown in Figure 3, Souza (2006) suggests adopting the indicator called unitary production ratio (RUP) as a measure of productivity by linking the human effort, measured in hours x men (Hh) or equipment x time (Eqh), with the amount of work performed, *Equation* (1). It is emphasized that, according to the setting made, a high value indicates productivity worse than a low value.

$$RUP = \frac{Hh}{Amount\ of\ service} \qquad \textbf{(1)}$$

4.2 Unitary Production

The unitary production (PU) translates the amount of service produced for the equipment (or workers) at the moment available for the service. He is the inverse one of the RUP, *Equation* (2).

$$Unitary\ \ \mathrm{Pr}oduction = \frac{1}{RUP} = \frac{\mathrm{Amout\ of\ Serviçe}}{H_{available\ to\ the\ service}} \qquad \textbf{(2)}$$

4.3 Model of factors

According to Souza (2006), the unitary production (PU) of equipment and labor may vary according to age rather large amplitude. Figure 4 justifies the assertion that demonstrates that the production unit for the asphalt pavers ranges from 400 m^2/h to 800 m^2/h. The wide variation in the unitary production for the construction work force leads to the following conclusion: we cannot make good decisions without the knowledge of such ranges and the reasons why they change.



Figure 4 – Range of variation of the production unit: Asphalt Pavers (m^2 / h)

It has arrived, then, to another important question: why does the unitary production of the equipment and the labor vary? Conceptually, the model of factors would have an answer to the question. In an attempt to classify the factors potentially altering the unitary production presented in the various parts of the production process, it is said that the unitary production

can be influenced in the presence of the normal manner by factors linked to the content and related to factors having the service context under consideration. In addition, the unitary production can be changed when anomalies occur. They are usually factors related to the content on the characteristics of the "product" running and "processed resources" such as materials and components. The context factors normally associated with "processing resources" such as labor and equipment and the "boundary conditions", such as temperature and usual attitude of the unions. Abnormalities would be "offsets" exacerbated by the regular features of the content and context cited.

4.4 Use of quartiles

The maximum and minimum values represent the extremities of the range, representing, obviously, situations have limited the available database; the medium value represents the central region of the data set, that is, it represents the central value of the data set.

Completing this reasoning, for the determination of the high and low values, the concept of Quartile will be used. Alternatively to the presentation of the maximum and minimum raised values, the processing of the data will be concentrated in the First and the Third Quartile as the extreme of the variation range to be argued. Ramos (2003) recommends this methodology (the application of quartiles) as a tool of statistical control. In the civil construction it is indicated by some authors such as: Souza (1998); Albuquerque *et al.* (2007); Duarte and Lamounier (2007).

4.5 Details of equipment hours

It is a common situation having a product and during some periods of time not having work to allocate it, becoming idle in the company. Within the period in which the equipment is available for service is the time it is effectively working, in other words, the power is on. This leads to the definition of "working hours". To develop this work it will be used these two moments of the incidence of equipment hours, the hours available for service ($H_{service}$.) and hours in operation ($H_{operation}$). Deducting from the “available hours for the service” the “hours in operation” one has the “unproductive hours” (H_{improd}). Figure 5 presents an example of application of these definitions.

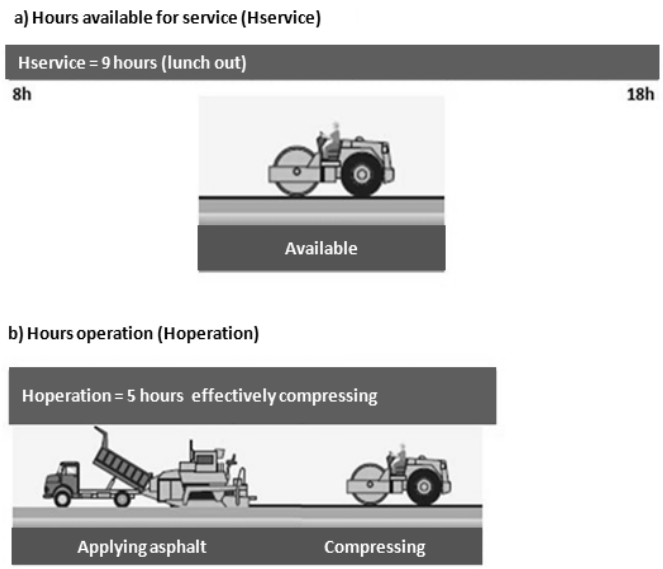

Figure 5 – Different moments in the highway asphalt pavement construction

5. Application example of the methodology proposal

Studied the subject (literature, five manuals and two case studies). A proposed approach to the compositions was performed. The indicators of the manuals were adequate according to this proposal. Tracks contemplating productivity variable (1st quartile, median, 3rd quartile), referring to manuals and case studies were developed. Based on all the learning acquired abnormalities were identified and the factors that make the productivity of these tracks vary. This study was presented to experts who opined on indicators and scored abnormalities and factors. The result of this research led to the improvement of the understanding of productivity in services asphalt paving.

Among the various services related to the construction of asphalt pavements for highways, aiming to exemplify the application of the proposed method, the hot bituminous concrete machined (CBUQ) is presented below.

In terms of the different parts of the service of CBUQ part of the scope the values shown below: cleaning; the release (discharge, spreading, leveling and pre-compression) and compaction of mix asphalt.

The ranges of unit output of the equipment shown below were made with the following considerations:

- to show ranges of values for the production unit including the equipment and his operator (Table 2).

- those bands are related to the factors which lead to an expectation better or worse than the value of the output indicator unit. In another word, a greater closeness of the extreme right or left, respectively, of the band (Table 3).

Table 2 – Hot bituminous concrete machined - cover or binder - esp. 5 cm

a) Step: spreading and leveling asphalt coating (trucks supplying the asphalt paver and this spreads the material layer and leveling)						
Equipment	Unitary Production ($m^2/H_{service}$)			$H_{operation}$		
	1º Quartile	Median	3º Quartile	1º Quartile	Median	3º Quartile
Asphalt Paver	400	600	800	70%	80%	90%
b) Step: Compression layer						
b1) pre-compacting and finishing (the tandem vibratory roller compaction starts making the accommodation of the original material. After compaction itself. the pneumatic tire compactor. tandem returns and finishes the layer)						
Equipment	Unitary Production ($m^2/H_{service}$)			$H_{operation}$		
	1º Quartile	Median	3º Quartile	1º Quartile	Median	3º Quartile
Tandem Vibratory Roller	400	650	820	70%	80%	90%
b2) compaction of the layer (after pre-compression. performed by the tandem vibatory roller. the pneumatic tire compactor compresses the tire itself)						
Equipment	Unitary Production ($m^2/H_{service}$)			$H_{operation}$		
	1º Quartile	Median	3º Quartile	1º Quartile	Median	3º Quartile
Pneumatic Tire Compactor	400	550	715	70%	80%	90%
c) Stage: support						
c1) water for smooth rollers (a water truck is available to provide water for the smooth rollers)						
Equipment	Unitary Production ($m^2/H_{service}$)			$H_{operation}$		
	1º Quartile	Median	3º Quartile	1º Quartile	Median	3º Quartile
Water truck	400	500	650	10%	15%	20%

Table 3 – Factors and abnormalities: hot bituminous concrete machined - cover or binder

Approaches the 1st Quartile	Approaches the 3rd Quartile
Unstable weather conditions	Stable weather conditions
Low effective capacity of the plant (fewer hours working)	High effective capacity of the plant (largest amount of hours in operation)
Operator untrained	Trained operator
Poor continuity and sequence of operations	Good continuity and sequence of operations
Preliminary tasks to be performed (e.g. lead paint)	Preliminary ready tasks (e.g. lead paint)
Low quality of mass produced at the plant	High quality mass produced at the plant
Equipment in poor condition and calibrated	Equipment in good condition and calibrated
Improvisation prevails	Plan activities in advance

6. Conclusions

Studies in the economic area indicate that the development of infrastructure is essential in determining the level of income "per capita" of a country. Providing this infrastructure represents a major public investment and long-term planning.

In recent decades in Brazil investment in highway infrastructure is far below the needs of the country. It is, therefore, that the highway pavement is a technology area with development potential and needs sorted investments in various sectors.

This paper proposes studies of productivity variation in the highway asphalt pavement in Brazil and discusses the differences among budget manuals. In the first moment, the Hot Bituminous Concrete (CBUQ) was presented as an example of service, and variations between 643% and 1042% were found.

Concluding, for the services of highway asphalt pavement there are, in Brazil, many budgeting manuals, but the indicators are sometimes presented as the theoretical basis without empirical proof, extremely variable and, the factors that do vary are not perceived. This imprecision makes it difficult to trust decisions, affecting the budget processes and production management.

To solve this problem the prediction method of asphalt paving productivity was propose. The model was developed based on the concept of variable productivity (productivity indicators presented through ranges of values) that in addition to unprecedented heavy construction subsector in Brazil, the approach uses the Model Factor (demonstrates the guiding factors for the decision on which embrace value).

Improving the understanding of productivity in performing asphalt paving of roads, proposed here, can mitigate the failures presented in the Brazilian budgeting manuals and thus help to bring the technological highway to new level of productivity and efficiency.

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Assessment of the Building Code of Australia to Inform the Development of BIM-enabled Code-checking Systems

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Abstract

Building projects in Australia are traditionally checked manually against the Building Code of Australia (BCA) – a set of continuously changing and increasingly complex regulations. Manual certification processes are error-prone and time-consuming tasks (J. Jeong & G. Lee 2010; Tan et al. 2010). Technical developments in Building Information Modelling (BIM) provide the potential for a new-generation of software tools to assist the checking of compliance with building codes. These should improve efficiency and accuracy for designers as well as for governing bodies. This paper reviews the requirements of certification processes for commercial buildings with specific emphasis on fire codes. We describe the selection of building class, the assessment of fire rating and the interpretation of fire codes. The characteristics of these requirements are explored, and ways for BIM-enabled checking systems to access these data are identified.

Keywords: BCA, IFC, code-checking system, BIM

1. Introduction

Within the construction industries, building designs require approval by governing bodies before construction works can commence. In Australia, the approval documents that applicants need to obtain are Development Approvals (DA) and Construction Certificates (CC) (Building Professionals Board 2011). Several studies have identified the time-consuming and error-prone nature of checking building designs against building codes (J. Jeong & G. Lee 2010; Tan et al. 2010). These problems result largely from the manual certification processes conducted by certifying authorities and are compounded by the continuous changes and increasing complexities of the building codes (Tan et al. 2010; Greenwood et al. 2010). If building designs are found to be not compliant, delays and budget overruns ensue (Abrantes 2010; Tan et al. 2010). Moreover, this may compromise the quality of the construction works (Building Professionals Board 2012).

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Some studies have suggested developing code-checking systems to improve the certification process for both certifying authorities and designers (L. Ding et al. 2004; Abrantes 2010; J. Jeong & G. Lee 2010), thereby improving efficiency and productivity. Currently, Building Information Models (BIM) are acknowledged as an effective platform for exchanging information between design team members (Babič et al. 2010; Grilo & Jardim-Goncalves 2010; Succar 2009). BIM has the potential to drive the development of applications that conduct rigorous analyses for team members before construction works start (Rogers 2012). Additionally, related research notes that BIM has the potential for new-generation software tools to facilitate the checking of compliance with building codes, hence improving the efficiency and accuracy of the checking processes for designers as well as for governing bodies (Greenwood et al. 2010; Yang & Li 2001). Examples of such BIM applications have been developed in several countries (including Singapore and Norway) and have been demonstrated to be beneficial for stakeholders (Eastman, J. Lee, et al. 2009). Moreover, the development of BIM-enabled code-checking systems for Australia has also been demonstrated in a buildingSMART Australasia report (buildingSMART Australasia 2012).

This present study seeks to extend earlier developments for the Australian construction industry. In next section, it reviews the characteristics of existing code-checking systems to identify the information required by BIM-enabled checking systems. Afterwards, the procedures of fire code-checking and the ways of interpreting fire codes are discussed in section 3. This section also sets out a methodology for the interpretation of building codes for future studies.

2. Current Code-Checking Systems

The concept of developing code-checking systems that use BIM is not new. However, the factors that affect the development of code-checking systems are complex and these applications are not yet mature. A leading exponent of BIM-enabled code-checking systems has been CORENET (Construction and Real Estate NETwork) in Singapore, where a significant proportion of the nation's building regulations can be checked through Industry Foundation Class (IFC) models (Eastman, J. Lee, et al. 2009; Khemlani 2011). CORENET was funded by the Ministry of National Development in Singapore. CORENET may be seen as the catalyst which promoted the development of code checking systems in countries such as Norway (Statsbygg), Australia (DesignCheck) and the United States (International Code Council, ICC) (Eastman, Jae-min Lee, et al. 2009). A comparison of these and three additional code-checking systems viz. LiCA (Portugal)(Martins & Monteiro 2013), ACCBEP (Canada) (Tan et al. 2010) and GTPPM (Korea) (J. Jeong & G. Lee 2010) is shown in Table 1. This table identifies the types of *BIM Models* used and the ways of interpreting *Building Codes* that these seven code-checking systems adopt (Shih & Sher 2012). The key attributes of *BIM Models* and *Building Codes* are described below.

BIM Models: BIM data may be exported to code-checking applications in various formats such as IFC and Step (buildingSMART 2010). These provide geometric information (including points, lines and polygons) that code-checking applications may be instructed to interrogate. The BIM models of all code-checking systems shown in Table 1 adopt IFC-

Table 1 Comparison between code checking systems

	Singapore:CORENET	Norway: Statsbygg	United States: ICC	Australia: DesignCheck	Portugal: LicA	Canada: ACCBEP	Korea: GTPPM
Target rules	Building code	Accessibility	Building code	Disabilities (AS1428.1)	Water system	Building envelope	Fire resistance
Checking platform	FORNAX	SMC	DA's SMART codes for SMC, XABIO	EDM	LicA	Rule Engine	Checking engine
BIM Models							
Using IFC-based model	YES	YES	YES	YES	YES	YES	YES
Add new properties using enhanced objects	YES, called FORNAX	YES, Adding geometry data	YES, using DA's SMART codes for SMC, XABIO	YES, using internal model schema to define objects and properties	NO	NO	YES
Export IFC properties to new format	NO	NO	NO	NO	YES, using LicAXML to create XML-based model	YES, XML-based model	NO
Building codes							
Translating by programmer	YES	YES		YES	YES	YES	YES
Employs predicate logic or similar derivation process	YES		YES				
Rules coded in	Computer code	Parametric Tables	SMART code builder	Rule-based language	XML-based parametric Tables	XML based Decision Tables	Computer code
Reference	(Khemlani 2011)	(Sjøgren 2007)	(ICC 2006)	(Lan Ding et al. 2006)	(Martins & Monteiro 2013)	(Tan et al. 2010)	(J. Jeong & G. Lee 2010)

based format for communication with rule engines. Furthermore, LicA and ACCBEP have highlighted the creation of software components to extract the required information from IFC-based BIM models or to integrate IFC models into a new digital schema (e.g. ifcXML format) (Martins & Monteiro 2013; Tan et al. 2010). XML schemas are able to store and manage properties and definitions extracted from IFC files in the XML format, thereby enhancing exchangeability across applications.

Building Codes: The context and content of building codes need to be defined in logical and readable ways so that they can be related to the BIM data being checked. This involves an interpretation process where the semantic structure of each regulation is translated into rules or parametric tables. These are then interrogated and acted upon by bespoke software. Although the outcomes of these code-checking systems are similar, the techniques are varied between them (such as computer code, parametric tables, XML-based parametric tables). Among these systems, Statsbygg, LicA and ACCBEP advocate the use of XML-based parametric tables because this approach provides users with the flexibility to modify software rules without the input of professional programmers (Sjøgren 2007; Martins & Monteiro 2013; Tan et al. 2010). To date, DesignCheck (developed in 2005) is the only application that is specific to Australia. It checks for compliance against the disability codes incorporated in Australian Standard AS1428.1 of the Building Code of Australia (BCA) (L. Ding et al. 2004; Lan Ding et al. 2006). Although DesignCheck provides an advance in code compliance technology for the Australian construction industry, some challenges remain. For example, the IFC objects that are constructed and / or assembled can vary between software vendors. In addition, rule-based engines are used to interpret the building code and it is difficult for designers and/or non-computer experts to change the rules. Furthermore, DesignCheck focuses solely on disability compliance, with rules for other sections of the BCA yet to be developed. Finally, DesignCheck has no facilities for presenting checking reports in a visual format while visual information has potential to improve the design awareness and cognition (Gu et al. 2007).

The code-checking systems noted in Table 1 have significantly improved the efficiency and accuracy of code checking processes for governing bodies (e.g. CORENET has been used throughout Singapore for the compliance of building designs). However, some studies have investigated additional advantages of these systems. For example, there is merit in integrating code-checking into the design process (Rogers 2012; L. Ding et al. 2006). We are thus attempting to develop a framework for a code-checking system that is specific to Australia and will facilitate designers in various phases of the design process. This framework will target the compliance of commercial buildings with fire codes set out in the BCA. Fire codes provide a useful vehicle for such a framework because they demonstrate the integrated nature of design. Compliance requires close relationships between design geometry and the ways in which designs are interpreted to satisfy the rules contained within the code. This paper focuses on the interpretation of building codes to inform the development of Australian code-checking systems.

3. The requirements of fire code checking

The BCA, part of the National Construction Code (NCC), consists of various codes included in Volume One (Class 2 to Class 9 buildings) and Volume Two (Class 1 and Class 10 buildings) (Australian Building Codes Board 2010). The Australian Building Codes Board (ABCB), the main body responsible for the BCA, states “The goal of the BCA is to enable the achievement of nationally consistent, minimum necessary standards of relevant, health, safety (including structural safety and safety from fire), amenity and sustainability objectives efficiently.” (http://www.abcb.gov.au/)

The fire resistance of commercial buildings (class 5 to 9) is regulated through section C of the BCA Volume 1. Fire resistance deals with fire resisting construction, compartmentalisation of buildings into “fire resisting cells” and the “protection of openings” in elements that are required to be fire resisting. Section C also contains a performance hierarchy including “deemed to satisfy (DTS)” provisions, “alternative solutions” and the combinations of both of these methods. However, alternative solutions or combined methods vary from project to project. This study therefore focuses on the “deemed to satisfy” provisions.

Ensuring the safety of building occupants by catering for the eventuality of fire is most important for certifiers and developers. This involves complex procedures including the identification of fire codes for each building project. Initially a building class needs to be selected, followed by an assessment of fire ratings. Finally, building designs need to be checked to ensure they are in accordance with the codes relating to the assessed fire ratings. The following sections of this paper introduce the ways that each procedure is applied in BIM-enabled code-checking systems.

3.1 Building classes

Fire code requirements vary from building to building. The building classifications in Table 2 need to be evaluated first so that building designs can be checked against appropriate fire codes. The classes shown in Table 2 can generally be divided in two main groups: residential buildings (Class 1 to Class 4) and non-residential buildings (Class 5 to Class 10). The latter includes commercial buildings from Class 5 to Class 9. The determination of building classes is a challenge for code-checking systems because the proposed use of a building is technically difficult to determine. Although the information embedded in BIM models can represent the characteristics of geometric objects (such as walls, doors etc.) and the functions of spaces (such as meeting rooms, parking spaces etc.), it is challenging to provide criteria which will allow code-checking systems to identify the use of buildings. For example, a building consisting of meeting rooms can be used for many different purposes (e.g. an office or a laboratory). A pragmatic solution is to require users to manually define the class of building. This means users need to identify the class of buildings manually before code-checking commences.

Table 2 Classification Summary of Buildings and Structures defined in the BCA

Class		Definitions
Class 1	Class 1a	A single dwelling being a detached house, or one or more attached dwellings, each being a building, separated by a fire-resisting wall, including a row house, terrace house, town house or villa unit.
	Class 1b	A boarding house, guest house, hostel or the like with a total area of all floors not exceeding 300m2, and where not more than 12 reside, and is not located above or below another dwelling or another Class of building other than a private garage.
Class 2	A building containing 2 or more sole-occupancy units each being a separate dwelling.	
Class 3	A residential building, other than a Class 1 or 2 building, which is a common place of long term or transient living for a number of unrelated persons. Example: boarding-house, hostel, backpacker's accommodation or residential part of a hotel, motel, school or detention centre.	
Class 4	A dwelling in a building that is Class 5, 6, 7, 8 or 9 if it is the only dwelling in the building.	
Class 5	An office building used for professional or commercial purposes, excluding buildings of Class 6, 7, 8 or 9.	
Class 6	A shop or other building for the sale of goods by retail or the supply of services direct to the public. Example: café, restaurant, kiosk, hairdressers, showroom or service station.	
Class 7	Class 7a	A building which is a car park.
	Class 7b	A building which is for storage or display of goods or produce for sale by wholesale.
Class 8	A laboratory, or a building in which a handicraft or process for the production, assembling, altering, repairing, packing, finishing, or cleaning of goods or produce is carried on for trade, sale or gain.	
Class 9	A building of a public nature -	
	Class 9a	A health care building, including those parts of the building set aside as a laboratory.
	Class 9b	An assembly building, including a trade workshop, laboratory or the like, in a primary or secondary school, but excluding any other parts of the building that are of another class.
	Class 9c	An aged care building.
Class 10	A non-habitable building or structure -	
	Class 10a	A private garage, carport, shed or the like.
	Class 10b	A structure being a fence, mast, antenna, retaining or free standing wall, swimming pool or the like.

(Source from: Australian Building Codes Board 2010)

3.2 Fire ratings

In determining the fire code requirements for a commercial building it is necessary to assess the appropriate type of fire resisting construction for that building. There are three types of construction, being type A (the most fire resistant), B and C (the least fire resistant) (Australian Building Codes Board 2010). In addition to the aforementioned classification, the required type of fire resisting construction is determined based on the rise in storeys, floor area and volume of that building. The first step is determining the "preliminary type of construction" through the use of a building classification and rise in storeys. Table 3 (source from BCA Table C1.1) shows the types of construction required.

Table 3 Rise in Storeys X Class of building.

Rise in storeys	Class of building	
	2, 3, 9	5, 6, 7, 8
4 or more	A	A
3	A	B
2	B	C
1	C	C

(Source from: Australian Building Codes Board 2010)

The next step in determining the fire code requirements of a specific building is to check the floor area and volume against the building classes. Table 4 (source from BCA Table C2.2) shows that the size of any fire compartment or atrium in a Class 5 to 9 building must not exceed the relevant maximum floor area or the relevant maximum volume (floor area times internal height). In terms of measuring the floor area of a fire compartment in a BIM model, some important properties need to be defined: heating, ventilation, lift equipment, water tanks, or similar service units are not counted. The volume of the target space is required to be calculated because it effectively relates to the fire load. In the manual certification process, certifying authorities normally use the average ceiling height or average height to the underside of trusses to calculate the volume. BIM-enabled code-checking systems can improve the accuracy of these measurements when BIM models are correctly defined. After checking the building classifications, storeys, floor areas and volume, the required type of construction (fire ratings) can be generated, followed by checking the BIM model according to the appropriate fire codes. The methods of interpreting fire codes are discussed in the next section.

Table 4 Maximum size of fire compartments or atria

Classification		Type of construction of building		
		Type A	Type B	Type C
5, 9b or 9c aged care building	Max floor area -	8 000 m^2	5 500 m^2	3 000 m^2
	Max volume -	48 000 m^3	33 000 m^3	18 000 m^3
6, 7, 8 or 9a (except for patient care areas)	Max floor area -	5 000 m^2	3 500 m^2	2 000 m^2
	Max volume -	30 000 m^3	21 000 m^3	12 000 m^3
Note: See C2.5 for maximum size of compartments in patient care areas in Class 9a health care buildings				

(Source from: Australian Building Codes Board 2010)

3.3 Interpretation of fire codes

Most building-related codes and regulations are presented as well-structured documents. However their semantic complexities make it difficult to devise rules that accurately represent code clauses and the subtleties of their meaning. To address this challenge, several studies have developed different methods of analysing the characteristics of regulations or codes. In this section, two practical approaches for interpreting building codes are described.

3.3.1 RASE semantic rules (Hjelseth & Nisbet 2010)

This semantic approach enables AEC professionals to develop rules that can be applied to the semantic content of IFC-based BIM models. The general rules contained in regulations consist of more than one “check” that typically represents a section of a regulation. A check can be analysed into four constructs: *Requirement, Applicability, Selection* and *Exception (RASE)*. *Requirement* is related to the imperatives “Shall” or “Shall Not”, and a check needs

to contain at least one requirement. Some specific texts are identified as the *Applicability* of the check. For instance, "internal walls" compound the "internal" and "walls" concepts. The construct *Selection* is similar but distinct from *Applicability*, which is used for alternative subjects (e.g. doors, windows and other openings). The last construct, *Exception*, is the opposite of the *Applicability*. These can be summarized as a regulation that includes more than one "check" and each check contains a number of the four constructs described above. The formulations and an example clause are shown as below (Table 5):

Table 5 RASE formulations and examples

Formulations:	Check: C0 = R0 or NOT A0 or NOT S0 or E0 Regulation: Regulation0 = C0 and C1 and C2…Cn
Example Clause: (ICC IECC 2006 502.5 Moisture control)	All framed walls, floors and ceiling not ventilated to allow moisture to escape shall be A S S E provided with an approved vapour retarder having a permeance rating of 1 perm or … R R

Legend: R – Requirement; A – Applicability; S – Selection; E – Exception; C – Check

(Adapted from: Hjelseth & Nisbet 2010)

3.3.2 Dialogue Language (DL) (Omari & Roy 1993)

According to Omari and Roy's (1993) study, a Dialogue Language (DL) has been developed to interpret Life Safety Codes (LSC) for Australia in an expert system. It adopts a consistent interpretation to represent the code clauses as well as the interactions between users and the expert systems. The DL provides systematic structures that organize the hierarchical dialogue of codes. These structures contain eight primary items (Table 6). Among them, the *comment* is used to explain the semantic meaning of the clause text. It is related to the object defined by the code violation and assists in explaining the noncompliance of the building design to the codes. Figure 1 provides an example of the structure of a building code using the DL approach.

Table 6 the components of Dialogue Language (DL) structure

Dialog_id	An identifier which references a dialog.
Parent_id	An identifier which points to the dialog from which the current dialog was referenced.
Code_violation	The id of the object to which evaluation error messages are to be attached.
Clause	The actual text of the clause from the BCA which is embodied within the current dialog.
Condition	The DL interpretation of the conditions which must be satisfied for this dialog to be applicable.
Action	The DL interpretation of the actions to be carried out if the conditions for application of the dialog are met.
Comment	An explanatory note which describes the reasons for the application of this dialog. This field is primarily to indicate to the user, why a particular dialog has failed, in simpler terms than can normally be available from the raw code clauses. This text field is attached to the frame identified by the Code violation field to indicate non-conformance of building model elements of the BCA.
Dependency	A list of property value identifiers which is used during the evaluation of a dialog. This field can be used to indicate the values of the properties used by the dialog. As such they provide a reference by which the user can determine the exact property which is not valid.

(Adapted from Omari & Roy 1993)

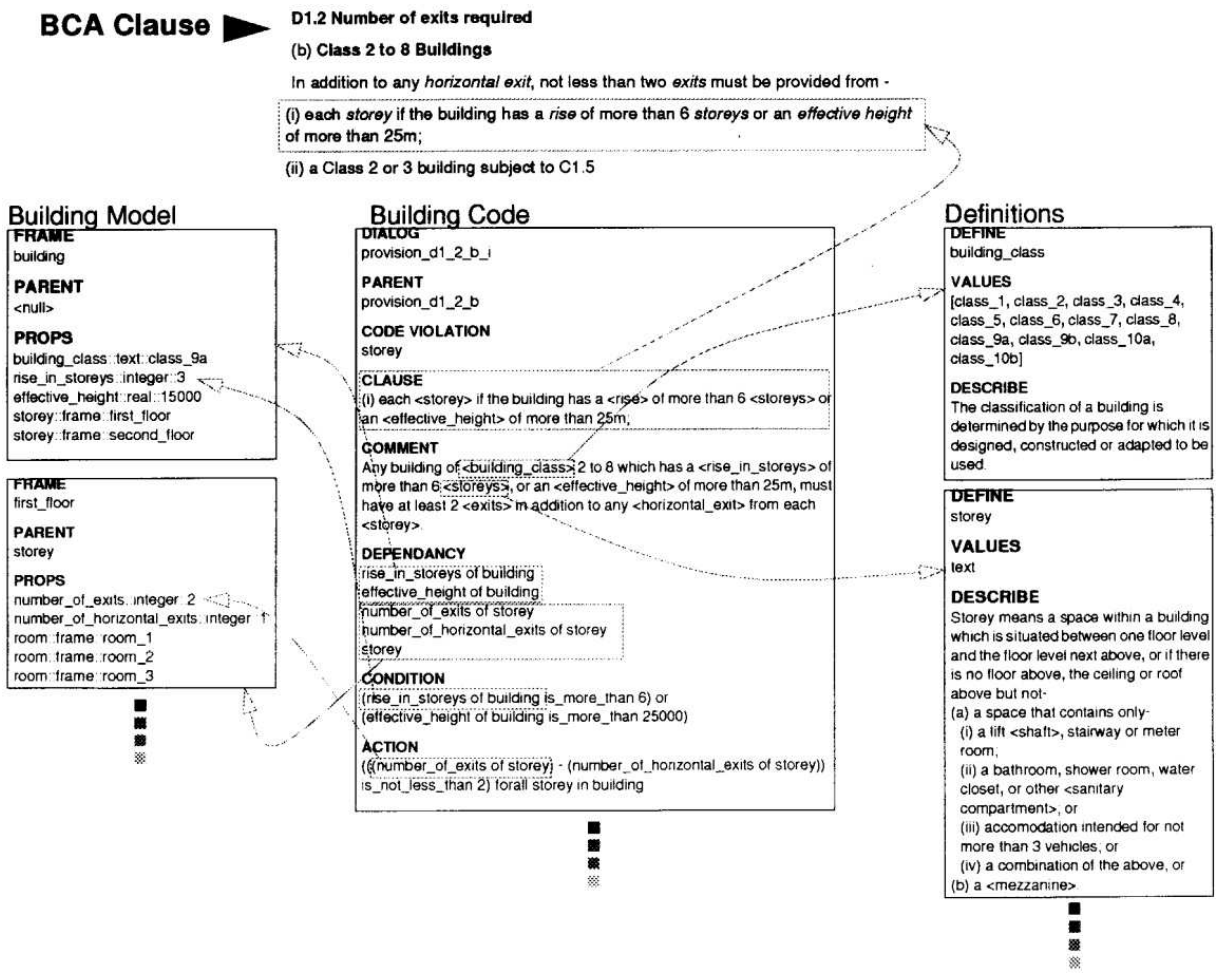

Figure 1 An example of relationships between DL elements

(Source from Omari & Roy 1993)

3.4 Discussion

The DL provides a clear structure that enables users to manage the hierarchical building codes and their interactions with BIM models. In addition, the hierarchical structure of the codes can assist in generating meaningful reports for designers. The RASE approach emphasizes the semantic logic of code clauses thereby enhancing the in-depth analysis of DL's *clause* and *comment*. Therefore, this study will adopt a combination of these two approaches as the primary tool for interpreting fire codes in our code-checking system. This will support the use of XML-based parametric tables. In addition the definition of conditions will be conducted logically using the semantic theory approach described above. Besides the straightforward rules within the building code, cross-reference rules, which result from the exceptional descriptions in the regulations, can be represented in decision tables. An XML-based parametric table provides a flexible mechanism to represent complex temporal data, and can be used to express the logic of building codes and their dependency (Noh & Gadia 2006).

Several significant challenges need to be overcome when defining the information that needs to be extracted from BIM models to allow for code-checking. The definitions of BIM

models vary between software vendors. The ifcXML schema is beneficial in communicating information with XML-based interpretation of building codes. Some studies report the use of “Enhanced Objects” to add information to BIM models (Sjøgren 2007; Lan Ding et al. 2006), although this requires designers to spend additional time and effort on this task.

It is important to note that we focus on the ‘deemed to satisfy’ provisions of the BCA. However, assessing the compliance of building projects that require alternative solutions presents additional difficulties, particularly with commercial buildings. Alternative solutions are necessarily varied, having to accommodate the peculiarities of different performance requirements. Opportunities exist for relevant cases to be collected and arranged in a database as reference for future projects.

Finally, many studies have noted that BIM and its applications have the potential to improve collaboration between team members. The implementation of BIM-enabled code-checking systems for Australian construction industries is expected to enhance the collaborative performance of designers and certifying authorities. Further research into assessing the effectiveness of these collaborations would be beneficial.

4. Conclusion

This paper has provided an overview of existing BIM-enabled code-checking systems. It has identified the challenges of using BIM models and interpreting fire codes of the BCA. Moreover, the procedures involved in assessing the extent to which designs comply with fire codes have been investigated to inform the development of approaches of translating building codes into XML-based tables. This provides a foundation for the development of code-checking systems using BIM to assess compliance with the BCA. Not only do code-checking systems have the potential to enhance designers’ awareness of building codes, they have the potential to improve collaboration and communication among project stakeholders.

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The Great Australian Dream: Density and Aspirations in Sydney

Laila Mehrpour[1] and Sebastian Macmillan[2]

A global assessment of the relevance of aspirations in driving spatial planning strategies

During the post war period, Sydney has experienced high levels of growth and urban sprawl resulting in declining and costly infrastructure, a lack of affordable housing close to amenities and increasing economic segregation. Demand for low density suburban housing is consistently cited as the primary obstacle to higher and more sustainable densities, with high density housing widely viewed as an affront to the *Great Australian Dream* – the aspiration to own a detached house on its own quarter acre plot. (Winter and Stone, 1998)

This study assesses the continued relevance of the Great Australian Dream as a driver of housing development in Sydney. It also looks at Sydney's hopes to be a global city[3] and how these are affected by the Great Australian Dream. Using a method based on demographics and households, a comparison is drawn between Sydney and four global cities: London, New York, Copenhagen and Detroit. In each of the four, equivalent households to the Australian 'aspirationals' are identified, together with the types of housing they occupy. The study shows that the 'aspirationals' are present in each of the four cities, but that detached housing is at negligible levels in both London and New York, and at a low level in Copenhagen; in this comparison Sydney emerges as most like Detroit. Overall, the Great Australian Dream was found to be at best a redundant driver of development strategies, and at worst a destructive force for the longevity of the city; it needs to be redefined if Sydney is to protect its longevity and prosperity.

Keywords: density, aspirations, lifestyle, affordable, housing

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[3] city is defined in this context as the geographical and administrative areas subject to the studies outlined by the Globalisation and World Cities Research Network, http://www.lboro.ac.uk/gawc/index.html

1. Introduction

The predominant form of housing in Sydney has remained largely unchanged since the postwar period, despite the changing needs of the city and its more recent wider aspirations to be a global city. This is ostensibly driven by demand. Planning is largely informed by the popular aspiration to own a house on a *quarter acre block*, dubbed The Great Australian Dream. As a result, property prices in the urban capitals have risen to well beyond the means of lower income households, who are driven progressively further towards the urban fringes and away from essential infrastructure.

Despite the clear need for a more proactive approach to managing growth, a fear of producing 'undesirable' and thus, unprofitable, housing has meant that many of the attempts at incorporating so-called smart growth strategies have been largely token or piecemeal in nature. This approach has impacted their effectiveness, and in the process, negatively impacted the image of higher density housing and urban consolidation efforts amongst Sydneysiders and Australians in general.

The aims of this paper are two-fold: The first aim is to identify the connection between the housing aspirations of Sydneysiders, the origins of these aspirations and why aspirations have become and remained such a significant driver in the development and planning profile of the city. The second is to compare these findings against those of a selection of other cities around the world that are using both passive and proactive planning policies and the way in which such decisions have shaped these cities.

The ultimate aim of this paper is to determine whether the notion of the Great Australian Dream is still a relevant development and strategic planning driver for the future of Sydney.

2. Methodology

The Metropolitan Development Program (2008/09), the main planning instrument for the Sydney metropolitan area (defined as the administrative area governed by the Metropolitan Development Program), and its associated paper, the Metropolitan Strategy Review: Sydney Towards 2036 Discussion Paper (2011) include data on the Local Government Areas which have experienced the highest levels of housing growth in the last ten years, including the areas in which this growth has been primarily in the form of detached, low density housing in Greenfield areas. Greenfield areas are an important parameter as development in these areas has materially contributed to the horizontal expansion of the city and the resulting strain on infrastructure. It has also contributed to the growing economic segregation within the metropolitan area, which has seen low income households driven progressively further towards the urban fringes.

In order to measure and quantify the housing aspirations of the residents of Sydney, this study will make use of consumer segmentation analysis, a highly interrogated form of census and population data, which will determine the resident profile of the low density sprawl paradigm. The tool used for this assessment is a geo-demographic segmentation tool known as Mosaic, developed by Experian PLC, which also offers a globally consistent

classification system, known as Mosaic Global. There is currently Mosaic data available for 24 countries worldwide. Mosaic Global operates on the basis that the world's cities share the same residential patterns – that is, that people everywhere are essentially the same and as a result, can be classified using a consistent taxonomy.

This is most helpful in enabling cross-comparisons across geographies. In the context of this study, once the resident profile of Sydney has been determined, the same groups of people will be examined in a selection of cities worldwide, employing both proactive and passive growth management strategies. The ultimate aim of this exercise is to determine the types of housing acceptable to the same types of households in other cities globally, and the contextual parameters that influence these choices. These parameters can then be assessed against the factors that drive housing choices in Sydney, and assist in the assessment of the Great Australian Dream as a relevant policy driver.

2.1 City Selection Process

The determining factor behind the selection of the cities has been the quality of the available Mosaic data for each city option. The four cities selected for this exercise are London, New York, Copenhagen and Detroit. According to Sydney's Metropolitan Strategy Review (2011), "The future of the Sydney region and more broadly the whole of New South Wales (NSW) is integrally linked to the success of Sydney as a Global City. The city's global status needs to be enhanced." (NSW Department of Planning and Infrastructure, p.7) According to the research carried out by a variety of global journals and research bodies such as the Foreign Policy Journal and the Global and World Cities Research Network on the topic of the nature of global cities, both London and New York consistently and invariably feature at the top of global cities indexes. This forms the basis of their selection for this study.

Copenhagen has also been selected as it is widely acknowledged to have qualities to which cities such as London and New York aspire, due to its highly successful urban planning mechanisms. Indeed, the term 'Copenhagenisation' is derived from the efforts undertaken by the city to progressively reduce its reliance on travel by private car, and improve the mobility of its residents through other means (most notably by bicycle). It was formally integrated into the spatial planning strategies of many global cities, including both London and New York.

The equivalent types of households who are seen to be the primary market for detached housing on the urban fringes in Sydney are assessed in these three cities to determine the extent to which they make up the resident base of each, and the dwelling types which make up the housing norms for these types of households in each city.

Also as part of this study, one additional city adversely affected by the global economic downturn is assessed. In the United States, the advent of global economic crisis has brought the argument for better planned cities into relief as many middle-American towns and cities bear the brunt of the economic crisis. A notable example is the city of Detroit. By undertaking the outlined exercise, the aim is to demonstrate the potential impacts of market led housing strategies and conversely, of proactive growth management on the long term liveability and prosperity of the city.

3. Sydney's Housing Quandary

As a general trend, due to an aging population (ABS, 2011) households are shrinking in size (number of people per household) (Kelly et al, 2011b). However, higher density housing in Sydney still represents little more than a quarter of all dwellings (Darcy, 2008). It was recently revealed that in 2009 Australia overtook the US in producing, on average, the largest houses in the world. (Johanson, 2011) It is therefore a fair assessment of housing supply in the Sydney market to say that while households (number of persons per dwelling) are shrinking, houses themselves are growing in size.

Sydney was endowed with a sophisticated and extensive heavy rail system relatively early in its life which meant that the upper and middle classes and even some better paid members of the working class, could now aspire to a house and garden in fresh country air. These new residential suburbs were built along train lines radiating out from the city centre. (Forster, 2010)

Additionally, federal government policies greatly favoured owner occupation through a highly incentivised taxation system for home owners. Home ownership was all but synonymous with new, detached housing, and had become no longer a luxury but an expectation, as had car ownership. The low level of investment in the inner city suburbs, other than in the form of freeway infrastructure, had also helped to make the suburbs more desirable by comparison. Therefore, as Forster points out, "while Australian families may have freely chosen the suburban way of life, the circumstances, partly shaped by governments, had made it difficult for them to make any other choice". (Forster, 2010, p.25)

The subdivision and development of previously rural or vacant (so-called Greenfield) areas around Sydney has formed a large part of the accommodation strategy for Sydney's growing population since the city's inception, but escalated in particular since this period.

While the release of land for detached development has slowed in recent years, there is an ongoing belief in both public and private enterprise that continued land subdivision should form at least part of the ongoing housing strategy of the city, and this is reflected in the current metropolitan plan for the city, despite a recent planning history that abstractly acknowledges that this manner of continued growth is unsustainable.

Under environmental and economic pressures, and in response to the increasing prevalence of smaller households, the last two decades have seen a growing trend towards increasing the number of denser multi-unit apartment buildings. This, combined with changes to planning laws designed to address concerns over the environmental and economic costs of urban sprawl, resulted in a 30 per cent increase in the number of apartments in Sydney between 1996 and 2006. (Darcy, 2008)

However, even such incremental change in the housing profile of the city has engendered vehement protests from various quarters, both private and public sector, with the president of one community action group stating in a widely distributed report "Unless we are vigilant, high-density zealots will do their best to reverse centuries of gains and drive us back towards

a Dickensian gloom." (Recsei, T, "Save Our Suburbs" in Demographia, 2011) The reasons behind this apprehension are manifold, but as pointed out by Kelly et al:

Despite the easygoing bravado, Australians have a pronounced private streak. They don't want their pleasure or pain heard by neighbours and resent being drawn into the daily lives (...) of those around them. Living in smaller, communally oriented spaces brings this fear to the forefront. (2011b, p. 12)

To contextualise this however, in general, the housing profiles of cities are slow to change (Kelly et al, 2011a). The enduring prevalence of the Great Australian Dream as a housing aspiration and development driver is at least partly driven by the fact that aspirations for new housing are invariably driven by the existing stock (Kelly et al, 2011a), and thus the paradigm continues to perpetuate itself.

4. Sydney in a globalising context



Figure 1: Global Cities by Area and Density

Figure 1 shows the current area of Sydney at the same scale alongside the other global cities. The delineations have been made based on the boundaries of each city. The darker area shows the confines of the traditional boundaries of the metropolitan area. The lighter area shows the exurbs primarily dependent upon the metropolitan city proper.

Table 2: Global Cities by Area, Population and Density

City / Metric	Sydney	Copenhagen	London	New York	Detroit
Area (km^2)	12,145	456	1,572	1,214	10,130
Population (millions)	4.575	1.199	7.825	18.223	4.296
Density	377	2,632	4,978	15,006	424

At a glance the diagram shows Sydney to be physically similar in size to Dublin, Madrid and Detroit, all cities noted for their passive urban planning. Sydney has the largest core metropolitan area and the second lowest population density after Dublin.

5. Consumer Segmentation

The control group defined for this study represents the collective groups of households who share in the biggest percentage of uptake in developments on the urban fringes of the capitals. In Australia, developers spend much time and resources identifying this category of people, where they come from, what they value and most importantly, how they want to live. A percentage of the control group are also occasionally referred to as 'the aspirationals' or 'Aussie battlers', who, in an urban context, can range from long term outer suburban working class to the long term economically disadvantaged.

Firstly, the way in which people live in Sydney today is assessed. The method selected for this analysis is heavily reliant on so-called consumer segmentation analysis. Consumer segmentation "is the process of classifying people into groups that have some set of similar characteristics, resulting in the ability to be studied and targeted" (XTREMEimpakt, 2008). One of the most comprehensive and widely used global consumer segmentation tools is Experian's Mosaic. The Mosaic Australia *Groups* and sub-groups (known in Mosaic as *Types*) and the percentages of each in Sydney and Australia are shown in Table 2. In Mosaic Australia, there are eleven Groups and forty seven Types.

5.1 Sydney's Mosaic Profile

Mosaic profiling is particularly powerful as the data is geographically accurately mapped. Through this mapping it is possible to identify the residential patterns in the city. Each (coloured) dot represents an individual household, and the colour itself denotes the Mosaic Type to which the household belongs. It indicates the clustering of demographics across the city from the harbour and seaside suburbs to the outer urban ring.

5.2 How is the control group identified?

The Metropolitan Development Program (2011) has identified the local government areas with the highest levels of detached housing development in Greenfield areas in the last 10 years. By identifying the Mosaic Types most likely to buy and live in these areas in detached housing, a finite group can be created for the purposes of comparison with other cities around the world.

In order to identify who the control group is in Sydney by Mosaic Type, the Mosaic map of Sydney is overlaid with the areas that have the highest levels of detached housing development in Greenfield areas in the last 10 years (as identified in the Metropolitan Development Plan for Sydney (2011) Table 2 shows the results from the overlay of these outputs. It shows a finite list of the top Mosaic Types which together form the Mosaic profile of the control group in Sydney.

Table 2: Sydney's aspirationals by Mosaic Type

Rank	Type		Label	Description	% Syd	% Aus
1	A04		Executive Residents	High consuming maturing families in comfortable outer suburban locations	2.6	2.5
2	D13		Cul-de-Sac Kids	Mortgaged families living in the better value outer metro fringe areas	2.4	2.2
3	E17		Home Entertainment	Blue collar families living in the older pockets of the outer suburbs	3.9	4.2
4	A05		Family Success	Well off family households in desirable outer suburban locations	6.4	2.5
5	F22		Devoted Diversity	Mature and religious close-knit families in newer metro fringe developments	3	1.5
7	E16		Families in Formation	Couples and families with young children living in recent outer suburban locations	1.2	2.7
8	D15		Mortgaged Aspirations	Culturally diverse young families living in high density suburban communities	4.6	1.3
9	D14		New Lives, New Landscapes	Young families living in recently developed outer suburbs of larger cities	0.9	1.6
10	E18		Domestic Divides	Single parent and varied family structures in outer suburban communities	2.2	3
12	E19		Conforming Kinship	Cash-strapped late middle aged traditionalists in outer metro areas	1.8	3.9
16	F20		Intercontinental Connections	Established Eurasian migrants in mid to outer suburban locations	6.1	3.1
20	F23		Mediterranean Style	Established low income migrant home owners around suburban retail centres	0.4	1.6
23	F24		Bilingual Backgrounds	Mixed age multi cultural areas of mainly blue collar employment	7.7	1.7

Source: adapted from data derived from Google Maps, 2011 and Pacific Micromarketing Mosaic 2011, courtesy of the Lend Lease research license

Based on this data, the control group in Sydney forms a total of 43.2% of the population of Sydney – a significant proportion. In the following global assessments, the Types identified in Sydney are examined in other cities around the world.

6. London

The case study for the city of London focuses on the area known as Greater London. They are as follows:

Table 3: Mosaic UK Types of Sydney's control group in London

Type		Label	Description	% London	% UK
B05		Mid Career Climbers	Families enjoying the fruits of career success in pleasant detached houses	0.26	2.3
B07		Distinctive Success	Successful business people, often self made, living in large detached houses in semi-rural locations	0.05	0.48
B08		Dormitory Villages	Comfortably off families in spacious homes in pleasant settings but within easy reach of jobs	0.05	1.29
B09		Escape to the Country	Families choosing to give their children a country lifestyle while commuting to urban jobs or running businesses from home	0.03	1.31
D17		Jacks of All Trades	Blue collar workers and traders, serving the needs of small market towns	0.01	1.99
D18		Hard-working Families	Married couples approaching retirement age, in not especially fashionable small town locations	0.14	2.63
F24		Garden Suburbia	Mid-life families with above average incomes living in the nicer middle ring suburbs of larger cities	2.20	2.14
F25		Production Managers	Middle income married couples, owning unpretentious, semi-detached housing	0.03	2.63
F26		Mid-Market Families	Families with many grown-up children still living at home, living in cheaper suburban semis	0.12	2.7
F27		Shop Floor Affluence	Employees earning reasonable incomes, living with their families in relatively inexpensive semis in industrial towns and cities	0.32	2.73
F28		Asian Attainment	Comfortable middle aged families with school aged and older children, predominantly from an asian background	2.48	0.98
G30		Soccer Dads and Mums	Parents of school age children, owning large recently built detached houses with mortgages funded by their successful careers	0.06	1.34
G31		Domestic Comfort	Families with high incomes derived from managerial positions and considerable property wealth in their suburban detached houses	0.04	1.09
G32		Childcare Years	Young, well educated and well paid couples, either married or cohabiting, most of whom are starting families	0.13	1.52
H37		First to Move In	People living in the most recently built, brand new housing	0.17	0.37
I38		Settled Ex-Tenants	Older couples whose children have flown the nest working in low skilled occupations and living in ex-council housing	0.06	2.06
I39		Choice Right to Buy	Middle aged couples, some with older children still at home, living in the more desirable ex-council areas	0.19	1.72
I40		Legacy of Labour	Older families on low incomes living on council estates in areas where industry was once prevalent	0.01	2.68
I41		Stressed Borrowers	Middle aged people renting or owning in council areas, many of whom are over-stretched with debt 2.20	0.70	2.2
J43		Streetwise Kids	Large young families with many single parents, often unemployed and claiming benefits, living on deprived council estates	0.32	1.05
J44		New Parents in Need	Young parents, often single, bringing up young children in barely adequate council terraces facing considerable disadvantage	0.00	1.8
M55		Backyard Regeneration	Singles and families in affordable but respectable terraces which for the young are a stepping stone to better things	0.15	2.06
M56		Small Wage Owners	Owners living in inexpensive private terraces in a range of relatively low paid occupations	0.55	3.09
N57		Back to Back Basics	Young sharers and couples with young children, starting out in low price, older terraces	0.05	1.97
N58		Asian Identities	Traditional South Asian families owning relatively small terraces for their many family members	0.16	0.88
			TOTAL	8.28	45.01

Source: adapted from Mosaic UK Interactive Guide, Experian, 2011

The low percentages corresponding to each Type and the low total percentage for these Types in London would indicate that while there may be a significant percentage of Britons who are corresponding Types to Sydney's control group, only a small percentage actually live in London. As indicated by the descriptions, many of these Types have deliberately chosen semi-rural lifestyles, outside the confines of the city. Others live in public housing, a tenure which accounts for far greater numbers in the UK where it has a much stronger and

more robust history, than in Australia. Spatially, development areas in London are limited, and the current London Plan notes the housing shortage and consequent lack of affordability of housing in London to be the most urgent of issues. (GLA, 2011)

There is very little detached housing available in London and what little there is, is well out of the financial reach of most people in general. For this reason, the Types to whom detached housing is an important lifestyle factor will forego living in London itself in favour of smaller towns in London's exurbs.

7. New York

New York City is naturally contained by its peninsular topography and has a population of over 8 million people covering an area of just 790 square kilometres. (NYC Dept of City Planning, 2011) The equivalent Types to Sydney's control group make up well over half of the overall population of the city. However, detached living in New York City is almost unheard of, even in the minor boroughs. The following figures are drawn from both US Census information and an in depth Mosaic analysis by zipcode for each of the five boroughs of New York City.

Table 4: Mosaic USA Types of Sydney's control group in New York City

Type		Label	Description	% NYC	% USA
P57		Meager Metro Means	Mid-scale African-American singles established in inner-city communities	20.67	0.62
P58		Fragile Families	Multi-cultural singles and families with mid and low incomes living settled lives in urban apartments	19.11	0.73
A06		Jet Set Urbanites	Mix of affluent singles and couples living high rise, fashionable lives in urban neighbourhoods	10.08	0.48
H26		Progressive Potpourri	Mature, multi ethnic couples with comfortable and active lives in middle class suburbs	2.21	1.00
D18		Soulful Spenders	Upper middle class African American couples and families living in the expanding suburbs	1.91	1.45
P61		Humble beginnings	Multi-ethnic singles and single-parent households with mid-scale incomes in city apartments	1.76	0.99
B10		Asian Achievers	Affluent, mainly Asian couples and families enjoying dynamic lifestyles in metro areas	1.35	0.56
D16		Settled in Suburbia	Upper middle class diverse family units and empty nesters living in established suburbs	1.09	0.77
I32		Latin Flair	Conventional Hispanic Gen X families located in selected coastal city homes	0.31	0.98
P60		Ciudad Strivers	Mid-scale Hispanic families and single parents in gateway communities	0.13	1.12
B08		Babies and Bliss	Middle-aged couples with large families and active lives in affluent suburbia	0.01	1.65
			TOTAL	58.64	10.35

Source: adapted from Experian Mosaic USA Interactive Guide, 2011

Unlike London, there is an over-representation of Types who are suburban in nature, but who choose to live in the denser surrounds of New York City. In the United Kingdom, the same types tended to choose not to live in London at all. As with London, the lack of available detached housing sees negligible numbers of New Yorkers who fit the control group profile actually living in detached housing in the confines of the city. Unsurprisingly, the housing types of all of New York's five boroughs are at a higher density than elsewhere in the country with a distinct under-representation of detached dwellings anywhere in New York City.

8. Copenhagen

The first regional plan for the Copenhagen area was initiated in 1947, primarily to combat the uncontrolled urban growth arising from industrialisation. Called the "Finger Plan", it divided the Copenhagen suburbs into five 'fingers' which were built around the S-train railway lines.

The area of Copenhagen is just 1/48th of Sydney's but its density is at nearly seven times that of Sydney. Denmark is highly urbanised reflecting the metropolitan primacy observed in Sydney, with approximately 85% of the population residing in cities. 34% of the total population resides in Copenhagen.

Table 5: Mosaic Denmark Types of Sydney's aspirationals in Copenhagen

Type		Label	Description	% Denmark
B04		Suburban Managers	Successful suburban families with time for everything	2.54
B05		Aspiring Younger Families	Successful young families in newer homes	1.53
B06		Mid-range Commuters	Commuting couples who live under the same roof	2.88
C08		Better-off Pragmatists	Families in series or chain houses with decent economy and fortunes	2.69
C09		Middle of the Road	Mr. and Mrs. Denmark - row on row	4.39
C10		Challenged Families	Rows of small and exposed economies	2.54
F18		Big City Flat Dwellers	Tenants in the cities from diverse backgrounds and with manageable economies	3.05
F19		Metro Melting Pot	Smaller, younger households with low income and wealth in the city swarm	2.67
F20		Multicultural Challenge	Multicultural people in rental housing in cities, small fortunes and challenges	2.70
F21		Urban Counterculture	Terraced houses in urban areas - young families with scarce resources	2.93
			TOTAL	27.92

Source: adapted from unpublished Mosaic Denmark data, courtesy of Experian UK 2011

The equivalent Mosaic Types to Sydney's control group forms just under a third of the Danish population. As with London, a number of the Types that align with Sydney's control group in Denmark are actually not likely to live in Copenhagen at all, but rather in semi-rural areas within easy reach of the large cities.

The most recent publicly available dwelling data available from Statistics Denmark shows the spread of detached housing in the different regions of Denmark. When viewed in conjunction with the Danish Types identified as Sydney's control group, the data showed that in Copenhagen, 62% of dwellings are indeed apartments, with just under 23% of people living in detached dwellings and a further 12% living in semi-detached dwellings. It would indicate that the reasonable trade-off for living in the capital region is to accept a denser housing model.

Amongst the most prevalent groups, as is clearly demonstrated by the data, there is a strong bias towards higher density dwelling models, particularly apartment style living, with the sole exception to this rule appearing to be the A Group, in the north of Copenhagen. As the spread of wealth appears to be across the entire city, it would appear that a significant portion of higher income earners also live in apartments both in the inner city and in the suburbs. This is in direct contrast to the Sydney situation where apartment living in the suburbs is invariably the mainstay of low income earners.

9. Detroit

One of the most prominent examples of passive, industry led planning and its possible consequences is the city of Detroit in Michigan, USA. With a peak population of nearly 5 million, Detroit was once the capital of the United States megalithic auto industry. Detroit is also a case study in the long term effects of economic and ethnic segregation on the health and wellbeing of the city.

Table 6: Mosaic USA Types of Sydney's aspirationals in Detroit

Type		Label	Description	% Detroit	% USA
S69		Soul Survivors	Older, down-scale African-American singles and single parents established in modest urban neighbourhoods	32.64	1.32
R67		Hope for Tomorrow	Young, low-income African American single parents in second city apartments	17.78	1.03
D18		Soulful Spenders	Upper middle class African American couples and families living in the expanding suburbs	10.89	1.45
P59		Nuevo Horizons	Middle-aged, mid-scale income Hispanic families living mainly within US border cities	2.26	1.26
P60		Humble beginnings	Multi-ethnic singles and single-parent households with mid-scale incomes in city apartments	0.59	1.12
R66		Ciudad Strivers	Mid-scale Hispanic families and single parents in gateway communities	0.58	1.89
P56		Rolling the Dice	Middle aged, mid scale singles and divorced individuals in secondary cities	0.63	1.69
			TOTAL	65.37	9.76

Source: adapted from Experian Mosaic USA Interactive Guide, 2011

The analysis process for the profiling of Detroit was carried out by identifying the top three dominant Types by zipcode in Detroit. The Mosaic Profile for Detroit shows that while there are only seven Types in total that make up the Mosaic USA equivalents of Sydney's control group in Detroit, they make up a staggering 65.37% of the overall population of Detroit. Indeed, there are more of these Types of households in Detroit than there are in Sydney.

The bulk of the population of Detroit is shown to be made up of only a small number of Mosaic Types indicating that while there is a large African American population in the city (indeed, a majority), there is little ethnic or economic diversity. The housing typologies also remain fairly low density with an over-representation of detached housing in 46.42% of the population. The higher density groups are only in medium density formations of up to nine units.

10. Conclusion

As evidenced by the market assessment carried out in this paper, while there is a desire for a continued low density profile for Sydney, and large suburban homes, there is also a desire for Sydney to take its place amongst the global powerhouses and to secure global opportunities for the continued prosperity of the city.

These findings are in stark contrast to the widely publicised and sensationalist figures published annually in the mass media in Australia. A brief interrogation of the figures published indicates them to be neither comprehensive nor rigorous in their assessments. The widely publicised findings of reports such as Demographia's Annual International Housing Affordability Survey has had a negative impact on the image of higher density housing, and has succeeded in ensuring that land releases continue to form a part of any housing strategy proposed for the city in fear of alienating the 'Aussie battler' and 'aspirational' electorates.

The Mosaic profile for Sydney indicates that the control group in this study forms over 40% of the overall population of the city and tend to live over 20km from the city centre. When aligned with the same groups globally, it was found that in London, New York and Copenhagen, the majority of the same Types of people tended mostly not to live in the confines of the city at all but to live in surrounding towns with their own sets of local amenities and infrastructure, and where required, commuting to centralised services in the city. This has had the effect of maintaining the confines of the city and ensuring that the area of the city remains sustainable for the provision of infrastructure of services.

In Detroit, however, the percentage of the control group equivalents in the failing city was found to be an astounding 65.37% of the total population of the city. As with Sydney, the physical area that the city covers is so large, residents can be living in semi-rural areas many miles from the city and still be considered to be living in Detroit, due to the city's ill-defined boundaries. The danger for Sydney is that fear driven policy and media induced panic about the implications of higher density development will continue to drive the demand for detached housing and subsequently, sprawl, to well beyond what the city can service.

In order to meet Sydney's macro aspirations of growth on a global scale, it is important for the strategic planning of the city to address the unchecked sprawl that has become a burden on the provision of infrastructure to the city. While this may mean that Sydneysiders will have to adapt to living in higher density dwellings, it will, as demonstrated through the Mosaic analyses of other cities around the world, ensure that those for whom living close to the city centre is an important factor will continue to live in the city and will readily make the sacrifice of living in smaller better designed dwellings. The main problem in Sydney is one of supply – there simply isn't enough affordable choice with regard to housing types in the suburbs in which people want to live.

It is for these reasons that it can also be surmised that the days of allowing the Great Australian Dream to drive development are long since gone – not simply because the city can no longer bear this burden, though this is an important driver, but because with the changing needs of the population, it is simply not aligned with the complex desires of the people anymore.

It is for this very reason that it is important to assess and interrogate the available market data using geo-demography tools and consumer segregation data, as the needs of the population of cities are no longer as simple as they once were. Developers and private enterprises have already started to use this information to drive solutions tailored to their desired outcomes, and it is important for public policy drivers and strategists to make use of all of the available information to make informed choices for the city.

This does not mean that the Australian egalitarian cultural ideals of opportunities for all, inherent in the concept of the Great Australian Dream, should be abandoned, rather that the new Great Australian Dream should be redefined to embrace the true meaning of sustainable development to ensure that equitable access to quality housing opportunities are available to future generations of Sydneysiders.

Acknowledgement

This paper is based on a thesis prepared by the first named author for the Interdisciplinary Design for the Built Environment masters programme at the University of Cambridge.

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Sustainable Construction Modelling: A Systems Engineering Approach

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Abstract

Modelling in the architecture, engineering, and construction (AEC) industry is a fundamental step for product and project delivery, and serves multiple purposes from visualization, communication, simulation, analysis, decision making, to performance assessment. For long, the AEC industry has used different types of modelling schemes. Typical examples include 2D and 3D models that capture geometric and spatial information, project schedules that capture sequence and durations, and process models that capture methodologies and work flows. With the advent of sustainable construction, it was realized that modelling in the AEC industry has to capture a new array of information and correlate such information to both the construction product and process. Examples of these information include embodied energy content, emission of pollutants, resource consumption, and noise and acoustics, just to name a few.

Modelling for sustainable construction requires representing parameters pertaining to the environment and sustainability as well as different information related to the building geometry and its production method and execution plan. As part of a research undertaken by the authors, this paper proposes a systems-based model where: (1) the environmental system, (2) the building system (the product), and (3) the construction system (the production/management system) are represented as three interacting systems of systems that fundamentally exchange (1) energy, (2) matter, and in some cases (3) information, according to systems theory. While other modelling approaches are based on proceeding individually and sequentially in the process of evaluating environmental impacts caused by different multidisciplinary practices in the AEC industry, this systems-based model shall facilitate simultaneous evaluation of sustainability by the system as a whole. The focus on system flows of energy and materials shall highlight focus areas for impact mitigation and performance optimization as outlined in the paper. The Systems Modelling Language (SysML) is utilized to build the model.

Keywords: sustainable construction, systems engineering, SysML, construction modelling, sustainability parameters

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1. Introduction

A model is an abstraction, simplification or idealization of reality that can be used for realization, simulation or as a prototype (Turk, 2001). Modelling in the architecture, engineering and construction (AEC) industry has always revolved around products and processes. Typical models used included geometric models (2D and 3D models), process models, project schedules, etc. Such models served well for long, as much as the governing industry paradigm has been that well-known triad of *time, cost,* and *quality.* For more than three decades, the time, cost, and quality triad has been continuously challenged by new factors and parameters such as safety, efficiency, and recently sustainability. These new parameters continuously stress the need for altering or extending the current techniques of modelling used in the AEC industry, or the introduction of new ones.

For sustainable construction modelling in particular, models have to capture and create links between multiple types of information pertaining to sustainability and the environment including embodied energy content, emission of pollutants, resource consumption, noise and acoustics, etc. while simultaneously linking these to different project executing entities and across different phases of a project lifecycle. Current industry models and techniques, however, inefficiently address the multidisciplinary requirements of sustainable construction by focusing – each, individually – on one sole aspect of the industry: the products, the processes, the geometry, the sequence, the durations, etc. Moreover, whenever sustainable construction is considered, it is usually addressed by different industry entities both in sequence and individually. This typically results in fragmented and inefficient evaluation of only parts of the system, not the system as a whole.

This paper proposes a systems-based modelling approach using the principles of systems engineering and analysis to facilitate proper realization of sustainable construction.

2. Modelling in the AEC Industry

Models are fundamentally related to identifying, specifying, and communicating data and information related to a specific product. For long years, the AEC industry has used different models to capture and utilize information related to its products. The following sections briefly refer to the most common modelling approaches used by the AEC industry and point to their utility and possible shortcomings addressing sustainable construction.

2.1 Common Modelling Techniques

The most common modelling techniques used in the AEC industry typically served the purposes of detailing and communicating (1) building product design; e.g. dimensions, geometry, spatial orientation, material specifications, (2) process; including workflow, inputs and outputs, (3) schedule; including durations and work breakdown, and (4) financials; e.g. costs and cash flows. The following table has been compiled based on Aouad et al (2012), Azhar et al (2011), El-Gohary (2008) and Chen and Li (2006) to provide a brief overview of common modelling techniques used in the AEC industry.

Table 1 Common modeling techniques used in the AEC Industry

Modelling Technique	Modelled Information	Key Uses	Typical Examples
Product Models	Mainly geometry and spatial information	- Product Design - Product Specification - Multidisciplinary technical communication	- 2D drawings - 3D drawings - Building Information Models (BIM)
Process Models	- Workflow and sequence - Inputs, outputs, and conversion	- Process optimization and reengineering - Productivity Assessment	- IDEF0 - Generic Construction Process Modelling Method (GEPM) - Information/Integration for Construction (ICON)
Schedule Models	- Project activities and durations - Sequence and logic	- Project Planning - Project Management	- Gantt Charts - CPM and PERT networks - Line of Balance (LOB) technique
Economic & Financial Models	Financial information related to costs and revenues	- Cost Estimation - Financial feasibility analysis - Calculation of investment ratios	- Activity Based Costing (ABC) - Financial feasibility models - Cash flow models

Each set of these techniques focuses on the modelling, estimation and assessment of information related to one or more aspect(s) of an AEC industry product/project. Each of these techniques could contribute *indirectly* to the evaluation and assessment of sustainability parameters, for example by allowing the quantification of materials used as a prerequisite for assessing consumption of resources or embodied energy content, or by identifying inputs and outputs of construction processes as a prerequisite for measuring efficiency and identifying waste. However, considering the multidisciplinary nature of sustainable construction and its key parameters, none of these modelling techniques provides neither direct nor thorough means for environmental computations and assessment. For example, none of these models directly considers the emission of pollutants to the atmosphere or the noise produced during construction activities. The ultimate capacity of such techniques, from a sustainable construction perspective is to provide information for further compilation in other more sustainability oriented models, such as life cycle assessment (LCA).

2.2 Modelling Techniques that Directly Consider Sustainability

There still is a set of other modelling techniques and tools that are used in the AEC industry, and even address sustainable construction. Amongst these is Life Cycle Assessment (LCA). Crawford (2011) adopts a definition of LCA as a tool “to determine and evaluate the environmental loadings and impacts of a particular product or process, including those

effects associated with processes upstream in the supply chain." LCA is one of the most powerful tools for evaluating environmental loadings and assessment of sustainability. To date, however, it cannot be easily utilized by typical industry practitioners due to its complexity. Moreover, it requires case by case truncations and adaptations to identify where to stop and how to set boundaries when addressing AEC projects (Crawford, 2011).

3. A Systems Approach to Sustainable Construction

In spite of its recognized importance and the development of knowledge through over 20 years, sustainable construction is not yet a standard practice of the industry. Recent statistics list a total number of some 110,000 BREEAM certified buildings and some 35,000 LEED participating green building projects worldwide. These figures represent much less than 1% of buildings worldwide (The Zofnass team, 2012). Matar et al (2008 and 2010) list a number of barriers that hinder the widespread implementation of sustainable construction as a standard practice of the industry. One of the most important barriers is the *inefficiencies* of current tools and approaches to sustainable construction.

The Zofnass team (2012) identified approximately 120 rating systems and sustainable construction evaluation tools either in use or under development up to early 2012. Although much of these tools agree on many criteria for sustainability evaluation, they still leave many other criteria in argument, pointing to an absence of a solid consensus on what issues are key and important, and hence their relative weights upon consideration. Furthermore, most of the current tools were developed and have shown adequacy principally addressing the design phase of a building project, leaving a strong need for addressing the construction, operation and maintenance phases of a built facility (Shen 2005, and Chen et al, 2005).

Moreover, the top two ranking tools by use are BREEAM and LEED. Alarmingly, a detailed evaluation of LEED by the US National Institute of Standards and Technology (NIST) has identified discrepancies in the calculation method leading to disparities and inconsistencies of calculated outcomes (Scheuer and Keoleian, 2002). The Zofnass team (2012) also identified that LEED tends to favour "credit popularity" over science in order to facilitate marketing LEED to stakeholders. While encouraging widespread use of the tool and promoting sustainable construction is desirable, relaxing scientific rules raises questions and concerns (Scheuer and Keoleian, 2002).

This paper proposes a systems-based modelling approach that can lay a robust foundation for realizing sustainable construction. The following sections list some fundamental principles and definitions then proceed to build the model according to the needs and requirements of sustainable construction.

3.1 Basic Definitions

3.1.1 Systems and Systems Engineering

The "Guide to the Systems Engineering Body of Knowledge" defines a system as "an interacting combination of elements viewed in relation to function" (INCOSE, 2004). Wasson

(2006) defines a system as “an integrated set of interoperable elements, each with explicitly specified and bounded capabilities, working synergistically to perform value-added processing to enable a User to satisfy mission-oriented operational needs in a prescribed operating environment with a specified outcome and probability of success.”

Systems engineering also has a large number of definitions, but in the most general form is defined as “an interdisciplinary approach and means to enable the realization of successful systems” (INCOSE, 2004).

3.1.2 Systems of Systems

Recently, with the rapid technological advancement and intricacies in the 21st century, there has been a growing interest in shifting the paradigm from addressing particular systems individually to considering *classes of systems* whose constituents are themselves complex (Jamshidi, 2009). These have gradually become to be described as “System(s) of Systems.” Typical examples of such systems of systems have been proven to exist in aerospace, manufacturing, security, and disaster management disciplines and industries, just to name a few.

A practical definition for a System of Systems (SoS) is that “it is a super-system comprised of other elements that themselves are independent complex operational systems and interact among themselves to achieve a common goal” (Jamshidi, 2009). There is an increasing interest in achieving synergy between these independent systems to achieve desired overall system performance or performance objectives.

3.1.3 The Systems Modelling Language (SysML)

The Systems Modelling Language (SysML) was developed under the leadership of the Object Management Group (OMG) as a general-purpose graphical modelling language that supports the analysis, specification, design, verification, and validation of complex systems. These systems may include hardware, software, data, personnel, procedures, facilities, and other elements of manmade and natural systems. The language is intended to help specify and architect systems and specify their components and interactions principally through identifying, specifying, or developing a system (1) structure, (2) requirements, (3) parametrics, and (4) behaviour. SysML utilizes nine types of diagrams to serve its purposes and objectives (Friedenthal et al, 2008).

3.2 A System of Systems Model for Sustainable Construction

The previous sections of the paper compared modelling techniques, highlighted some key definitions, and concluded a strong need for some well-defined approach that adequately addresses critical areas of sustainability in line with the current framework of the AEC industry, as a multidisciplinary industry with extremely diversified products and a large number of executing entities and stakeholders.

The following sections outline a systems-based model where: (1) the environmental system, (2) the building system (the product), and (3) the construction system (the production/management system) are represented as three interacting systems of systems that fundamentally exchange (1) energy, (2) matter, and in some cases (3) information, according to systems theory. Each of these systems is described using SysML notation and a System of Systems model is described afterwards. A system of systems model is crucial for the case of sustainable construction, because the ultimate objective is to consume resources at a rate that neither overloads the environmental system nor depletes its resources at an unsustainable rate, meaning simultaneous optimization for all of: the environment, the built facility, and the construction system. The multidisciplinary nature of the AEC industry, with products that comprise architectural, structural, and electromechanical components designed and executed by a large number of entities, requires a holistic model that can simultaneously evaluate the environmental loadings and sustainability impacts generated by a myriad of entities at different stages and project lifecycle phases.

3.2.1 The Environmental System of Systems

The Environmental System of Systems, refers to the natural systems that primarily support the existence, development and evolution of all other systems of systems on planet Earth (Hipel et al. 2009). The Environmental SoS principally comprises five main component systems. According to Wasson (2006), Jorgensen (2007) and Hipel et al. (2009), these are:

- The *atmosphere* system component, representing the gaseous layer that extends from the surface of a planetary body outward to some pre-defined altitude.

- The *lithosphere* system component, comprising the rigid or outer crust layer of Earth, including continents, mountains, islands, etc; containing most of material resources.

- The *hydrosphere* system component, consisting of all liquid and solid water systems such as lakes, rivers, rain, underground aquifers, oceans, etc.

- The *biosphere* system component, defined as the environment comprising all living organisms on Earth, including all environments that are capable of supporting life above, on, and beneath the Earth's surface as well as the oceans. Thus, the biosphere overlaps portions of the atmosphere, hydrosphere, and lithosphere.

- The *energy* system component, which is most fundamental for all systems; natural or manmade, to operate and perform their roles and missions. There are essentially seven forms of energy, most of which are commonly encountered in everyday life, such as heat, electromagnetic (e.g., light), kinetic (or mechanical) forms.

Figure 1 represents a *block definition diagram (bdd)* for the Environmental system and its subsystems using SysML notation.

Many of the currently available building rating systems and sustainability evaluation tools show no clear basis for classifying and categorizing environmental impacts considered. The systems-model, however, visualizes the environment as a system of components and subsystems, providing a logical way to classify and categorize environmental impacts and sustainability parameters according to the exact subsystem they affect and are related to.

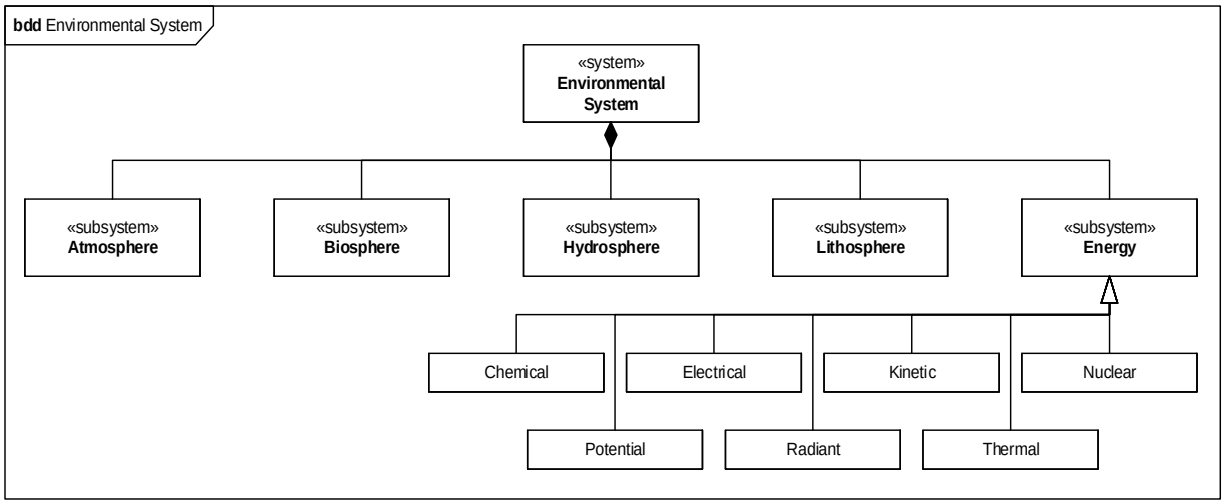

Figure 1: The Environmental System and its subsystems

Figure 2 illustrates sustainability impacts considered in the SoS model according to this logic. Most impacts recognized fall under the principles of generating undesirable particulate materials and emissions, consuming resources at unsustainable rates, and generating waste through inefficient conversion processes. All of these categories are efficiently recognized by the systems-model.

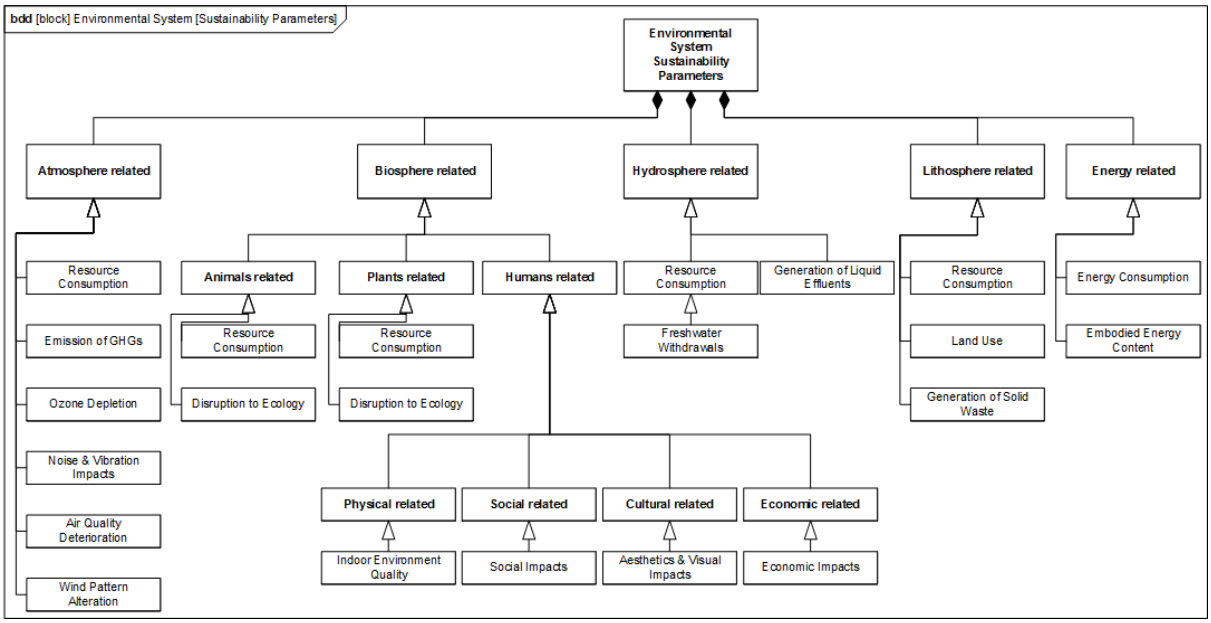

Figure 2: Sustainability Parameters

3.2.2 The Construction Product System

Construction products generally comprise buildings and infrastructures. Either of them could be visualized as a group of independent but interacting systems. Typically, these systems are the architectural, structural, mechanical, and electrical systems. The minimum for any construction product is at least to have a structural system to support its components. Figure 3 illustrates the general case for a construction product and its subsystems.

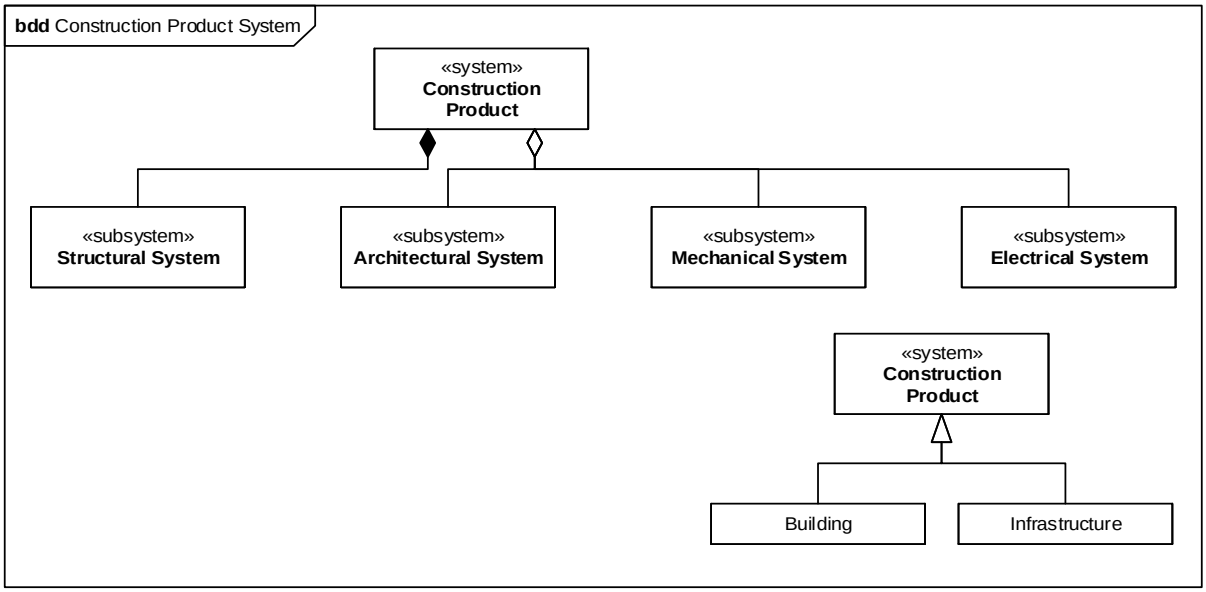

Figure 3: Construction Product System

By SysML notation, the structural system is represented as an elemental, compositional element, while the other three systems might or might not exist according to case. Buildings typically have all of the four subsystems, while an underground pipeline might have only a structure (with some electromechanical sensors in case of sophisticated pipelines). The subsystems of a construction product together define its function, shape, utility, comfort, and environmental performance.

- The *architectural* system defines the volumes, functions, and aesthetics of a building. It is usually the lead system: designed at the very beginning according to specific brief and requirements, and sets course and boundaries for other building systems.

- The *structural* system is fundamentally concerned with the support and transfer of all building loads to the ground. The structural system primarily uses different techniques and materials in specific skeletal arrangements to achieve the primary functions of load bearing and load transfer, in addition to helping in providing building shape, and functional objectives of other systems within the building.

- The *mechanical* systems in a building are designed to perform a variety of functions. They are responsible for heating, ventilating, and cooling the indoor environment as well as supplying freshwater and disposing of wastewater. In addition to these, mechanical systems extend to include fire protection systems.

- The *electrical* systems in buildings are primarily the electrical power supply systems, and data/communications and signal systems. Electrical systems include lighting, alarm systems, distribution systems, acoustic and auxiliary systems.

To produce these systems at the construction/production phase of a built facility life cycle, resources are consumed and co-products are released to the environmental system of systems. During the life span of the built facility, these systems continue to consume resources and produce products and co-products (wastes, emissions, etc.) The efficiency of their operation determines their performance with regard to environmental sustainability.

3.2.3 The Production and Management System

The third system of systems involved is the construction production/management system, as exemplified in Figure 4. The term “production” is intentionally used in analogy to other industries, as any construction project is, in fact, a series of conversion and flow, value-adding and non-value-adding activities that start from project inception and end by operation through the operational life of a facility, and finally by possible deconstruction.

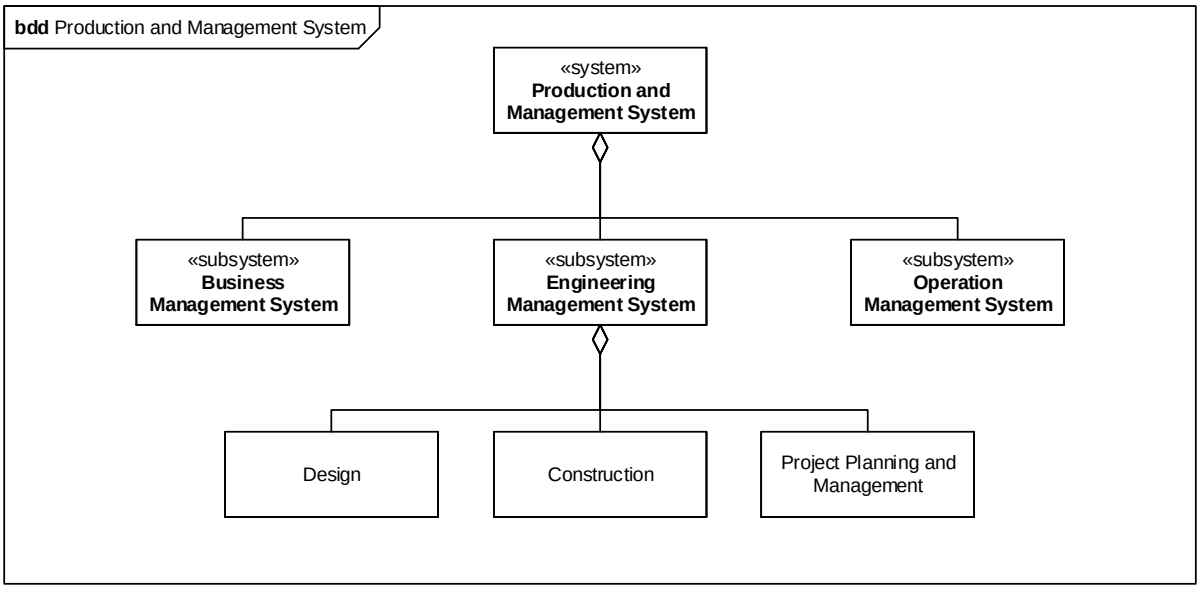

Figure 4: Essential Components of the Production and Management System

This production system involves a number of interacting subsystems that include, for instance:

- The *business* system necessary for the management and operation of any construction industry organization and its project endeavours.

- The *design* management system responsible for the production of the whole package of design drawings and specifications for the built facility system of systems, including architectural, structural, mechanical, and electrical systems.

- The *project planning and management* system principally responsible for realizing project goals of scope, time, cost, and quality.

- The *construction* system responsible for field production of a built facility system of systems.

- The *facilities management* system responsible for operating and maintaining a built facility with all of its subsystems at maximum efficiency.

Each of these systems operates to deliver its products and goals, consuming resources and producing loadings at different levels of hierarchy, ranging from the organizational, project, and activity levels all the way to the operation, process, and work task levels (Halpin 2006).

3.3 Using the System of Systems Model for Sustainability Evaluation

There are some basic principles that govern the behaviour of the proposed systems model, derived from standard rules that govern systems behaviour in general, and the environmental system in particular as described by Wasson (2006) and Jorgensen (2007). Amongst these rules, the following two principles are fundamental for the utility of the proposed System of Systems model for assessing and evaluating sustainability and environmental impacts/loadings:

1. All natural ecosystems are open systems embedded in an environment from which they receive energy-matter input and discharge energy-matter output.

2. Mass and energy are conserved. This principle permits writing balance equations to track material and energy flows and conversions, where:

$$accumulation = input - output$$

Environmental loadings could be defined as the increase or decrease of specific materials and constituents that alters the system state to a new state other than the “best” condition. For example, a construction process that results in emissions and pollutants to the atmosphere in a specific area does not harm the atmosphere itself; it just changes the concentration of particles in that specific area. However, this change in concentration could render air harmful for breathing, for example, or at least decrease its quality.

Another dimension of sustainability includes the rate of consumption of resources and the generation of waste. Resource consumption in itself should not represent a problem; it is the rate of consumption of resources that is. If the rate of consumption exceeds the rate of the environmental system capacity to generate or substitute consumed resources, then such resources will simply be depleted. Moreover, if the consuming system conversion processes were inefficient, then the conversion processes will result in waste. Minimizing waste is one key pillar of construction sustainability. The systems model proposed is designed to capture material and energy flows between the three interacting systems of systems. Figure 5 illustrates the essential high level system flows during typical construction, using SysML notation for *internal block diagrams (ibd)* and *flow ports.*

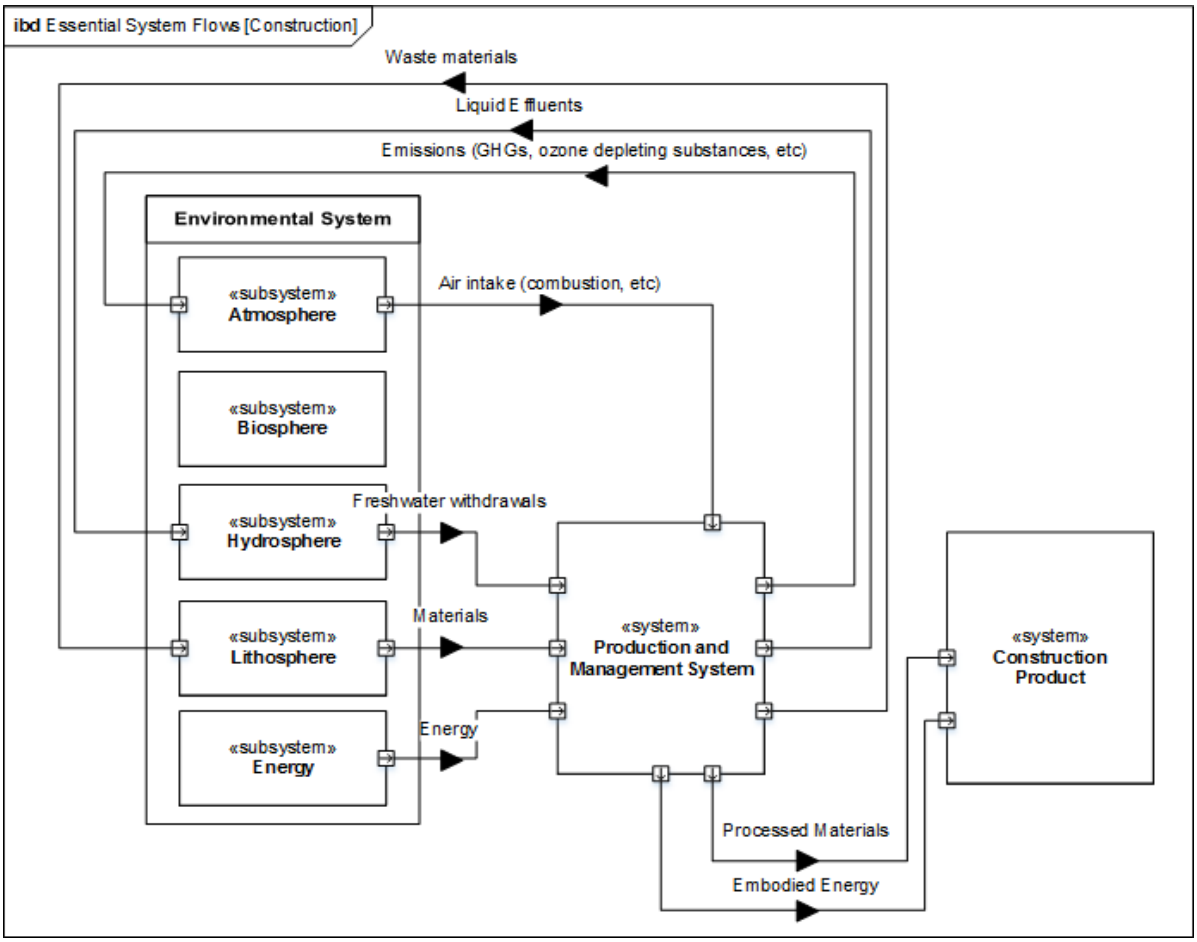

Figure 5: Essential System Flows during Construction

Tracking the flow of undesirable materials will identify what emits pollutants, their quantities as accurate as possible, and hence means for minimization. Tracking the flow of energy and materials in general and using balance equations will facilitate recognizing systems efficiencies and where wastes are generated. The multidisciplinary nature of the systems model allows recognizing all subsystems of a construction product system together and hence help visualizing a complete picture of sustainability performance of the construction product as a whole and its production/management system. In contrast to all other geometry based modelling techniques, where material, energy and environmental performance data in particular are captured as static values (at best, and hence are evaluated on a case-by-case basis), a systems model can accommodate geometry-based values – especially if linked to a BIM database – and multidisciplinary information simultaneously to allow dynamic, systems level evaluation. The versatility of systems engineering allows addressing sustainability performance at different levels as desired. Systems engineering and SysML can model systems at the top, system level, all the way down to the activity and process levels. For example, the model can address the consumption of energy to construct the building foundations in total, or can address a specific part of the process, such as excavation. Figures 6 and 7 illustrate an example for the definition of constraints and then the utilization of a *parametric diagram* to capture the consumption energy for a typical excavation activity. Equations governing the calculation of excavation area and excavation energy are defined within the system package through *constraint blocks* as shown in Figure 6.

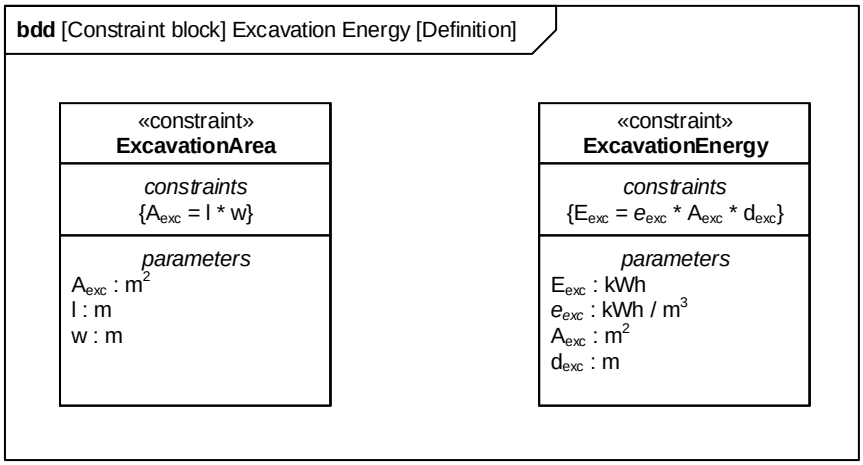

Figure 7: Constraint Blocks Capturing Equations for Excavation Energy Calculation

As illustrated in Figure 7, the system calculates energy consumed during excavation utilizing equations defined in the constraint blocks within the *bdd* for excavation energy calculation, augmented by case-by-case inputs such as the "*ExcavationEnergy.Unit*" representing the kWh consumption by excavating machine according to the type of soil, and the "*ExcavationDepth*" variable that differs according to the building and foundation design.

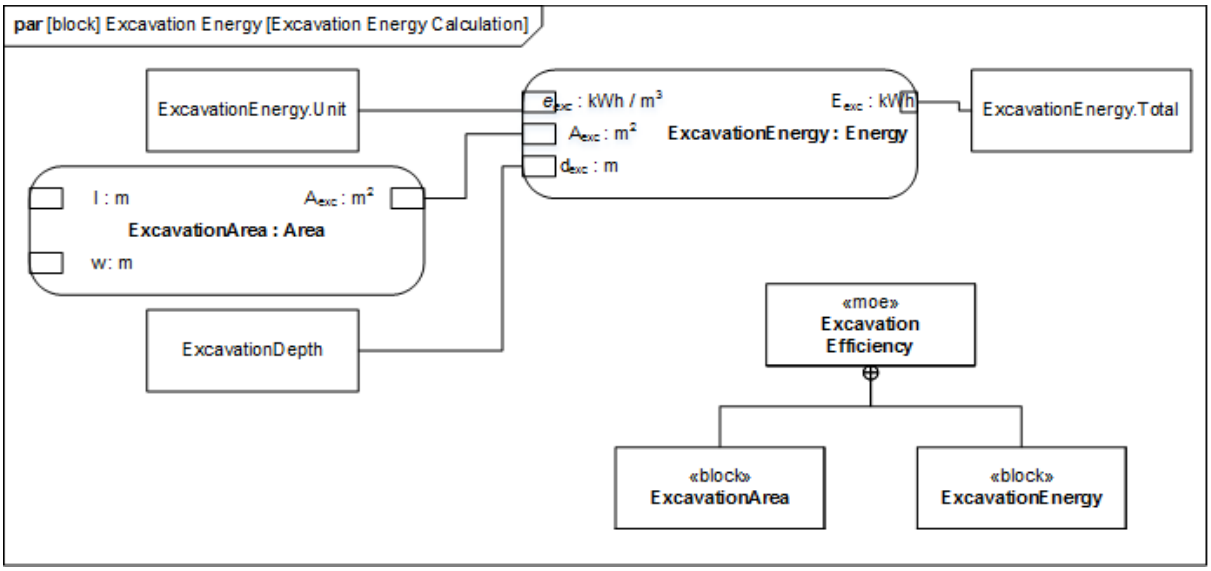

Figure 6: Calculation and Performance Evaluation for Excavation Activity

Evaluation is done through defining *measures of effectiveness (moe);* in this case evaluation is based on minimizing the excavated area (that is, not to excavate large areas unnecessarily), and minimizing the overall excavation energy consumed, as illustrated in the lower section of Figure 7.

4. Conclusions and Future Work

A systems model has been developed to enable and facilitate the realization of sustainable construction across the multiple disciplines involved in delivering any AEC project and across different lifecycle phases. The environment, the construction product, and the

production/management systems have been modelled as three interacting systems of systems and were described using SysML notation. This setup has been useful in the development of a logical classification of sustainability parameters according to which environmental subsystems they are related to, and identifying what exact production activities generate which environmental impacts.

The systems model developed addressed a number of key issues faced by traditional models that usually hindered their capacity to directly model, evaluate and hence contribute to the realization of sustainability in the AEC industry. While traditional models were typically developed by different disciplines to capture specific phases and instances of a project in its lifecycle, the holistic approach used addresses the product, the processes, and the environment altogether. This facilitates the tracking of energy, item flows, environmental loadings, etc. in terms of where they are consumed/ generated, when, and by which project entities. The versatility of the model allows addressing sustainability performance at the top, system-level, all the way down to the activity and process levels. Moreover, the adoption of SysML opens a clear path to system automation, especially upon linking to a BIM model.

Future work should investigate automation through linking the systems model to BIM environments in order to directly read construction product data from different design disciplines. This should facilitate dynamic optimization and accelerate the sustainability evaluation process.

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Developing Self-Directed Learning Strategy for a Construction Project Management Course

Cynthia Changxin Wang[1]

Abstract

Self-Directed Learning is generally regarded as an important skill throughout life and is encouraged in the tertiary education. However, in the courses implemented with self-directed learning approach, we also see students get off track, fail to make progress, or complain not being assessed fairly. It is observed that many of our construction project management students in the postgraduate program, especially those with working experiences, have a strong desire for a self-directed and autonomous learning experience. In this research, a self-directed learning strategy is adopted and developed over two years in the teaching of a postgraduate course. Investigation and comparison of students learning experience were conducted by using student surveys, and selected students were further interviewed to gain the insights of their opinions and experiences in this course. Problems in current course model were identified and ways to better support self-directed learning in the course are suggested to improve the level of student satisfaction.

Keywords: Construction industry, education strategy, self-directed learning, SDL

1. Introduction

In the Master of Construction Project Management program in the Faculty of Built Environment at the University of NSW, it is observed that the students' experience and maturity vary significantly, while some students need close guidance and supervision to make progress in their study, many others wish to have more flexibility in their postgraduate learning experience. A Self-Directed Learning (SDL) approach is adopted in one of the courses in the program, aim to enrich students' learning experience and increase students' satisfaction.

Self-directed learning (SDL) is a method of instruction used increasingly in an adult education within tertiary institutions, and is often embraced as an important educational goal throughout life (Bolhuis 2003).

SDL can be defined in terms of the amount of responsibility the learner accepted for his or her own learning (Fisher, King et al. 2001). Many previous studies have proved the benefits of self-directed learning such as saving training costs and increase employee effectiveness in their jobs (Chien 2004), researchers also identified risks of developing SDL strategies and

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provided recommendations. Self-directed learning projects are not for everyone and may cause extreme anxiety and frustration in some students (Fisher, King et al. 2001). The SDL approach may be less successful with a less mature audience that younger learners had difficulty handling the greater freedom of a self-directed learning experience (Ellis 2007).

Based on the literature review findings, the SDL strategy was cautiously introduced to students over two years in 2011 and 2012. It is used in the postgraduate course as students are generally more mature and have some working experience. However the students' background and level of experience vary significantly. This study aims to determine the right SDL strategy for students, and find a "balance point" between the flexibilities and instructions/restrictions given to students in their course study.

2. Course Background

2.1 Pre-teaching Survey

The postgraduate course "Construction Planning and Control" is offered as a core for the Masters of Construction Project Management program in the Faculty of Built Environment at the University of New South Wales, Sydney, Australia.

The course introduces students to various programming and scheduling techniques suitable for planning of long, medium and short-term projects and tasks. A very important strategy to implement the SDL approach in the course is to conduct a pre-teaching survey. This is a postgraduate course and according to the lecturer's experience, there is a wide variety of students' background and experience. Some students may have worked in the project planning area for many years and some may have never touched the field, and others can be anything in between.

The pre-teaching survey serves two purposes:

1. To facilitate effective teaching and successful SDL experience. The survey conducted at the beginning of the semester investigated the pre-knowledge level of the students in the construction scheduling and planning area.

2. To determine whether the students background in 2011 and 2012 are similar and therefore the "end-of-term" survey on their learning experience with SDL strategy are comparable.

The first question is to ask if the student's work is/was related to project planning and scheduling. For both years, about ¼ of the class students believe their work is closely related to this area, ½ of the class think it is related but not much, the remaining ¼ of the class think their work is not related to it at all.

The 2nd and 3rd questions ask students' knowledge in two most basic skills in construction planning – calculation of critical path and use of MS Project as a scheduling software. The responses are similar, 46% in 2011 and 48% in 2012 answered that they are aware of

critical path, but do not know how to calculate it or have forgotten most of it, and 40% in 2011 and 52% in 2012 know a little bit of MS Project, but think they need to learn more. About 25-32% students do not know these two skills at all. Therefore calculating critical path and using MS Project software are included in the teaching syllabus, though these are the two skills usually have been covered in the undergraduate course. More detailed survery results in 2011 were reported by Wang and Han (2012).

There are further two questions that asked students' awareness and knowledge on Primavera and other scheduling and planning software. The responses in 2011 and 2012 are very similar too. Very few, only 8-10% of the students have knowledge or skills on those software. Primavera software is taught in the course as it is a widely used planning software in construction industry.

2.2 Self-directed teaching and learning strategies used in the course

According to the pre-teaching survey results, the teaching strategies and SDL plan were established for this course. The lecture material will be presented in an interesting and challenging manner with the aim of actively engaging students in the learning process and encouraging students to take responsibility for their own learning. Students are also encouraged to practice their skills outside the class time. Guest lectures are organized to present students with industrial case studies, and to provide students an opportunity to gain new experiences. Question and discussion sessions with the industrial people will allow students to relate theory to practice. Other self-directed teaching and learning approaches used in this course include:

1. All the lecture materials, including presentation slides, reading text, tutorial sheets and solutions were put on the online system of Blackboard. To facilitate students to explore a particular learning topic more, there were extra web links and reading materials and tutorial questions and solutions in Blackboard. These materials were marked optional and students have the flexibility to read and do it according to their own interest and need. Therefore students can select their own reading material, and explore beyond the basic requirement of the course.

2. A real industry project was adopted as the major assignment project. The assignment project requires students to use the scheduling techniques developed in the course of the study, to solve a problem using a similar approach used in the industry. Industry guest lecturer is invited to brief students about the project. Students are asked to form their own groups to work on the project. Establishing their own collaborative group is part of the SDL approach. Students are encouraged to communicate with their peers and form a group with various skill strength to produce high quality work.

3. As identified in the literature, peer assessment is also part of SDL experience. Therefore students are allowed to use a peer assessment form to grade themselves against their group mates in contributing to the group assignment. The lecturer then

used their peer assessment marks combined with their group mark to calculate individual mark.

4. The 3 hour teaching block is arranged as 2 hour lecture and 1 hour tutorial. It is compulsory to hand in the tutorial work at the end of the class for assessment purpose. Due to the different level of pre-knowledge of students, additional tutorial questions and solutions are provided online to give students flexibility to practice more and at their own time. Additional consultation time is also allocated each week to give students assistance outside of the class.

5. Computer lab sessions are arranged according to the pre-teaching survey. Both MS Project and Primavera are taught in the lab sessions. Several students who are expert users of the software completed the tasks in a very short time in the lab sessions and provided support and help to others. Tutors extended the lab sessions to support less capable students. Software manuals and additional lab sheets are provided to students for them to explore more on the software.

3. Evaluating the Self-Directed Learning and Teaching Strategies

3.1 Survey design

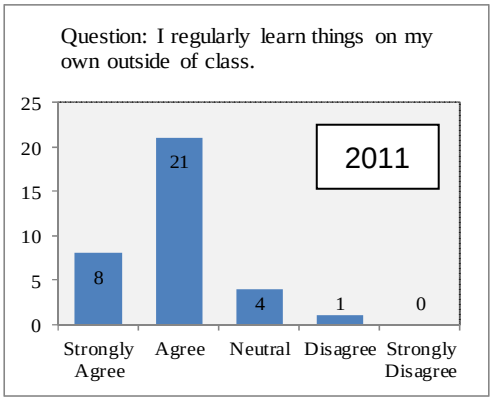
Many previous studies used questionnaires to collect feedbacks from students and evaluate the outcomes of students' self-directed learning (Zhang, Zeng et al. (2011) and (Victori 2007). The questionnaire comprises both Likert-scale type questions as well as semi-open questions. Stewart (2007) designed a questionnaire to evaluate the SDL readiness of final year civil engineering students at Griffith University, Gold Coast, Australia.

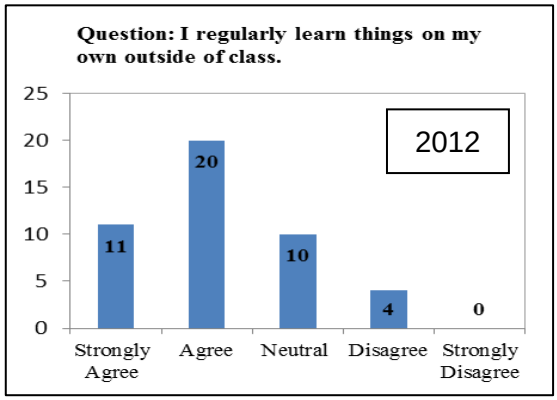
In this research, questionnaire surveys are also used to evaluate the SDL strategies adopted in the course. The survey was conducted at the end of the semester in 2011 and 2012, and it is to evaluate the teaching model and SDL strategies used in this course, and investigate students' SDL ability and students' satisfaction with the SDL strategies used in the course. 34 students in 2011 and 45 students in 2012 participated in the survey, and two students from each year are further interviewed to get their feedback on the SDL experience.

Altogether there are 22 survey questions with a Likert scale in the survey. Questions are grouped in different areas of teaching and learning and they are reported below.

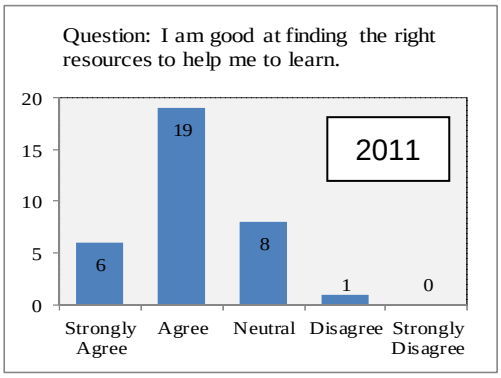
3.2 Students' SDL ability

There are five questions in the survey are related to students' SDL ability, and the response are summarized in Figure 1.



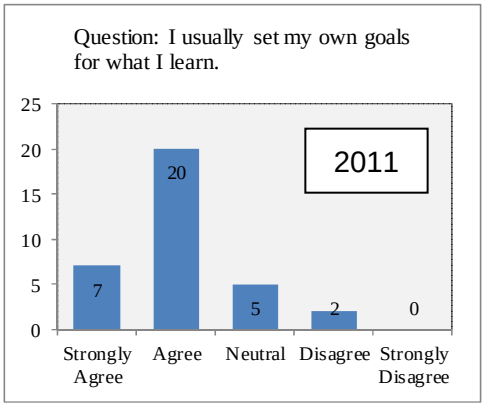


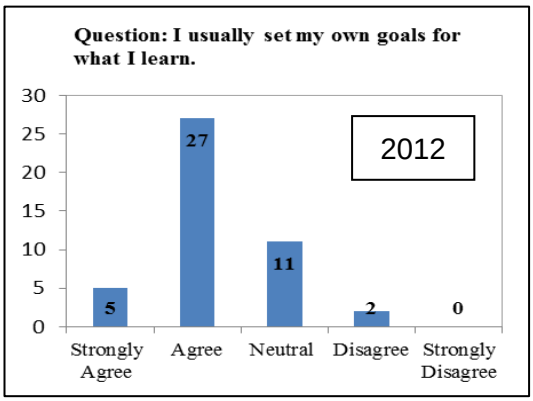
(a) Question 1: I regularly learn things on my own outside of class



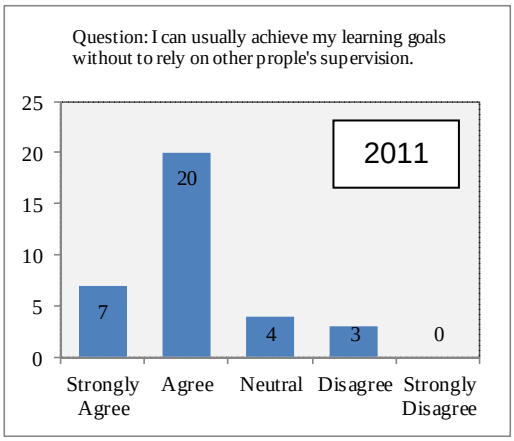


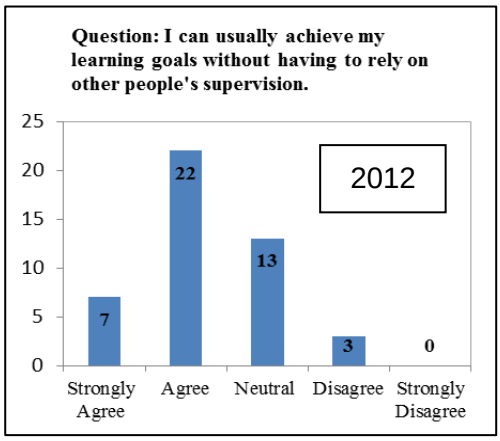
(b) Question 2: I am good at finding the right resources to help me to learn



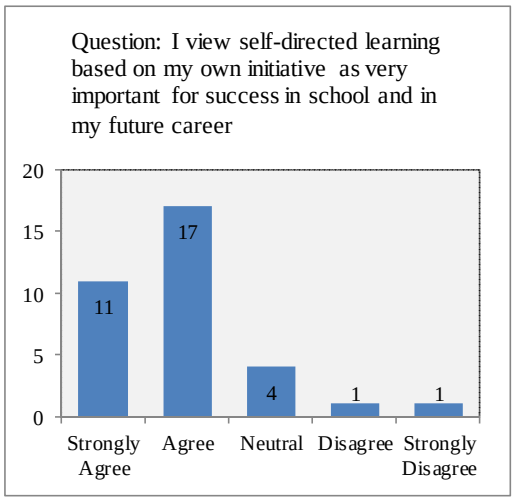


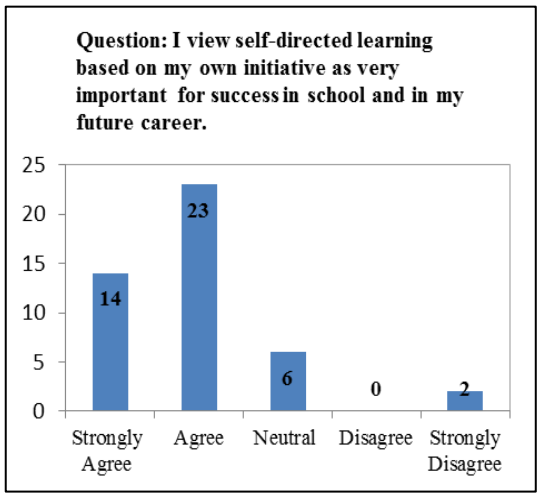
(c) Question 3: I usually set my own goals for what I learn





(d) Question 4: I can usually achieve my learning goals without having to rely on other people's supervision





(e) Question 5: I view SDL based on my own initiative as very important for success in school and in my future career

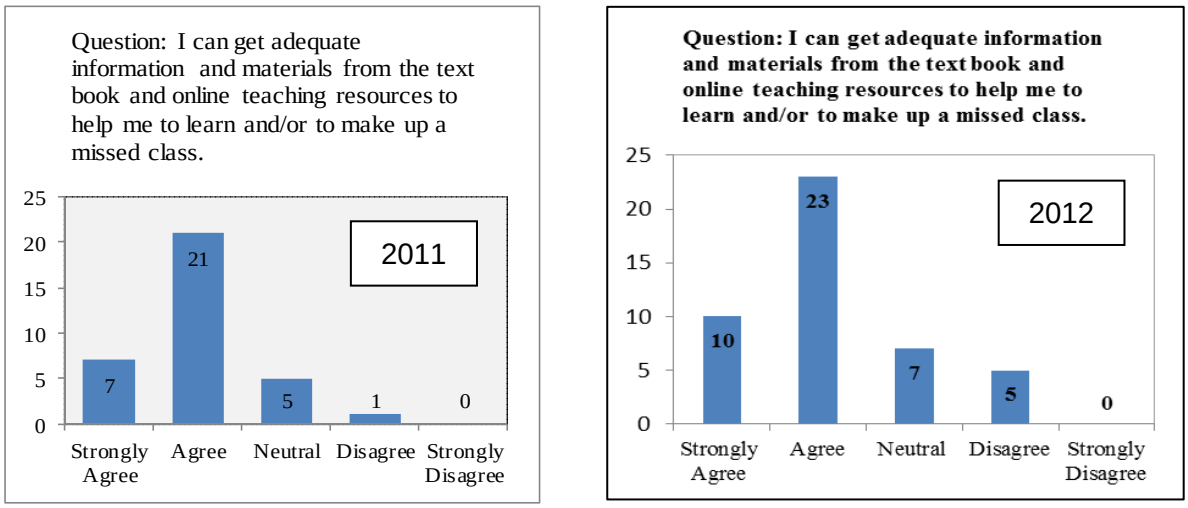
Figure 1. Comparison of 2011 and 2012 survey responses on students' SDL ability

The response given in Figure 1 shows that the students responses in 2011 and 2012 are very similar. Generally about 75% of the students are very confident about their self-directed learning ability and view themselves as good self-directed learners. This means students are comfortable with the SDL ability required in this course, and they are not stressed by the choices and flexibility provided to them.

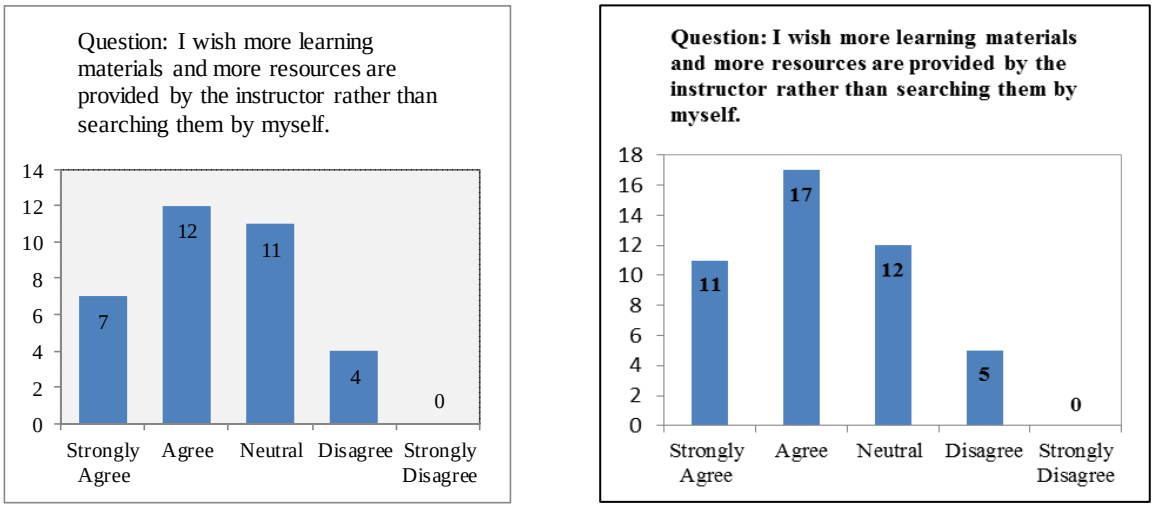
3.3 Teaching and learning resources

There are a wide range of learning materials provided in the course, and the survey comprises two questions to obtain students' feedback on learning materials and the outcome is in Figure 2. While over 80% students think they can get adequate information and

materials from the lecturer-provided resources, 55% of the students wish more learning resources would be provided. Further interview with the students indicate that the assignment project is the main task that they feel they are in need of more material. The intention of the lecturer is to challenge students to search necessary material themselves, as this is an important part of SDL ability. The students' feedback reflect that they believe there are adequate material for them to complete the assignment, but they wish more material are available for them to complete the assignment with high standard. They students feel they had to spend too much time in searching additional material by themselves.



(a) Question: I can get adequate information/materials to help me to learn

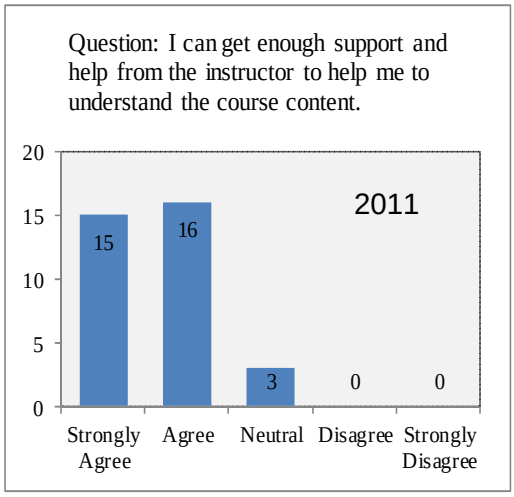


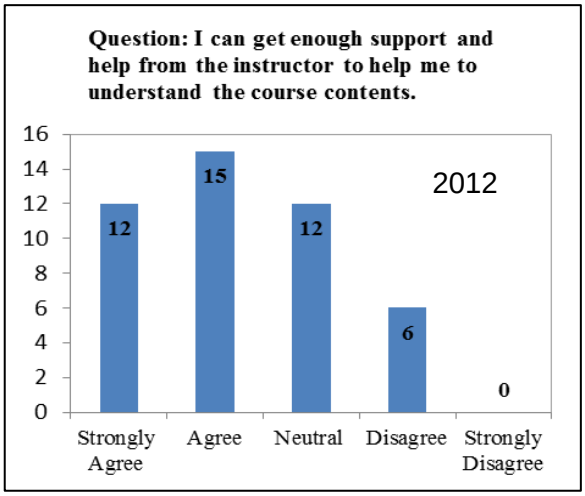
(b) Question: I wish more learning materials are provided rather than searching by myself

Figure 2. Students' feedback on the provided teaching resources

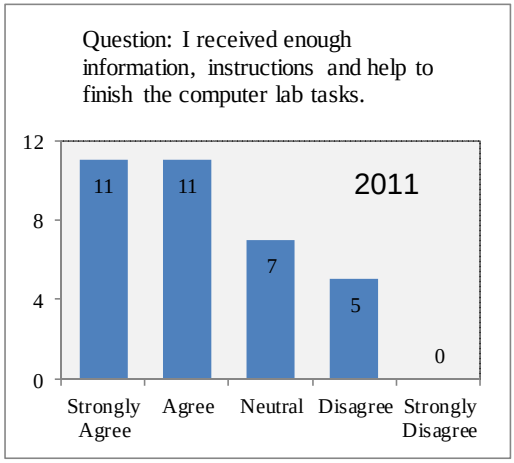
3.4 Lecturer and tutor's support

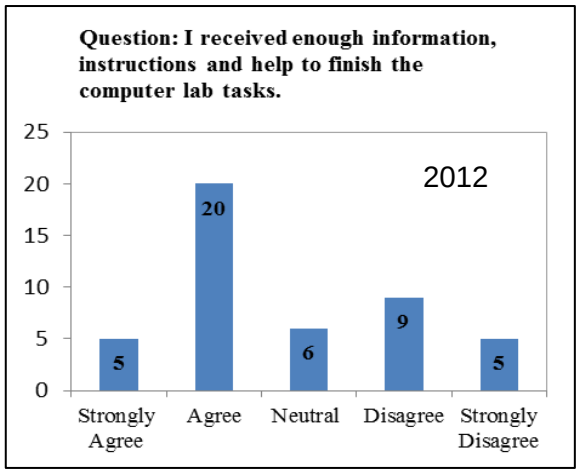
Self-directed learning should be adequately supported and guided by teaching staff. About the support from the lecturer and tutors, the students' feedback are given in Figure 3.





(a) Question: I can get enough support and help





(b) I received enough information/instructions and help in the lab

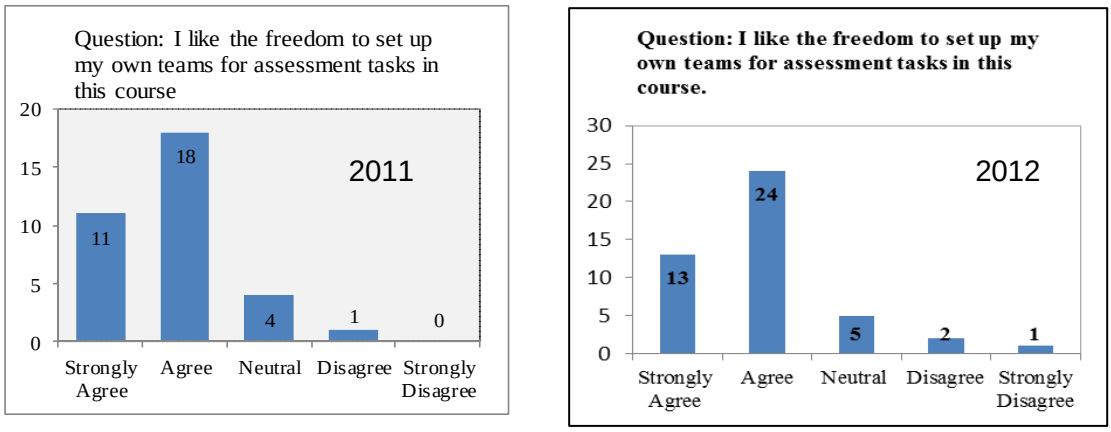
Figure 3. Students' feedback on lecture's and tutors' support in the course

An obvious difference can be seen from the students' response in 2011 and 2012. In 2011, generally all students think they can get enough support to understand the course content. In 2012, there are 6 students who think that the instructors didn't provide enough support and the other 12 students are not sure whether they have got enough support or not. When asked about the lab sessions, more students in 2012 believe that they didn't receive sufficient help and support from the staff. This response is in line with the fact that in 2012, more flexibility is given to students and less spoon-feeding style help is provided. Another

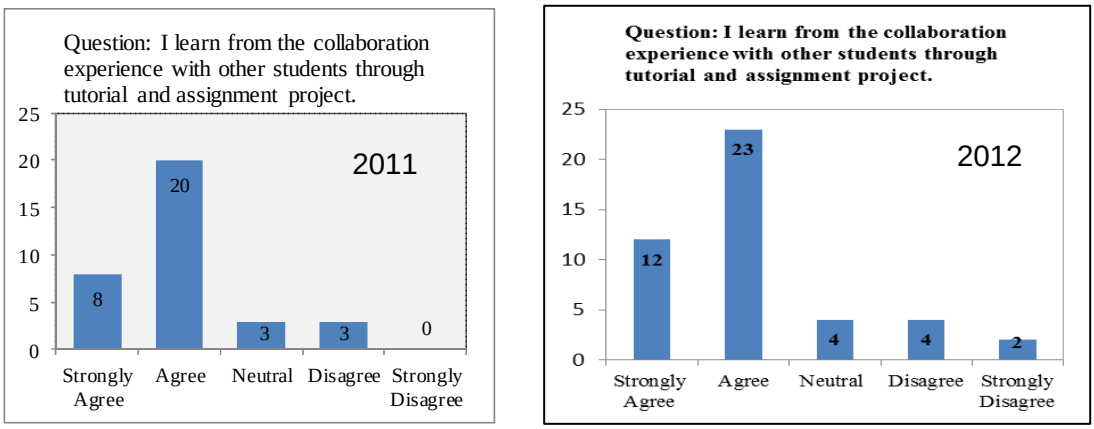
factor that has influenced the responses is that the requirement of using Primavera software in 2012 has increased.

3.5 Collaboration and Peer support

About the collaboration and peer support experience in the course, students' feedback are given in Figure 4. Most students are very positive about their peer learning experience, however, a few students have disagreed as they do not believe they learnt much from peers. The peer assessment method also was regarded by over 40% students as not necessary**.**



(a) Question: I like the freedom to set up my team for assessment tasks in this course



(b) Question: I learn from the collaboration experience with other students through tutorial and assignment project

Figure 4. Students' response on collaboration and peer support

The responses from students on collaboration and peer support are very similar in 2011 and 2012. The approach used in both years are similar. The only difference is in 2012, up to 4 students can choose to be in a group to complete their assignment project, while in 2011, only 2-3 students are allowed to be in one group. The increase of the group size didn't show negative impact on the students learning experience.

3.6 Overall satisfaction on self-directed learning strategy

The increased use of online teaching and lab-based learning has facilitated SDL strategy to be used in this course. This study found that our postgraduate students are quite capable self-directed learners, and they are confident about their own self-directed learning capability. Figure 5 shows the students response to their overall capability in SDL strategy in 2012 (This survey question was not included in 2011 survey). The postgraduate students are from a wide variety of background and experience, the SDL strategies in this course aim to provide possibilities for them to learn at different pace, focus more on different area, and support each other.

Based on the survey results in 2011, which indicated general support of using SDL strategy in this course, more flexibility and less instruction were given in 2012 in order to increase the level of self-directed learning. From the above sections, it is obvious that although students are generally supportive in using the SDL strategy in the course, more students indicated in the survey that they expect more resources and support provided to them. The overall satisfaction of the SDL is about 50%, with about 40% are neutral and 10% students are not satisfied with the SDL strategy (Figure 6).

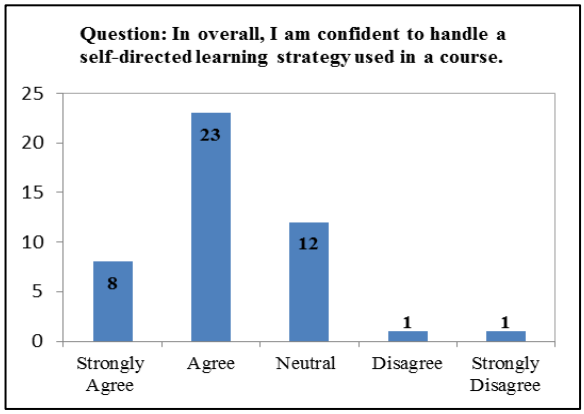


Figure 5. Students' overall confidence of their own self-directed learning ability

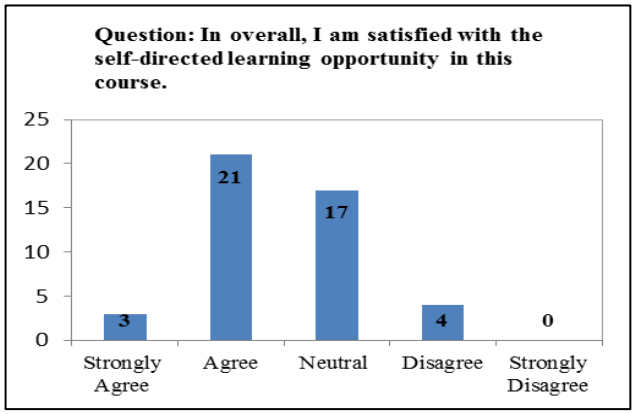


Figure 6. Overall satisfaction on the self-directed learning opportunity in this course

4. DISCUSSION AND CONCLUSIONS

The greatest challenge of successful implementation of SDL strategies is how to balance between the instructions given in lectures and the freedom of SDL to provide satisfactory learning outcome. To decide the right "balance point", more flexibility and less instruction/guidance were given to 2012 students based on the overall supportive response to SDL strategies from 2011 students. The responses from students are mixed in regard to provided learning materials, instructor's support, and the flexibility offered by the current SDL approach. Based on the survey findings, the following are proposed to improve the SDL strategies in the postgraduate teaching:

1. Due to the wide range of postgraduate students' background and experience, pre-teaching survey is always helpful in determining appropriate teaching contents, setting the difficulty level and establishing the SDL strategies for the course. The pre-teaching surveys in 2011 and 2012 have indicated similar students background and distribution in industry experience and pre-knowledge related to the course.

2. Most of the postgraduate students see themselves as capable self-directed learners, but the level of support they need varies. Based on the 2011 survey results, a more flexible teaching model is adopted in 2012, e.g., more allocated consultation time and optional after-class exercises, less restrictions on the methods of completing assignment project, less instructions on how to complete lab tutorial tasks, etc. With this change, it is found that some students are not satisfied with the reduced support from instructors. Individual or small group consultations are welcome by students but mostly they are used by students who have great difficulty in completing compulsory tasks rather than by capable students who are willing to explore more in the area. It is suggested that "bonus points" to be used in future teaching to reward students who learn beyond the basic requirement.

3. While some students expect more flexibility in choosing the topics and contents to fit their personal goals, it is noted that some of them do not enjoy the process to explore the topic area and searching for materials. It is suggested that more learning resources be provided to students, therefore they can search "within a boundary" and more likely to find the information they need in an efficient way. This is particularly important to the small portion of the full-time (especially international) students who have not worked in the industry, as they are usually confused when too many choices are presented to them. In another aspect, it should be made clear to students that one of the learning objectives for SDL is to enhance their skills in searching and selecting additional and relevant information to complete a set task successfully, and encourage them to develop their capability in this area.

4. The survey results in 2012 have indicated the flexibility given to students have "gone beyond desirable". The satisfaction reduced rather than increased, therefore it is suggested that better defined topic area and clearer requirements for the tutorial tasks and assignment project be given to future students. Although the capability to search and identify the most appropriate material to complete a task is one of the

important aspects of SDL, it is observed that many students feel it is too time-consuming. This indicates that students need more guidance on obtaining relevant material.

5. As a large portion of postgraduate students works or worked in the industry, many of them have valuable experience. Over 80% of students appreciate the collaboration experience in the group work, which provides them with opportunity to learn each other. It is suggested that online discussions be established in the course as it could facilitate students' learning from peers. Ongoing web-based blogs and online discussion/forum could also enhance students' learning and promote deep learning.

After two years "trial and error" approach in adopting the SDL strategies in the postgraduate course, it is expected that the "balance point" between flexibility and instructions are now better defined and enacting the above suggestions will improve students' satisfaction to the course in 2013!

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Comparing Safety in Design Approaches and Tools in the US, UK, and Australia

Kihong Ku[1]

Abstract

Excepting Europe and Australia that have enacted laws to increase the level of involvement of designers in the Prevention through Design process, contractors in many parts of the world are often found to be the sole implementers of construction hazard prevention. In depth analysis of literature related to occupational safety hazards indicates that addressing worker safety during design is a valuable contributor to the reduction of hazard rate of workers found in the construction industry (Gambatese et al. 2005). This research aims to determine tools and processes architects and designers are currently utilizing in conjunction with construction experts to address construction worker safety during design. The focus of this research is to determine the influence of tools and emerging technologies such as BIM and to harness collaboration between professionals in the field to aid designers in considering worker safety on construction sites. Based on the findings from the present stage of the research, it can be concluded that BIM can be a valuable tool for implementation of construction worker safety by designers. Along with other strengths of BIM, it also incorporates multiple facets of the construction industry. However, in countries such as the United States, where the laws have not yet been enacted for designers to practice construction worker safety, it is recommended that the concerns of professional and legal liability of designers and knowledge barriers should be addressed before considering utilization of BIM.

Keywords: PtD, Design, Safety, BIM, Hazard

1. Introduction

Funded by the National Institute of Occupational Safety and Health, as part of an industry wide Prevention through Design initiative, this research aims to determine tools and processes that can harness an earlier application of construction hazard, Prevention through Design. Occupational fatalities in the construction industry account for 23% of all work related fatalities, while they only employ 7% of the workforce (Behm 2008). Earlier studies on Prevention through Design (PtD) indicate that the design aspects of a project can significantly impact the rate and extent of construction site accidents. One such study aimed at analysing policies regarding accident prevention on construction sites, particularly the efficacy of one of the first directives that incorporated Prevention through Design. The study

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found that accident and incident rates had declined by at least 10 percent after the directive went into effect in ten countries in the European Union (Aires et al. 2009).

However, barriers in the industry are preventing widespread and thorough implementation of construction hazard prevention through design. These barriers include but are not limited to perceived legal and professional liability, lack of knowledge of the construction industry, lack of motivation for designers to take construction hazards into consideration, and lack of facilitation of collaboration between designers and constructors earlier in a project (Gangolells et al. 2010). In this article, we discuss findings from a study on how tools can overcome some of these barriers, and help designers in practicing construction hazard prevention in the design phase.

2. Research Objectives and Methods

The motivation for conducting research in this area lies in determining existing tools used by designers to address construction worker safety, and the effectiveness of these tools in harnessing collaborative insights of other professionals in the field for a comprehensive application of construction hazard prevention through design. The research also simultaneously attempts to analyse the existing barriers, if any that exist for designers in applying design for safety and, to explore if any tools and methodologies can mitigate the impact of these barriers.

The tools and methodologies that are under consideration in the research are Integrated Project Delivery (IPD), Hazard Identification Tools, Risk Assessment Tools, Procedural Guidelines, Visualization Tools, BIM, Semi-Automated Decision Support Systems. It must be brought to attention that the research found discrepancies in how literature defined these tools and methodologies, and how individuals practiced them. Thus, what can be summarized from the interviews is a more general overview of tools and methodologies that firms are utilizing for applications of Construction Hazard Prevention through Design. This research has been conducted in three phases to cover aspects of design for safety.

The first phase consists of expert panel interviews in order to gain general insight into the existing tools and methodologies, and their application in design for construction worker safety. Experts interviewed are determined through their academic publications, organization affiliations, and the innovative nature of the firm they work for. The first phase is not a comprehensive phase as its objective is to set the stage for the next two phases of in depth research.

The second phase incorporates a comprehensive industry wide survey to gain a greater sample size, and gather key metrics that indicate observable patterns in ways different professionals are utilizing Prevention through Design tools. Subsequently the survey aims to identify the most effective and accepted tools and the strength, weakness, and opportunity for further development of tools. The third phase focuses on assimilation and analysis of data collected in phase two; to identify tools being utilized and the method of implementation of tools in the applications of prevention through design in projects. Additionally, the third stage of the research is an in depth case study that aims at receiving more specific insights

of what tools are being utilized and how they are implemented in the applications of Prevention through Design in practice. In this paper, the findings from the first phase expert panel interviews are discussed.

2.1 Expert Panel Participants

The expert panel interviews in the first phase consist of interviewing thirteen professionals in the design and construction industry in three countries: USA, UK, and Australia. The UK and Australia have been selected as comparison points with the United States, because of existing established regulations that allocate responsibility on designers for addressing worker safety. In the UK, CDM regulations have been allocating responsibilities onto the designer for addressing worker safety in the construction industry since as early as 1994 (Mackenzie et al 2000). Similarly, Australia has also put into effect a requirement for designers to address worker safety, for more than a decade (Bluff 2003). Due to the pre-established nature of these regulations, firms located in both countries have also had a considerable amount of time to refine their utilization and knowledge of designing for construction worker safety. However, in the United States regulatory requirements are still undeveloped and at a nascent stage. Therefore, a comparative study of regulatory environments for firms in Australia and UK to the United States served as a good indicator of the impact of applicability of tools in predicting barriers to implementation of design for safety.

Professionals interviewed have been selected from diversified backgrounds and belong to work in varying fields of specialization within the industry. The selection has been made to facilitate understanding of the correlation between professional backgrounds and the tools being utilized. Garnering multiple viewpoints on tool utilization aids in speculating as to how these tools can be used to harness collaboration of different backgrounds on design for safety. Table 1 categorizes the participants by company type and region. The firms being represented by the interviewees specialize in Architecture, Health and Safety Management, Construction Management, Design-Build, Façade Consulting, Structural Engineering, and Architectural Engineering. Of the thirteen professionals that have been interviewed, five of them were architects, one of whom with a background in health and safety working in a UK architecture firm, one an architect who is a US façade consultant, two US architecture firms, one who is directing the design division of a US design-build company, and one Australian architect.

Table 1: Expert Interview Participants

Region / Company Type	USA	UK	Australia	Total
Architecture	3	1	1	5
Engineering/Consulting	2	1		3
Construction	2			2
Safety Coordinator		1	2	3
Total	7	3	3	13

Safety coordinators were from the UK and Australia with backgrounds in health and safety and civil engineering. Additionally, Construction professionals from one US mechanical contractor and one US general contractor participated.

The information collected from the professionals interviewed has laid focus on their academic background and specialization, nature of their work, utilization of BIM and number of years of experience, strategies, and tools. The interviews also asked about knowledge of Prevention through Design(PtD), Design for Safety(DfS), buildability and/or constructability for worker safety, maintainability for worker safety, standards/regulations, company standards (laws, implementations), etc., and other tools and methodologies the firms may currently be using but not defined by literature yet.

3. Expert Interview Results

The primary objective of the expert interviews was to understand how designers incorporate construction workers' safety into the design process and what tools they use. Considering the different regulatory and industry context of US, UK and Australian practitioners, specific questions were asked.

1. How do practitioners consider worker safety in design in comparison to the design process identified in literature?

2. How do designers' approaches differ in the UK and Australia from the US?

3. What tools are mostly used by designers to prevent construction hazards?

3.1 Tools in Literature

Hazard analyses and risk assessments are central to safety in design approaches (Manuele, 2008a; 2008b). However, hazard recognition is quite difficult given the complexity and size of the building systems designed (Gambatese, 2008). Manuele (2005) indicates that construction planners typically rely on professional and personal experience and group assessments to determine risk levels. While PtD tools have the potential to support and improve designers' knowledge and skills of hazard recognition and facilitate communication between the designer and constructor, assisting designers to overcome their lack of expertise in construction safety and health issues, a limited number of tools are available (Ku and Mills, 2010). There are checklists such as the "Design for Construction Safety ToolBox (Gambatese et al., 1997), risk assessment forms in paper or software format (Duffy, 2004; Gambatese, 2004; Hecker et al., 2004) which are used by experienced professionals who qualitatively evaluate the risks of specific hazards and to rank the level of risk.

In order to facilitate hazard identification and risk assessment, a number of researchers have developed prototypes that automate hazard analyses and risk assessment. ToolSHeD (Cooke et al., 2008) captures expert reasoning through argument trees to assess the risk of falling from height during roof maintenance work. The prototype provides interactive risk assessment via an online interface that generates the risk level of specific activities or

materials. Nussbaum et al. (2009) developed a decision support system of residential panelised walls to identify high levels of musculoskeletal disorders risk. The tool is based on breakdown tasks and laboratory based simulations and modelling to mathematically and computationally calculate ergonomic risks, and supports design optimization of panels. Sacks et al. (2009) developed algorithms to estimate the likelihood of exposure of construction workers to loss-of-control events. Their prototype software was used to assess risk levels of spatial and temporal exposure events of falling objects onto workers below. Zhang et al. (2012) proposed to incorporate automated safety rule checking into BIM for falls hazards. Table 2 classifies research areas by their application algorithms and interfaces. The majority of tools focus on construction planning while a few extend their approach to design for safety. With the continuing adoption of Building Information Models (BIM) in construction, there is an increasing interest in utilizing 3D models and visualization for hazard analysis.

Table 2: Automated Hazard Analysis Tools

Algorithm / Interface	Construction Planning		PtD – Safety Design Optimization
	Hazard identification	Hazard Identification/Risk	
Text based interface			Cooke et al. (2008)
3D model interface	Zhang et al. (2012)	Sacks et al. (2009)	Nussbaum et al. (2009)

In addition to the above mentioned tools, others recommend a structured review process (Gambatese, 2004) such as the Australian CHAIR tool which provides detailed and systematic examination of the construction, maintenance, repair, and demolition safety issues. Under the UK CDM regulations, the Safety-in-Design knowledge benchmark (SiD) plan is promoting a standard for Safety in Design for designers.

While literature shows various approaches and tools to address construction safety, there is a lack of understanding of what tools design and construction professionals use in practice. The following sections describe the findings from the expert panel interviews.

3.2 Design for Safety (DfS)

Designers who were interviewed from the UK and Australia seemed more receptive and comfortable with the applications of construction worker safety. This was due to the fact that they were already working within the norms of established regulations that required designers to be involved in designing for construction worker safety. When the designers from the US were interviewed, we observed a pattern was found that indicated a lack of comfort on applications of designing for construction worker safety. In some cases, designers explicitly did not find any reason to practice construction worker safety, as they felt it was the contractor's responsibility. However, designers practicing in the US were knowledgeable on primarily operational and maintenance aspects of worker safety related to OSHA requirements. Due to the established regulatory requirements and the generally rigid

nature of role designations in the industry, designers in the United States felt obligated to address maintenance/operation worker safety. Other barriers to the applications of construction worker safety were legal liability, lack of comfort/knowledge of the construction trade, and lack of interaction with the constructor under specific project delivery methods.

3.2.1 Liability

Considering the liability concerns of design professionals, the expert panel was asked about how they addressed worker's safety. A UK architect of a full service high profile international firm mentioned that they develop method statements for cleaning, maintenance, and replacement operations which may involve hazardous conditions such as window cleaning at heights. This architect's firm designs a large number of non-standard buildings that involve complex geometries. Regarding construction worker safety and health concerns, the firm has a set of design guides addressing constructability and buildability that incorporate general safety concerns such as masonry unit sizes to reduce musculoskeletal injuries or use of prefabricated systems to reduce falls hazards. Similarly, an Australian architect of a small size firm who identified his focus on design for safety, explained his primary concentration on maintenance and operation phases rather than construction. But he also mentioned that prefabrication was a main consideration for buildability.

Interestingly, while the UK architect and Australian architects were receptive to practicing design-for-safety, their main area that they felt responsible for was on maintenance and operation phases similar to US architects.

The majority of the expert panellists mentioned that they would involve facility management personnel of the client, consultants, and constructors to address maintenance and operation safety issues. One architect of a US design-build company where the design team has direct internal relations with the construction team in addressing construction worker, mentioned familiarity with safety guidelines and risk assessment tools.

The research also indicates that incentives for designers to consider construction worker safety are very few; some of these incentives include contractual requirements on behalf of the client in highly specialized facilities.

3.3 Codes, Checklists, Company Manuals

To find out about the design for safety tools mostly used by designers, questions were asked about hazard identification, risk assessment, company manuals. The majority of interviewees, regardless of profession or country of origin agreed that written assessments and checklists were tools that were limiting and often ineffective. Designers believed that written assessments were not conducive to their design methodology, and suggested usage of more qualitative tools for risk assessment and hazard identification. The success of utilization of risk assessments and hazard identification by designers relied heavily on applying open ended and less prescriptive tools to prevent any constraint on the designer's objectives.

3.3.1 Hazard identification

Interviewees in construction and engineering firms identified themselves more with checklists and risk assessment matrices. A founder of a UK structural engineering known for their innovative projects mentioned the applicability of checklists for younger and inexperienced engineers to ensure that all integral aspects to a project had been addressed. Additionally, interviewees suggested a strong reliance on the expertise and knowledge base of key stakeholders in the project, or expert guidance from consultants outside of the project, instead of following set procedures or guidelines.

3.3.2 Risk assessment

In response to the use of risk assessment tools, an Australian safety professional detailed that their firm was utilizing process mapping rather than risk assessment matrices to identify health and safety drivers. Another designer mentioned that their UK based firm utilized a less prescriptive methodology in addressing risk assessments. The interviewee described the risks being segregated into low, medium, and high risk categories, and diagrams and drawings were attached to each category to make it user friendly for designers.

3.3.3 Company manuals

The expert panellists also described internal company databases that were compiled and updated based on changing (1) regulatory requirements and (2) lessons learned from projects. The majority of the US designers did not have formal databases but referred to OSHA standards. A US general contractor explained their use of a searchable database for lessons learned and OSHA requirements. The UK architect and UK CDM coordinator described the use of internal knowledge management platforms and company standards that integrated lessons learned and best practices. An innovative design firm in the UK also mentioned their internal program that was responsive to designer specifications.

3.4 Quality Control

The panellists were asked about utilization of structured design reviews during various phases of the project. The design review process is a quality control measure and serves as a method of lessening the perceived liability by designers. Incorporating the insights of experts and key stakeholders not only aids in ensuring quality control, but also helps the designer to feel more confident about applying design for safety principles.

3.4.1 Design review

All US, UK, and Australian designers described the use of a review process that incorporated constructability reviews and/or code reviews. One US architect who works for a general contractor mentioned the use of constructability reviews (30%, 60%, 90% completion) through work groups who would have experience with incident reviews. The three US architects explained that internal senior technical reviewers or consultants would review design documents. One of them required facility personnel to be a part of the design

and construction review process, to ensure that aspects of the building process were consistently addressed. However, construction workers' safety was not part of such reviews. The UK architect explained the participation of specialized groups and peer reviews that would involve people with construction backgrounds and design backgrounds to ensure the adequacy of the deliverables. The Australian architect mentioned engaging all related stakeholders through assessment workshops. Another prominent structural engineering firm utilized a designated formal review team to inspect adequacy of project deliverables.

An Australian Safety Professional mentioned the utilization of CHAIR, Construction Hazard Assessment Implication Review, which facilitate collaboration between various stakeholders in order to address construction, maintenance, and demolition safety risks. He explained this as a three stage process of (1) identifying issues and concerns, (2) risk assessment, and (3) identifying residual risks, which would be facilitated through workshops with stakeholders including the designers. As a CDM coordinator of a UK firm explained, they would coordinate safety in the same manner whether they would work with internal engineers or external team members.

The majority of architecture and engineering firms in the US were unfamiliar with a similar formalized process that addresses worker safety as there no such regulation in the US. One variation of a procedural guideline was a project delivery manual in a US Architecture firm that was utilized as a quality control method to incorporate the expertise of senior level technical professionals that participate in determining if construction documents complied with regulatory codes.

3.5 Building Information Modeling (BIM), Visualization, and Automation

Building Information Modeling Systems that interviewees most commonly mentioned were Revit, Navisworks, Tekla, and AutoCAD. Synchro LTD for 4D simulation and Solibri for code checking were also acknowledged. In spite of observed differences in the motivations for reasons why firms practiced design for safety, the majority of the interviewees provided similar insights into the strengths of utilizing Building Information Modeling (BIM) in the field. Interviewees stated that the strengths of BIM lied in physical clash detection, managing larger and more complex projects, and aid in collaborating with other professionals and stakeholders on the project. The ability of BIM to manage a large amount of information in a project, ranging from the project schedule to analysing the constructability of a building made it a powerful tool in fostering the collaboration of a wide variety of expertise in the industry.

Overall, BIM was seen as a beneficial tool in communicating various aspects of a project, and design firms emphasized its a value as a visualization tool in communicating all aspects of a design, and communicating effectively to the constructor, and receive feedback about their project during design reviews.

The collaboration through BIM tools seemed beneficial to the designer as it lessened the extent of legal liability through enhanced collaboration. As a result, the designer may be better placed to practice design for worker safety. Interviewees mentioned utilizing BIM to analyse the constructability of a building, as well as operation and maintenance. A US

architect of a design-build firm asserted on more than one occasion, that designer's would prefer utilizing BIM to consider worker safety over checklists and other prescriptive tools that were traditionally used by contractors. One of the main reasons was the belief that checklists and risk assessments stifled innovation and creativity of designers due to their prescriptive nature.

The US architect of the design-builder mentioned utilizing BIM to check code requirements in their respective country. The other US construction company mentioned using BIM to check if the structure complied with all operational and maintainability requirements by OSHA.

Perceived drawbacks of BIM included difficulty of managing and navigating larger projects, and the time and resources that tended to be invested into managing a BIM document. Therefore, in order for the BIM model to be completely successful in utilization for design for safety, further development of BIM is necessary.

When asked about (semi) automated Decision Support Systems, none of the panellists suggested using such tools, due to the nascent stage of this tool in research and practice. The majority of interviewees were not familiar with it. However, interviewees did show an interest in integrating current company processes into a tool that incorporates other tools they are utilizing. Additionally, existing usage of internal company databases and manuals indicated an opportunity to apply databases to automated tools.

4. Conclusions

As part of a three stage research, the expert panel interview conducted with thirteen US, UK, and Australian professionals on the implementation of construction hazard tools led to preliminary insights of the different and similar attitudes of designers in the US, UK, and Australia. Coinciding with the common belief, US designers have a resistance towards the consideration of construction hazards during design stages because of the lack of in depth knowledge of construction processes and safety hazards. The US panellists were also not clear as to how the construction hazards could be incorporated into the design phase of the project. Fear of legal and professional liability was a major deterrent for them to consider implementation of these worker hazards. However, while the UK and Australian architects demonstrated more confidence and familiarity with the notion of construction hazard prevention, their primary focus of hazard identification and risk assessment related to the maintenance and operation of buildings rather than construction hazards. This corresponds to the responsibility of US architects who similarly consider maintenance and operation worker safety. Hazards during maintenance and operation phases of a building such as window cleaning, safe access to equipment on roofs, etc., required design considerations by architects in all three countries.

The extent of identification activities of maintenance and operation hazards by designers was somewhat different between US, UK, and Australian designers. The UK and Australian architects explained internal procedures of design guides, assessment workshops, and structured reviews that address not only code requirements but also lessons learned throughout their projects. The US designers were concerned more with satisfying code

requirements (OSHA) and had not developed or used internal design guides or assessment workshops but some involved stakeholders beyond the design team if requested by the client.

Regarding hazard prevention tools for design, all architects indicated that prescriptive checklists were ineffective and preferred visualisation tools in general. The UK and Australian architects emphasised that hazard identification also depended mostly on the experience and knowledge of personnel and was oftentimes assured through design reviews of senior technical personnel. In contrast, the UK structural engineer found checklists effective for entry level engineers.

US designers were mostly unaware of hazard identification checklists and risk assessment forms. UK and Australian architects utilized risk assessment forms to qualitatively rank low/medium/high risks but mentioned that those forms were rather used for reporting purposes and the panellists warned that the forms are prone to get challenging and time consuming on larger projects.

The expert interviews also revealed that the panellists consider BIM an effective communication and visualization tool. But it is currently not well integrated into processes and should incorporate more functions that can facilitate and motivate designers in practicing construction worker safety. Structured review processes do harness collaboration and ensure quality control of company processes, but are depend on who they can incorporate into their reviews. By establishing a standard set of procedures for firms to practice and address some of the shortfalls of BIM, developing a motivational force for designers to practice construction hazard prevention may be possible.

The expert panel interview results have offered valuable insights of design for safety practices in US, UK, and Australia. The results are used to guide the second phase of this research which will gather broader perspectives of US, UK, and Australian practitioners through an online survey.

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ANALYSING THE COLOMBIAN LOW-INCOME HOUSING MEGAPROJECTS FROM A MANAGERIAL PERSPECTIVE

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Abstract

Over the last two decades, Colombian government has promoted private low-income housing production through implementing a series of financial and managerial mechanisms. These have sought to increase the participation of non-public firms in providing solutions for low-cost urban households. Despite these efforts, the deficit has not sufficiently diminished. For such reason, since 2008, the national administration has implemented a new policy called the Low-Income Housing Megaprojects (LIHM). These have been proposed mainly to generate improved urban design in city expansion areas and obtain scale economies. This study aims to examine the challenges that project management faces in terms of facilitating social housing production so as to reduce the Colombian affordable dwelling shortage through implementing the LIHM strategy. Since this is an on-going investigation, only preliminary results are presented. Analysis is performed by taking into account two LIHM located in the cities of Soacha (near Bogota) and Cali. Both projects are explored through identifying their main actors based on organisational field and project governance concepts. Our findings are directed towards making clear the real organisational complexity of developing LIHM, and emphasise the necessity of more collaboration among institutions (i.e.: public, private, and non-profit organisations) so as to provide adequate living conditions for the low-income population.

Keywords: low-income housing, megaprojects, organisational field, governance, project management

1. Introduction

One of the most important challenges faced by governments in developing countries is the provision of adequate living conditions for the low-income urban households. Before the 1980s, public institutions were in charge of producing housing solutions for the poor.

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However, over the last three decades, governments have started to address the housing problem by adopting a neo-liberal approach in which they have become a facilitator rather than a producer. Under this economic paradigm, the state seeks to perform fewer public functions and implement private sector practices in order to increase the efficiency of the residential sector. Over the last two decades, the Colombian government has promoted private low-income housing production through implementing a series of financial and managerial mechanisms. These have sought to increase the participation of non-public firms in providing solutions for low-cost urban households. Despite these efforts, the dwelling shortage has not sufficiently diminished. For such reason, since 2008, the national administration has implemented a new policy called The Low-Income Housing Megaprojects (LIHM). This strategy is a central government programme that aims to reduce the Colombian housing shortage and produce large-scale affordable residential initiatives through generating urban soil more efficiently than other regional-based approaches.

LIHM have many features in common with several global engineering projects. Both exert a significant impact on the communities where they are built and require a substantial amount of money to be developed. They also involve the interaction of many actors from many different backgrounds. Additionally, the two types of initiatives are carried out within a neo-liberal economic framework in which the private sector plays a paramount role. Based on these shared characteristics, we argue that LIHM can be examined, from an organizational standpoint by using the concepts of organisational field and project governance. This paper is organised in the following way: first, a description of the Colombian housing policy is presented. Secondly, the concepts of organisational field and project governance are introduced. Based on the national policy and the theoretical ideas shown, the research methodology is explained and the two case studies under examination are described. Subsequently, the actors and organisations involved in the development of the LIHM are identified and examined. Finally, conclusions are presented and recommendations for further analysis are highlighted.

2. A brief review of the Colombian social housing policy

Social housing policies in Colombia have experimented dramatic transformations over the last 20 years. These changes have been intended to diminish the dwelling shortage by incentivising the private sector to take part in providing housing solutions and allowing public strategies to be specifically focused on facilitating access to housing through offering different forms of financial aid. According to these new policies, since 1991 private construction companies have been in charge of developing low-income housing projects and government agencies have been responsible for financing them through supplying bank loans and subsidies to the future homeowners. Thus, government strategies have sought to reduce the deficit through implementing a demand-oriented housing policy for the last two decades.

The new policies required a different institutional framework in order to undertake their transformations. Several new organisations were created so as to manage and grant loans and subsidies: i) the Ministry of Housing, Cities, and Territory, ii) the Housing National Fund (FONVIVIENDA) in charge of proving financial aid to informal workers; iii) the Family Welfare

Agencies (FWA) focused on serving formal employees; iv) FINDETER (a public rediscount bank), a bank responsible for approving social housing construction projects; v) the Military Housing Promotion Agency; and vi) the Public Agricultural Bank for rural households (Arbelaez et al., 2010).

The demand-oriented policy has been directed towards diminishing the housing shortage through implementing drastic budget reforms, changing the State's organisational structure, and promoting an active participation from the private sector (i.e. banks, construction firms, etc.). However, this strategy has not proven to be successful in terms of improving social conditions for the most vulnerable population. For example, according to the National Department of Statistics (DANE), the housing shortage for 2005 corresponded to more than 3.8 million units both in qualitative (i.e. 2.5 million dwellings with inadequate living conditions) and quantitative (i.e. 1.3 million families without shelter) terms. With these numbers in mind, it is easy to affirm that the mentioned housing policy is neither enough for solving the housing problem in Colombia nor adequate for serving the low-income people (DPU, 2006).

2.1 The Low-Income Housing Megaprojects (LIHM)

Taking into account the increasing housing shortage for the low-income population, in 2006, the national government started to design the LIHM strategy in order to reorganise and streamline the process of getting access to land for affordable housing. Over the last seven years, the new policy has sought to develop housing projects throughout the country by making land available and providing adequate urban infrastructure (i.e. public services, urban facilities, etc.). This is being carried out through establishing a public-private partnership among the national government, local government agencies, and private developers. Under the LIHM scheme, the central government seeks to produce large-scale affordable residential initiatives through generating urban soil more efficiently than other regional-based approaches (Decree 4260-2007).

The execution of the LIHM has not been exempted from problems. Firstly, so far it is not clear how the municipal authorities have to adapt their local urban planning regulations so that a LIHM can be developed. Secondly, since either a private developer or a public agency can promote a LIHM, there have been multiple problems in terms of properly managing such initiatives. Thirdly, taking into account that the final goal of the LIHM policy is to efficiently generate land, there are many megaprojects located in peripheral urban zones with a clear lack of transportation infrastructure.

Currently, there are more than 31 on-going large-scale housing initiatives. In this paper, we are going to analyse two of them: Green City (GC) and Santa Helena Hills (SH). The former is located in Bogota (the Colombian capital) and involves the construction of 40 thousand units in a 107-hectare tract. The latter is situated in Cali (the third most important Colombian city) and comprises the development of 3.5 thousand dwellings in a 35-hectare lot. Additionally, while GC is an initiative led by a private developer, SH has been conceived by the local mayor's office. Despite the differences, both schemes have similar problems related with the government capacity to ensure not only the construction of low-income

housing solutions, but also the provision of infrastructure and public services for the two projects

3. The concept of organisational field

According to DiMaggio and Powell (1983), the concept of organisational field refers to a group of organisations that constitute a recognised area of institutional life. For instance, key suppliers, consumers, regulatory agencies, and other institutions that produce similar products or services. In other words, the organisations within a field comprise a well-defined social sector and interact in a specific functional area (Machado da Silva, 2010). Based on Carrillo (2009), an organisational field is a collection of actors that belong to a particular social context. For example, an educational system is a field that consists of an aggregation of actors, such as, schools, parent associations, departments of educations, etc. In the same way, the LIHM can be understood as a specific functional sector. For this particular field, the participants are the organisations that work in providing social housing for the poor: construction companies, government agencies (at the local and national level), urban designers, the local community, the landowners, developers, etc.

Jooste (2010) argues that an organisational field has three main components: actors, logics, and arrangements. The actors are the institutions and organisations that belong to the same functional sector. They can influence such functional area at the local, national, and transnational levels. The logics are the beliefs and conceptual maps that guide the actors' behaviours. The logics among the participants might be in open contradiction If a particular field is comprised by public and private institutions. Finally, the arrangements are the governance mechanisms required for having an adequate coordination among actors and their logics.

4. The concept of project governance

There are many definitions for governance. In this study, we have adopted the one given by Carrillo (2009). According to such author, governance is a concept for describing a set of game rules within a social system. The rules are those formal and informal regulations that belong to a particular social context and are dependent on its specific characteristics. A social system refers to a family, an enterprise, or social communities (at the local, national, or global levels). In terms of urban management studies, the idea of governance plays a key role in explaining how a state (i.e. central government), within a liberal economic framework, has to seek collaboration from other private and public organisations in order to properly implement urban policies and projects. Therefore, Rakody (2003) and Healey (2006) argue that the concept of urban governance is based on the idea that there has to be a regulatory framework (i.e. a set of game rules) so as to properly make decisions and execute programs at the urban level.

The definitions provided by Carrillo (2009), Rakody (2003) and Healey (2006) are useful in terms of explaining the urban complexities. However they are not directly oriented towards examining the difficulties in developing large-scale urban projects. These types of projects have always been a societal challenge due to their great number of participants. Henisz et

al. (2012) propose the concept of project governance as a theoretical framework for understanding the interactions among the actors involved in large-scale initiatives. Since Henisz et al. (2012) work on the basis of the ideas proposed by Scott (1995), they suggest that each project can be analysed from three governance perspectives: regulative, normative, and cognitive.

The regulative perspective refers to the set of formal rules, incentives, and sanctions (i.e. laws, decrees, professional regulations, etc.) that control the project participants' behaviour (Henisz et al. 2012). Based on regulative mechanisms, project participants tend to do only what the project contract establishes. In other words, from a regulative point of view, actors only do what they are compelled to do. On the other hand, the normative standpoint refers to a series of expectations and exchange processes that are collectively shared by all the individuals involved in the initiative. According to this viewpoint, actors tries avoid social punishes (i.e. ridicule, isolation, etc.). Finally, the cognitive perspective seeks to create common identities, shared interests, and long-lasting relationships among the participants (Henisz et al. 2012).

Taking into account the three governance perspectives, many authors have analysed large-scale infrastructure projects. For instance, Joose (2010) analyses public private partnership schemes in Australia, South Africa, and Canada. Henisz et al. (2012) show the importance of social exchanges through presenting examples of projects in Argentina and the Philippines. Chi et al. (2012) examines the development of two Chinese projects by employing the concept of relational governance. Since LIHM have many features in common with several global infrastructure projects (e.g. the impact on the communities, the amount of money required, the interaction of many actors from many different backgrounds), we argue that they can be examined, from an organizational standpoint, in a similar way as many infrastructure projects have been previously analysed. In order to do that, the next section shows the research methodology employed for this study.

5. Research methods

The main research question for this study is: how to ensure, since the conception phase, an adequate coordination among the different institutions that participate in the development of the LIHM, in order to benefit the low-income population? This was based on the evolution of the Colombian housing sector, its current neo-liberal organisation scheme, its stakeholders, and its existing difficulties (Jaramillo and Cuervo, 2010; CENAC, 2006).

We sought to answer the research question through employing a multiple-case study approach based on Yin (2003), Eisenhardt (1989), Corvin and Straus (2008), and Jooste (2010). The two cases (i.e. GC and SH) were selected because: (i) they were developed under the LIHM scheme; (ii) the two projects shared similar problems (i.e. lack of coordination among stakeholders); and (iii) they had different execution strategies (i.e. GC was managed by a private company and SH was directed by the City of Cali). The information was collected through a literature review, observation exercises (i.e. site visits), archival analysis (i.e. examination of laws, decrees, local regulations, and project-based information), and two rounds of semi-structured interviews with leading representatives of

organisations involved in the development of the two projects. For each case, 20 interviews (i.e. 10 interviews per round) were conducted with individuals from different institutions, such as local government agencies, national government institutions, project management firms, urban designing companies, main contractors, professional organisations, and universities. The interviews were recorded, transcribed, and analysed by using QSR Nvivo (a total of 20 hours of audiotape were examined).

Based on the literature review, the archival analysis, the first round of interviews, and the concept of organisational field, the data was categorised in three conceptual groups: actors, logics, and institutional arrangements. The analysis was conducted through identifying similarities and differences within the three theoretical classes in the two case studies. Based on this exercise, the information for each project was subsequently grouped in four sub-groups (i.e. public services, accessibility, urban facilities, economic opportunities). Once the conceptual categories and sub-categories were completely defined, a second round of interviews was performed. However, this time, the information was examined through the lens of the concept of governance. Through this approach, conclusions have been directed towards proposing improvements for the types of governance perspectives employed in the LIHM in order to enhance coordination among institutions and benefit the Colombian low-income population. In this paper, we only present a series of preliminary results based on the examination of the organisational field (i.e. the actors that participate in the projects) for the two cases under study. The analysis is supported by the organisational and governance concepts previously presented.

6. Case studies: a basic description

6.1 Green City (GC)

The LIHM of GC is located in Soacha, one of the biggest municipalities that have a border with Bogota. This urban centre has a housing shortage of approximately 36 thousand households. Over the last tears, Soacha has experimented an increasing demographic growth due to migrations originated by forced displacement phenomena, expansion of Bogota's bordering neighbourhoods, and conurbation processes. This rapid increment in the number of inhabitants took place without any formal governmental control and has incentivised the development of several illegal urbanisations.

GC has a total area of approximately 327 Ha, which includes 107 Ha for housing, 18 Ha for urban infrastructure facilities, and 35 Ha for commercial and service land use. The project intends to generate 42 thousand social housing units, it started to be executed in December 2009, and it is expected to be finished by 2018 (Henao, 2011). In terms of its development strategy, the initiative has been led and promoted by private actors (i.e. a housing construction company) and it has been financed through a combination of private funds (i.e. landowners, bank loans, trust funds, etc.) and public mechanisms (i.e. facilitation for changing the land-use).

6.2 Santa Helena Hills (SH)

The LIHM of SH is located in Cali, the third main city in Colombia. Cali is situated in the south-western region of Colombia, it has a population of about 2.5 million people and a housing shortage of approximately 580 thousand households. The project is intended to generate five thousand units and has an area of around 306 Ha, of which 70% corresponds to land for housing use. The initiative has a duration of 60 months and has been led and promoted by the local government (i.e. the local housing agency) and the national administration (i.e. the ministry of housing). Since this project is a governmental initiative, it is important to highlight its funding and managerial mechanisms. On the first hand, the project's funds are controlled through a trust scheme. A committee that consist of representatives from the national and local administrations manages such scheme. On the other hand, a local FWA (i.e. Comfenalco) undertakes the project management tasks related with institutional, commercial, financial, and technical aspects (i.e. marketing activities, subcontractor hiring procedures, etc.).

The following table presents a comparison between the two projects under analysis.

Table 1: A comparison between Green City and Santa Helena Hills

LIHM / Category	Green City (GV)	Santa Helena Hills (SH)
Location	Soacha (border with Bogota)	Cali (third main city in Colombia)
Size	327 Ha – 42 thousand units	31 Ha – 5 thousand units
Urban context	Housing shortage: 36000 households Lack of urban facilities and public service infrastructure Illegal urbanisation processes	Housing shortage: 85000 households Illegal urbanisation processes
Developers	Private construction company	National and local administrations
Financial mechanisms	Trust scheme Integration among 7 construction firms	Trust scheme Project management contract

7. The organisational field for the LIHM: actors and organisations

As it was mentioned before, an organisational field consists of an aggregate of organisations that forms a recognised area of institutional life (DiMaggio and Powell, 1983). We argue that the Colombian LIHM can be analysed from an organisational-filed point of view because the development of such projects involves multiple institutions with formal and informal relationships at different levels. Although an organisational field has three main components (i.e. actors, logics, and governance arrangements) (Jooste, 2010), in this paper we only discuss the actors that participate in developing the megaprojects. Since there are many organisations involved in the delivery of the housing initiatives, we only focus on those who exert the greatest influence.

7.1 The national government

The Ministry of Housing and the Housing National Fund (Fonvivienda) are the two main governmental agencies in charge of developing the LIHMP throughout the country. The ministry focuses on analysing the project conceptual phase, examining the feasibility and technical studies, producing the decrees that regulate the initiatives, and participating in the trust scheme committee. Fonvivienda is in charge of managing the resources for developing the project. Such resources comprise the funds required not only to build the housing units, but also to build the urban infrastructures.

In the case of GC, the Ministry of Housing, in conjunction with a private company (i.e. the project developer), developed the conceptual phase, undertook the feasibility study, and approved the initiative submitted by the private firm. Additionally, it was in charge of obtaining the environmental approvals for the project. Although that was not competence of the national government, one of the interviewees claimed that was a necessary step in order to streamlining the feasibility and approving procedures. On the other hand, in terms of transportation accessibility to the project, the Ministry also committed to make agreements with the local municipalities so as to build an extension of one of the current lines of the Bogota's mass transit system In the case of SH, the national government was specifically in charge of approving the project and giving resources for the construction of both housing units and urban infrastructure facilities. Since the local housing department led the initiative, the national agency had to sign an inter-institutional agreement with them in order to establish the trust scheme for the project. Although, at the beginning, there were high expectations regarding the national government participation, there have been severe delays in delivering the promised urban facilities. This has deteriorated the relationship between the local and national levels.

In short, it is clear that national agencies are in charge of generating the decrees that regulate the housing initiatives and take responsibility for approving the project concept and its feasibility and technical studies. These procedures may vary depending on who is the project leader. In GC, for instance, the main project sponsor is a private company; in SH, the main promoter is the local administration.

7.2 The local administrations

The analysis of this actor took into account elements, such as its role for ensuring an adequate public services provision and a satisfactory construction and operation of the urban infrastructure facilities. In the case of GC, the municipality of Soacha is an extremely weak urban centre in terms of the maturity of its institutions. For example, such city does not even have an agency specialised in housing issues. These are managed jointly by the local planning and infrastructure offices. In respect to public services provision, Soacha is not responsible for the project's water and sewage systems (this is responsibility of the developer). Regarding the development of the urban facilities, the municipality does not have resources for financing the amenities. For such reason, it established an agreement with the developer through which the sponsor may finance them in exchange of tax exemptions or urban land.

In contrast to Soacha, the City of Cali has a housing agency. Its role in the development of the SH project has consisted in providing funding for developing the initiative through supplying urban land and offering subsidies for the future households. Based on that, the Cali's city hall is, in conjunction with the Ministry of Housing, the main sponsor of the megaproject. The local housing agency has been in charge of the conceptual phase, it has undertaken the technical and feasibility studies, and it has established a management contract with a local FWA so as to administer the design, procurement, and construction stages of the megaproject. Furthermore, The regional housing department has also been responsible for the public services provision and the construction of the required urban infrastructure (i.e. access roads, facilities, etc).

7.3 The public utilities

The Bogota Water and Sewerage Company (BWSC) and the Cali Public Services Provider (CPSP) are the two main state-owned firms that exert a great level of influence in the development of GC and SH, respectively. On the one hand, taking into account that the BWSC provides its services to Soacha, such company has played a key role in the development of the GC project. For instance, before beginning construction, the private developer had to obtained a certificate of technical feasibility in order to show that the BWSC could provide water for the 42 thousand housing units. However, currently, there are still some discussions about how to provide the services. While the promoters (i.e. an aggregate of private construction firms) argue that they can build the water and sewerage infrastructure and operate it through paying a fee to the BWSC, the BWSC wants to design, build, and operate the system by itself.

On the other hand, the CPSP is in charge of providing services related with water, sewerage, energy, and telecommunications. Although over the last years the state-owned company has had budget difficulties and problems with its Union, it continues to be the main public services provider in Cali. In the same way than the BWSC, the CPSP had to give a certificate of technical feasibility in terms of supplying the water and sewerage infrastructure for the SH megaproject. Although, during the project's conceptual stage, the company ensured the services viability, it was later on discovered that the water supplier did not have the capacity to build the required infrastructure for ensuring an adequate service provision. This caused time delays and cost overruns.

7.4 The Family Welfare Agencies (FWA)

The FWA have played a key role in the development of the housing megaprojects. In Cali for example, a local agency (i.e. Comfenalco) has been in charge of managing the project. In other words, Comfenalco has participated in the conceptual, design, procurement, and construction phases. It has also been involved in selecting the future residents, supervising the contractors, and ensuring an adequate financial administration of the project trust scheme. In contrast, the FWA in Soacha have only been limited to provide urban facilities when required. For instance, a local FWA has won the contract for developing a school in the GC premises. This is because a private company has managed the GC project since its conception.

7.5 The private sector

In Soacha, a private construction company has been the main sponsor of the project. The company conceived the idea, established an association with the landowners, and presented the proposal to the Ministry of housing. The same company has been also responsible for funding the project through bank loans and forming a consortium with other construction firms in order to build the 42 thousand units. In this case, a single enterprise has directed the whole initiative and been responsible for linking the interest of both public and private entities. Conversely, private firms did not participate during the conceptual and feasibility phases of the SH project. They did not provide any form of funding and have been involved in the initiative after the procurement stage.

8. Key issues in the organisational field

Taking into account the main actors within the organisational field, there is a series of critical issues that hinder the generation of low-income housing to the poor through the LIHM.

8.1 Lack of administrative capacity of the local administrations

The LIHM initiative represents a real challenge to the traditional public sector capacity. For the Soacha administration, the development of GC highlighted the necessity for having a better institutional framework so as to manage large-scale projects. It is clear that the municipality was not prepared for supervising a megaproject. For instance, there are not local agencies specialized in housing-related issues. This would have helped to have better control mechanisms in order to ensure that the private actors respond not only to their own interest, but also to the city's concerns. Conversely, Cali was very prepared for big housing initiative because its local administration had not only a local housing agency but also a special office to deal with the megaproject's issues.

Despite having public organisations for dealing with the LIHM, the Cali administration has shown capacity-related weaknesses due to constant changes of city's directives. For example, there was a change of mayor between the project conceptual and construction phases. In other words, the mayor that initially sponsored the initiative was not the same than the one who was in charge of its construction. This implied diverse changes in the project scope due to political differences.

8.2 Leadership

Neither in GC nor in SH, there has been a clear project leader. Although a private actor has led the initiative that takes place in Soacha, this has not been able to properly negotiate with the Bogota utilities about the provision of public services, such as water, sewerage, and transportation. The mentioned negotiations have not been successful due to political differences between the utilities' general manager (i.e. the mayor of Bogota) and the owner of the construction company that conceived GC. In the same way, the local administration in Cali has not been able to manage the SH project due to a lack of coordination among its own agencies and deficiencies in communication procedures with the national government.

8.3 Urban facilities and public services

Urban facilities and public services are one of the most important concerns in terms of stability of the LIHM in the long-range. Based on the two cases under analysis, it is not clear who is going to be the sponsor of the several amenities required for both initiatives. So far, GC has made an agreement with a FWA in order to build a private school; in Cali, the project manager has also established an association between the national and local governments so as to develop a kindergarten institution. The development of any other kind of amenities remains unknown. On the other hand, for both projects is clear that there is not a strong relationship between the project managers and the local utilities for ensuring and adequate service provision. Neither of the two local public utilities (i.e. the BWSC and the CPSP) has strongly supported the LIHM development.

9. Conclusions

Based on account the information collected from the GC and SH projects, it is clear that the main participants in the LIHM are: the Ministry of Housing, the private sponsors, the local administrations, and the FWA. Unfortunately the relationships among them are primarily based on formal regulations. The lack of a formal regulation for controlling the communication among two or more actors creates conflicts, project delays, and in some cases, cost overruns. This is case of the public service provision for both projects because there is not an adequate communication channel between the local administration, the national government, and the public utilities. It is evident that it is necessary to implement governance mechanisms related with the normative and cognitive perspective. Additionally, there is not an adequate integration among the institutions within the organisational field. As it can be seen in Figure 1, there is not a single institution in charge of the whole lifecycle for both projects. Such diagram shows that Green City (see GC boxes on figure 1) has been primarily controlled by a private sponsor; and Santa Helena Hills (see SH boxes on figure 1) has been managed by the local administration. Further studies are required in order to show how to implement relationships based on relations (i.e. relational governance) instead of always relying on formal regulations.

ACTORS	THE ORGANISATIONAL FIELD IN THE LIHM LIFECYCLE				
	IDEA	FEASIBILITY	PROCUREMENT	EXECUTION	OPERATION
MInistry of Housing	GC SH	GC SH	GC SH	GC SH	
Local Administrations	SH	SH	GC SH	GC SH	GC SH
Private Sponsors	GC	GC	GC	GV	
FWA	SH	SH	GC SH	GC SH	SH
Public Utilities			GC SH	GC SH	GC SH
Banks				GC SH	GC SH
Contractors				GC SH	
Residents and Neighbours				GC SH	GC SH

Figure 1: The organisational field in the LIHM lifecycle

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How can trust facilitate the implementation of Early Contractor Involvement (ECI)?

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Abstract

A successful partnering should begin early, prior to contract award or the procurement selection process in order to deliver the best value to a project. The benefit will be maximised if during the planning and design stages, the construction knowledge is introduced. Early contractor Involvement (ECI), a form of relationship-based delivery system fosters the involvement of contractor in the preliminary stage of a contract and allows the contractor to contribute its construction knowledge to planning and design. A trust-based relationship between owner and contractor is also realised as the foundation for achieving successful partnering. Factors affecting the degree of trust include intention, ability, competence and motive. The more one party believes that another party will fulfil the commitments to the relationship, the more that party will trust the other one. Although there is wealth of literature about ECI and its benefits for all project participants, few paid attention to the impact of trust development between parties on implementing an ECI contract. This paper therefore aims to investigate how trust can improve the innovation and encourage the contractor to share his construction knowledge in the early stage of project based on contextualisation and review of existing literature. The conclusion drawn is that since trust is one of the significant factors in facilitating knowledge sharing and increasing innovation, it should not be treated as a shot in the dark proposition and similar to other aspects of the project, a successfully developed trust-based relationship can be the result of proper management of the entire trust building process.

Keywords: Early Contractor Involvement, ECI, Trust, Knowledge sharing, innovation

1. INTRODUCTION

Emerging project delivery methods increasingly rely on collaboration between project participants, and are aimed at developing longer term positive relationships (Scheepbouwer & Humphries 2011) Early Contractor Involvement (ECI) is one of these newer delivery

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methods which promotes innovation, facilitates value management and value engineering, minimises claims and reduces time and cost of project by involving the contractor at the early stage of the project normally soon after the feasibility planning approval process is completed. The development of ECI was based on the premise that traditional methods create the team much too late in the project development and there is little scope for innovation and consideration of constructability (Edwards 2009), hence using alternative project delivery methods with embedded partnering concept could alleviate some of these issues. In recent years, many countries have utilised ECI mostly for their big, complex projects with a relatively high risk profile however they customise this method based on their needs and situations. Some countries such as UK adopt a relationship-based approach throughout the whole life of the project while others such as Australia adopt a hybrid model where the contract starts with a collaborative approach and moves on to a more conventional type of contract such as Design and Construct (D&C).

ECI , therefore, falls under the relationship-based approach category and as with all relationship-based methods, a critical element in achieving partnering effectiveness, amongst the most common success factors, is establishing and nurturing trust between the project partners (Child 2001; Das & Teng 1998; Ford et al. 2003; Ha, Park & Cho 2011; Lazar 2000) Despite the wealth of literature related to the importance of trust in enhancing the partnership, limited studies have a deeper investigation on the importance of trust in facilitating knowledge sharing by a contractor when the contractor is required to instil its construction knowledge into planning and design stages and in improving innovation embedded in an ECI contractual model. The present paper aims to contribute to this underdeveloped area by synthesising the existing literature relevant to the subject. The structure of this paper is as follow. First, the paper begins by providing some definitions about trust, identifying different types of trust, the generating and developing trust in a relationship, and the factors affecting trust development in a relationship. Second, the influence of trust in knowledge sharing and innovation is examined. Finally, a conclusion is presented, about the role of trust in facilitating the implementation of an ECI

2. TRUST AND ITS CHARACTERISTICS

Trust has been studied widely by many researchers in various fields based on how it is viewed and hence different definitions have been provided to describe its concept. Rotter (1971)views trust as an individual characteristics and defines trust as "a generalized expectancy held by an individual or group that the word, promise, verbal, or written statement of another individual or group can be relied on". Mayer, Davis and Schoorman (1995) have a different perspective on the concept and suggest that trust is an expectation that is related to a specific transaction and the specific person with whom one is transacting where the vulnerability prevails (Bhattacharya, Devinney & Pillutla 1998). They define trust as "the willingness of a party to be vulnerable to the actions of another party based on the expectation that the other party will perform a particular action important to the trustor, irrespective of the ability to monitor or control the party" (Mayer, Davis & Schoorman 1995). In contrast to the latter definition, Barney and Hansen have no such limitation on their definition of trust. Their view is that “trust follows from the ability to structure contracts or rewards and punishments so that individuals behave in a pre-specified manner”

(Bhattacharya, Devinney & Pillutla 1998) and define trust as "the mutual confidence that no party to an exchange will exploit another's vulnerabilities" (Barney & Hansen 2006). Bhattacharya, Devinney and Pillutla (1998) suggest a number of characteristics for trust based on combination of the existing scholars and definitions as:

- **Trust exist in an uncertain and risky environment**: in an environment of certainty and sureness, trust doesn't mean a lot or it has very little impact on the outcomes. Individuals are not at the risk of losing any privileges in a non-risky, immune situation and therefore trust cannot exist in such an environment.
- **Trust reflects an aspect of predictability**: trust as expectancy is a multi-dimensional concept (Rinehart et al. 2004)and it is important to recognise which characteristics of trust are being studied. According to Bhattacharya, Devinney and Pillutla (1998), trust is not an expectation but can become part of an expectation and Individuals act based on their understanding of the actions of others and if their understanding changes at any point in time, the way they act will change based on the alteration in their understanding of other people's behaviour.
- **Any definition of trust must account for the strength and importance of trust**: being trustworthy is not an indication that everyone has necessarily the same degree of confidence on the trusted person's behaviour and the importance of her or his behaviour may have different value to them.
- **Trust exists in an environment of mutuality**: the extent to which an individual can be trusted is much depended on the situation that individual encounters and the people with whom she or he would interact.
- **Trust is "good"**: speaking of trust indicates positive outcomes not negative. Sometimes the meaning of trust is lost in the sarcasm where the statement ironically aims to express that a person will or will not do something in a negative sense.

As discussed before, trust is defined differently based on the context it is perceived (e.g. personality psychological context (Rotter 1971; Rotter & Stein 1971), social psychological context (Mayer, Davis & Schoorman 1995) and economic context (Dasgupta 2000; Kreps 1990; Zucker 1986)).Thus, proposed trust models by theorists are influenced by these different perspectives. There have been also some theorists who attempted to integrate different perceptions of trust (Barney & Hansen 2006; Lewick & Bunker 1995). However, this paper focuses only on the economic model of trust as the economy is significantly influenced by the construction industry and would also have tremendous effects on the construction (Hampson & Kwok 1997; Harvey & Ashworth 1993; Industry 1998; Lange & Mills 1979). Generally the aim of construction projects is improving the economic situation of involved parties (either public or private sector). Public organisations strive to achieve value for money through their construction projects and are accountable to demonstrate it to tax payers and private construction organisations endeavour to enhance the profitability of their business. This can be through a single construction project or a long-term strategic partnering relationship. Henceforth, the term of trust being used in this paper will address the economic model of trust which dominates the construction environment

3. TYPOLOGY OF TRUST

There are many different kinds of trust and various researchers have classified trust into different categories.Lazar (2000) views the process of creating trust and categorises it into three types and two main domains. He suggests that trust can be (1) rational or calculus where it can grow and develop over time; (2) spontaneous where it appears emergently and unexpectedly in a relationship; or (3) pre-existed where it is already extant typically based on the reputation of an organisation or individual (Bhattacharya, Devinney & Pillutla 1998).The two trust's domains he proposes are Intra or Inter. The intra- domain refers to the relationship between people within a community (e.g. relationship between personnel of an organisation at different levels in the company's hierarchy) and Inter- domain refers to the relationship between two or more different communities (e.g. relationship between two organisations in an alliance). For this paper domain of inter-organisational relationship is examined as the involved partners in a construction project are generally from independent organisations (Contractor, Designer and Client). Since the construction industry is frequently described as being dominated by a 'culture of confrontation' in which a vicious cycle of mistrust, conflict and waste dominates (Seymore & Fellows 1999), it is unlikely that trust between partners exists in forms of spontaneous or pre-existing at the beginning of a contract . Trust in a typical construction environment begins with its lowest level and gradually, if it is meant to, grows throughout the project life time. However, regardless of the type of the trust existing between organisations, the research findings emphasise that a consistent cooperative behaviour is required to maintain spontaneous and pre-existing trust and to develop the rational or calculus one.(Lewicki, McAllister & Bies 1998; Whitener et al. 1998). Lewick and Bunker (1995) categorise trust based upon the source of expectations. Their definition of trust falls under three categories: (1) Calculus-based trust in which the expectations arise from a rewards/punishments mechanism; (2) Knowledge-based trust where the expectations are based on the predictability of others behaviour; and (3) Identification-based trust when the expectations depend on the other's internalised intentions. Barney and Hansen (2006) with modern economic perspective typify trust to three forms: weak form, semi strong form, and strong form. Weak form trust refers to a relationship where neither party has any vulnerability that can be exploited by the other one. In this form there is no need for a contractual arrangement or governance mechanism between parties to build trust. Semi strong form refers to the circumstances when vulnerability exists between parties however there is a risk of opportunistic behaviour by parties and hence trust should be created by a contractual arrangement or governance mechanism. Finally strong form is related to a form of trust where vulnerability exists and regardless of whether or not a contractual arrangement or governance mechanism exists to control the relationship between parties, trustworthiness of the parties is in exchange. This form of trust is developed when opportunistic behaviour would contradict the standards, values and principles that have been internalised by parties to the exchange (Barney & Hansen 2006). Since involved organisations in a construction project are generally bound by a legal contract (except for some types of collaborative delivery systems such as alliancing in which an informal agreement is substituted with a binding contract between partners), the dominant form of trust between the participants typically begins with its semi strong and calculus-based trust where a reward/punishment mechanism is governing the relationship.

4. GENERATING AND DEVELOPING TRUST

Amongst several models proposed by researchers for building and developing trust between organisations intended to work together, this study adopts the model proposed by Child (2001) which is quite applicable to a collaborative approach in the construction context. He suggests that trust in the relation between organisations develops through a process and consists of three major stages:

1) **Calculation (Information Stage):** This form of trust is based on a calculation of the probable outcomes related to the risks and cost of maintaining or serving commitment in initiating a business relationship. Trust in new relationships between partners or team members with no other social connections, is likely to be calculative trust. The concept of calculative trust can be applied to the formation of a new collaboration between two organisations. Prior to the formation process, the prospective partners try to learn as much as possible about each other to ascertain the strategies between them are aligned. This stage is of significant importance for the ECI model as the main contractor is appointed through a qualification-based selection process. In this process both client and contractor assess each other against the criteria prevailed in their own organisation. A sound selection process initiates trust between partners from beginning of the contract

2) **Mutual Understanding (Mutual Knowledge):** At this stage, the partners develop common pragmatisms as a result of sharing experience and information whilst they are gathering more knowledge about each other. The mutual confidence created through this process rests on mutual knowledge and common experience among the partners. The mutual understanding and predicting the thinking and actions of the other enables the partners to develop the trust between them further and reduce the sense of uncertainty which partners may have about each other. This stage of trust usually happens in an ECI contract whilst the contractor is sharing his construction knowledge and expertise at the design and planning phase of the contract.

3) **Bonding:** The third stage is incorporated with strong personal relationships. Long term relationship between parties when they meet each other personally in a regular basis, establishes a mutual psychological bond between them. This form of trust "…permits stable, ongoing relationships to develop, relationships both between people in the collaborating organizations who have a responsibility for (or interest in) the collaboration and between people working on an everyday basis in joint ventures where these have been established. They are in a position to accumulate knowledge about each other, and this tends to reinforce the relationship" (pp. 281-282). This type of trust is unlikely to be formed in a one off ECI contract or when the contract begins with a collaborative approach and proceeds to a transactional one.

5. THE DETERMINANTS OF TRUST

There are many factors that influence trust building between partners. Some studies looked at trust and its associated influencing factors to a more personal level (Ha, Park & Cho 2011; Whitener et al. 1998) while some other studies viewed trust at the inter-organisational trust

(Lazar 2000). As mentioned earlier, this paper focuses on trust and factors affecting trust building at inter-organisational level however, it is noteworthy that trust amongst both dimensions is interconnected (Dasgupta 2000) and both are associated with keeping commitments and demonstrating cooperation (Lau & Rowlinson 2009). Lazar (2000) emphasises on competency and behavioural strategies as potentially important factors in trust development. He asserts that the successful trust development and maintenance highly depend on consistent reciprocal cooperative behaviour and require competency to perform as a component of trustworthiness. Ha, Park and Cho (2011) support this statement by analysing trust within the context of inferential models and categorise it into two areas, namely affective trust and trust in competency. The elements constitute an affective trust include openness, benevolence, liking, honesty, understanding, and respect, while trust in competency consists of the dimensions such as ability, knowledge, skills, business judgment, and specialty. Das and Teng (1998) investigate trust in the strategic alliance context and propose some significant trust building techniques including risk taking, equity preservation, communication, and inter-firm adaptation. In a research conducted by Khalfan, McDermott and Swan (2007), trust is examined in the construction industry. They categorise factors influencing trust in relationships into five main groups: Individual behaviour, company factors, project factors, contract and macro-economic factors. Similarly, Lau and Rowlinson (2009) investigate trust through a number of partnering and non-partnering construction projects from clients, consultants, contractors and subcontractors perspective. They draw a conclusion that keeping commitments and demonstrating cooperation are the typical actions expected from trust. The other factors affecting trust suggested by other researchers include motives, intention, experience, expertise and willingness to reduce uncertainty (Crosby, Evans & Cowles 1990; Zaltman & Moorman 1988).

6. TRUST AND KNOWLEDGE SHARING

Knowledge sharing refers to the process of transferring, distributing and creating knowledge (Soekijad & Andriessen 2003). It is evidenced in knowledge management that inter-organisational knowledge sharing within parties involved in a project, enhances the competitive advantage of all the partners as a whole (Holland 1995). Knowledge sharing is also recognised as one of the key principles of ECI as the contractor contributes his construction knowledge and experience to design in order to deliver best value to a project(Song, Mohamed & AbouRizk 2009)There is, however a wide range of conditions that influence knowledge sharing between organisations. These conditions are related to characteristics of each organisation, the exchange relationship between the parties involved, and the type of knowledge shared (Soekijad & Andriessen 2003). Amongst various conditions mentioned in the literature, trust is recognised as a necessary condition for inter-organisational knowledge sharing (Davenport & Prusak 2000; Dyer & Chu 2000). Trust plays a key role in facilitating and strengthening inter-organisational relationship leading to a profound mutual relationship as a prerequisite for knowledge sharing (Davenport & Prusak 2000; Dyer & Chu 2000; Sahay 2003; Soekijad & Andriessen 2003). Trust is also seen as a means for minimising risks developed by exposure to opportunistic behaviour by partners, uncertainty, ambiguity and incomplete information (Panteli & Sockalingam 2005). In an environment that trust is lacking between partners, the quality and accuracy of knowledge exchanged are likely to be poor (Currall & Judge 1995).

7. TRUST AND INNOVATION

According to Sher and Yang (2005) innovation is any incremental or radical change embodied in product and process, and includes changes in value activities such as service and administration.Egbu (2004) explains this dichotomy between radical and incremental innovation that “Innovation can be radical, in response to crisis or pressure from the external environment, but it can also be incremental where step by step changes are more common” (p.305). Zaltman, Duncan and Holbek (1973) view innovation in the context of organisational culture and borrow the term of innovativeness. They define innovativeness as adoption of an idea or behaviour that is new to the adopting organisation. Innovativeness in organisations is seen as openness to new ideas which stems from the organisation’s culture and considered as a measure of the organisation’s orientation toward innovation (Hurley & Hult 1998). Innovation within the construction industry context has attracted many researchers’ attention in recent years. Rogers (1995) attempts to adopt the industrial innovation concept in the construction while defining innovation as an idea, practice, or object that is perceived as new by an individual or other unit of adoption. Ling (2003) consolidates this statement by providing supposedly the most comprehensive definition of innovation in construction that innovation is an implementation of a new idea to a construction project with the intention of deriving additional benefits, although there might be some associated risks and uncertainties. The new idea may refer to new design, technology, material component or construction method deployed in a project. Given the project based nature of the construction industry, innovation is the actual use of a nontrivial change and improvement in a process, product, or system that is novel to the institution developing the change (Slaughter 2000). Since the construction industry faces consistent changing conditions (Asad et al. 2005), there is a general agreement amongst researchers and professionals that innovation in construction is an essential proponent of success or more prosaically of survival. (Egbu 2004; Gann, D 2004; Khalfan & McDermott 2006; Slaughter 2000; Walker & Hampson 2003). In order to achieve competitive advantage in market, build long-term relationships with clients, increase organisational motivation and make improvements to the systems and processes, it is vital for the construction organisations to be innovative (Asad et al. 2005). Nevertheless, the process of innovation initiation and implementation require an appropriate climate to bring success and improvement. There are different factors that drive or hinder innovation within the industry. The intrinsic characteristics of the construction industry such as industry sector fragmentation, boom-and-bust market cycles, use of relatively low technology, antagonistic procurement policies, project-based nature of industry, and inadequate source of information are known as barriers in the way of innovation (Sexton & Barrett 2003; Toole 1998). On the other hand, in the general innovation literature, there is a range of external and internal drivers that fuel innovation including organisational capability for innovation (Burgelman, Maidique & Wheelwright 2004), attitude and behaviour of parties involved (Blayse & Manley 2004; Gann, DM & Salter 2000), procurement method (Blayse & Manley 2004; Walker & Hampson 2003), type of relationship between parties(Anderson & Manseau 1999; Miozzo & Dewick 2002), regulations and standards(Blayse & Manley 2004; Gann, DM & Salter 2000), and culture of innovation(Blayse & Manley 2004; Love 2002). The influence of trust in innovation has been drawn from some established bodies of innovation knowledge (Ghosh & Fedorowicz 2008; Panayides & Venus Lun 2009) but it is still very much in its embryonic stage in the

construction industry context. A study by Panayides and Venus Lun (2009) highlights that trust can positively influence innovativeness and improve the performance of the all the partners as a whole. Contextualising its finding in the construction, it shows that the parties with high level of trust towards the other parties involved in the project are more likely to adopt innovations and that in the context of a trustworthy relationship such innovations will lead to improvement in performance.

8. CONCLUSIONS AND RECOMMENDATION

Knowledge sharing and innovation are two main components of ECI delivery system which make this method attractive to the construction industry but they have not been sufficiently explored to form a robust body of knowledge about the factors influencing them in their own right. This paper, therefore attempted to investigate the significance of trust as one the essential parameters in these two elements. A comprehensive literature review was conducted to explore the role of trust in building a collaborative relationship, knowledge sharing, and increasing innovation. It is generally accepted that trust is of paramount importance in building and developing a partnering relationship however the adversarial nature of construction industry negatively influences the level of trust between organisations. Trust generally does not appear in pre-existent or spontaneous form in construction and requires an initiator. The qualification-based contractor selection process embedded in the ECI can be potentially seen as an adequate tool to generate trust between the owner and contractor. It is important to notice that the factor of trust has to be considered during this process and should not be treated as a shot in the dark proposition. Once the contractor is appointed and the partnering is formed, the parties should work together to identify improvement areas to maintain and develop the trust. This can be facilitated while contractor is sharing its construction knowledge and experience. To achieve the benefits of inter-organisational knowledge sharing, a cooperative relationship between all the parties is required (Dyer & Singh 1998). Trust and knowledge sharing are mutually constitutive. The stronger trust-based relationship is established, the more accurate and complete knowledge will be shared between partners and vice versa. In addition, although the body of literature on ECI method has not sufficiently addressed the impact of trust on innovation throughout the contract, it stills offers valuable insight into how trust can positively influence innovativeness between the partners and lead to performance improvements. Finally, building and development of trust should be managed carefully at both interpersonal and inter-firm levels with different value bases; and middle managers should understand the value of interpersonal and inter-firm trust (Lau & Rowlinson 2009), thus, trust should not be assumed to emerge innately in partnerships.

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Variable Productivity in Earthwork Services of Roadwork's in Brazil: the Divergence between the Opinions of Different Budgeting Manuals

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Abstract

Introduction: The participant agents in the chain of Civil Construction have increasingly been charged as its efficiency increases, as a result of a series of changes in the market, such as intensification of the competition among the active companies, the larger consumer awareness and more effective control by the Government. Therefore, the agents of Civil Construction have been working in order to seek such increase of competence, which can lead to changes in the indicators used in the unitary compositions available to assist the prediction of costs. Thereby, it is considered necessary the continual improvement of systems of productivity indicators to mark the analysis of costs in Civil Construction. **Study objectives:** This work studies the productivity variation in the highway earthwork and discusses the differences among the opinions of Brazilian budget manuals. **Methods:** Based on the Model of Factors (this approach entails the prediction based on aspects observation related to a greater or lower expectation of efficiency of equipment in a certain service), the selection of research methods covers the objectives outlined, including literature review, exploratory studies and field surveys. **Conclusions:** Regarding services of highway earthwork, there are many manuals, however each one deals with the execution steps differently and the productivity indicators presented are extremely variable. Furthermore, it is not possible to know (reading the manual) which factors were considered when the manual indicates a specific value for a certain service. Accordingly, its usage (the manuals) as a tool for budgeting and management is inefficient. The result of budget manuals study is presented and new methodology is proposed.

Keywords: productivity, earthwork, highway infrastructure.

1. Introduction

Providing infrastructure represents major public investments and a long-term planning. It is essential that the functionality is in line with the useful life of the enterprise. Its usage spans several generations during which the society will pass for dramatic changes. This long period of time means that the development in transportation of people and goods should be

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assessed and planned quite in advance in order to make the right choices not only for today but also for tomorrow (Fehrl, 2008).

Aware of this reality and the social importance and needs of the sector, between 2007 and 2010 several works were completed in Brazil: 1.306 kilometers of roads were doubled, 1.789 kilometers were paved and 3.282 kilometers were granted to private companies, which manage 15.000 kilometers - less than 1% of the paved mesh. There are duplication works on 1.592 kilometers and 3.524 kilometers of pavement in execution, besides signposting and maintenance services hired for more than 50.000 kilometers of network. For the private sector, there is immediate potential to grant, at least, over 12.000 kilometers (Abdib, 2011).

1.1 Available pointers of productivity

In general, the execution of a highway is through the hiring of private companies by public organs, preceded by public bidding. The highway budgets are the result of the combination of quantitative services extracted from projects and the compositions of unitary prices of services (Pedrozo, 2001).

In Brazil, for the forecast of the productivity the cost data manual use is common. However, it is perceived in practice, that the productivity pointers can have a great variability requiring knowledge of the factors that make them vary.

In the revision / perfection work developed for the Polytechnic School of São Paulo, USP (EPUSP, 2008) of the prognostic costs effected by the Brazilian Federal Government for the airport construction it was found a great variability of relative efficiencies to the pavement service (according to study in construction and consults to specialists, manuals and technical documents). Examples of variability are presented in Figure 1.

Excavation and loading equipment 1st category

Loader tire (h)	Bulldozer (h)	Labor (h)
		
0,008 0,058	0,008 0,068	0,108 2,0
771%	879%	1874%

Figure 1 – Change (%) among the yields for the excavation service (number of equipment hours to launch a cubic meter of soil)

This example, which varies from 771% to 1874%, is a warning about not being able to make reliable decisions based on imprecise indicators.

1.2 Study objectives

This paper proposes studies of productivity variation in the highway earthwork in Brazil and discusses the differences among the instructions from Brazilian budget manuals. Built on the concept of productivity variable (unprecedented in the subsector of heavy construction) and it uses the approach of Model Factor. This approach entails a prediction based on careful

observation of various aspects related to a greater or lesser expectation of labor productivity and the efficiency of equipment in a particular service.

2. Material and methods

The improvement of understanding the productivity of highway earthwork started from the finding that many available methods assume postures that prevent them from making different decisions: those related to budgeting to those associated with production management.

Thus, the following steps were developed: a) expert opinion survey; b) use of theoretical and empirical methods; c) review the different executive phases of each type of service; d) present the indicators of these services through ranges of values (representing the variable productivity), e) and allies to the tracks are the guiding factors for the decision on what value to adopt. Therefore, based on ranges of values (productivity variable), and abnormalities of the factors that affect the productivity of earthwork, data obtained from eight sources studied (five books and two case constructions), and grounded in bibliographical studies, presents the following is the proposal to improve the understanding of productivity. This proposal aims to apply the concepts of variable productivity in Earthwork Services of Roadwork's.

The following criteria were used to choose the Brazilians manuals adopted in this work: technical recognition; degree of detail as the description of the cases examined, avoided use of manuals with the same sources of information.

The manuals used in this study are derived from the following sources:

a) National Department of Transport Infrastructure – DNIT (Brasil, 2007);

b) Company of Public Works of the State of Rio de Janeiro – EMOP (EMOP, 1999);

c) Municipal and Urban Infrastructure Works – SIURB (Sao Paulo, 2010);

d) Composition Table Prices Budgets – TCPO (TCPO, 2008);

e) Department of Civil Engineering at the Polytechnic School of the University of São Paulo (EPUSP, 2008).

The results of data collection processing and the posterior analysis are originated from the system presented in Figure 2.

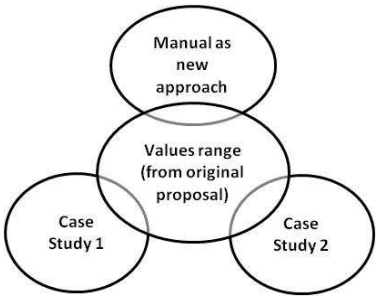

Figure 2 – Range of values: build system

3. Divergence between the Brazilian budget manuals

Amongst the services related to the highway asphalt pavement construction, aiming at illustrating the application of the productivity improvement, the service of the earthwork will be presented as follows.

In the study effected in some cost data manuals the variety of equipment teams met a great difference and the same enters the productivity adopted for service. The variations found were: a) Harrow to Farm Tractor was 313%; b) Motor Graders was 270%, c) Soil Compactor was 123%; d) Water Truck was 278%; e) and Farm Tractor was 303%. Table 1 illustrates this situation.

Table 1 – Compression embankment service in layers of 20 cm. Degree of Compaction (DC): 90-95% (m^3/h)

Discrimination	DNIT	EMOP	SIURB	EPUSP
Harrow to Farm Tractor	313.2	175	100	138.9
Motor Graders	539.4	350	200	285.7
Soil Compactor	215.7	175	200	208.3
Water Truck	156.6	175	100	277.8
Farm Tractor	303.4	175	100	277.8

4. New approach for productivity prediction

The method of prediction of productivity of asphalt paving services, proposed here, is divided into five parts, as the matters described below:

a) Unitary Production Ratio;

b) Unitary Production;

c) Model of factors;

d) Use of Quartile;

e) Details of equipment hours.

According to Souza (1996), productivity could be defined (Figure 3) as the efficiency (and, to the extent possible, the effectiveness) in the transformation effort by workers or equipment on construction products (the work or its parts).

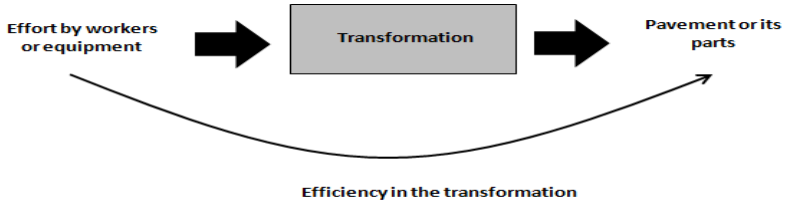

Figure 3 – Definition of productivity

4.1 Unitary Production Ratio

The accepted definition of productivity shown in Figure 3, Souza (2006) suggests adopting the indicator called unitary production ratio (RUP) as a measure of productivity by linking the human effort, measured in hours x men (Hh) or equipment x time (Eqh), with the amount of work performed, *Equation* (1). It is emphasized that, according to the setting made, a high value indicates productivity worse than a low value.

$$RUP = \frac{Hh}{Amount\ of\ service} \qquad \textbf{(1)}$$

4.2 Unitary Production

The unitary production (PU) translates the amount of service produced for the equipment (or workers) at the moment available for the service. He is the inverse one of the RUP, *Equation* (2).

$$Unitary\ \ \mathrm{Pr}oduction = \frac{1}{RUP} = \frac{\mathrm{Amout\ of\ Serviçe}}{H_{\,available\ to\ the\ service}} \qquad \textbf{(2)}$$

4.3 Model of factors

According to Souza (2006), the unitary production (PU) of equipment and labor may vary according to age rather large amplitude. Figure 4 justifies the assertion that demonstrates that the production unit for the compression landfill ranges from 884 m^2/h to 2746 m^2/h. The wide variation in the unitary production for the construction work force leads to the following conclusion: we cannot make good decisions without the knowledge of such ranges and the reasons why they change.

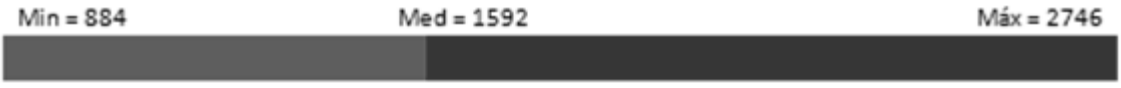

Figure 4 – Range of variation of the production unit: compression landfill (m^2 / h)

It has arrived, then, to another important question: why does the unitary production of the equipment and the labor vary?

Conceptually, the model of factors would have an answer to the question. In an attempt to classify the factors potentially altering the unitary production presented in the various parts of the production process, it is said that the unitary production can be influenced in the presence of the normal manner by factors linked to the content and related to factors having the service context under consideration. In addition, the unitary production can be changed when anomalies occur. They are usually factors related to the content on the characteristics of the "product" running and "processed resources" such as materials and components. The context factors normally associated with "processing resources" such as labor and equipment and the "boundary conditions", such as temperature and usual attitude of the unions. Abnormalities would be "offsets" exacerbated by the regular features of the content and context cited.

4.4 Use of quartiles

The maximum and minimum values represent the extremities of the range, representing, obviously, situations have limited the available database; the medium value represents the central region of the data set, that is, it represents the central value of the data set.

Completing this reasoning, for the determination of the high and low values, the concept of Quartile will be used. The Quartiles allow the division of a data set into four equal parts (Figure 5).

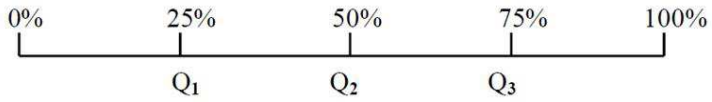

Figure 5 – Quartiles

Alternatively to the presentation of the maximum and minimum raised values, the processing of the data will be concentrated in the First and the Third Quartile as the extreme of the variation range to be argued.

Ramos (2003) recommends this methodology (the application of quartiles) as a tool of statistical control. In the civil construction it is indicated by some authors such as: Souza (1998); Albuquerque, Costa and Pereira (2007); Duarte, Lamounier (2007).

4.5 Details of equipment hours

It is a common situation having a product and during some periods of time not having work to allocate it, becoming idle in the company. Within the period in which the equipment is available for service is the time it is effectively working, in other words, the power is on. This leads to the definition of "working hours". To develop this work it will be used these two moments of the incidence of equipment hours, the hours available for service ($H_{service}$.) and hours in operation ($H_{operation}$). Deducting from the “available hours for the service” the “hours

in operation" one has the "unproductive hours" (H_{improd}). Figure 7 presents an example of application of these definitions.

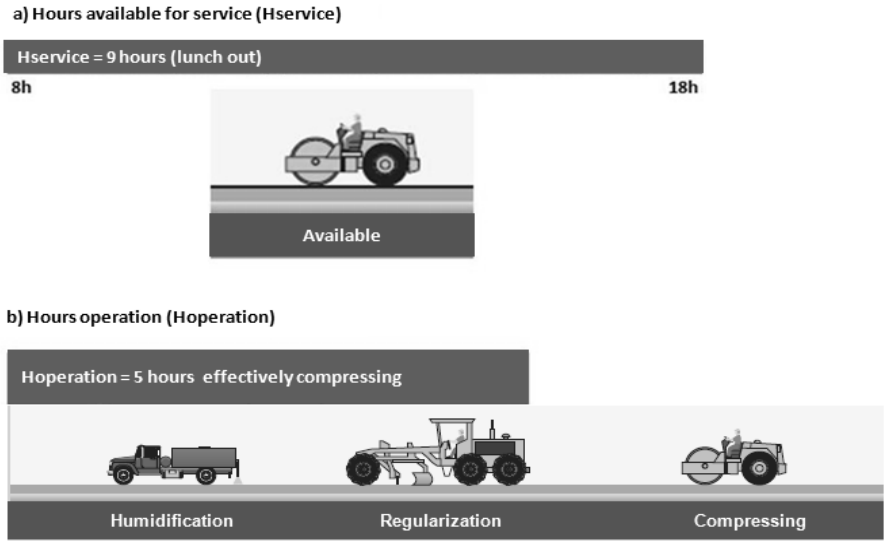

Figure 7 – Different moments in the highway earthwork compressing service

5. Application example of the methodology proposal

Studied the subject (literature, five manuals and two case studies). It is how services were handled / broken by hand. It was proposed a breach of these new services. A proposed approach to the compositions was performed. The indicators of the manuals were adequate according to this proposal. Tracks contemplating productivity variable (1st quartile, median, 3rd quartile), referring to the manuals and case studies were developed. Based on all the learning acquired abnormalities were identified and the factors that make the productivity of these bands vary. This study was presented to the experts, who judged and scored on indicators of abnormalities and factors. The result of this research led to the improvement of understanding the productivity variation in the highway earthwork.

In terms of the different parts of the earthwork service, part of the scope, the values shown below: scattering, leveling, aeration or homogenization, wetting, compacting the layer.

The ranges of unit output of the equipment shown below were made with the following considerations:

- to show ranges of values for the production unit including the equipment and his operator (Table 2).

- those bands are related to the factors which lead to an expectation better or worse than the value of the output indicator unit, in another word, a greater closeness of the extreme right or left, respectively, of the band (Table 3).

Table 2 – Compaction embankment service in layers of 30 cm.

a) Step: scattering of the soil (after unloading by trucks)						
Equipment	Unitary Production ($m^2/H_{service}$)			$H_{operation}$		
	1º Quartile	Median	3º Quartile	1º Quartile	Median	3º Quartile
Dozer	250	550	350	50%	68%	80%
b) Step: leveling layer (the motor grader levels the soil layer)						
Equipment	Unitary Production ($m^2/H_{service}$)			$H_{operation}$		
	1º Quartile	Median	3º Quartile	1º Quartile	Median	3º Quartile
Motor Grader	1000	1200	1400	80%	83%	90%
c) Step: aeration and / or homogenization of the layer (if you need the tractor to make the grid aeration or mixing of soil)						
Equipment	Unitary Production ($m^2/H_{service}$)			$H_{operation}$		
	1º Quartile	Median	3º Quartile	1º Quartile	Median	3º Quartile
Farm Tractor with harrow	1000	1200	1400	68%	73%	90%
d) Step: wetting layer (if you need to moisten the soil by water truck)						
Equipment	Unitary Production ($m^2/H_{service}$)			$H_{operation}$		
	1º Quartile	Median	3º Quartile	1º Quartile	Median	3º Quartile
Water truck	1075	1322,5	1500	58%	65%	70%
e) Step: compacting the layer						
Equipment	Unitary Production ($m^2/H_{service}$)			$H_{operation}$		
	1º Quartile	Median	3º Quartile	1º Quartile	Median	3º Quartile
Soil Compactor	300	450	600	70%	83%	90%

Table 3 – Factors and abnormalities: Compaction embankment service

Approaches the 1st Quartile	Approaches the 3rd Quartile
Unstable weather conditions	Stable weather conditions
Equipment with high maintenance during operation	Equipment with low maintenance during operation
Operator untrained	Trained operator
Poor continuity and sequence of operations	Good continuity and sequence of operations
Preliminary tasks to be performed (e.g. drains)	Preliminary ready tasks (e.g. drains)
Improvisation prevails	Plan activities in advance
Team equipment less compatible (different equipment, different weights, quantity incompatible with the degree of compaction)	Team equipment compatible (similar equipment, like weights, quantity compatible with the degree of compaction)
Less trained laboratory staff	Trained laboratory staff

6. CONCLUSIONS

Studies in the economic area indicate that the development of infrastructure is essential in determining the level of income "per capita" of a country. Providing this infrastructure represents a major public investment and long-term planning.

In Brazil, in recent decades, investment in highway infrastructure is far below the needs of the country. It is, therefore, that the highway pavement is a technology area with development potential and needs sorted investments in various sectors.

This paper proposes studies of productivity variation in the highway earthwork in Brazil and discusses the differences among budget manuals. In the first moment, the Compaction Embankment Service was presented as an example of service, and variations between 123% and 313% were found.

Concluding, for the services of highway earthwork there are, in Brazil, many budgeting manuals, but the indicators are sometimes presented as the theoretical basis without empirical proof, extremely variable and, the factors that do vary are not perceived. This imprecision makes it difficult to trust decisions, affecting the budget processes and production management.

To solve this problem the prediction method of highway earthwork productivity was propose. The model was developed based on the concept of variable productivity (productivity indicators presented through ranges of values) that in addition to unprecedented heavy construction subsector in Brazil, the approach uses the Model Factor (demonstrates the guiding factors for the decision on which embrace value).

The improvement of understanding about productivity in highway earthwork construction projects proposed here can mitigate the failures presented in the Brazilian budgeting manuals and thus help to bring the technological area of highway pavement to a new level of productivity and efficiency.

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Fire Safety of Buildings Based on Realistic Fire Time-Temperature Curves

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Abstract

In recent times, fire has become a major disaster in buildings due to the increase in fire loads, as a result of modern furniture and light weight construction. This has caused problems for safe evacuation and rescue activities, and in some instances lead to the collapse of buildings (Lewis, 2008 and Nyman, 2002). Recent research has shown that the actual fire resistance of building elements exposed to building fires can be less than their specified fire resistance rating (Lennon and Moore, 2003, Jones, 2002, Nyman, 2002 and Abecassis-Empis et al. 2008). Conventionally the fire rating of building elements is determined using fire tests based on the standard fire time-temperature curve given in ISO 834. This ISO 834 curve was developed in the early 1900s, where wood was the basic fuel source. In reality, modern buildings make use of thermoplastic materials, synthetic foams and fabrics. These materials are high in calorific values and increase both the speed of fire growth and heat release rate, thus increasing the fire severity beyond that of the standard fire curve. Hence it suggests the need to use realistic fire time-temperature curves in tests. Real building fire temperature profiles depend on the fuel load representing the combustible building contents, ventilation openings and thermal properties of wall lining materials. Fuel load is selected based on a review and suitable realistic fire time-temperature curves were developed. Fire tests were then performed for plasterboard lined light gauge steel framed walls for the developed realistic fire curves. This paper presents the details of the development of suitable realistic building fire curves, and the fire tests using them. It describes the fire performance of tested walls in comparison to the standard fire tests and highlights the differences between them. This research has shown the need to use realistic fire exposures in assessing the fire resistance rating of building elements.

Keywords: Fire safety, Standard fire curve, Fuel load, Realistic fire time-temperature curves, Light gauge steel frame walls.

1. Introduction

Fire resistance of building elements has been traditionally determined using standard fire tests specified in ISO 834 (ISO, 1999). Fire Resistance Rating (FRR) determined from these tests should be sufficient in a fire event, for safe evacuation, fire service intervention and for

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rescue activities. Recent researches have shown that the actual FRR of building elements exposed to real building fires is significantly less than that obtained from standard fire tests (Lennon and Moore,2003, Jones, 2002, Nyman, 2002 and Abecassis-Empis *et al*. 2008). Fire testing of building elements is generally based on the standard time-temperature curve given in ISO 834. This curve was developed in early 1900s based on wood fuel burning furnaces, and was later modified slightly to give a faster temperature rise for the first few minutes of burning to represent the gas fired furnace temperatures (Babrauskas and Williamson, 1978). Many fire resistance tests have been undertaken at great expenses, and a vast database of FRR times has been collected over the years. However, this approach was not based on the knowledge of fire severities in real buildings. Since then, no significant change has been made to this standard time-temperature curve, which is being used to calculate the FRR of building elements until now. Many countries also use ISO 834 or have standards similar to ISO 834. Therefore there is a concern on the appropriateness of the standard fire in representing the real fire conditions in modern building environment.

In reality, commercial and residential buildings incorporate both traditional wooden furniture and modern items such as cushion/fabric furniture, mattresses, fabric coated partitions and many other items, which make use of thermoplastic materials, synthetic foams and fabrics. The increasing use of thermoplastic materials is clearly evident with the introduction of desktop computers, fabric coated drywall systems and upholstered furniture in modern commercial and residential buildings. Also the calorific value for cellulosic material is only 17 MJ/kg while it varies from 25 to 35 MJ/kg for plastics depending on its type (ECS, 2002). During a fire, thermoplastic materials melt and flow to the floor and starts to burn. These fires burn significantly faster, with higher heat release rates. Bwalya *et al.* (2007) conducted room-scale fire tests to evaluate the impact of new construction products and systems on the fire safety of single family residential dwellings. For this, a fuel package consisting of a sofa constructed with exposed polyurethane foam (PUF) and wood cribs were considered. The sofa was ignited first and the wood cribs provided the remaining fire load. The results showed that the rate of temperature rise during the fire growth period was more rapid than that of ISO 834 (1999) time-temperature curve.

Table 1: Composition of Fire Loads (Bwalya et al., 2008)

Room Usage	Fire load Percent Weight (kg)			Fuel load Percent Fire Load (MJ)		
	W	P	T	W	P	T
Kitchen	86.5	13.5	<<1%	80.2	19.8	<<1%
Living Room	65.8	32.9	1.4	57.4	41.4	1.2
Dining Room	72.6	26.6	0.8	65	34.0	0.8
Primary Bedroom	42.3	26.4	31.4	37.8	34.1	28.1
Secondary Bedroom	39.8	29.8	30.3	35.2	38.0	26.8
Basement Living Room	61.0	39.0	0.2	51.8	48.1	0.2

Note: W: Wood and Paper; P: Synthetic Plastic materials (including polyurethane foam); T: Textiles (including clothing); <<1%: much lower than 1%

Recently Bwalya et al. (2008) conducted a fire load survey for family dwellings based on information from real estate websites in Canada to quantify and to determine the composition of the combustible contents in residential dwellings. Table 1 summarizes their survey results. The composition of the combustibles in all the rooms was categorized into three main material groups: wood and paper (cellulose-based), synthetic plastics and textiles (or fabrics). It is evident from these results that wood-based materials form a significant proportion of the total combustible mass in residential dwellings. Although the cellulosic material takes up the highest contribution, plastics occupy nearly 13 to 39% by weight (kg) and contribute 20 to 48% to the fire load (MJ). The increase in percentage of fire load was due to the higher caloric values of synthetic plastics than cellulosic materials. This shows a significant contribution from synthetic plastic materials to the fire loads in residential dwellings. It must be noted that plastics were not present when the standard time-temperature curve was established. As mentioned, these modern synthetic materials increase both the speed of fire growth and peak heat release rate, thus increasing the fire severity than the standard fire curve used to obtain the FRR. Hence construction elements may not ensure safe evacuation, or offer the required life safety for occupants and fire rescuers as indicated in the technical manuals of building assemblies.

Fire testing using the standard time-temperature curve will give good comparative results for building systems tested under identical conditions, and also valuable basic data. However, these results do not provide accurate FRR for residential and commercial buildings, which have a high fire severity as shown by Lennon and Moore (2003), Jones (2002) and Abecassis-Empis *et al*. (2008). These researchers used compartment fire tests for this purpose, where the maximum temperature of a natural fire exceeded the standard ISO curve within a short period of time from ignition. In a building fire, the fire growth, fully developed and decay phases depend on aspects such as the total fuel load present in the room, fuel type and configuration, ventilation openings and thermal properties of compartment lining materials. Among them, fuel load was selected to represent the combustible contents in modern residential buildings based on the literature, and appropriate realistic building fire curves were developed. This paper presents the details of the development of such realistic fire time-temperature curves. It also describes the fire performance of steel wall panels tested under both the developed realistic fires and the standard fires (ISO 834, 1999) and highlights the differences between the effects of standard and realistic building fires.

2. Realistic fire time-temperature curves

Several equations and computer models have been developed by researchers to predict the fire behaviour. These are of two types: pre-flashover and post-flashover fire models to represent the behaviour of a fire. The post-flashover fire scenario models focuses in the analysis and design of building fire safety systems and pre-flashover fires involves fire spread around the building and toxic gas production. These time-temperature curves were derived using mass and energy balance equations, heat release rates and curve fitting to temperature profiles obtained from compartment tests. The literature on post-flashover time-temperature curves shows that it is very difficult to envisage the time-temperature profile of a fire in a compartment. Many researchers used different types of fuels and ventilation conditions to obtain and validate their fire curves. Hence most of these equations have

limitations, and their range of application is limited. Similarly for computer models, reliable and detailed time-temperature data from large-scale fire tests are needed for validation.

The review of the non-standard time-temperature post-flashover fires identified that three basic parameters define the time-temperature curve in a compartment, namely, Fuel load, Ventilation and Thermal properties of lining materials. Also it is clear that a standard fire curve (ISO 834, 1999) to suit the real building fires is unrealistic and the fires have to be based on the above three parameters. Several approaches have been used to determine the equivalent severity of fire, for which, 'equal area' and 'time equivalent' concepts are commonly used. Equal area relates to the area under the time-temperature curve while time equivalent concept relates the time of exposure to the standard fire an element would need to be exposed to reach that in a real fire. It includes 'maximum temperature' 'minimum load capacity' and 'maximum deflection', and empirical formulae were developed. Empirical formulae in CIB (1986), Law (1983) and Eurocode (2002) have been derived based on these principles, and are available for computing the time equivalence for building elements. The time equivalent concept provides only an approximate value to that of real fire behaviour when comparing it with the standard fire. Also the empirical formulae are based on equivalent time of exposure to the standard fire and are derived for a particular set of design fire time-temperature curves only. Hence considering their accuracy to realistic fires and to develop realistic time-temperature profiles, Eurocode parametric curve (ECS, 2002) and Barnett's (2002) 'BFD' curve fire profile were selected.

Eurocode 1 Part 1-2 (ECS, 2002) prescribes a simple mathematical relationship for 'Parametric' fires, allowing a time-temperature relationship for a combination of the above mentioned parameters. The curves were developed for both heating and cooling phases. The rate of temperature rise and peak temperatures in the Eurocode parametric curves are well above those in the standard fire curve and the decay rates are linear and rapid, leading to a shorter fire decay durations. The fire parameter values used in deriving the realistic fire time-temperature curves are shown in Figure 2. On the other hand Barnett's 'BFD' curve is much closer to the real fire time-temperature distribution and uses a single log-normal equation to represent both heating and cooling phases. Barnett (2002) states that 'BFD' curves has been developed using curve fitting to 142 natural fire tests with a range of fuels and different enclosure materials. The 'BFD' curve takes the shape of the natural fire curve and closely agrees with the actual fire test results than other models. Hence in order to study the behaviour under natural decay phase of a fire, Barnett's 'BFD' curve is also considered.

3. Development of realistic fire time-temperature curves

3.1 Fire loads in residential buildings

The design fire curves are determined based on three parameters, namely; fuel load, ventilation openings and thermal properties of wall lining materials. Of these fuel load is an important parameter since it represents the combustibles in a compartment. It affects the burning duration and peak temperature of the compartment. The term fuel load is defined as the energy (MJ) that could be released by the complete combustion of compartment contents. The fuel load in a compartment is expressed as Fuel Load Density (FLD). It is the

heat energy released/m^2 of floor area of a compartment by the combustion of the fuel loads within the compartment. The fuel load in a room is made up of permanent and variable loads. Permanent fuel load includes materials that are rarely moved or changed during the service life of the building such as electrical, ventilation fittings, etc. Variable fuel load varies during service life, and is temporarily placed and movable such as furniture and ornaments.

Fuel loads in residential buildings depend on the geographic location, home construction and furnishing styles. Also they vary within a building depending on the room usage. The changes in the fashion trends and materials used for furnishing have resulted in significant differences in the composition of fuel load densities in modern buildings. As mentioned rapid usage of plastics in many household items over the past decade or two has greatly increased the fuel load energy in buildings. Some plastic materials burn rapidly as pool fires, therefore plastics in any item should be considered as a potential fuel load. To determine the variable FLD, surveys have been conducted in many countries and suitable values have been published in the standard codes of practice. The available mean fuel load density values for residential dwellings are summarized in Figure 1.

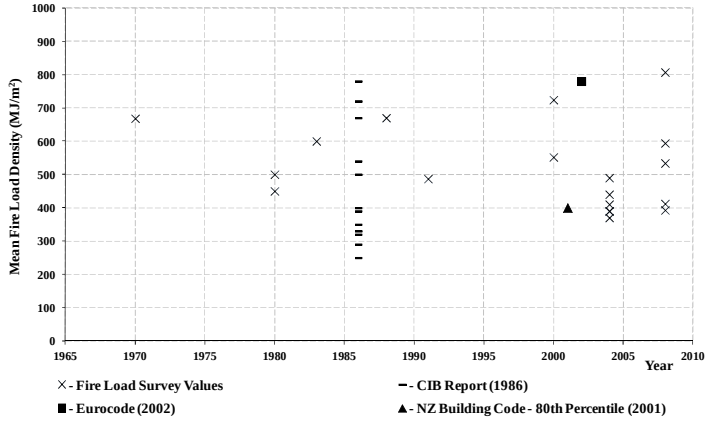


Figure 1: Summary of mean variable fuel load density values for residential dwellings

It is uncertain which mean value and percentile are to be selected in determining the time-temperature curve to represent a more realistic fire scenario for residential buildings. Hence this question was raised with many academics, researchers and experts in the field of fire engineering, whose common recommendations were to select a realistic value from the available literature that is justifiable to the present building environment than using a value obtained 20 years ago. Also there is no definitive value for a type of building, and the fuel load density value alone does not provide a realistic time-temperature curve. Instead parameters such as, fuel load composition, heat release rates, ventilation opening sizes and thermal properties of wall lining materials are also important in obtaining a more realistic time-temperature profile. However for design purposes it is obvious to select the worst case fire scenario, which reflects the actual fire profile in a modern building. Therefore an average value of 780 MJ/m^2 was selected from Eurocode 1 Part 1-2 (ECS, 2002), which is very close to Bwalya et al.'s (2008) recent fire load survey results (807 MJ/m^2) obtained for Canadian residential buildings. Also for design load, an 80th percentile value of 948 MJ/m^2 was selected and taking into account the factors such as combustion for cellulosic materials (m=0.8), fire activation risks for compartment area (δ_1=1.5), type of occupancy (δ_2=1) and active fire fighting measure (δ_n=1) as given in Eurocode 1 Part 1.2 (ECS, 2002), the design variable fuel load density for residential building was determined as 1138 MJ/m^2. For

permanent fuel load density National Fire Protection Association (NFPA) proposes a value of 130 MJ/m^2.

3.2 Realistic fire time-temperature curves

The compartment geometry considered was 3600 (L) x 2400 (W) x 2400 (H) mm based on ISO 9705 compartment geometry (Nyman, 2002). The boundary of enclosure materials for this research was chosen to be light steel frame partition walls lined with single and double layer gypsum plasterboards for walls and ceiling, and concrete floor slab to represent a typical single storey residential dwelling. The corresponding thermal inertia for the compartment was determined to be 715 J/m^{2}S$^{1/2}$K for plasterboard lined walls and ceiling, and concrete floor compartment. To account for different fire scenarios, two opening factors, 0.08 and 0.03 m$^{1/2}$ were chosen to represent a rapid fire and a long-drawn-out fire for single and double plasterboard lined wall fire tests, respectively. The opening factor is defined as $O = A_v\sqrt{h_{eq}}/A_t$ where A_v - area of vertical openings on all walls, h_{eq} - weighted average of opening heights and A_t - total area of enclosure.

Both Eurocode parametric fire (ECS, 2002) and Barnett's 'BFD' fire (Barnett, 2002) curves were drawn for the same parameters and the 'BFD' curve was modified to derive more realistic time-temperature curves for design. In comparison with the Eurocode parametric fire, the peak temperature values of 'BFD' curve are much less, but the shape of the curve fits well with the natural fire curve. The 'BFD' curve calculates the maximum temperature from the equation recommended by Law (1983) based on many experimental fires. This equation may not incorporate the temperature rise due to the modern materials as it was developed in early 1980s. Hence it was decided to use the maximum temperature of the Eurocode parametric curve (ECS, 2002) for the 'BFD' curve. Figure 2 shows the modified 'BFD' curves and Eurocode parametric curves drawn for the realistic design parameters.

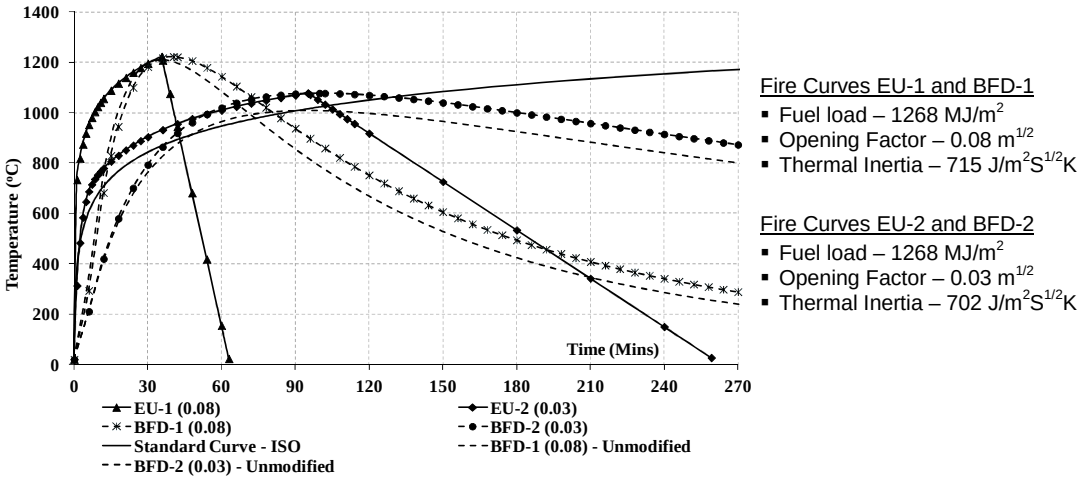


Figure 2: Realistic fire time-temperature curves

At present, experimental and analytical studies have been performed to understand the structural and thermal performances of steel frame wall panels subjected to heating based on the standard time-temperature curve. As mentioned before standard fire tests will provide good comparative results for materials tested in identical conditions, but do not reflect the true time-temperature profile during a real fire in a building. Therefore, full scale fire tests

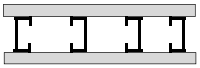
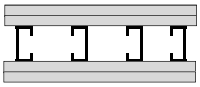
were performed to study the behaviour of light gauge steel frame wall panels lined with single and double plasterboard layers for the developed realistic time-temperature curves.

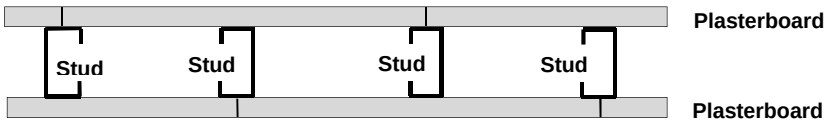
4. Fire testing of light gauge steel frame wall panels

4.1 Test wall specimens

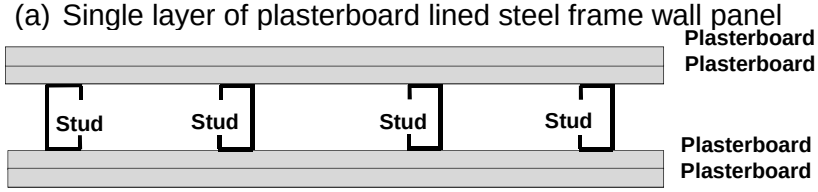
Test program consisted of four load bearing light gauge steel frame (LSF) wall panels of 2400mm width and 2400mm height, lined with 16 mm thick Firestop$^{(R)}$ gypsum plasterboards under the developed fire time-temperature profiles in Section 3. Tests were conducted to determine the fire resistance of these four load bearing LSF walls under realistic fire curves shown in Figure 2. Table 2 gives the details of the four load bearing test wall specimens.

Table 2: Details of test wall specimens

Test	LSF Wall Configuration	Fire Profile	Load Ratio (Load per Stud)
T1	Single layer of Pb 	EU-1 (0.08)	0.2 (15 kN / Stud)
T2		BFD-1 (0.08)	
T3	Double layer of Pb 	EU-2 (0.03)	
T4		BFD-2 (0.03)	



(a) Single layer of plasterboard lined steel frame wall panel



(b) Double layers of plasterboard lined steel frame wall panel

Figure 3: Light gauge steel frame wall panel configurations

Each test wall panel included four steel studs (90 x 40 x15 x 1.15 mm) at a spacing of 600 mm, and were attached to top and bottom unlipped channel section (92 x 50 x 1.15 mm) tracks using D-Type self drilling 16 mm long flat head screws. The studs and tracks were fabricated from 1.15 mm galvanized steel sheets having a minimum yield strength of 500 MPa. Test specimens T1 and T2 were lined with single layer of 16 mm plasterboards on both sides of the steel frame while test specimens T3 and T4 were lined with two layers of 16 mm plasterboards (Figure 3). The standard sizes of 16 mm gypsum plasterboard were 1200 mm by 2400 mm and the density is 13 kg/m^2. D-Type self drilling bugle head screws of 25 and 45 mm length were used to fix the first (base) and second (face) layers of

plasterboards. The base layer plasterboard (Pb1) was screwed at 200 mm spacing along the studs where the plasterboard joints exist, and 300 mm spacing along the intermediate studs. The second layer of plasterboard (Pb2) was fixed at 300 mm screw spacing for the double layer wall panels. The base layer has vertical joints over the studs and the face layer was placed to have a horizontal joint. The plasterboard joints were sealed with two coats of plaster-based joint compound and 50 mm wide cellulose based joint tape was sandwiched between the two coats of joint compound.

4.2 Test set-up and procedure

The wall fire tests were conducted in a propane fired gas furnace lined with ceramic fibre insulation. The time-temperature curve of the furnace was monitored and controlled by four Nicrobell coated rod type thermocouples, which measure temperatures up to 1200°C. These temperatures were used to control the fuel and air supply to the chamber to obtain the required time-temperature fire curve. Tests were conducted in a specially designed test rig shown in Figure 4, where a pre-determined (load ratio =0.2) axial compression load was applied to the individual studs of LSF panel from the bottom. This axial compression load was based on 0.2 times the ambient capacity of the stud (79 kN) determined by Kolarkar (2010). A lower load ratio of 0.2 was selected as it would delay the failure of the panel, enabling sufficient data to be obtained from the test. The test specimen was placed with the centroids of the studs aligning with those of the loading plates and hydraulic ramps. The axial compression load was applied by four individual ramps and transmitted through the loading plates. Each loading plate was connected to an individual hydraulic ramp while a single pump was used to apply the required axial load.

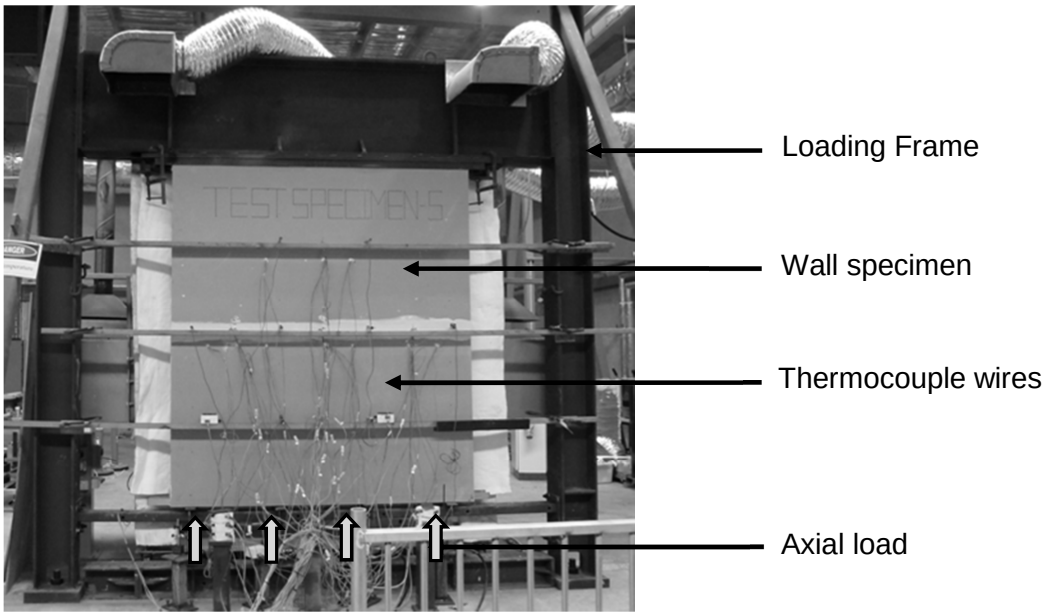


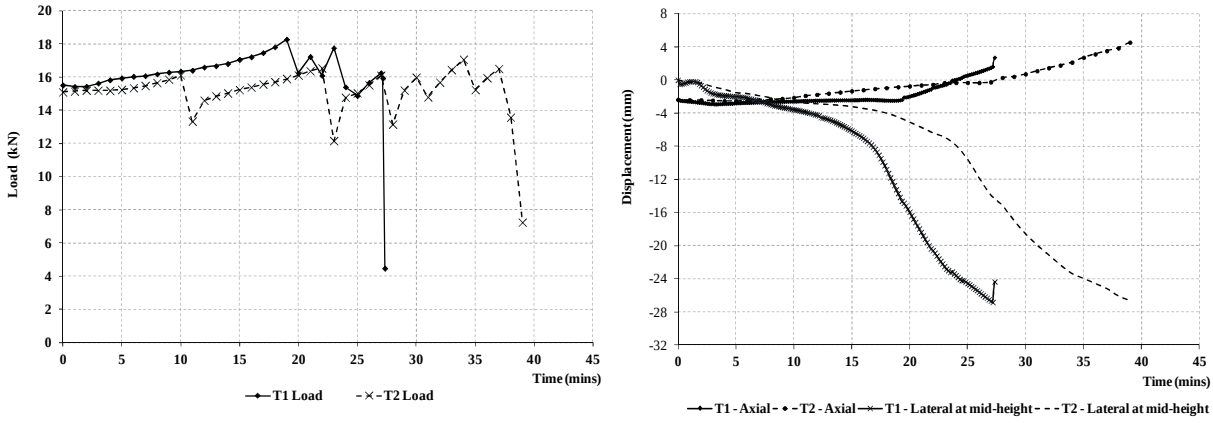
Figure 4: Fire test set-up

4.3 Observations and results

During the fire test, the furnace air and fuel (propane gas) valves were regulated such that the average furnace temperature inside the furnace followed the target fire curve. The proposed realistic design fire curves shown in Figure 2 were achieved reasonably well (within 50°C) in all the tests, except in Test Specimen T1 where it was nearly 100°C less for the entire duration of the test. The structural failure of the studs occurred before the insulation or integrity failure in all the tests except Test Specimen T3 that did not fail even under insulation or integrity criteria. The failure times are given in Table 3. They were based on the time when the pressure in the hydraulic ramps could not be maintained. In all the tests, after a few minutes of starting the furnace, smoke was visible at the top of the specimen while water drops were seen along the edges of the loading frame. Smoke and steam were then seen to escape from the furnace chamber during the test. This was due to the burning of plasterboard paper layer on the fire exposed side.

Table 3: Failure times of test specimens

Test	LSF Wall Configuration	Fire Profile	Failure Time
T1	Single layer of Pb	EU-1 (0.08)	28 mins
T2		BFD-1 (0.08)	39 mins
T3	Double layers of Pb	EU-2 (0.03)	No Failure
T4		BFD-2 (0.03)	139 mins



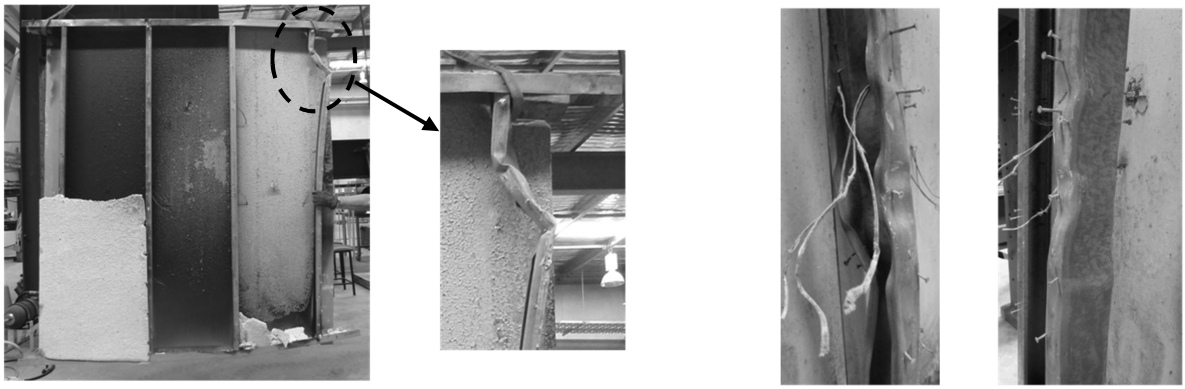
a. Applied load vs. time profiles

b. Stud displacement vs. time profiles

Figure 5: Applied load and stud displacement profiles for Test Specimens T1 and T2

Figure 5a shows the average measured applied load to the studs and the decrease in the load confirms failure times to be 28 and 39 minutes for specimens T1 and T2, respectively. From the ignition of the furnace, the wall was observed to thermally expand until the failure in test specimen T1, T2 and T4. Near the failure this deformation decreased and the test panel deformed in the opposite direction. In specimen T3 the wall was observed to expand thermally until 140 minutes and then it started to contract due to the rapid decrease of the furnace temperature in the decay phase of the fire (EU-2 (0.03)). This showed that studs

were regaining their strength and the chance of failing structurally was impossible. Also the wall specimen was observed to bend towards the furnace from the beginning of the fire test. Figure 5b shows the axial deformation and lateral deflection of the failed studs in specimens T1 and T2. Figure 6 shows the failure modes of test specimens T1 and T4. Single plasterboard lined test specimen T1 failed structurally after 28 minutes of fire exposure.



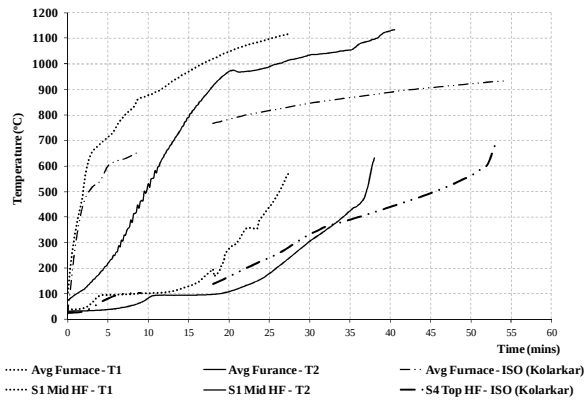
a. T1 – Stud 1 b. T4 – Stud 2

Visual inspection after the test revealed that the exposed plasterboard strip over stud 1 had fallen off, which led to Stud 1 losing its lateral support and failing by flexural torsional buckling. Similar observation was also noted in specimen T2. The middle stud (Stud 2) in specimen T4 experienced local buckling of the entire cross section near the mid-height.

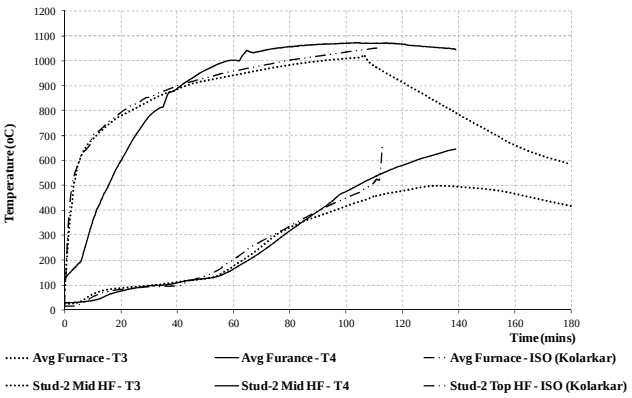
Figure 6: Test specimens T1 and T4 after fire tests

4.4 Discussions

Test specimens T1 and T2 were identical in wall configuration (lined with single plasterboard layer), but were exposed to realistic fire curves of EU-1(0.08) and BFD-1(0.08), respectively. In both tests, the failure occurred in the stud that had the 150 mm strip plasterboard joint (over Stud 1), and partial collapse of this plasterboard initiated the failure. Kolarkar's (2010) standard fire test also showed the same behaviour. T1 and T2 specimens failed after 28 and 39 minutes, respectively, and the corresponding failure time in the standard fire test was 53 minutes (Kolarkar, 2010).



a. Specimens - T1, T2 and ISO834



b. Specimens - T3, T4 and ISO834

Figure 7: Average furnace and stud hot flange temperatures at failure

Figure 7a shows the stud hot flange temperatures at failure together with the average furnace temperature profiles for specimens T1, T2 and Kolarkar's (2010) standard fire test. In T1 and T2 realistic fire tests, the furnace temperatures were much higher than the standard fire test (ISO 834, 1999), and were also maintained at higher temperatures. A rapid temperature rise with a short plasterboard dehydration period can be seen in the stud hot flange for specimen T1. In T2 and standard fire tests, the stud temperature rise was gradual compared to T1 fire test. The higher heat flow must have caused the plasterboard to partially collapse at a lower temperature. Plasterboard calcinated and shrunk rapidly at higher temperatures, and the rapid temperature rise caused the studs to fail earlier than in the standard fire test. The stud hot flange temperature of specimen T2 (630°C) at failure under the 'BFD' curve differs from those for the Eurocode parametric (561°C) and standard fire curves (550°C). This is possibly due to the plasterboard fall-off at different temperatures resulting in a rapid temperature rise in the studs and causing them to fail earlier than in the standard fire test.

Test specimens T3 and T4 were double gypsum plasterboard lined walls and exposed to Eurocode parametric and 'BFD' curves, respectively. Specimen T3 did not fail even after 180 minutes of fire exposure. Specimen T4 failed when the stud hot flange temperatures reached 645°C, which is similar to Kolarkar's standard fire test (663°C). Kolarkar's (2010) standard fire test failed at 111 minutes. Specimen T3 stud hot flange temperature reached only 497°C at 140th minute during the decay phase of the fire. Stud temperatures were seen to increase for nearly 35 minutes even in the decay phase of the fire. This implies that LSF wall studs could also fail during the decay phase of the fire. The wall panels were seen to fail in the fire tests when the studs reached the critical temperatures depending on the lateral stability provided by the plasterboard restraints. Hence it is clear that the failure time of LSF wall panels depends on the real design fire curves. Severe fires in terms of fire temperature and duration will significantly influence the failure time of wall panels.

5. Conclusions

This paper has described the differences between the standard and realistic building fires and the need to assess actual fire resistance ratings of building assemblies under realistic fires. It presents a review of the fuel loads for residential buildings, based on which appropriate realistic building design fire time-temperature curves have been developed. The paper also describes a series of tests of LSF walls conducted under the developed realistic design fires, and compares the fire test results with Kolarkar's (2010) standard fire test results for similar wall panels. This study confirmed that the failure time of steel wall panel depends on the characteristics of the realistic fire profile. Further research is in progress to better understand the behaviour of steel wall panels when exposed to realistic design fires.

6. Acknowledgements

The authors would like to thank Australian Research Council for their financial support and the Queensland University of Technology for providing the necessary facilities and support to conduct this research project.

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CIB 2013 World Congress
Fire Safety of Steel Wall Systems Using Enhanced Plasterboards

Keerthan Poologanathan[1], Mahen Mahendran [2], Ray Frost[3]

Abstract Title

Fire safety design is important to eliminate the loss of property and lives during fire events. Gypsum plasterboard is widely used as a fire safety material in the building industry all over the world. It contains gypsum (CaSO4.2H2O) and Calcium Carbonate (CaCO3) and most importantly free and chemically bound water in its crystal structure. The dehydration of the gypsum and the decomposition of Calcium Carbonate absorb heat, which gives the gypsum plasterboard fire resistant qualities. Currently plasterboard manufacturers use additives such as vermiculite to overcome shrinkage of gypsum core and glass fibre to bridge shrinkage cracks and enhance the integrity of board during calcination and after the loss of paper facings in fires. Past research has also attempted to reduce the thermal conductivity of plasterboards using fillers. However, no research has been undertaken to enhance the specific heat of plasterboard and the points of dehydration using chemical additives and fillers. Hence detailed experimental studies of powdered samples of plasterboard mixed with chemical additives and fillers in varying proportions were conducted. These tests showed the enhancement of specific heat of plasterboard. Numerical models were also developed to investigate the thermal performance of enhanced plasterboards under standard fire conditions. The results showed that the use of these enhanced plasterboards in steel wall systems can significantly improve their fire performance. This paper presents the details of this research and the results that can be used to enhance the fire safety of steel wall systems commonly used in buildings.

Keywords: Fire safety, Steel wall systems, Enhanced plasterboards, Chemical additives, Fillers, Thermal performance, Standard fire conditions.

1. Introduction

In recent times, LSF wall and floor systems are increasingly used in low-rise and multi-storey buildings, but without a full understanding of their fire performance. Currently LSF wall and floor systems are made of cold-formed thin-walled steel lipped channel sections and gypsum plasterboards. Under fire conditions, cold-formed thin-walled steel stud and joist sections heat up quickly resulting in fast reduction in their strength and stiffness. Therefore they are

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commonly used in structural wall and floor systems with plasterboard linings on both sides used as fire protection (see Figure 1).

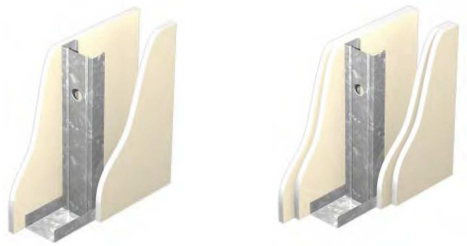


Figure 1: LSF wall systems with gypsum plasterboard lining

Cavity insulated LSF walls are regularly used for the purpose of climate control in exterior and party walls and acoustic benefits. However, they are also required to be fire rated. Hence many researchers investigated the fire resistance ratings of LSF wall systems with different types of insulations in the wall cavities. Sultan (1995) found that when rockwool was used as cavity insulation the fire resistance rating increased by 54% over the non-insulated wall assemblies. Recently Kodur and Sultan (2001) found that LSF wall assemblies without insulation provides higher fire resistance compared to cavity insulated LSF wall assemblies. Feng et al. (2003) found that the thermal performance of steel channel wall panels was not affected by the type of insulation and that the thermal performance of wall panels improved with the use of cavity insulation. In summary, past research has provided varying results about the benefits of cavity insulation to the fire rating of LSF wall systems. Kolarkar and Mahendran (2008) developed a new composite LSF wall panel system in which a thin insulation layer was used externally between plasterboards instead of the conventional cavity insulation located within the stud space. Since the new composite LSF wall panels have an external insulation layer between the plasterboards, they also provide climate control and acoustic benefits. Kolarkar and Mahendran (2008) found that composite LSF wall panels provided a better quality thermal envelope than the cavity insulated LSF wall panels. However, the use of such composite panels is considered expensive due to the complicated installation process and higher labour cost. This research therefore aims to use alternative methods based on enhanced plasterboards to develop LSF wall systems with increased fire rating.

Many research studies have investigated the thermal behaviour of conventional gypsum plasterboards, mostly under a standard fire (time-temperature) curve. Limited research has been undertaken on thermal behaviour of enhanced plasterboards. The dehydration of gypsum associated with the decomposition of calcium carbonate absorb heat, giving the plasterboard its fire protection qualities. However, the fire protection qualities of gypsum plasterboards have not been improved much despite their use for many years. Keerthan and Mahendran (2010) found that currently available Australian plasterboards showed that calcination is associated with two dehydration reactions at 100 to 150°C and 150 to 200°C, respectively, and resolved the contradictions among past researches. They have improved the understanding of the thermal performance of conventional Australian plasterboards under standard fire conditions including their thermal properties as a function of temperature, and developed validated thermal numerical models for plasterboards and LSF wall systems (Keerthan and Mahendran, 2012).

The 16mm standard plasterboard currently used in construction only provides 60 minutes of fire protection (non-load bearing LSF wall). When wall designs require increased fire resistance rating, multiple plasterboards are used to increase the fire resistance rating (FRR). By improving the specific heat capacity and reducing the thermal conductivity of the gypsum plasterboard, its fire rating could be increased to negate the need for additional plasterboards. The chemical composition of the gypsum plasterboard could be modified through the addition of chemical additives and fillers to improve the thermal properties of plasterboard. Figure 2 demonstrates the time-temperature profiles of standard and enhanced plasterboards under standard fires.

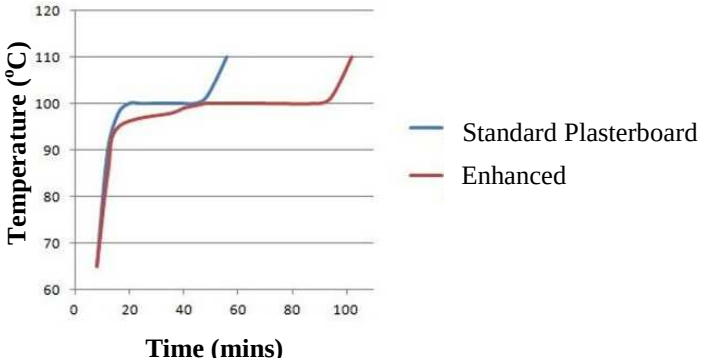


Figure 2: Time-temperature profiles of standard and enhanced plasterboards (Unexposed Face)

Plasterboard manufacturers use additives such as vermiculite to overcome shrinkage of gypsum core and glass fibre to bridge shrinkage cracks and enhance the integrity of board during calcination and after the loss of paper facings in fires. Attempts were made to reduce the thermal conductivity of plasterboard using fillers (Baux et al., 2008 and Baspinar et al., 2011). However, no research has been undertaken to enhance the specific heat and the points of dehydration using chemical additives and fillers. Thirty specific heat and density tests of powdered samples of plasterboard mixed with chemical additives and fillers in varying proportions were conducted. In this research, finite element (FE) models of enhanced plasterboards were also developed to simulate their thermal behaviour under standard fire conditions using SAFIR. Measured thermal properties of enhanced plasterboard were used in these FE models. This paper presents the details of experimental and numerical studies into the thermal performance of enhanced plasterboards and the results that can be used to enhance the fire safety of steel wall systems commonly used in buildings.

2. Thermal properties of standard plasterboard

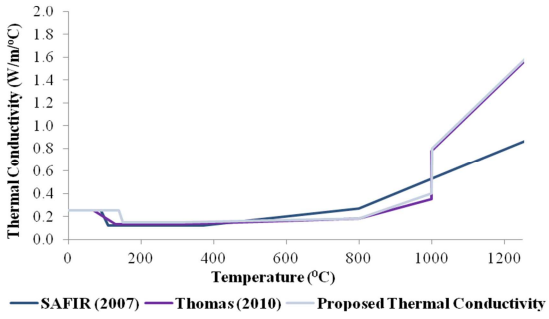
In order to develop suitable finite element models of Australian gypsum plasterboard, thermal properties of gypsum plasterboard were summarized based on a series of experimental results (Keerthan and Mahendran, 2011) and past research (Cooper, 1997; Thomas, 2010). Figure 3(a) shows the proposed thermal conductivity of gypsum plasterboard. In order to include the effect of ablation, the thermal conductivity of plasterboard was modified to 0.80 W/m/K at 1000ºC.

Past research showed some discrepancy in relation to the second dehydration reaction. However, it is concluded that the first and second dehydrations occur at 100 to 150ºC and

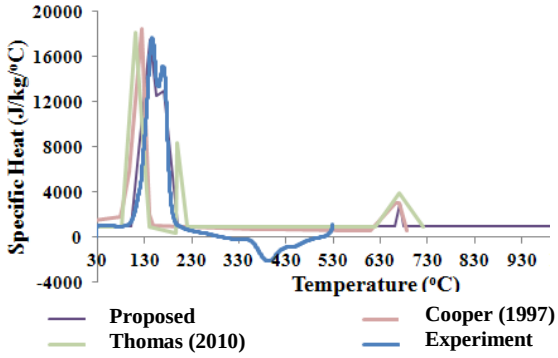
150 to 200ºC, respectively, based on our experiments (Keerthan and Mahendran, 2012). Figure 3(b) also shows the proposed specific heat values as a function of temperature and compares them with test and other researchers' specific heat values (Cooper, 1997; Thomas, 2010) while Figure 3(c) shows the relative density values as a function of temperature and compares them with test and other researchers' relative density values (Cooper, 1997; Thomas, 2010). Further details of the proposed thermal properties of plasterboards are given in Keerthan and Mahendran (2012). The specific volumetric enthalpy of gypsum plasterboard is given by the area under the specific heat multiplied by the density versus temperature curve as shown in Equation (1).

$$E(T) = \int_{T_A}^{T} C_p(T)\rho(T)dT \qquad (1)$$

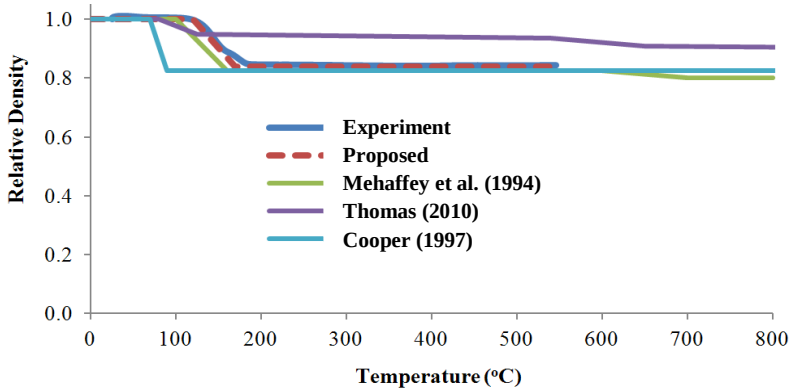
where E(T) is the specific volumetric enthalpy in J/m^3 at temperature T, Cp(T) is the specific heat (J/(kgºC)) and ρ(T) is the density (kg/m^3) at temperature T, and T_A is the ambient temperature. Keerthan and Mahendran (2012) recommended a convective coefficient (h) of 25 W/m^2/K for the exposed side of plasterboard and 10 W/m^2/K for its unexposed side. They recommended 0.9 as emissivity of plasterboard for both exposed and unexposed surfaces. When the proposed thermal properties were used as input to SAFIR, the time-temperature profiles agreed well with Kolarkar's (2010) fire test results.



(a) Thermal conductivity



(b) Specific heat



(c) Relative density

Figure 3: Proposed thermal properties of standard plasterboard (Keerthan and Mahendran, 2012)

3. Thermal properties of enhanced gypsum plasterboard

3.1 Literature review

In order to enhance the fire resistant rating (FRR) of gypsum plasterboard, past researches have investigated the effects of fillers and additives on the thermal properties of gypsum plasterboard. Baux et al. (2008) investigated the effects of silica based filler on the thermal and mechanical properties of gypsum-based panels. They also investigated the effects of silica filler on shrinkage and cracking caused during the dehydration of gypsum. Figure 4 shows the thermal conductivity of gypsum board as a function of the filler content. The results show that adding the filler dramatically decreases the thermal conductivity.

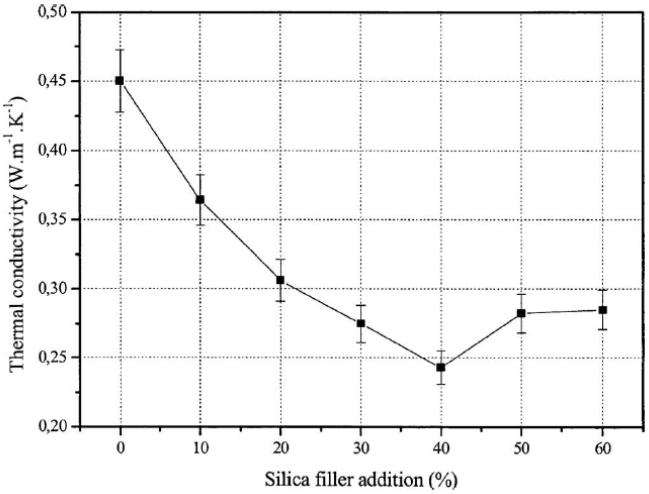


Figure 4: Thermal conductivity versus Silica filler addition (Baux et al., 2008)

Figure 5 shows the time-temperature profile of 40 mm gypsum panel (Temperature measured 30mm from the exposed face of the gypsum panel). Baux et al. (2008) observed that the time-temperature profile consisted of three stages when there was no filler addition and four stages when the silica fume was present (see Figure 5). The exposed side of the panels after fire tests is shown in Figure 5 (Baux et al., 2008).

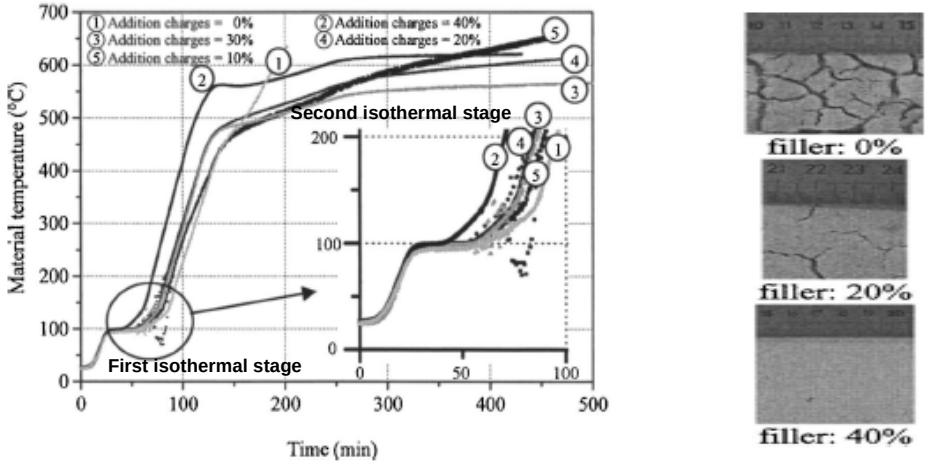


Figure 5: Time-temperature profile of 40 mm gypsum panel (Baux et al., 2008)

Baux et al. (2008) found that the length of first isothermal stage depends on the gypsum amount. They found that the shrinkage induced by the dehydration increases the heat flow through the panels and consequently increases the temperature of the unexposed side.

The two first stages of gypsum panels with silica fume are similar to those of the gypsum panels without filler. The length of the first isothermal stage depends on the filler amount. Addition of fillers (silica fume) decreases the specific heat of gypsum. The second isothermal stage at 600°C is not induced by another phase change (see Figure 5). It is due to the stabilization of the heat flow activated by thermal conduction and convection (Baux et al., 2008).

Baux et al. (2008) found that adding small amounts of silica filler to the plaster gives the following advantages. The propagation of the microcracks related to the dehydration of gypsum is blocked. The compressive strength increases as the density decreases and the thermal conductivity is reduced. One drawback is the reduction of specific heat capacity due to the substitution of gypsum by silica fume. Baux et al. (2008) found that the use of aluminosilicate fillers is promising above 1000°C.

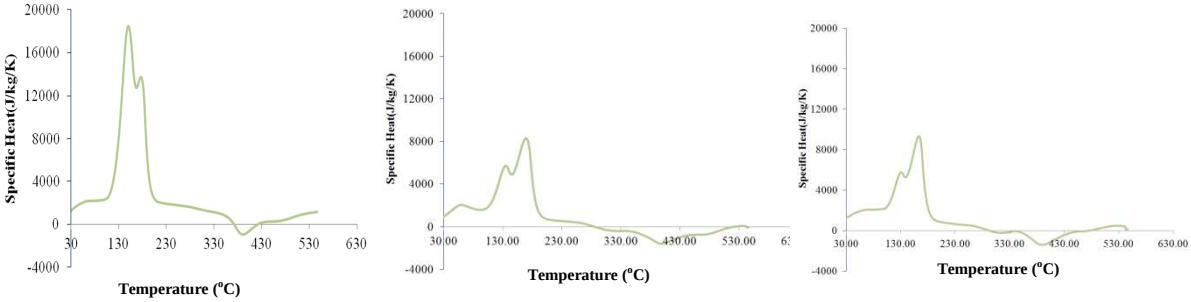
Baspinar and Kahraman (2011) found that addition of expanded silica gel granules to hardened gypsum decreased the bulk density of product significantly without any significant loss in compressive strength. They also found that Macroporous foam like structure of expanded silica gels decreased the thermal conductivity of hardened gypsum at around 61.3%. High temperature durability of the hardened gypsum product was also improved when the expanded silica gel granules were added. They concluded that expansion of silica gel is a controllable process and its addition to gypsum product improves many properties. Table 1 shows the results of thermal and mechanical test results. It shows that adding the silica gel dramatically decreases the thermal conductivity of gypsum.

Table 1: Properties of gypsum-expanded silica gel samples (Baspinar and Kahraman 2011)

Name of the series Expanded silica gel (wt.%)	G0 0% (control series)	GS5 5%	GS10 10%	GS15 15%
Water absorption	22.98	21.88	21.59	17.91
Apparent porosity (%)	30.07	24.13	21.68	Not measured
Bulk density (g cm^{-3})	1.31	1.10	1.01	0.89[a]
Compressive strength (MPa)	3.21	3.09	2.73	2.38
Flexural strength (MPa)	2,51	2.16	1.86	1.14
Ultrasonic wave Velocity (m sn^{-1})	4760	5750	6620	7190
Calculated ultrasonic Young modulus (GPa)	29.68	36.24	44.26	46.01
Thermal conductivity (W/m K)	0.31	0.25	0.21	0.16

3.2 Thermal properties of enhanced plasterboards

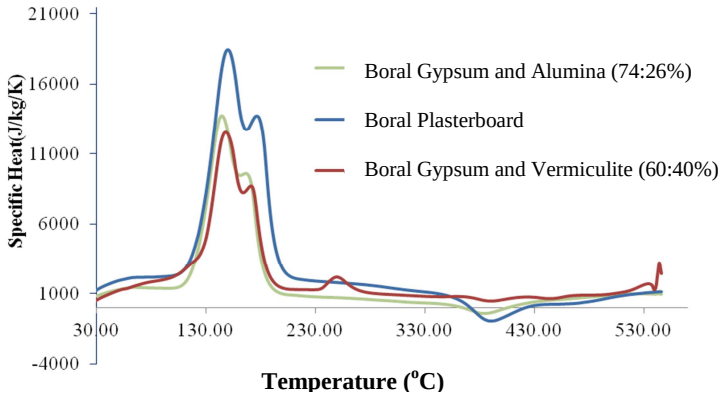
The thermal properties of conventional/standard plasterboards (Boral, CSR and Knauf) were measured (see Figure 6), which showed that Boral Firestop plasterboard's thermal properties are superior to those of other conventional plasterboards. Hence only the Boral Firestop plasterboard was considered in this research to further enhance the thermal properties.



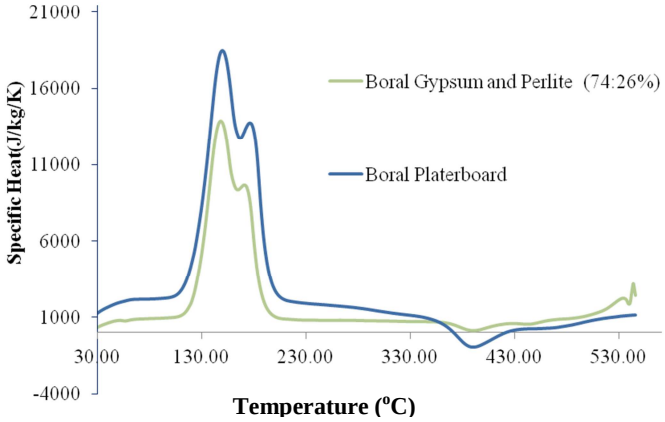
(a) Boral Plasterboard *(b) CSR Plasterboard* *(c) Knauf Plasterboard*

Figure 6: Specific heat of different types of Australian plasterboard

Thirty specific heat and density tests of powdered samples of plasterboard mixed with chemical additives and fillers in varying proportions were conducted using differential scanning calorimetry (DSC) and thermo-gravimetric analysis (TG) to determine suitable combinations that improve thermal properties.

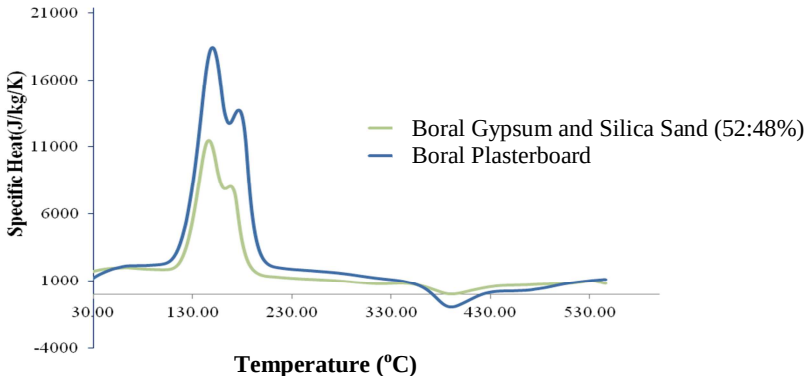


(a) Alumina and Vermiculite



(b) Perlite

Figure 7: Effect of chemical additives on the specific heat of plasterboard



(c) Silica sand

Figure 7: Effect of chemical additives on the specific heat of plasterboard

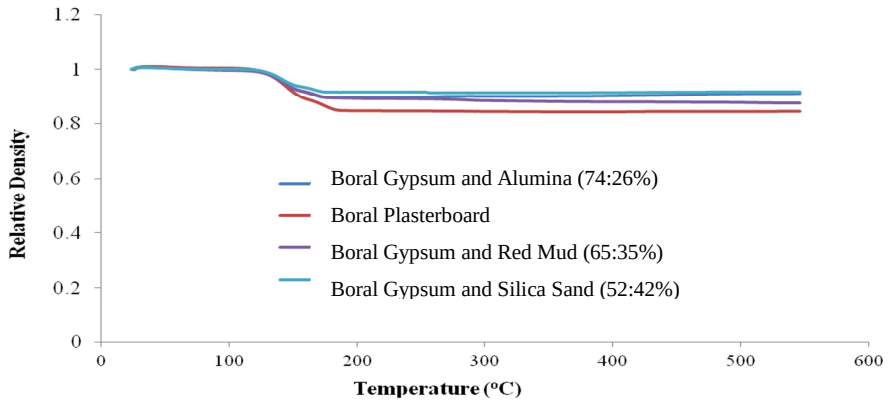


Figure 8: Effect of chemical additives on the relative density of plasterboard

Initially chemical additives and fillers such as Perlite, Alumina, Silica Sand, Calcium Silicate and Vermiculite were considered. Figures 7(a) to (c) show the effects of using them on the specific heat of the gypsum plasterboard while Figure 8 shows the effects on the relative density of the gypsum plasterboard. Figure 7 shows that chemical additives and fillers such as Vermiculite, Alumina, Perlite and Silica sand reduce the specific heat of the plasterboard, and this is not desirable although Vermiculite produced a third peak at approximately 260°C. Figure 8 shows that adding Vermiculite, Alumina, Red Mud and Silica sand increase the relative density of plasterboard, which is useful. These chemical additives and fillers will also reduce the shrinkage induced by the dehydration and reduce the heat flow through the panels. Overall, the use of Perlite, Alumina, Silica Sand, Calcium Silicate, Red Mud and Vermiculite is not likely to produce significant improvements to the thermal performance of plasterboards.

In the second stage of our tests two chemical additives that are by-products of industrial waste were attempted. Figure 9 shows that the use of these chemical additives (A and B) are able to enhance the specific heat of plasterboard with four peaks and increased the enthalpy of plasterboard. During heating, the relative density of plasterboard reduces slightly (Figure 10) and therefore the specific volumetric enthalpy given by the area under the specific heat multiplied by the density versus temperature is the most important parameter

governing its thermal performance. By increasing the enthalpy and reducing the thermal conductivity, fire resistant qualities of plasterboards can be significantly improved. Test results in Figure 9 show the presence of four peaks instead of two observed for standard plasterboards and the resulting enhancement of enthalpy by 35%. Its thermal conductivity is reduced from 0.25 to 0.1 after two peaks. Hence four peaks will lead to further reduction in thermal conductivity (0.05). However, thermal conductivity of standard plasterboard was used in our numerical studies conservatively.

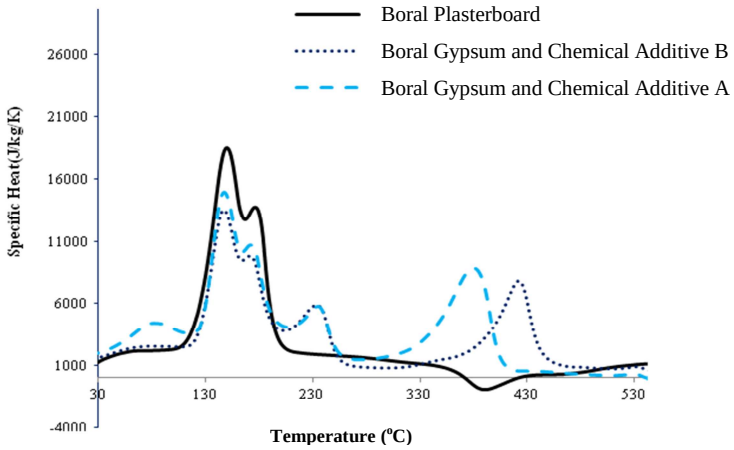


Figure 9: Effect of chemical additives A and B on the specific heat of plasterboard

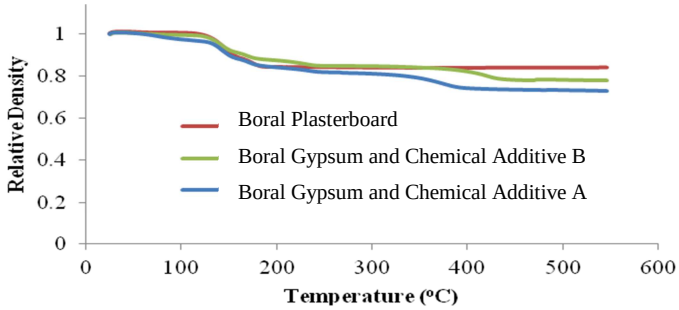


Figure 10: Effect of chemical additive B and Red Mud on the relative density of plasterboard

It was found that Boral gypsum with chemical additive A provided the higher specific heat capacity and resulting enhancement of enthalpy by 35%. Hence the measured thermal properties of Boral gypsum with chemical additive A were used in numerical studies.

4. Numerical studies of the thermal behaviour of load bearing LSF wall panels with enhanced plasterboards

4.1 General

This section presents the details of the numerical studies into the thermal behaviour of the load bearing LSF walls with enhanced plasterboards and their results. Recently many numerical heat transfer models have been developed (Alfawakhiri, 2001; Franssen, 2005). There are also many general finite element packages that can be used for thermal analyses. The finite element model employed in this study to predict the thermal behaviour of load bearing LSF wall panels with enhanced plasterboards was based on SAFIR (Franssen,

2005). SAFIR is a special purpose finite element program for the analysis of structures under ambient and elevated temperature conditions. In this research the GID software was used to create the input file for the models as well as analysing the model output results.

4.2 Thermal boundary conditions and material properties

The heat flux at the boundary will be calculated from the temperature of the fire curve T_g and the temperature on the surface T_s according to Equation (2).

$$q = h(T_g - T_s) + \sigma\varepsilon(T_g^4 - T_s^4) \quad (2)$$

where q is the total heat flux, ε is the relative emissivity, σ is the Stefan–Boltzmann constant (5.67E−08W/m^2/K^4), T_g and T_s are the gas and surface temperatures, respectively. For fire exposure to the standard cellulosic curve, T_g = 345log(8t+1)+293. Convective heat transfer coefficient (h) is approximately 25 W/m^{2}K on the fire exposed side, and it is 10 W/m^{2}K on the unexposed side. Emissivity of 0.9 was used for both exposed and unexposed surfaces. Default thermal properties (specific heat and thermal conductivity) for both Type X and Type C gypsum plasterboards within SAFIR are based on Cooper's (1997) research. However, the measured thermal properties of enhanced plasterboard in Section 3.2 were used in this research (Boral gypsum with chemical additive A). Since the thermal conductivity of enhanced plasterboard was not measured, thermal conductivity of standard plasterboard was used in numerical studies conservatively. Figure 11 shows the finite element models of LSF wall with two enhanced plasterboards on each side. Here three voids were created to transfer the heat through radiation and convection. Elements surrounding an internal void were assigned in the counter clockwise direction.



Figure 11: Finite element modelling of LSF wall panel

It is necessary to validate the developed finite element models for the thermal analyses of standard and enhanced plasterboards and load bearing LSF walls with enhanced plasterboards. This was achieved by comparing the time-temperature profiles with the corresponding fire test results of standard plasterboard and load bearing LSF walls with standard plasterboards (Kolarkar, 2010). Hence validated finite element models can be used for the thermal analyses of load bearing LSF walls with enhanced plasterboards. Details of the validated thermal finite element models are given in Keerthan and Mahendran (2012).

To demonstrate the improved thermal performance and associated high FRR, the validated thermal FE model developed in Keerthan and Mahendran (2012) was used with the measured thermal properties of enhanced plasterboards to predict the time-temperature curves in LSF walls. Failure time (FRR) of load bearing LSF wall with two 16 mm standard plasterboard is 111 mins for a load ratio of 0.2. Figure 12 shows that the LSF wall steel stud temperatures [hot (HF) & cold (CF) flanges, web] are considerably reduced in comparison to standard plasterboards under standard fires. This means that the failure time (FRR)

increases from 111 to 146 mins based on the limiting temperature of 500ºC when enhanced plasterboards are used, ie. 32% increase. Figure 13 shows the temperature distributions of LSF walls with two 16 mm enhanced plasterboards under standard fire conditions. Fire resistance rating is determined based on insulation, integrity and structural failure. This paper focus on limiting temperature of the stud, which is an indirect measure of the structural failure.

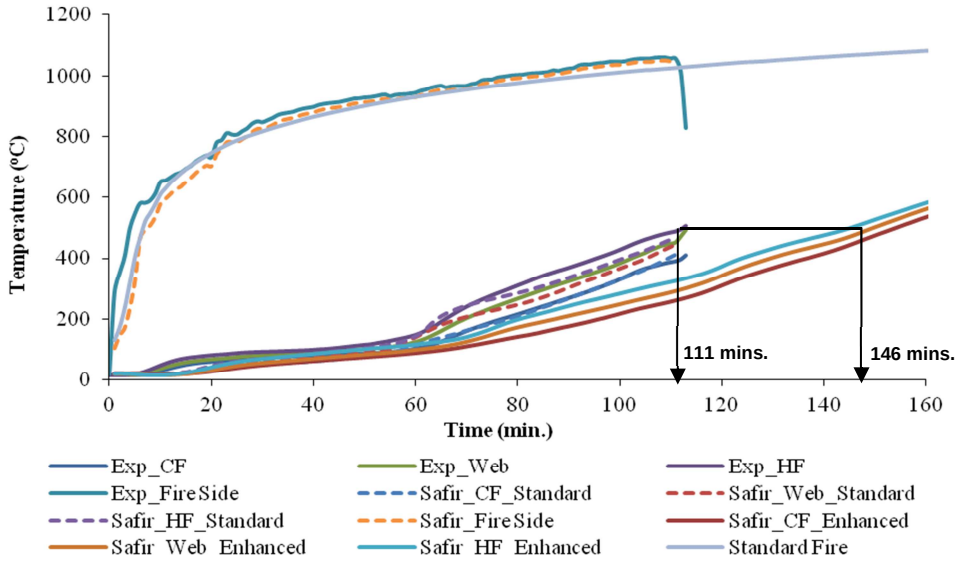
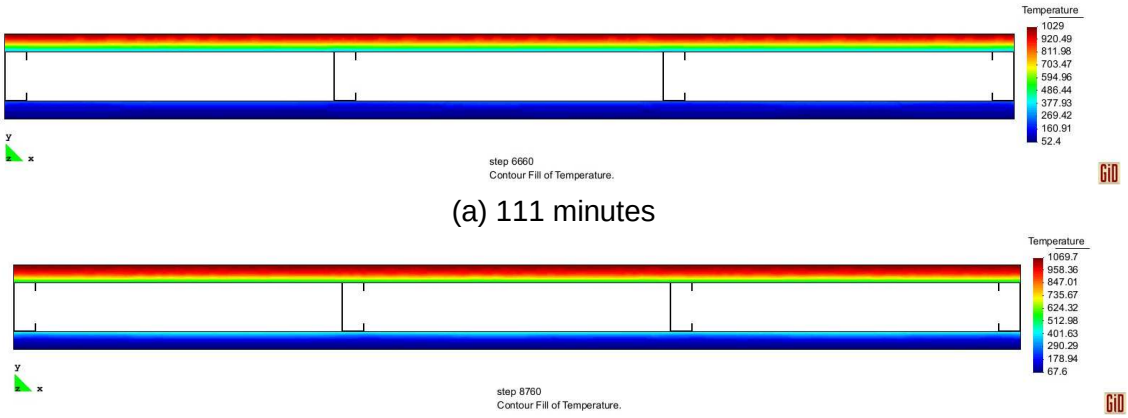


Figure 12: Time-temperature profiles of LSF wall with two 16 mm enhanced plasterboards



(a) 111 minutes

(b) 146 minutes

Figure 13: Temperature distributions of LSF walls with two 16 mm enhanced plasterboard under standard fire conditions

5. Conclusions

This paper has presented the effects of using chemical additives and fillers on the thermal performance of gypsum plasterboard. It was found that the use of suitable chemical additives is able to enhance the specific heat of plasterboard with four peaks and increased area under the curve (Enthalpy). Numerical models were also developed to investigate the thermal performance of load bearing LSF walls with enhanced plasterboards under standard

fire conditions. The results showed that enhanced plasterboards can be used with LSF walls to significantly improve their fire resistance rating.

6. Acknowledgements

The authors would like to thank Australian Research Council for their financial support and the Queensland University of Technology for providing the necessary facilities and support to conduct this research project.

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Offshoring engineering

- Experiences of Scandinavian Engineering Consultants

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Abstract

Offshoring, a strategy of transferring activities across national boarders, is becoming increasing attractive for engineering consulting firms operating in Europe. Offshoring may occur through using external resources (outsourcing) or through relocating internal activities (foreign direct investment, captive arrangement). The consulting companies may experience lack of skilled personnel and or an increasing pressure on costs. Moreover countries like India offers highly qualified engineers at a relative low pay.

The aim of this contribution is to investigate Scandinavian based consulting engineers' experiences using offshoring. It often begins with a single project, but early positive experiences and for example Indian flexibility quickly can lead to a much more profound collaboration and even to a strategic transformation of the Scandinavian firm.

Theoretically the paper builds on international business and strategic management approaches. The empirical method is desk research looking at selected companies in Denmark, Sweden and Norway. The study is of exploratory nature and focus on a single case supplemented with a preliminary status of the 30 largest consulting engineering companies in Denmark, Norway and Sweden. Through the literature search on offshoring in general and a compilation of studies of engineering offshoring it is shown that offshoring involve significant strategic choices and are not sufficiently dealt with if understood as single project endeavours. Moreover even within the project frame, trust, communication and proper (soft) management are important. The results thus show that a transactional approach to the collaboration appears to be insufficient and that the offshoring firm can be seriously challenged in its strategy. Offshored task encompass BIM design, design of standard bridges and even larger infrastructure projects. The firm strategies in using offshoring are differentiated; in house, outsource, offshore, and captive local investment. Consulting Engineering firms in Scandinavia entering offshoring should practice openness

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for a longer term journey of learning and strategic engagement even if the collaboration start with a single project and even possibly ends there.

Keywords: Offshoring, Consulting Engineering, Scandinavia, International Business.

1. Introduction

Engineering outsourcing is expected to be a business worth US$150 billion a year by 2020, which would make it five times larger than it was in 2010 (Sehgal et al 2010). It is common to assume that companies are seeking to cut costs for an expensive activity, i.e. the engineering of new products, by placing it in low cost countries (Sehgal et al 2010). The largest engineering offshoring destination is India, with about 25 percent, but China is also an important location and its role will increase in the coming years (Sehgal et al 2010). Together India and China graduate more than 800,000 new engineers each year, most of them willing to work at pay far below the Western levels (Messner 2008, Sehgal et al 2010). A series of other countries also host offshored engineering such as Philippines, Malaysia, Thailand, Brazil, Hungary, Ireland, and the Czech Republic. Companies doing offshoring of their engineering works are predominantly based in United States accounting for 70 percent of the business, with Europe and Japan covering the rest (Sehgal et al 2010).

The aim of this contribution is to investigate Scandinavian based consulting engineers' experiences using offshoring. It often begins with a single project, but Jensen (2009) shows how early positive experiences and Indian flexibility quickly can lead to a much more profound collaboration and even to a strategic transformation of the Scandinavian firm. In an international perspective the Scandinavian consulting engineering companies are mediumsized. The largest having an annual turnover just above 5 billion and headcount in the range 4-8000 (The Swedish Federation of Consulting Engineers and Architects, STD 2010).

Theoretically the paper builds on international business and strategic management approaches. The results from this strand of research is reviewed and drawn upon. The empirical method is desk research looking at selected companies in Denmark, Sweden and Norway. A single case is described and analyzed along with the status of the consulting engineering companies. Managerial implications are drawn for the Scandinavian companies.

2. Method

The overall approach is multidisciplinary, but with a basis in the Resource Based and Knowledge Based Views of the firm (RBV and KBV, Bunyaratavej et al. 2011, Grant, 1996, Vivek et al., 2009). An interpretivist and abductive epistemology is used (Dubois & Gadde, 2002).

The theoretical frame is first informed by a literature review carried out in summer 2012, following Hart (2009) and Webster & Watson (2002). The search's aim was to assess the knowledge accumulated in leading journals on offshoring companies' longer-term development and their internal and external organization. The delimitation of the search –

following Hart (2009) – was aided by relying on previous literature reviews of the area (Bunyaratavej et al., 2011; Hätönen & Eriksson, 2009). These reviews suggest that international business, strategic management, operation management (supply chain management), (industrial) marketing and purchasing would be important research strands to pursue, not giving construction or consulting engineering special attention. The three search engines used were primarily Science Direct, secondarily ABI/Informs and Business Source Complete (EBSCO). The time scope selected was 2007 and on, focusing on the most mature offshoring setups. Articles and journals oriented toward IT technology were disregarded (but not business studies of IT sector firms). Several consecutive searches, were made, giving a seven-article sample with longitudinal studies of offshoring. This focused sample includes four articles from *Journal of World Business* (Jensen, 2012; Lampel & Bhalla, 2011; Periera & Andersson, 2012; Vivek et al., 2009), one article from *Journal of International Management* (Jensen, 2009), one from *European Management Journal* (Hutzschenreuter et al., 2011), none from *Journal of Operations Management* and many other journals included in the first search.

Second supplementary references on engineering offshoring in the global construction industry were gathered (Jarvenpaa and Keating 2012, Messner 2006) as well as broader studies of engineering offshoring (CEO 2008, Lewin et al 2009). A Science Direct search in the two areas revealed very scarce sources, Jensen (2009) being one exception.

To identify the largest Scandinavian engineering consulting companies, the STD (2010) study was used. The ten largest in Denmark, Norway and Sweden measured on turn over and number of employees was selected. Each of them was studied through desk research using annual reports, media coverage, linkedin data and other types of information. Material on offshoring was found on consulting engineering companies operating in Scandinavia with headquarters in Denmark and Sweden, but not in Norway. Two long term cases were particularly well described. For anonymity reasons the case description below is a mixture of the two, and Danish sources are left out (translation from Danish is carried out by the author). The case should be considered as early stage exploratory, relying on secondary sources. Also the desk study material of the largest engineering consultancy companies constitute an early stage exploratory study of offshoring, and it was chosen only to use this material in the discussion only as comparison to the case company.

The limitations of the present research work are thus the limited empirical basis it is built on. It is for example not possible to discern global presence of the investigated consulting engineering companies with a local business in say India, from offshoring of tasks from Western Europe to India. Moreover a theoretical contribution should develop a framework for understanding project based companies doing offshoring and the longer term impacts.

3. Frame of Understanding

First a definition of offshoring is provided then offshoring developments in general is described and finally within engineering and construction.

3.1 Definition of Offshoring

Offshoring is defined here as a strategy of transferring activities across national borders, which may occur through using external resources (outsourcing) or through relocating internal production activities (direct foreign investment, captive arrangement) (Bunyaratavej et al., 2011; Hätönen & Eriksson, 2009). It follows that outsourcing and offshoring overlap and is related, as shown in table 1.

Table 1. The four main strategic options of offshoring /outsourcing (adapted from Bunyaratavej et al., 2011)

	Insourcing	Outsourcing
Onshore	1.Internal domestic Provision	3. Domestic outsourcing
Offshore	2.Captive/foreign subsidiary Offshoring	4. Offshore outsourcing

Offshoring and captive setup refers to the situation where the firm owns and runs offshored units in another country (Bunyaratavej et al. 2011), whereas offshore outsourcing refers to the situation with simultaneous transfer of ownership and location of an activity (Hätonen & Eriksson, 2009: 147). This definitional model is challenged by multiple practices of the companies that involve a range of hybrids, in-betweens, intermediaries, expats etc.

3.2 Long term offshoring tendencies

Offshoring has been around for some time and longer term trends are emerging. Hutzschenreuter et al. (2011) study the development of white collar offshoring and Hätönen & Eriksson (2009) the practical and theoretical development of outsourcing in a systematic manner. The parallels between the two studies lead to adopting Hätönen and Eriksson framework as covering offshoring as well. Although the framework is tentative and ex-post, it can be used as a systematic attempt to conceptualize longer-term offshoring developments. The framework consists of four phases:

- Transactional
- Resource seeking
- Transformational
- Developmental

The first phase is transaction. Hätönen & Ericsson (2009) characterize it as a “big bang”, where the make or buy dilemma seriously tilts toward buy. Activities are turned over to outside vendors in the belief that market mechanisms of distant markets result in lower transactions costs. Transaction Cost Economics (TCE) is the main theory. The second phase is resource seeking. Here, companies rely on external sources to provide production components and services. The main theory becomes the Resource Based View (RBV) (Hätönen & Eriksson, 2009: 152).

The third phase is transformational. The main theory is RBV, in combination with organization theory. In this phase, all parts of an organization can in principle be turned over to outside vendors (Hätönen & Eriksson, 2009: 152). And as offshoring and outsourcing become integrated legitimate tools in the management repertoire, the concerns turn to the timing of offshoring.

The fourth phase is developmental. Here, the organization becomes increasingly boundaryless and managing business development and continuous improvement of internal activities can even become part of offshoring/outsourcing arrangements (Hätönen & Eriksson, 2009: 152). Management takes the form of portfolio management, as many internal activities are project-oriented. Yet, longer-term perspectives of external sourcing are employed, even as a ‘lifecycle’ perspective. This implies that the main theory applicable is RBV according to Hätönen & Eriksson (2009).

The studies reviewed show that, by 2012, almost any part of a classical hierarchical organization can be subjected to offshoring and provide a range of examples. Most longitudinal studies occur in the service sectors (Finance, IT and engineering; Hutzschenreuter et al., 2011). They cover R&D, Engineering, IT development, HR support functions and more (Jensen, 2009, 2012; Lampel & Bhalla, 2011).

The longitudinal studies do not equivocally comply with Hätönen & Eriksson’s (2009) framework. Firms offering low-cost service products continually use offshoring with a strong cost focus (Lampel & Bhalla, 2011). Even when the companies achieve high-value core activities, they may be forced to continue outsourcing and offshoring to stay in their market segment and keep their overall costs low. Lampel & Bhalla (2011) offer this type of case in telecommunications. Over a six-year study period, the company offshored more and more and struggles with increasing coordination (employees travelling back and forth) to handle this. Activities offshored include customer services, software development of an internet order portal, a billing system and a triple-play system (offering customers TV, broadband and telephone). Offshored core value-creating activities have to be tightly coupled to the main firm. Lampel & Bhalla (2011) use configuration theory, combining strategic positioning and organizational design elements; however, their analytical result remains close to the rich longitudinal case, which is thus implicitly viewed as unique.

Jensen P. (2009, 2012) combines RBV, activity-based and international business network to cover internal and external elements of offshoring outsourcing. He study three cases, two financial and one engineering consulting firm. In two of three cases, the longitudinal scope is three and five years (Jensen, 2012), while the third covers one year (Jensen, 2009). All three

longitudinal cases show a high level of interconnectedness between the Danish firms and their Indian offshoring partners. They use project organization as the first organizational instrument, in the collaboration with the Indian software providers. Jensen (2012) finds that the company emerges into viewing offshoring as a new strategic opportunity. One firm realizes a quick expansion of the first offshored project, and soon several hundred Indian consultants are involved, 30% of them at the Danish site. After the transfer of a first project, another firm even experiences a rather quick development through project expansion (resource seeking) to a transformation of strategy (Jensen, 2009), due to the Indian partner's European customer portfolio, which provides a strategic expansion option for the Danish firm to the European market. Both the two longer-term case companies establish IT development centers at their Indian partners' facilities and station expatriate managers at these centers. These expatriate managers facilitate coordination and communication between the Danish and Indian parts of the cooperation.

Summarising, the literature study on longer term offshoring development conducted, reveals varying responses to the long-term pattern. Bengtsson & Berggren (2008), Hätonen & Eriksson (2009) and Vivek et al. (2009) find a shift from transactional relations to relation-based approach and complementarity. Lampel & Bhalla (2011) and Periera & Anderson (2012) find continued focus on transactions and low cost. On this basis, it is not possible to follow Hätönen & Ericsson (2009) and Vivek et al. (2009) in their claim that transaction cost economics is becoming obsolete to the benefit of the resource-based view and other complementary resource-oriented theories.

3.3 Engineering and Construction

Within engineering and construction one can find a similar tension between companies that continue to focus on the single project cost when collaborating with domestic and global partners, and others that change their business strategy and enter a transformative and developmental mode (COE 2008, Jensen 2009, 2012, Messner 2008).

The committee of offshoring engineering, COE (2008), suggests a distinction between engineering, procurement and construction (EPC) and Architecture, Engineering and Construction (AEC). Where EPC have considerable experience and practice within offshoring, in their delivery of civil engineering, infrastructure and large plant facilities, AEC is –suggests COE- focused on dwelling and residential housing. COE (2008) finds that 62% of the EPC companies were using offshoring for many projects in 2004. Also some AEC companies consider offshoring but to a far lesser degree than EPC companies Messner (2008). The EPC sector often require many hours of engineering work, much of it related to detailed engineering (Messner 2008). Messner provides examples like the sizing and routing of piping; the design and location of electrical conduits and wiring; and the detailing of structural elements (Messner 2008). He claims that this type of repetitive, detailed engineering work makes offshoring more attractive than in some other design practices, because it appears possible to systematize this type of work and it requires less direct communication between the designers.

Messner (2008) points out that most EPC companies appear to have international offices and are participating in multi-office execution strategies for the delivery of projects. Many of them have offices in low-cost engineering locations, such as India, China, Czech Republic, Russia, Romania, Poland, Mexico, and Taiwan (Messner 2008). Some of these offices were established specifically to provide low-cost engineering services for company projects. Others were developed to perform specific design tasks for domestic construction projects. STD (2010) points out however that business models of consultancy firms encompasses many that cut across EPC and AEC. The STD study points at a group of companies that are multidisciplinary and other that are more specialized. The largest companies however at a time exhibit multidisciplinary regional proximity to Scandinavian markets and a multinational more narrow profile, such a Norconsult within hydropower or COWI within large bridges. These companies thus combine multidisciplinarity and multinationality (Koch 2004).

When offshoring is carried out on the basis of single projects, it provides other conditions than in longer term alliances or in captive subsidiary arrangements. Jarvenpaa and Keating (2012) study a project based collaboration between a US engineering company and its Indian collaborator occurring as first several consecutive projects and then as a captive arrangement realised through the US company acquiring its Indian partners. The suggested pattern by Hätänen and Erikson (2009) was in this respect refound. On the other hand the engineering firm set up also included a Romanian company which recurrently had projects with the US company yet remained independent.

The project collaboration studied by Jarvenpaa and Keating (2012) involved design of parts of a processing plant including components such as piping, pumps, foundations, and meters. It involved coordination of multiple engineering disciplines (e.g. piping, structural, instrumentation, and electrical). Detailed design representing 30–60% of the project was completed while engineers worked geographically apart. The coordination demands were highest in relation to the operations in India and Romania, where expat engineers either were not used on the project team, or were used only for brief periods and which therefore relied on technology mediated communication. Although co-location of the onshore and offshore engineers happened in the beginning of the project in the context of kickoff meetings, afterwards only occasional and brief travel occurred between the sites.

Jarvenpaa and Keating (2012) find outspoken project member articulation of need for more communication. Project plans and task allocation between onshore and offshore are frequently changed during the project. This trigger overwork at the Indian party and formalisation from the Romanian party, whereas the US party appears to lack behind in additional follow up planning. The set up come to exhibit asymmetric trust where the offshore teams are forced to trust the onshore team, whereas the opposite is not quite the case (Jarvenpaa and Keating 2012:76). The use of technology mediated communication changes communication from informal and de-central to formalised and centralised. It is difficult for the teams to use formalised roles and rules as unrecognised formal and informal hierarchies of the participating organisations “intervene”. The managerial practices of the project managers exhibit a range from dominance to coaching, where Jarvenpaa and Keating (2012: 81) observe that the coaching oriented management role appear most effective.

It can be noticed that both EPC and AEC construction frequently uses constellations of new team members where swift trust and occupational stereotypes are important (Koch and Thuesen 2011). And where mechanisms parallel to the ones found by Jarvenpaa and Keating occurs. Even if offshoring scholars like Bunyaratavej et al. 2011, Hutzschenreuter et al. (2011)and Hätönen & Eriksson (2009) expect offshoring relations to mature, the construction industry is "used" to the costs of excessive transactions and projectbased offshoring might therefore prevail.

4. Case

The case study discusses a Danish owned multinational consulting engineering enterprise, a regional and international firm with main office in Denmark (called ConsultCo). Main activity areas comprise engineering consulting on energy, environment, infrastructure, building and operations, construction management, economics, general management and information technology. These areas are organised in nine strategic business units (SBU) supported by a general services department encompassing the IT organisation and staff. Major part of business development occurs within the SBUs. The company employs some 2000 in the parent company in Denmark, and its international organisation. Some 50% of the turnover is generated in Denmark.

The company has for long followed a strategy of globalisation combining leading edge expertise in selected products within civil engineering with a broadband regional presence in Northern Europe. This strategy has led to a number of mergers and acquisitions as well as offshoring of engineering design and other activities. Civil Engineering is a strong business area involving presence and engineering activities at a range of sites and countries around the world. The mergers and acquisitions have several times involved integrating captive units in low cost countries. Some routine engineering tasks have thus been produced in India in a fully owned subsidiary over around 30 years. The whole set of expansive activities has required integrative managerial actions.

A new wave of offshoring activities commenced roughly ten years ago. Initially SBUs throughout the company were hesitant and for this reason only small project works were offshored from time to time. A director stated:

"We cannot force our managers and staff to engage in offshoring to India. They must have a real incentive to do it, and it is therefore crucial that we are able to show good examples and positive results from offshoring that can create this kind of incentive across the organization"

However the offshored projects showed good results. The works was of good quality and documented cost savings were around 40%–50% in some types of projects, and between 20% and 30% in others. This gradually diffused across the various managerial levels and catalyzed an internal strategy development process about how the company could exploit the opportunity.

By 2012 Consultco's strategy is based on integrating the Indian units in its business. Some 450 employees in India encompasses 70 within detailed engineering design and it's an

strategic aim to continue growing the Indian unit. This implies however an interdependence and the Indian engineers are by now perceived by HQ to be demanding in terms of wages and task content. A Liaison officer responsible for contacts between Danish based and India based employees in Consultco puts it this way

“The Indian engineers knows exactly what they want. They ask critical questions, are voluntarily suggesting ideas and are clearly stating that they want to be along on the demanding tasks rather than just entering data”

The need for competence development, HR policy and practices is thus outspoken. The liaison officer continues

“Many of (the project members offshore at) our infrastructure projects are senior engineers, and several have requested to be part of the design of the motorway itself rather than just the exit ramps. We have tried to provide that”

The liaison officer is backed up by a senior manager pointing at the possibility of winning contracts of Indian infrastructure based on the companies competences, improving their attraction as work place for Indian engineers.

5. Discussion

First the case, then the sample of large Scandinavian consulting companies are discussed. The case company Consultco combines local and global presence and cover both EPC and AEC. It appears however that its offshoring activities are mostly related to its EPC activities. Its overall growth are by now dependent of a much differentiated performance of different business areas. Some are negatively impacted by the crises (the local Danish market), whereas others (India and civil engineering) are successful. The case shows how consulting engineering companies in Scandinavia can transform their business based on long term presence in India. The case shows a high level of interconnectedness between the Danish firm and their Indian offshoring partner. They use project organization as the first organizational instrument in the collaboration. After the transfer of a first project, the firm experiences a rather quick development through project expansion (resource seeking) to a transformation of strategy (Jensen, 2009), also because of the Indian partner’s European customer portfolio, which provides a strategic expansion option for the Danish firm to the European market. The firm station expatriate managers at their Indian subsidiary’ facilities and also use a liaison officer to enable the coordination and collaboration. Expatriate managers and liaisons officers are seen as facilitating coordination and communication between the Danish and Indian parts. Moreover the strategic transformation also implies that the two companies engage in a mutual dependency where retention of employees at the offshored unit also becomes an issue for the west European company.

Jensen P. (2009, 2012) raises the question of what impact offshoring professional services will have on the core company’s resources, referring to the risk of ‘hollowing out’ the core company. His engineering consulting case exhibit surfacing of new opportunities rather than hollowing out.

Other Scandinavian companies such as Ramboll, COWI, and Thyréns have followed this pattern, and there are some who follow the project set up pattern (for example ÅF). The preliminary screening or the largest Danish, Norwegian and Swedish companies shows moreover that many (Alectia, EK Jørgensen, Sweco, WSP Sweden), and especially some of the Norwegian do not operate offshoring at present (Asplan Viak, Hjellnes, Multiconsult, Norconsult). Hammarström et al (2012) interviewed nine CEOs of Swedish consulting engineering companies and find that they observe and follow the IT-companies offshoring practice, yet refrain from practising it themselves. Compared to large multinational engineering consultancy this status can be seen as ambivalent supplication to offshoring (STD 2010). Among the companies following a long term strategies of offshore presence there is infrastructure engineering companies who have operated worldwide with punctual presence for a much longer period than the last wave of offshoring reflects (such as Niras and Norconsult). They have thus long term experiences being multinational and can operate offshoring like arrangements internally. Offshored tasks encompass BIM design, design of standard bridges, motorways and even larger infrastructure projects. There was no examples of back office tasks like travel accounting, recruiting or other business processes being outsourced/offshored (re Pereira and Anderson 2012). The differences between firm strategies in using offshoring shows elements of in-house reliance on the regional market, and project or transformational offshoring set up, either as outsourcing, or captive local investment. Future research with have to address the particularities of project based construction companies in offshoring.

6. Managerial Implications for Scandinavian Consulting Engineering

Both amongst theorists and practitioners there are continued divergence as to whether offshoring should be a short term controlled exercise (project by project) or a long term transformation. Sehgal et al (2010) take the most initial point of departure in discussing the managerial approach to the very first project to offshore. Their advice is fivefold:

1. Choosing the Right Project
2. Identifying the Appropriate Business Model
3. Teaming Up with the Right Vendors
4. Creating Iron-Clad Performance Metrics
5. Establishing a Strong Governance Structure

They recommend not taking the most business critical and/complex projects, to go beyond the dichotomy of either outsourcing or establishing a captive unit (a subsidiary). This recommendation go along with the results of the literature study where many variants of set ups were found. While the recommendation of creating iron-clad performance metrics might sound attractive in addressing a core company manager's anxiety of risks of spending in vain. Jarvenpaa and Keating (2010) and the case reminds us of other -side- effects of establishing rules and regulations for carrying out engineering work. Jarvenpaa and Keating (2012) results underpin that strong governance might imply soft management, such as Consultco's Liaison officer also reflect. When recommending scrutiny of possible vendors

Sehgal et al (2010) suggest going beyond price and look into the vendor's capability and other experiences. This can be tackled through bidding procedures they claim.

However in focusing on the very first project in an offshoring relationship Sehgal et al (2010) seem to fall short of relating to the longer term strategic choices that are involved. Experiences in and outside construction point at emergent journeys of offshoring (Jørgensen and Koch 2012, Lampel and Bhalla 2012, Pereira and Anderson 2012). This insight puts the first project in another light. Then it's more of an initial probe of a possible future strategic partner, than a single business operation to be terminated as such.

7. Conclusion

The aim of this contribution was to investigate Scandinavian based consulting engineers' experiences using offshoring. The study are of exploratory nature and came to focus on a single case supplemented with a preliminary status of the 30 largest consulting engineering companies in Scandinavia, i.e. Denmark, Norway and Sweden. Through a literature review of offshoring in general and a compilation of studies of engineering offshoring it has been made indicative that offshoring involve significant strategic choices and are not sufficiently dealt with if understood as single project endeavours. Moreover, even within the project frame, trust, communication and proper (soft) management are important. There are indications of an ambivalent hesitation among the companies concerning offshoring. Consulting engineering firms in Scandinavia entering offshoring are suggested to exercise openness for a longer term learning and strategic engagement even if the collaboration might start and end with a single project.

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E-tendering -an emerging design – construction IT-bridge

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Abstract

E-tendering is gaining terrain these years, mostly as stand-alone solutions. This occurs in parallel to the received attention to Building Information Models (BIM) with its ambitions of integration and scope in the building processes. E-tendering is a much more direct practical type of IT solution use. E-tendering can be viewed as an island of IT as it often is implemented as stand-alone systems without much integration to processes before or after the tendering. Equally however E-tendering can be seen as a bridge especially between clients and contractors. The paper adopts a sociotechnical approach to IT systems and their use. It develops a tentative typology of e-tendering systems. The method is a desk study. The exploratory status made of E-tendering in several countries, especially UK, Germany and Denmark is presented. The status indicates an increasing use of E-tendering and with varying integration up and downstream. The paper discusses the increasing use of simple stand-alone systems and identifies four different concepts of E-tendering. The possible integration to BIM is understood as a long term goal that should be reached stepwise.

Keywords: E-tendering, IT, Denmark, public procurement, private procurement

1. Introduction

A Danish popular insight can be phrased ‘don’t let the best be the killer of the good’. IT in construction has often faced exactly that, conceptualizing grand programs of IT systems and IT-architecture that has little bearing in practice and which therefore tend to block more practical and modest steps forward. This paper sets out examining e-tendering in a context where BIM in various versions is all dominating the IT change agenda for construction (Bernstein 2010, 2012). Moreover in a Danish context a major development program is attempting to develop a classification system capable of solving the interoperability issues of the national building sector (cuneco 2013).

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The aim of this paper is to develop an analytical frame for analysing e-tendering systems and their use. And to carry out an exploratory investigation of found national sociotechnical E-tendering systems.

This paper adopts a sociotechnical approach to IT use in construction. When identifying concepts of E-tendering it is argued that technical organizational, economic and other social issues cannot be viewed as separate but has to be understood as a whole.

2. Method

The theoretical perspective of this paper is a sociotechnical approach to information systems and their use, viewing the software hardware, architecture and their business context, the economic and social aspects as inseparable (Linderoth 2010, Koch 2007).

The paper builds on a small study made in Denmark for the Danish Ministry of Climate, Energy and Building on digital tendering.

A selective literature study of journal articles and conference papers has been used to gather both practical experience from various countries, concepts addressing the tendering processes, and their placement in broader business processes. The texts have been found first by a search in the database 'Business Source Complete', second via Google obtaining the practice oriented material. In both searches using the search words 'E-tendering', 'e-bidding', 'e-business', 'procurement', 'construction procurement', 'purchasing' and 'construction procurement'. An element of iterative search has been used. Finally also material known by the project group was used. Only a small body of articles and papers was found and used.

To understand the emergence on BIM, three survey studies of diffusion of BIM was used (Bernstein 2010, Bernstein 2012, Samuelson 2011). It should be noted that these studies only partly cover the same countries as the desk literature study did.

It should be noted that it has been chosen not to reference primary material in Danish as the audience for this material would be limited in an international context.

It is a limitation of the country and concept comparison carried out below, that studies and materials used operates with different understandings of the involved business processes, differences going beyond simple country differences. Moreover the evaluation of advantages and disadvantages depends of the point of departure. This includes for example the present quality of tendering material. Another limitation stems from the resources granted to the study which excluded the study from systematically to assemble practical material and software supplier material of the many E-tendering portals avaible. The resource limitation has increased the study's dependency of scientific sources.

3. E-Tendering Conceptual Framework

Jung Lee (2010), drawing on Williams & Hardy (2007) and OECD (1999), proposes to understand E-tendering systems as being on different maturity levels. The three main dimensions of maturity are readiness, intensity and impact. According to Jung Lee (2010) and Williams & Hardy (2007) readiness describes the current use of e-procurement by organizations. This concept and 'intensity' is used to characterize the types of activities, products, and technologies that are part of e-procurement. Finally 'impact' characterise outcomes from the use of e-procurement; major benefits obtained; costs involved, challenges to further progress; and transformations arising from e-procurement initiatives. Below these concepts are adapted to characterize E-tendering. Using scope (of tasks) to cover the dimension of readiness and intensity, and diffusion (of the concept) as characterisation of impact. And finally these are complemented with social embedding (the organizational, financial, societal side) to emphasize and characterise the sociotechnical character of the E-tendering concepts.

3.1 Scope, coverage of building process steps

Jung Lee (2010: 417) proposes that maturity is measured across the following process:

Tendering, proposal making, evaluating, contracting, delivery, follow-up service

This conceptualization is however too narrow if more comprehensive BIM based models has to be considered. It is therefore proposed to evaluate the concepts across this understanding of the process

Briefing Design Tendering Contracting Planning Execution Operation

With a focus on tendering as the core interest, a tendering system can integrate upstream and/or downstream. Subcategories of tasks are used below when needed in the characterization of concepts, and the related costs and benefits. And for example "announcing" is understood as part of tendering and/or "sharing material with subcontractors".

3.2 Diffusion

The strength of the concepts in an industrial perspective relates a lot to its practical use. In a business with short profitability horizon, concepts should preferably be able to deliver on a 2-4 year basis. At the same time however concepts that are ready at the far end of such a horizon would be an option for innovation within the strategic reach of building companies. The concepts investigated thus reach from

Experimental, first implementation, many implementations, sector, national sector market, regional markets, globally

Linderoth (2010) for example view the diffusion process as an actor network development and gives examples of a number of barriers that BIM has experienced so far. The fragmented structure of the business and interoperability are two examples. Here the framework differs from Jong Lee (2010)'s as most of his dimension assumes that the domains has passed first time implementations.

3.3 Social Embedding

E-tendering and systems with a wider scope in the building process can be embedded several places. Systems might rest with the client, where a typical example would be the public sector clients. Or they might rest with the individual building companies, contractors, architects or consulting engineers. They could also be operated by various types of individual players such as associations or knowledge institutions. Especially when it comes to the business model of E-tendering, one could expect outspoken differences between social embeddings. The Business model could build on gratuity reaching to substantial long term investment by the buyer of the E-tendering service (and more services). The latter business model would be common by private suppliers of software, such as Autodesk or Bentley.

Summarising, the developed typology aims at with simple means to provide a characterisation of the sociotechnical E-tendering concepts, using scope, diffusion and social embedding as main characterisations. These concepts represent a modification of those of Jong Lee (2010), which are too oriented towards already implemented E-tendering on the one hand, and on the other fail to address E-tendering as part of comprehensive software packages covering substantial parts of the building life cycle processes.

4. International Concepts of E-Tendering

Our search for articles and materials found concepts from

- Australia (Gu & London 2010, Kajewski & Weippert 2004, Love et al 2001)
- Denmark (own material)
- Finland (Henttinen 2010)
- France (Prete 2010)
- Germany (Bauinfoconsult 2011, Scheig 2006)
- Korea (Jung Lee 2010),
- New Zealand (NZ Construction Industry Council 2006)
- Nigeria (Oyediran and Akintola 2011),

- Tyrkey (Isikdag et al 2011),
- United Kingdom (Lavelle & Barton 2009, Martin 2007,2008, BICS 2009)
- United States (Jung Lee 2010).

The Danish case build on the project material from the project mentioned above.

4.1 Found Concepts

Across the country experiences one can identify three characteristic concepts. The found concepts differ on technology, scope in the building process, the balance between electronic interaction and other interaction and business model. Each country usually encompasses several of the concepts.

4.2 Web Platforms

In a Danish context there would usually be a split between first briefing, design tools on the one hand and an E-tendering platform on the other hand, and second between the E-tendering platform and calculation systems used by the contractor. The tendering portal is not used in tandem with the calculation systems as most of the latter do no integrate. It's even so that seven E-tendering systems on the Danish market are entirely confined to the announcement of tenders, whereof the "Tenders Electronic Daily" (TED) is covering EU-tenders. Two systems provide higher scope in the E-tendering process "EU-supply" and "byggeweb". These are nevertheless thin portals with limited scope, but enjoy wide diffusion. They cover activities from announcement, distribution of tendering material and carrying out of the tender itself.

The Danish status of the building industry is use of a mixed form of paper and IT-tools in the tendering. A recent status made among contractors showed that roughly half of them had experienced using project web as tool in tendering and half of them had received bill of materials and volumes of materials electronically. Another survey showed that 39% of the building industry has downloaded tendering material of public tenders and 26% had delivered an electronic bid for a public tender. The tendering portals are primarily supporting the clients tendering process, the need to comply with EU- and Danish E-tendering rules. The portals do not support the contractors/bidders efforts in structuring the material and its further preparation through price and calculation systems. A well exercised example of a thin E-tendering portal is the system launched by Royal Institute of Chartered Surveyors (RICS) in United Kingdom in 2007. This E-tendering platform is operated by Building Centre for Information Services (BCIS), and is well documented (Martin 2007, Martin 2008, BICS 2009). The RICS concept builds on a relatively simple portal and does not integrate with other systems. RICS offers four types of digital tenders. The client/tenderer can distribute all documents via the portal to bidders (contractors). And a messaging system can be used to administer additions and changes. Building Centre for Information Services (BCIS) published a series of supportive and complementary material, such as price databases. According to Lavelle & Barton (2009) RICS found already in 2004 that 82% of the quantity surveyors in

United Kingdom used e-tendering to a certain extent and on a series of different portals. This result compares too that 54% indicated that the only accepted tenders on paper. In Australia, Williams & Hardy (2007) found that 43% of the member of a procurement association had used e-tendering. This result cuts across sectors. Similar to the Danish and UK market the Australian marked operate thin portals for e-tendering. The largest web-based tendering network in Australia is probably “Tenderlink” (Tenderlink 2012). It covers from initial advertising to bid response evaluation. Tenderlink has public and private clients. It uses a “pay as you go” business model. Another system is the public GEM system in Western Australia. This system covers tendering, purchasing and contracting in a loosely coupled set of software packages (Australian Government 2005).

4.3 Software integration of Tendering-contracting-invoicing

In Germany there is a combination of public and private systems. Scheig (2006) covers public German tendering portals at land level (as opposed to federal state level), while Bauinfoconsult (2011) covers a series of private software firms offering tendering management systems which are diffused among half of the German architects (Bauinfoconsult 2011). It appears that a German de facto standard has developed which integrates tendering, contracting and invoicing (”Ausschreibung-Vertrag -Abrechnung” AVA software, Bauinfoconsult 2011), where invoicing would occur after finalising the contracted work. Clients/ Tenderers in construction can thus acquire software packages which ties tendering, contract and invoicing in one digital process with the contractors/bidders. There is (even) a competition between private firms developing and maintaining these software packages. In a similar vein, but with a larger scope Jung Lee (2010) and Gallaher et al (2004) covers both concepts that integrates digital tender with previous and subsequent systems. Jung Lee (2010) compares public tendering systems in Korea, United States, Australia and New Zealand and shows that the centralised purchasing method used in US and Korea has led to more developed systems than in Australia and New Zealand, which uses more decentralised purchasing.

4.4 The Fully integrated BIM concept, private players

Many places in the world one can find a quickly raising number of building projects where a highly integrated BIM concept has been operated (Bernstein 2010, 2012). Henttinen (2010) reports a recent large Finnish project where BIM models are part of all phases even tendering, calculation and execution. It is therefore a more comprehensive system than the more widespread and well known design oriented BIM systems (Jarod 2011). It is however unclear how quantities and bill of materials are generated and calculated upon, and Bernstein (2012) notes low use of BIM in these activities. Prete et al (2011) investigates an experimental project in France where a BIM-model is used as basis for the digital tender for a large and complex project, Canopé des Halles. The software Rhinoceros was modified and extended so that it was able to deliver at IFC-compatible 3D-model with the necessary information for tendering. The model was delivered on a single DVD. A similar experimental project is Grilo and Jardim-Goncalves (2011). They conclude on their experiments with e-tendering integrated with BIM that the main challenge is

“the level of aggregation, as BIM objects tend to be very elementary and tenders focus on aggregate levels of products and services. Quantities for tendering are easy to obtain, directly from the BIM model, but how to organize the elements to be tendered is a rather complex issue, and the existing models do not reflect this need” Grilo & Jardim-Goncalves (2011:114) .

Experimental projects like Grillo et al (2011) and Prete (2011) often obtain partial public funding, but the diffusion of BIM-models are by now carried by market developments and private investments (Bernstein 2010, 2012). Bernstein (2012) finds 39 % “heavy” users a and 29% light users the latter having implemented BIM recently. Gu & London (2010) finds a large number of BIM applications at the Australian market, but only a few that supports IFC. Zhilang et al (2011) similarly finds that IFC can be used for tendering in China in the future. Reported new projects are surfacing fast in this area, such as Arayici et al 2011, Sanguinetti et al (2012) and Song et al (2012).

4.5 The Fully integrated BIM concept, private, association and public players

There has for long been exercised both national and international efforts to complement the market driven development of IT in construction. Standards and norms for interoperability and rules for measurement of materials etc. (volumes, weight, length) has been attempted for long. The Industry Foundation Classes (IFC) and ISO standards are internationally proliferated (Laakso & Kiiviniiti 2012), whereas a series of national interoperability standards also are in place. The development of BIM makes it possible to take such joint initiatives a step further. This is currently occurring in a series of countries. In a Danish context a development centre financed by EU has been set up (called Cuneco, Esperanto for common). This centre is currently developing a new building classification for the Danish building market prepared for BIM-modelling. The Cuneco vision is a strengthened interoperability and profitability through joint classification and measurement rules as a complement to the market drivers of standardization. It will be possible to follow up new classifications by public law or public building purchasing policies supporting the classification. The centre is scheduled to deliver by end of 2014.

4.6 Juxtaposition of Concepts

The four identified concepts can be juxtaposed as shown in figure 1. This shows their sociotechnical character as their technical characteristic (scope) *and* their social embedding that distinguishes them.

Table 1: E-tendering concepts

E-tendering concepts	**Social embedding**	**Scope**	**Diffusion**
Web-Platform	Sector association	Tendering alone	Several countries (UK)

Softwarepackage	Private firms and software suppliers	Tendering-contracting-invoicing	Germany
Fully Integrated BIM Market	Private firms, software suppliers	Building process all cycle Market based standards	Several countries but large trail blazer projects
Fully Integrated BIM Communal	Private firms, software suppliers *and* sector association or public body	Building process all cycle Joint classification and measurement rules	Several countries Experimental, Quick Development and large public attention

4.7 Impact of E-tendering

The impact is clearly highly dependent of the level the E-tendering is on referring to the four concepts discussed above. For each concept different impact are prevalent. Especially the RICS concept (a thin model) seems to be particularly evaluated on the impact. Martin (2008) thus finds the following cost types: Mobilization cost, monthly subscription costs, costs related to requirements for increased technology capability (such as upgrades of browser software) and costs related to proprietary systems. Martin (2008) also points at barriers for implementing a thin E-tendering system: lack of common standard, no non partial counselling and juridical and technical “traps”. In a similar vein Lavelle & Bardon (2009) finds that users of E-tendering sees the following main disadvantages; legal issues, difficulties in sharing information, security concerns and poor systems.

BCIS (2009) find that regular user strongly or somewhat agree to that they obtain reduced timescale of tendering. They also strongly agree or somewhat agree on a reduced effort in analyzing tenders, having lower administration costs, having better contact to subcontractors and having a reduced effort in clarifications. Interoperability with previous and subsequent systems is however not covered in this thin systems evaluation. Similar results are found by Kajewski and Weippert (2004) and Lavelle & Barton 2009). Early adoption is enabled by low fee –pay as you go- approaches (Martin 2007), which help overcome initial barriers, which apply less and less as the integration is furthered and investment increase.

The larger the scope the more complicated the impact gets. Gallaher et al (2004) provides estimation for cost of interoperability for the entire value chain for the US building industry, asking the players how much they could gain in interoperability was smooth. Gallaher et al (2004) operate with the following types of costs avoidance costs, mitigation costs and costs of delays. Gallaher et al (2008) finds that two thirds of the interoperability costs are carried by the building owners and operators. There is not a special focus on the interface between architecture, engineering and contracting, but these three types of firms carry each the same level of costs of poor interoperability.

Cretty (2011) points at transformation at several levels i. e. the project and the sector. The social embedding becomes more and more crucial the higher investment and advanced technology employed.

5. Discussion

The four concepts identified above can roughly be claimed to cover the broader sample of systems and concepts looked at. Several systems (such as the GEM in Australia) are placed in between the thin systems and the full circle BIM based and can therefore be labelled medium range systems. The scope is therefore more than a continuum of support to business processes.

When it comes to diffusion all four concepts experience growth. In one end – the most practical - it is common for the national studies to note that around half of the tendering is carried out on paper. Usually this builds on samples of bigger enterprises creating a possible bias for an even larger share if one in-calculated SMEs. In a sense the four concepts all represent the status of the bigger enterprises. In the other end – the more advanced- several contributions note the barriers for fully integrated BIM (Aryici et al 2011, Bernstein 2010, Gu & London 2010, Linderoth 2010). At the same time examples of integrated use of BIM proliferates (Bernstein 2012, Henttinen 2010).

It seems clear that the social embedding is primarily single enterprises. Constellations of software developers/suppliers with building clients around the thin clients, and AEC companies for the BIM oriented solutions. The dominance of market drive is probably also explanatory when it comes to the weak standardization and bridge building across the design construction divide. It is upstream players and not the contractors that dominate the field.

The software package concept represents a series of middle range systems, whereas the web platform is the thin –small scope version. Even the “fully” integrated BIM represents a number of variants. As the constitutive difference between the two BIM concepts lies with social embedding and the scope, we have chosen to label the fourth the communal BIM as shared classification operated by an independent body is central, counter to other BIM model where market forces are central.

6. Conclusion

The international markets of E-tendering and the experiences they represent appear quite diffuse. Four different concepts have been identified. It seems to be common features across the countries that there is a growing use of all four concepts, even if in different tempi and digital tendering is implemented piecemeal. The thin “low scope” solutions appear to be growing as quick as the large scope concepts. Possibly the medium range systems are the most important the coming years as they might address the most important interoperability issues. There is room in time and market for simple practical models, limited in scope, to tendering, whereas the big integrated models seem to have several years in front of them before they are broadly usable in practice. Here social embedding counts more than

technical functionality. A future Danish concept has been mentioned, which emphasizes joint classification and rules of measurement as a means to improve interoperability. But also elsewhere, internationally, there are voices requesting standardisation as an enabler for digital tendering.

Internationally the studies found points at qualitative and quantitative advantages and costs, barriers. The conditions for the evaluation of these costs and benefits are differentiated, but some general patterns can be found, as it is thoroughgoing to point out, that once initial investment cost has been employed, the benefits are reduced time consumption at developing bids, reduced work load during the analysis of tenders, lower administration costs and – work load, better contractor access to information for subcontractors and better security in the digital interaction. Even if two variants of BIM is included it should be underlined that these large scope, integrated system still appear to be quite far from mainstream tendering and E-tendering as around half of the players in the industry still tender with documents. The possible integration from E-tendering platforms to BIM is therefore to be understood as a long term goal that should be reached stepwise.

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Manual Tasks Risk Management: How the Construction Industry is PErforMing

Deidre[1],Rutherford[2]

Manual Tasks Risk Management: How the Construction Industry is PErforMing

Hazardous manual tasks continue to be a significant issue for the Queensland construction industry and one that needs to be managed. In addition, the construction industry is facing challenges such as an aging workforce, skills shortages, and competitive market conditions.

Workplace Health and Safety Queensland (WHSQ) conducted a pilot program at one large commercial construction site in Brisbane. The aim of the pilot was to trial the implementation of the Participative Ergonomics for Manual Tasks (PErforM) program in the construction industry. The PErforM program was developed by WHSQ, the University of Queensland and the Curtin University of Technology.

The pilot participants were very positive about the program and a number of learnings were identified including highlighting the role of the principal contractor, builder and sub contractors in managing manual tasks risks, the need to consider build ability at the design phase and the benefits of involving workers in manual tasks risk management.

WHSQ has a range of resources which will assist the construction industry to implement the PErforM program.

Keywords: **Participative ergonomics, manual tasks, risk management**

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1. Background

In March 2008, the Queensland Government, Department of Employment and Industrial Relations, Workplace Health and Safety Queensland (WHSQ) established a Musculoskeletal Injury Taskforce (now known as the Ergonomics Unit) to tackle the problem of increasing work related musculoskeletal disorders (MSDs) in industry. Ergonomics Advisors were allocated to strategic industry groups to manage specific MSD projects. Workplace Health and Safety Queensland is the government regulator for the Work Health and Safety Act 2011.

Over the last five years (2006/2007-2010/2011), MSDs accounted for almost half (46.8 per cent) of all non fatal workers' compensation claims in the Queensland construction industry. Of the MSD claims, over half (54per cent) were due to the performance of hazardous manual tasks.

The Queensland workers' compensation data indicated that in the construction industry muscular stress while handling, lifting, carrying, or putting down objects was the most common mechanism of injury. Falls were also a common cause of injury.

The parts of the body commonly injured were the lower back, knee, shoulder, elbow and wrist. Workers most frequently injured were labourers and tradespeople.

Building capacity to manage manual tasks risks in the construction industry is a WHSQ priority. One MSD initiative involved a pilot of the Participative Ergonomics for Manual Tasks (PErforM) Program. The construction work environment is unique in that it is constantly changing. Identifying the hazardous manual tasks and risk controls required is best achieved by following a systematic risk management process including worker consultation and participation. As PErforM has been successfully implemented in other industries, WHSQ decided to pilot the program in the construction industry in order to determine if it could be implemented within the construction environment.

The PErforM pilot program was supported by Abigroup at the Queensland Children's Hospital project. It was implemented with four sub contractors including form workers, steel fixers, concreters and block layers. Their work is labour intensive and involves a range of high risk manual tasks.

2. The PErforM Program

The PErforM Program is a simplified manual task risk management program which involves workplace-based teams devising manual tasks solutions for their high risk manual tasks. It is based on a participative ergonomics approach, an internationally recommended approach for reducing musculoskeletal disorders.

Participative ergonomics relies on good communication between all levels of staff and can contribute to improved worker morale and productivity.

The PErforM program was originally developed by WHSQ, the University of Queensland and the Curtin University of Technology as part of the manual tasks research project "Assisting High Risk Industries Implement the Manual Tasks Advisory Standard". This research demonstrated that PErforM has a positive effect on decreasing manual tasks risk. A significant reduction in manual task injury risks, as assessed by WHSQ Inspectors, was reported for workplaces receiving the PErforM intervention.

PErforM has been used in industries including mining, civil construction, aged care, food processing and timber and was successfully piloted in the manufacturing industry during 2010.

3. The PErforM Resource Package includes:

1. PowerPoint presentations for managers and organisations, trainers and work teams.

2. PErforM Resource Manual for workplace trainers.

3. PErforM Handbooks.

4. PErforM Frequently Asked Questions Fact Sheet.

5. Program evaluation tools.

6. Case studies.

7. No Sprains, Big Gains DVD.

This resource package is available on the WHSQ website at http://www.worksafe.qld.gov.au.

4. The PErforM Pilot in Construction Project

A pilot program was undertaken by WHSQ at the Abigroup Queensland Children's Hospital project from 2010 to 2012. The aim of the pilot was to trial the implementation of the PErforM program in the construction industry.

4.1 Project's Objectives

1. Determine if the PErforM program could be implemented at construction worksites.

2. Identify the barriers and enablers for successful implementation in the construction industry.

4.2 Methods

A number of construction organisations were approached about the PErforM pilot. Abigroup recognised its potential and agreed to participate.

4.3 Introductory stage

WHSQ initially introduced the PErforM Program to the project manager and safety team. Once management commitment was secured, the Abigroup project manager identified the trades to be approached for participation in the pilot and appointed the safety advisor as the PErforM site champion. His role was to work with WHSQ and facilitate the introduction and ongoing use of PErforM on the project.

4.4 PErforM for trainers workshop

Initially WHSQ delivered PErforM for trainers to key Abigroup staff including the project manager, engineers and safety team and also representatives from each of the participating sub contractors. It involved training the group in manual tasks risk management and also the critical requirements for successful implementation. This training took five hours.

4.5 PErforM for work teams workshops

Work teams were identified to participate in the PErforM for work teams training sessions. Suitable work teams were identified for a variety of reasons, for example:

1. The work they perform involves high risk manual tasks.

2. The team has experienced a number of manual tasks related injuries or incidents.

3. And/or their willingness to participate in the program.

Appropriate high risk manual tasks for assessment in the workshops were then identified and video footage obtained.

The pilot program included four sub contractors: block layers, steel fixers, form workers and concreters. It involved separate training of the work teams in manual tasks risk management and their participation in facilitated workshops to generate control ideas. The advantages to this method include:

1. Developing effective controls that will target the key risk factors and be designed for the work requirements to suit the workers.

2. Giving workers a greater sense of ownership and commitment to use the controls once they are implemented.

The training was delivered in three, one hour toolbox style sessions, as this amount of time was workable within the daily construction schedule.

The mix of people attending the work teams training varied depending on the trade but generally it included a leading hand, supervisor, 3-4 workers and the principal contractor safety advisor. The workshops were conducted in a training room which allowed for the use of video footage and a short PowerPoint presentation in each session. There were significant benefits gained from using a formal training environment on site such as the creation of a comfortable, quiet environment with minimal distraction so that participants could focus on the PErforM manual tasks risk assessment process.

Topics covered in the work teams training included:

1. Mechanism of injury associated with manual tasks.

2. Manual tasks risk factors.

3. Hazard identification.

4. Use of the PErforM risk assessment tool.

5. Hierarchy of controls.

6. Strategies for eliminating and controlling manual tasks risks.

The workshop included performing a risk assessment on one of the identified high risk manual tasks by analysing video footage of the task and using the PErforM risk assessment tool. The work team then developed risk control ideas for consideration and implementation by the subcontractor, the project safety team and the project manager.

5. Findings

The pilot participants were very positive about the program and a number of learnings were identified. These included the following:

5.1 Critical role of the principal contractor

1. Commitment and support from all involved, especially the principal contractor, was critical to the implementation of the program.

2. The program needs to be driven by the principal contractor. The sub contractors had difficulty progressing a number of the risk control ideas as many of the issues impacting on the hazardous manual tasks were outside their control, for example, time pressures, scheduling, design issues and procurement.

3. Build ability needs to be considered at the design phase in order to eliminate or minimise many of the hazardous manual tasks. It was difficult to implement higher level controls during the later stages of construction. The design team plays a critical role in this process.

4. The program needs to be embedded in existing occupational health and safety systems to ensure its sustainability within the organisation.

5.2 Worker involvement

1. The program gets workers involved in the risk assessment process and as a result there was greater ownership and input into initiatives that reduce risks. Overall, there was great participation and engagement at all levels including workers, subcontractors and principal contractor.

2. Some excellent risk control ideas were proposed. However, some ideas were complex so they were not progressed or were slow to be implemented.

3. A “tool box” style of training (40 minutes to one hour each session) worked well as it fitted in with work scheduling.

4. Workers were able to use the risk assessment tool following training.

5. The program served as a great training tool for educating all involved about the hazardous manual tasks risk factors, for example, due to an increased awareness, the principal contractor designers identified a greater number of hazardous manual tasks issues. They subsequently made contact with the WHSQ advisor to discuss their control options.

5.3 Barriers

5.3.1 Limited resources

The program implementation relied heavily on the WHSQ advisor as the principal contractor and contractors did not have the time due to other work pressures to facilitate the program. Provision of resources such as a dedicated site champion with the necessary attributes, that is, good communication skills and knowledge of ergonomics principles are critical for the program’s success. It is recommended that more than one champion is trained as staff leave or move to different positions within an organisation.

5.3.2 Limited skills and knowledge

All of those involved required coaching as they did not have the ergonomics knowledge and facilitation skills required to implement the program. Assistance was also required for action planning and preparing business cases to obtain approval for the implementation of controls.

5.3.3 Limited organisational learning

It was identified that learnings may not be captured resulting in things that worked or didn't work, not being shared or integrated into new projects.

5.3.4 Lack of systematic approach to hazardous manual tasks risk management

The principal contractor, contractors and workers considered the PErforM training a "one off" training program rather than as part of an ongoing systematic risk management process which is the aim.

6. Discussion

Based on observations and discussions with managers, occupational health and safety staff, sub contractors and workers on a large number of construction sites, the following general construction industry observations were noted:

1. Hazardous manual tasks are everywhere and accepted as "part of the job".

2. Hazardous manual tasks are not a priority hazard in the construction industry.

3. Manual tasks risk assessments are poorly done, possibly due to lack of knowledge, skills and time to perform this task.

4. Manual tasks' control measures in relation to elimination or design are given a low priority and not systematically managed.

5. There is a focus on attributing the injury to the worker, not the task.

6. Training is still seen as delivering back care "talks" or teaching outdated techniques such as "bend your knees/keep your back straight".

7. Stretching programs, back care or core stability programs are often relied on as the main manual task risk management strategy.

8. Male workers are seen as the most suitable for "heavy lifting" tasks.

Research has demonstrated that the PErforM Program has a positive effect on decreasing risk. A significant reduction in manual task injury risk as assessed by WHSQ inspectors was reported for workplaces receiving the PErforM intervention. In this research Burgess-

Limerick (2004), (p10) claimed that the program provides the best evidence available for the effectiveness of a participatory ergonomics program in reducing the risk of injury associated with manual tasks.

PErforM is based on the basic premise that the workplace is the best place to solve ergonomics problems and workers are an integral part of the process. A “train-the-trainer” program was developed to train suitable industry people to train up work teams in the principles of participative ergonomics and manual tasks risk management using the PErforM program. The principle of the program is that work groups or teams identify problem manual tasks in their work and go through a risk assessment process which requires them to develop control suggestions. Management then discusses and supports the implementation of key controls. Once controls are implemented, evaluation is required to ensure that the risk has been controlled and no new risks have been introduced.

7. Limitations of the PErforM Program

PErforM is a simplified manual tasks risk management approach and, as such, there are some compromises with the use of PErforM.

For example, complex tasks may require the use of other ergonomic assessment tools, or the engagement of an expert to assist with the assessment and development of controls. The need for greater expertise may also be identified when prioritising control options.

The risk assessment tool does not take into account the cumulative effect of the range of manual tasks a worker may perform during their shift. As a result, work teams will need to make some judgements about:

1. Which tasks are the hazardous tasks.

2. The priority order for their assessment.

3. Whether the worker is being exposed to similar risk factors throughout the shift despite performing different tasks.

8. Conclusion

This PErforM pilot project represents a preliminary trial of the use of an evidence based approach to manual tasks risk management in the construction industry. Implementation of the program can succeed provided organisations make manual tasks a priority. It requires executive commitment and leadership, the right people and the time and resources to make it happen.

The construction work environment is dynamic and constantly changing. An integrated, holistic approach to health and safety risk management with robust systems and processes which include manual tasks risk management will foster and improve safety culture and productivity and help the organisation’s long term sustainability and growth.

9. Acknowledgements

WHSQ would like to acknowledge the following organisations' involvement and thank them for their participation:

1. Abigroup.

2. Admiral Concreting.

3. Caelli.

4. FTF Bricklaying.

5. Johnston Steelfixing.

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Using agent-based simulation to manage logistics for earthmoving operations in construction

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Abstract

Planning earth moving projects involves numerous assumptions on the interactions between site vehicles, traffic and subcontractors which are described as agents in this paper. This paper discusses how agent-based simulations can be used to improve the planning of earthmoving activities in construction. This research is based on the London Gateway Port in which a significant portion of the project dealt with earthmoving operations.The observations based on this construction project indicated that dumper trucks were subjected to irregular travel routes and varying distances between the excavation and dumping areas. This was further compounded by related logistic activities affecting the progression of the earthmoving activity. Routing of material delivery affects both the cost and timing of the construction project. Efficiency gains based on reduction in working time can be optimised by planning a construction site from a logistics perspective. Estimating the delay of the earthmoving operation because of these interferences is difficult to measure and cannot be implemented at the planning process. Existing activity scanning tools typically eliminate surrounding logistic activities and therefore cannot be confidently relied upon during planning. Agents interacting with the earthmoving environment intend to underpin how the earthmoving operation might be planned to reduce spatial time clashes. The ability to use agent-based simulations to interact with the construction environment to predict efficiency and improve safety of the earthmoving operations is critical, as this cannot be implemented with existing activity scanning simulation tools.

Keywords: Earthmoving in construction, Agent-based simulation modelling, Dynamic spatial interferences, Site congestion, Site safety.

1. Introduction

It has been well documented that earthmoving operations in construction are very significant in terms of cost and productivity (Christian and Caldera, 1988; Navon et al. 2012). Earthmoving is characterised by the intensive utilization of machinery, therefore it is essential that sufficient planning is undertaken to optimise productivity of the relevant plant and machinery. At present there are no effective means of planning the earthmoving operations in the construction industry. As a result planners rely on their intuition and experience (Askew et al. 2002, Tawfik and Fernando, 2001) to determine activity duration

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and the optimum plant and equipment necessary for a particular operation. Surrounding site activities and clashes are often unaccounted for during the earthmoving operation planning process. Activity scanning tools can be applied in the field of mining; however they cannot be applied to earthmoving operations in construction specifically because of the nature of the operation. Clegg et al. (1997) highlight key characteristics of earthmoving operations in construction compared to mining:

- The quantity and type of material to be excavated can vary at different chainages;
- Excavation of material takes place over a series of chainages;
- The movement of dumper trucks are often affected by related construction logistic activities, causing bunching of trucks and irregular paths to their destination.

The motivation to discuss this research method was driven by a need to address these characteristics. The method described in this paper has been developed through a combination of the literature review regarding existing simulation tools and observations combined with qualitative data from the London Gateway Port Case Study which highlights the key areas for implementation of this proposed new tool. In this paper the methodology for a simulation tool using agent- based modelling for earth moving operations is presented. The applications are discussed in terms of how it can predict space time clashes within the surrounding site activities to promote productivity and site safety.

2. Case study: London Gateway Port Project

The observations for this case study were undertaken at the London Gateway Port Project between May to September 2011. Observations were undertaken using video footage of the operations onsite in the diaphragm excavation area as shown in figure 1. This data was subsequently studied to understand how the earthmoving operations are affected by the surrounding operations and logistics onsite. Construction of a diaphragm wall is a common repetitive process onsite which involves significant earthmoving operations and careful logistics coordination. This process is costly and often the inefficiencies cannot be predicted in planning using existing simulation tools. Figure 1 depicts a typical scenario taking place during the construction of a diaphragm wall, indicating other activities leading to inevitable spatial time clashes.

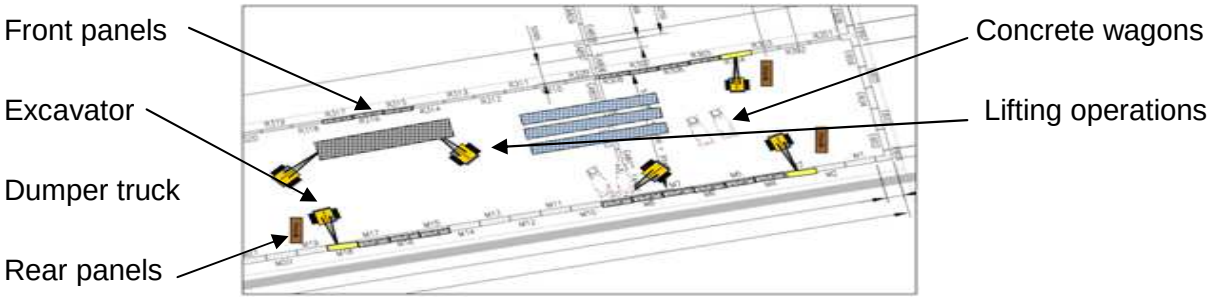

Figure 1: Typical plan view of a section of the construction site indicating other key activities

An earthmoving operation involved in diaphragm wall construction consists of three tasks: excavating material, hauling material and depositing fill material. The contractor used 2-3 articulated dumper trucks for the front wall and 3-4 articulated dumper trucks for the rear wall. In seldom cases one dumper truck driver will be allocated to interchange between different excavation panels. In this case study the dumper trucks were observed to gain qualitative and quantitative data regarding factors affecting efficiency onsite.

2.1 Excavation

The diaphragm walls (D-walls) are separated into six metre panels. The volume of earth which would be excavated from each panel varied slightly, therefore for the purposes of this study the volumes of the front and rear panels are taken to be 125m^3 and 475m^3 respectively. The time required to fill each bucket was a function of its capacity and the 'loadability' of the material being excavated as this varied with depth. At the start of each working day two dumper trucks are located near the excavator ready to be serviced. The average duration for excavating earth from 15 panels for the front D-wall was 12 minutes, and for the rear D-wall this average duration was 38 minutes.

2.2 Hauling Material

Once the trucks are filled they proceed along the haul route. Observations were made over three hours which indicated that there was a 75% probability that a truck would encounter spatial time clashes with other logistic activities which would delay its entry onto the haul curve. On reaching the discharge site the dumper truck queues briefly or deposits the material directly before returning to the excavation area. Upon arrival to the excavation area drivers were asked to park their trucks near the vicinity of the excavation area to minimise congestion in this area. These temporary 'holding areas' were often unmarked. As a result, they were often used by other subcontractors to execute their tasks. This caused unnecessary delays and confusion in terms of where the dumper truck should be held until it is called over to the excavation zone.

2.3 Summary of findings

The findings from the London Gateway Port identified the importance of incorporating the following in a planning tool:

(i) Defining waypoints for the articulated dumper truck to travel;

(ii) Spatial interferences affecting the productivity and movement of the earthmoving operation;

(iii) Average distance travelled by the truck from a loading area to the depositing area;

(iv) Interaction between different trades (subcontractors) leading to variation in productivity levels onsite;

(v) Spatial time clashes in alignment with safety onsite.

The site layout described in this paper is only a snapshot of site operations at a fixed time in space. It enables the authors to identify the aspects in which a simulation tool can be applied for planning of earthmoving operations.

3. Literature review of modelling scenarios on construction sites

3.1 Simulation Based Planning Tools

Simulation has previously been used in construction for process planning and resource allocation (Hammad and Zhang, 2011) because it is able to capture the dynamic behaviour of the processes being modelled (Marzouk and Moselhi, 2004). Many simulation tools have been developed, including CYCLONE (Halpin and Woodhead, 1976), MicroCYCLONE(Halpin 1977), RESQUE (Chang, 1986), COOPS (Liu, 1991), CIPROS (Odeh, 1992),STROBOSCOPE (Martinez, 1996) and, Simphony (Hajjar and AbouRizk, 1999). Of these tools, MicroCYCLONE (Halpin, 1973), STROBOSCOPE (Martinez, 1996) and Simphony (Hajjar and AbouRizk, 1999) are the most widely used systems in construction (Hammad and Zhang, 2011) because of their effectiveness and efficiency in simulating various construction projects. Zayed and Halpin (2001) applied simulation to concrete batching operations to investigate alternative solutions and resource management using MicroCYCLONE. Simphony was consequently used to model and analyse the tunnelling process using the Special Purpose Tunnel developed within the simulation tool (AbouRizk et al. 1999). Hassan and Grubber (2008) simulated concrete paving operations on the Interstate-74 using both EZStrobe and STROBOSCOPE. EZStrobe employs a simple graphical format based on activity cycle diagrams (Martinez, 2001). One of the advantages with this is the ability to model moderately complex systems without having to write advanced computer code, as it is required with the use of STROBOSCOPE (Hassan and Grubber, 2008).

3.2 Weaknesses of the current simulation based planning tools in construction

Whilst the simulation tools described in section 3.1 are able to provide information on the logistical relationships between the different resources, they are not well suited to define the spatial relationships between the different resources on the construction site (Hammad and Zhang, 2011). The main disadvantage with traditional scheduling techniques is their inability to define the spatial relationships between resources on the construction site (Dawood and Sikka, 2008; Dawood and Mallasi, 2006) which is regarded as a challenge in construction workspace management (Chavada et al. 2012). When modelling specific construction activities, these need to be carried out in a suitable simulation environment incorporating spatial time clashes onsite. Hammad and Zhang (2011) recommend that construction simulation models should be developed so that space can be represented explicitly to improve realism in simulation.

4. Spatial interferences affecting productivity

One of the benefits of simulating the construction environment and processes is that it is possible to ensure the reliability of the construction plan by checking it for potential collisions or other similar problems (Hammad and Zhang 2011) with obstacles on the site. Obstacles can be considered as *static* or *dynamic* (Hammad and Zhang, 2011). Static obstacles are primarily related to fixed objects and these are unable to move, as such information can be determined in advance. Simulation in construction predominantly deals with the static environment and therefore there is a need to also consider the dynamic aspects of the construction site (Hammad and Zhang, 2011). Dynamic objects are objects that move on site, such as mobile cranes, concrete wagons and other construction equipment. These obstacles need re-planning because of potential collisions (Hammad and Zhang, 2011). As such these obstacles influence the overall productivity of the earthmoving operation because of their route and hauling unit velocity. When modelling construction logistics during the planning stage it is important to include these obstacles as they influence the overall efficiency of the earthmoving system.

The above problems are also coupled with the workforce distribution density. As such, earthmoving projects in construction employ a fragmented workforce with a wide range of sub-contractors working on different areas of the site undertaking various tasks. For example construction of the diaphragm wall panel involves different subcontractors, such as excavators, banksmen, earthmoving operators, steel cage fixers, crane operators, concrete pour gangmen and concrete wagon drivers. These subcontractors work at different chainages and spatial time clashes are inevitable.

4.1 Methods for modelling spatial interferences in construction management

Researchers that have contributed towards this field have used multiple techniques to identify workspace congestion as it has been regarded as a major loss of productivity (Chavada et al. 2012). Zhang et al. (2007) used a cell-Discrete-Events systems Specification (DEVS) modelling approach to depict space resources in construction simulation. One of the advantages with this technique is that it enables conflict analysis, visualisation of the work site and availability of workspace which is critical in identifying bottlenecks to minimise delays (Guo, 2002). Ample research has been undertaken in relation to understanding spatial interferences in construction. Research undertaken by Sriprasert and Dawood (2003) proposed to use a multi-constraint planning algorithm which considered both time and space. Jang et al. (2007) used genetic algorithms to optimise space management with respect to material deliveries, staging areas and crane location. Mallasi (2009) developed a software prototype using genetic algorithm technique which optimised three decision variables: work execution direction, rate distribution types and quantity of work per week. Traditional methods of determining the optimal path in congested areas uses graphical techniques such as Djkstra's Algorithm (1959), A*(Hart et al. 1972) and genetic algorithms (Holland, 1975). Hassoun and Sanghvi (1990) developed the parallel unconstrained Dijkstra optimal path approach to resolve the acute turns. Whilst these methods can be applied they pose certain constraints as they do not reflect the natural motion of the articulated dumper

truck. It is essential that the method selected is able to generate a traversable path for a wheeled vehicle.

5. Methodology

5.1 Conceptual framework of agent- based model for planning site logistics

The key components of an agent- based simulation model for planning site logistics consists of the following (Walsh et al. 2007): (i) agents with diversity in agent types; (ii) work environment characteristics that relate to safety risks and are a function of location and space; (iii) plant and material equipment characteristics (iv) rules for interaction: agent to agent, agent to site, agent to plant and equipment; (v) agents adapting to certain properties and rules; (vi) changes in the work environment. The method proposed will have 3 key domains; agents in the construction environment, a path planning tool and a safe distance model for the agents.

5.2 Defining Agents in the construction environment

The methodology for this tool focuses on spatial time clashes between various agents onsite. These agents can be categorised into; static (concrete, diaphragm wall, muck away, site offices) and dynamic (heavy plant, vehicles, trajectory path). Subcontractors are not listed as agents within the scope of this methodology. Numerous interactions take place during the construction process which depends on the rules of participating agents. These typically include; agent to agent interaction (coordination), agent to site interaction (safety situations), agent to plant/ equipment (productivity). The agents will primarily continue executing the task until it is completed. The critical work environment characteristics that are relevant at this stage of the development include site layout, space availability, operating conditions and hazards. These factors arise as a result of site constraints, works scheduling and organisation practices which change continuously during the construction process (Haslam et al., 2005). The location of the work place and the availability of execution space affect both safety and productivity of the earthmoving operation.

5.3 Path planning using Bezier segments

5.3.1 Allocating a trajectory path

The technique of using interpolated B-splines is implemented (Arney, 2007) for generating a continuous trajectory using a series of waypoints to depict a static trail of the articulated dumper truck. This technique ensures accurate trajectory tracking coupled with efficiently avoiding unexpected obstacles. The main reasons for using B splines reflect the dynamic logistic movement of the articulated dumper trucks in construction, which are relevant in two ways: low order polynomials can be used to define a complex path comprising of tight turns and angles from the articulated dumper truck. Secondly changes in the construction environment are inevitable; therefore if any obstacles are present along the path of the route this needs to be reflected in the segment of the curve. The application of B-splines have gained ample attention in the field of dynamic path planning in construction logistics. Cubic

curves are selected to represent a Bezier segment which is able to handle points of inflexions as shown in Figure 2. In order to construct a Bezier segment between each way point, internal control points must be selected.

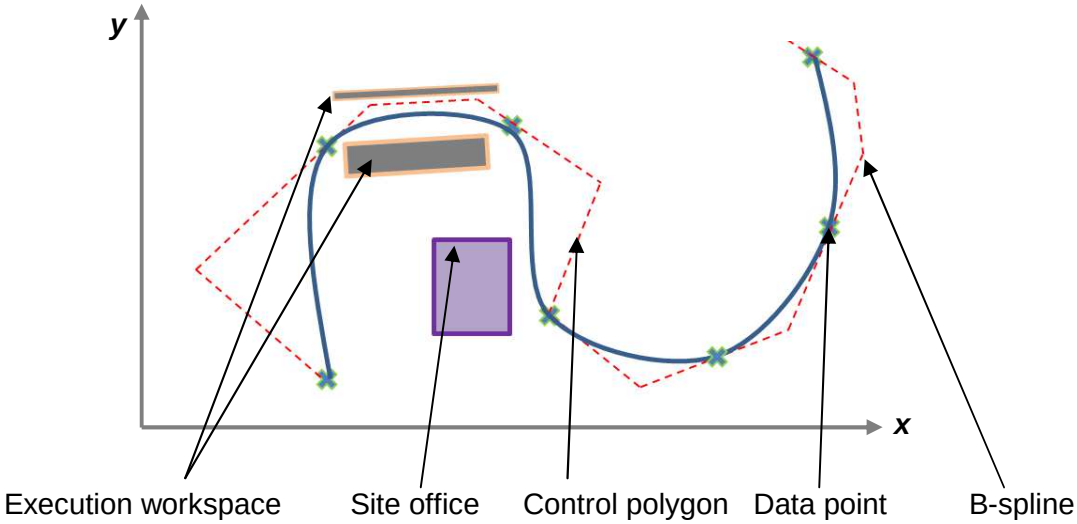

Fig 2: A cubic B-Spline precisely interpolating seven data points

Control points are defined by the tasks which need to be carried out by the agents. The user selects a series of points which will be denoted in Cartesian coordinates, whereby a cubic spline can be fit to this data set. Three vital properties can be said about this curve (Arney, 2007):

(i) The curve precisely interpolates the waypoints;

(ii) Curve lies entirely within polygon;

(iii) Continuous over entire parameter range.

The Bezier segment represents a smooth trajectory path by a dumper truck. This is beneficial as it can represent the path of a truck through different manoeuvres in congested areas which wouldn't be achieved using non smooth transitions. Another benefit of using this method is that it enables planners to identify the minimum distances which the dumper truck travels to other agents, leading planners to eliminate risk at its earliest stages. Further support to enhance decision making is made by the way the curve lies within the control polygon, which can reflect the curvature of the hauling route and positioning of road signs.

5.3.2 Avoiding obstacles onsite and defining safe travelling path

The nature of any construction site reflects the dynamic changes which takes place onsite. The initial path specification model provides a valid path based on a static environment. As such the initial described model would not incorporate dynamic activities such as other logistic activities and the construction personnel onsite. To incorporate dynamic obstacles, these are modelled as generating a force which is radially decreasing over a finite range and zero beyond it (Arney, 2007). The forces cause the path to be displaced if the object remains

within close range of the line of trajectory. The magnitude of the force can be specified to create a displacement which reflects the geometry of the obstacle.

5.3.3 Interaction between the Bezier Curve and Agents

The agents described within this environment are software entities that respond to stimuli to act upon their environment (Russell and Norvig, 1995), and typically share the following four properties (Woolridge and Jennings, 1995): (a) autonomous behaviour, (b) ability to sense their environment, (c) ability to act upon their environment, and (d) rationality. The flow chart in figure 3 depicts how the articulated dumper trucks traversing along the Bezier segment curve interact with the site agents. In this example two distinct dynamic obstacles (agents) are presented which traverse omnidirectional. In the flow chart presented one agent is a 'two hundred tonne' crane with linear velocity of less than 15mph and another is a concrete wagon with linear velocity greater than 15mph. Both these agents bisect the hauling curve of the articulated dumper truck. Based on site observations static obstacles can also account for some losses in productivity. Therefore the control traffic lights, temporary storage or works area can be modelled. The agents are highlighted in pale orange on figure 3. Queuing developed on the haul route is caused by the articulated dumper trucks. On-going research to develop this model includes modelling different subcontractors such as agents and material storage areas to quantify space utilisation onsite.

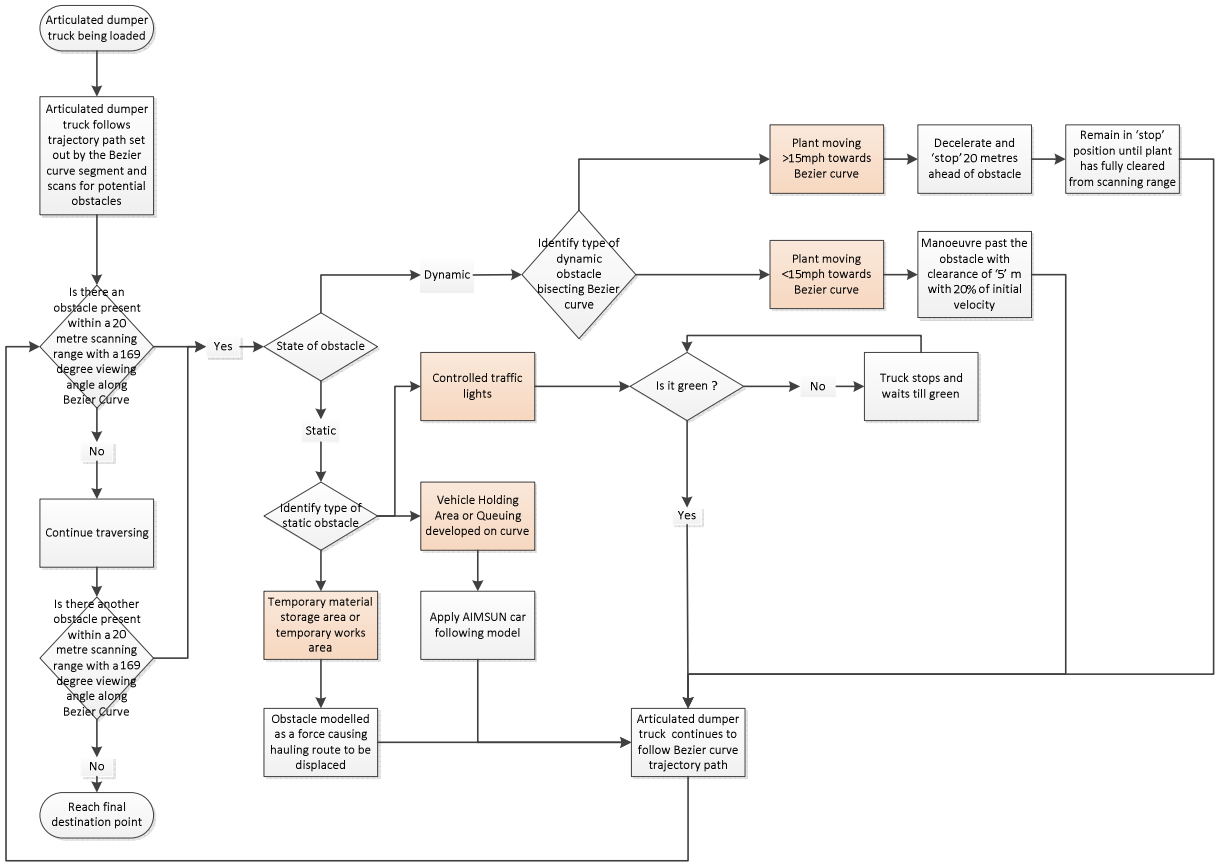

Fig 3: Flowchart to indicate the relationship of the Bezier Curve with the Agents

5.4 Avoiding dumper truck collision using AIMSUN car following model

The AIMSUN is a safety distance model, based on the model developed by Gipps (1981). Research conducted by Smith et al. (2010) emphasises the importance of estimating the variable plant speeds accurately which can be achieved using this model. The AIMSUN car following model reflects the scenario of the earthmoving construction site, as the dumper trucks will inevitably be temporarily stopped or slowed down to overcome unexpected obstacles, such as those described in the case study. Therefore a model which also incorporates a safe headway between the leading truck must also be considered. When a vehicle is constrained by the leading vehicle in front, the following vehicle tries to regulate its speed to maintain a reasonably safe headway with the leading vehicle to prevent a potential collision.

6. Discussion

When modelling construction logistics the environment which the agents behave in must be considered, so that a realistic estimate on productivity can be made on the earthmoving operation. Using agent-based simulation is a different approach to traditional approaches and takes into account the dynamic nature of the construction site. The interaction between the different agents' enables planners to change areas of the planning operation and adopt a logistics based perspective, through simulation. Furthermore this interaction will also enable planners to identify the reasons for delays and bottlenecks based on logistical delays onsite. It is expected that this method could enable planners to reroute the traversing paths. These measures could also lead to a safer site by identifying areas where hazards are more likely to take place.

Agent-based simulation can also be extended to analyse productivity on other logistic operations in depth. For example, in the case study productivity of the concrete batching plant was not fully optimised because there was no method to simulate the logistical operation for the concrete pour. It was identified through observations and discussion that concrete wagons which are required to fill the diaphragm wall after excavation are called upon based on the number of panels that require filling. Efficiency of this operation can be optimised using agent-based simulation in planning. This would ultimately reduce emission due to engine idling and queuing. Furthermore reduced number of trucks will reduce potential mishaps on a construction site.

In terms of emissions the proposed model does not take into account variations in terrain and ground altitude. Both these parameters can affect the distance travelled which also impacts levels of emission. Also in terms of safety the proposed model focuses on spatial time clashes with equipment and not personnel as this is a less predictable method. Validating how subcontractor agents behave can be difficult to prove, therefore the current methods which exist are limited. The 'interaction among root cause factors' (Walsh et al. 2007) framework is a potential method to address this issue.

Completion of the task in a timely and safely manner requires effective coordination of multiple agents (Walsh et al., 2007). Each agent has a set of properties based on personal

factors and job responsibilities. The variables which need to be incorporated in the work environment include; knowledge, skill level or competency, experience (duration onsite) and average designated hours per week (Halsam et al., 2005; Hinze, 1997).

7. Conclusion

This research has endeavoured to highlight how earthmoving operations in construction logistics can be planned and better managed using agent based simulation modelling. The case study intended to show how earthmoving operations were affected by other activities in the same working environment. Using agent-based simulation during planning in earthmoving operations involves modelling complex multiple repetitive interactions (Walsh, 2007).

This research has highlighted the relevance of simulating the dynamic nature of the construction site using a vehicle model to help planners identify and eliminate potential spatial time clashes onsite. The authors believe that this approach will optimise productivity by increasing the efficiency and safety of earthmoving operations.

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Post-Occupancy Evaluation Studies in a recently Refurbished Office Building: Energy Performance and Employees' Satisfaction

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Abstract

Existing buildings contribute greatly to global energy use and greenhouse gas emissions. In the UK, about 18% of carbon emissions are generated by non-domestic buildings; sustainable building refurbishment can play an important role in reducing carbon emissions. This paper looks at the performance of a recently refurbished 5-storey office building in London, in terms of energy consumption as well as occupants' satisfaction.

Pre- and post-occupancy evaluation studies were conducted using online questionnaire surveys and energy consumption evaluation.

Results from pre-occupancy and post-occupancy evaluation studies showed that employees, in general, were more satisfied with their work environment at the refurbished building than with that of their previous office. Employees' self-reported productivity improved after the move to the new office. These surveys showed a positive relationship between employees' satisfaction with their work environment and their self-reported productivity, well-being and enjoyment at work. The factor that contributed to increasing employee satisfaction the most was: better use of interior space. Although the refurbishment was a success in terms of reducing energy consumption per m^2, the performance gap was almost 3 times greater than that estimated. Unregulated loads, problems with building control, ineffective use of space and occupants' behaviour are argued to be reasons for this gap.

Keywords: Post occupancy evaluation, Refurbishment, Energy-saving, Occupants' satisfaction, Space utilization

1. Introduction

In the UK, non-domestic buildings account for approximately 18% of the carbon emissions in the UK (Carbon Trust 2009). The majority of non-domestic buildings in the UK were built

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before the 1980s, and more than half of all office space in the UK was built prior 1939 (Femenias and Fudge 2008). The age of the UK non-domestic stock indicates that for the country to meet its 80% CO_2 reduction target by 2050, refurbishment of existing buildings will play an important role.

Building refurbishment could also provide a more satisfactory work environment for the occupants, and, therefore, could improve productivity. This is explained in more detail in the following sections.

1.1 Work environment and employees' satisfaction

The 'habitability pyramid' developed by Vischer (2005) incorporates three groups of interrelated factors associated with employees' comfort in a workplace: physical, functional and psychological. According to Vischer (2005), all three groups need to be considered if a comfortable and productive workplace is to be provided. 'Physical comfort' includes the satisfaction of all basic human needs, which ensures one's health and safety; while 'functional comfort' concerns those features of the workplace that can help employees to perform their job well. 'Functional comfort' includes adequate lighting, flexible and adaptable furniture, designated spaces for different types of tasks, etc. 'Psychological comfort' involves feelings of ownership and control over one's environment.

It is usually assumed that employees who are more satisfied with the physical conditions of their workplace are happier and, therefore, are more productive than those who are less so (Leaman and Bordass 1999). Earlier studies indicate that there is a positive correlation between occupants' satisfaction and their perceived productivity (Leaman and Bordass 2001; J. C. Vischer 2007; Thomas 2010). These studies confirm the importance of improving physical features of workplaces, such as air quality, lighting, noise, and temperature and office layout. In a recent study, Thomas (2010) revealed that increasing daylight, glare control, noise management and access to the windows (views) increased occupants' satisfaction with their work environment.

1.2 Energy consumption assessment: Post-occupancy evaluation

The results from the PROBE (Post Occupancy Review of Buildings and their Engineering) studies, which reviewed post-occupancy of 23 buildings, showed that actual energy consumption in buildings is typically 2-5 times more than predicted at design stage (Menezes 2012). This is partly due to the fact that several sources of energy usage are not considered in the calculations of design targets. These sources are known as unregulated loads and include IT equipment, server rooms, external lighting and lifts. Unregulated loads accounted for more than 30% of the total energy consumption in an office building (Menezes 2012). In addition to unregulated loads, there are various other factors which can affect the accuracy of energy consumption predictions. Occupants' behaviour is one of these factors and, as this is often itself unpredictable, designers have to make assumptions about it (De Wit 1995).

This paper presents lessons learnt from a post-occupancy evaluation (POE) of Halcrow's recently refurbished HQ in London.

1.3 Background

Halcrow (a CH2M Hill company) delivers planning, design and management services for developing infrastructure and buildings worldwide.

In September 2010, Halcrow employees from the previous HQ, Vineyard House (VH) moved to the newly refurbished global headquarters (HQ), Elms House (EH). The poor environmental performance of VH, as well as its rigid and ineffective layout, generated the need for a new workplace. Halcrow decided to refurbish EH, which is located adjacent to VH (See Figure 1) and shares a common landlord with it, to be its new HQ building.

The main objectives of the refurbishment were to reflect a sustainable design and create a flexible and active work environment with appropriate spaces for different tasks. In this project, the design target for CO_2 emission was calculated to be 37 kg CO_2/m^2. This figure did not include unregulated loads. EH (marked with a circle in Figure 1) was completely stripped out and refurbished in 2010 and achieved a BREEAM rating of "Very Good" for its design. The key features of these two buildings are briefly described below.

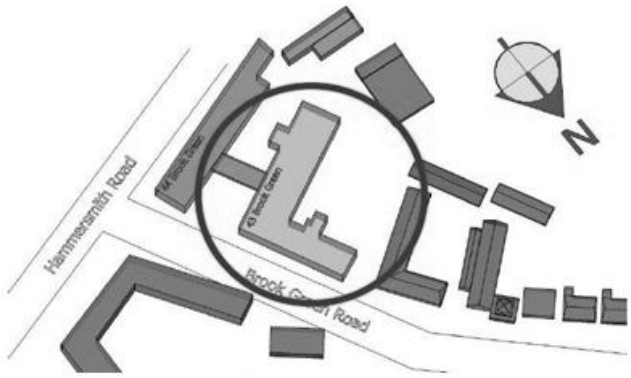

Figure 1: VH and EH locations

1.3.1 VH

VH is a 5-storey office building built in 1962, with a 5202.6m^2 floor area. When Halcrow's HQ, it was mainly open-plan, with few cellular offices and few formal meeting rooms with video conferencing facilities. There was a high level of lighting available at VH from both daylight and artificial (mainly fluorescent tube) sources. Although mechanical ventilation was available, because of the poor performance of the system, employees had to open the windows to get fresh air and, therefore, due to the location of the building, many employees were affected by the noise from the street. VH was heated by gas fired boilers via radiators throughout the building. These were complemented by portable heaters supplied to

individual members of staff. A small canteen was located on the ground floor. About 479 employees were working at VH in 2009.

1.3.2 EH

EH is a 5-storey office building which was built in the 1930's with a floor area of 11,725m^2. The offices are designed to be completely open plan with a number of small and large meeting rooms equipped with teleconferencing and video conferencing facilities. There are a number of designated areas for socialising and informal meetings as well as areas for concentration and contemplation; phone booths are available on each floor. A 60-seat restaurant is located on the ground floor, as well as kitchens on each floor. Facilities for cyclists are good, and include 6 showers. The office is mechanically air conditioned by use of fan-coils. A high level of lighting, from both natural and artificial sources, is available. The lighting system incorporates both daylight and PIR sensors to save energy. Half-hourly meters and electricity sub-meters are in use to monitor the energy consumption of the building accurately. Services at EH are mainly centrally controlled by a BMS system and the employees do not have control over their immediate environment. In 2011, 596 employees were working at EH.

2. Research approach

In this research, Post-Occupancy Evaluation (POE) was employed to evaluate the refurbishment project's success in terms of energy consumption, employees' satisfaction and employees' self-reported productivity. Surveys, observations, energy monitoring and benchmarking were used as research tools for this study. The actual performance of the building was compared to the UK's benchmark as well as to the design target. The results were used to identify areas for potential improvements.

There are different energy benchmarking tools available in the UK, such as CIBSE Guide F, ECON19 and CIBSE TM22. In this paper, ECON19 was used as a standard benchmark. For air-conditioned, prestige offices, the benchmarks are:

- Good practice:
  - fossil fuels: 114 kWh/m^2
  - electricity: 234 kWh/m^2
  - CO_2 emissions: 143.4 kg CO_2/m^2

- Typical:
  - fossil fuels: 210 kWh/m^2
  - electricity: 358 kWh/m^2
  - CO_2 emissions: 226.1 kg CO_2/m^2

The pre- and post-occupancy survey questionnaires used in this study were designed by the researcher to cover those workplace environmental factors identified as important influences in past studies (e.g., air quality, indoor temperature, noise level, outside view, personal control,

visual privacy, auditory privacy, office layout, office appearance, cycling facilities, on-floor kitchen, recycling facilities). The questionnaire, which took under 15 minutes to complete, comprised three parts. There were 17 demographic items, 38 satisfaction items and 16 items concerned with sustainability awareness. In the "demographic" section, occupants were asked to indicate their age group, gender, the floor and building occupied, employment status, office type, frequency of visiting the in-house restaurant and frequency of using the shower facilities. There were 3 groups of 'satisfaction' items, pertaining to: physical environment, interior use of space and indoor facilities. In the "sustainability awareness" section, occupants were asked whether they knew about their company's environmental sustainability targets and whether they felt personally responsible for meeting these targets. They were also asked to indicate what they considered to be the best method of communication for raising sustainability awareness within the building. Responses to the "satisfaction" items were sought on a 5-point scale, where 2= Strongly Agree, 1= Agree, 0= Neither Agree nor Disagree, -1= Disagree and -2 = Strongly Disagree. Most questions were positively worded; scores were reversed for negatively worded items. Analysis of the responses yielded mean values (a positive score indicating agreement with a positive statement) which allowed comparison between pre-occupancy (benchmark) and post-occupancy values.

The pre-occupancy online survey was carried out at VH in June 2010. The link to the survey, which stayed open for two weeks, was sent out to all employees at VH. This benchmark survey was used as a tool to enable the employees to confidentially express how they felt about their work environment. A full year's (2009) electricity and gas consumption data were also collected at VH. These data were used as benchmarks against which to evaluate EH's performance.

The post-occupancy survey was conducted at EH in February 2011 to measure any changes in employees' level of satisfaction with their work environment 6 months after the move. At the same time, observations were carried out by the author to assess two areas: interior space usage and occupants' behaviour towards energy saving. A full year's (2011) energy data were collected at EH to evaluate the energy consumption of EH in comparison with that of VH and the benchmarks.

3. Results and Discussion

The data gathered from the pre- and post-occupancy surveys and the energy data provided useful pictures from VH and EH overall.

The mean value of each variable from the pre-occupancy survey was compared with the post-occupancy survey. Where a mean value is quoted in this paper, number of respondents (N), standard deviation (SD) and the percentage of dissatisfied respondents (DS) are also stated.

3.1 Pre- and Post-Occupancy Surveys

Having excluded data from ineligible participants, a total of 162 and 183 respondents completed the pre- and post-occupancy surveys respectively, generating a response rate of 32% and 31%, which were considered acceptable. In the post-occupancy survey, 66% of the

respondents specified their previous workplace as VH; the other 34% indicated their previous workplace other than VH. In both surveys, the distribution of respondents across a number of demographic variables, including business group, employment status, and grade, mirrored well the actual distribution of all Halcrow's employees; the sample is considered to be adequately representative.

3.1.1 Work Environment Satisfaction

The scale reliability of responses to the 28 'satisfaction' questions (overall) was assessed for VH and EH; Cronbach's alpha was found to be 0.91 and 0.92 respectively, indicating excellent reliability.

The results confirmed that VH, with overall satisfaction mean score of -0.29 (N= 141, SD=0.50, 36%DS), had a poor workplace environment. Respondents at EH were statistically significantly more satisfied with their work environment, 0.39 (N=153, SD=0.52, 5.2%DS) than those in VH, $t(292) = 11.54$, $p<0.001$.

With about 50% of respondents indicating their dissatisfaction, the physical condition of VH was identified as the main issue. The post-occupancy survey showed that EH was a more satisfactory environment, especially to those who had moved from VH. Although, the physical condition of EH was still not quite satisfactory, 0.12 (N=160, SD=0.65, 17.5% DS), it showed a significant improvement compared with VH, $t(307) = -7.51$, $p<0.001$. Interior use of space and indoor facilities, with the mean scores of 0.53 (N=174, SD=0.65, 7.5%DS) and 0.52 (N=181, SD=0.57, 3.9%DS), were satisfactory at EH but not at VH, -0.17 (N= 154, SD=0.60, 27%DS) and -0.24 (N= 157, SD=0.65, 29%DS) respectively.

In the following sections, the results of the surveys are discussed with regards to aspects of comfort, spaces and indoor facilities.

3.1.1.1 Physical environment

'Physical environment', overall, was the least satisfactory element of both VH (Cronbach's alpha =0.79) and EH (Cronbach's alpha =0.78). The main problematic areas at VH were indoor temperature in summer, -1.31(N=162, SD=0.95, 84.6%DS), the level of personal control, -0.83 (N=161, SD=1.11, 65.2% DS), indoor temperature in winter, -0.81 (N=161, SD=1.10, 62.1%DS), and the air quality, -0.67 (N=159, SD=1.11, 59.1%DS). The responses to open-ended questions indicated more concerns of feeling "freezing cold" in winter and "stuffy" in summer.

The HVAC system and lighting at EH were controlled centrally and the windows were non-openable. All these caused a lot of dissatisfaction with the level of personal control at EH, -1.19 (N= 178, SD=0.98, 78.1%DS). Open ended comments revealed that there was also no quick response to office environmental complaints. , in addition to level of personal control, the majority of the respondents at EH were dissatisfied with the temperature in winter, -0.70 (N=181, SD=1.22, 63%DS). The BMS system was set to maintain the temperature at EH at 23°C. Further investigation done by observations, informal chats with the employees and some open ended comments in the survey revealed that the main issue was the draughts

from the air conditioning units and from the windows. About 20% (N=11) of the open ended comments described the workplace (EH) as draughty.

3.1.1.2 Interior use of space

The scale reliability of responses to the questions in this group was assessed in VH and EH; Cronbach's alpha was found to be 0.88 at VH and 0.90 at EH. VH was reported by the respondents to be, in general, a poor workplace in terms of space, -0.17(N= 154, SD=0.60, 27%DS), Whilst, in comparison, respondents at EH were statistically significantly more satisfied with their space, 0.52 (N=181, SD=0.57, 3.9%DS), $t(326)=10.10$, $p<0.001$. At VH, the two dissatisfactory elements with interior use of space were areas for contemplation, -0.66 (N=161, SD=1.0, 62.1%DS), and auditory privacy, -0.65 (N=162, SD=0.96, 58.6%DS). At EH, provision of a number of phone booths and informal meeting rooms on each floor improved employees' satisfactory in these areas, with mean scores for contemplation area and auditory privacy as 0.45 (N=182, SD=1.04, 17.6%DS) and -0.15 (N=183, SD=1.24, 38.8% DS) respectively.

3.1.1.3 Indoor facilities

In terms of indoor facilities, there was no unsatisfactory element in VH (Cronbach's alpha = 0.78) and EH (Cronbach's alpha = 0.75). However, at VH, shower facilities with mean score of -0.43 (N=160, SD= 0.92, 35% DS), and canteen facilities with mean score of -0.46 (N=159, SD=1.02, 48.4%DS), were close to unsatisfactory. Respondents in EH were statistically significantly more satisfied with the indoor facilities at their building than those at VH, $t (333) =10.86$, $p<0.001$. Respondents at EH were more satisfied with both their shower facilities, 0.14 (N=182, SD=0.71, 8.8%DS), and restaurant facilities, 1.10 (N=183, SD=0.77, 3.8%DS).

In answer to the question: "*How often, on average, do you visit the restaurant in your office building?"* it was found that about 50.0% of the respondents at VH visited the restaurant (canteen) at least one day a week. This figure increased to about 85% at EH.

With regard to the shower facilities, however, about 80% of the respondents at VH indicated that they never used the shower facilities at their building when answering the question: "*How often, on average, do you use the shower facilities in your office building?"* This figure increased to about 88% at EH. Responses explained that the showers were not maintained regularly and often broken.

3.1.2 Perceived productivity, well-being and enjoyment at work

Employees were asked to determine to what extent they agree that their current workplace had positive effects on their productivity, well-being and enjoyment at work. The respondents used the same 5-point scale as for the "satisfaction" questions. At VH, respondents did not believe that their work environment had a positive effect on their perceived productivity, -

0.02 (N=160, SD=0.90, 30.6% DS), well-being, -0.18 (N= 159, SD=0.88, 35.2%DS), and enjoyment at work, -0.10 (N= 160, SD=0.88, 30.6%DS). In comparison, EH environment had a statistically significantly more positive effect on respondents' perceived productivity, 0.31 (N=183, SD=0.94, 16.9%DS), t (341) = 3.24, p<0.001, well-being, 0.25 (N=183, SD=0.93, 20.2%DS), t (340) =4.34, p<0.001, and enjoyment at work, 0.37 (N=182, SD=0.92, 14.8%DS), t (340) =4.81, p<0.001.

3.1.3 Relationship between workplace environment and perceived productivity, well-being and enjoyment at work

As shown in Table 1, in both buildings the employees' perceived productivity, well-being and enjoyment at work were positively correlated with physical environment of the workplace, interior use of space and indoor facilities. This result is in agreement with those of the previous studies mentioned earlier in this paper, showing that, amongst other factors, the latter ones are important.

Table 1: Correlation between work environment and perceived productivity, well-being and enjoyment at work

		Correlation Coefficients (r)		
		Physical environment	Interior use of space	Indoor facilities
Productivity	VH	r=0.56, N=148, p<0.01	r=0.59, N=152, p<0.01	r=0.37, N=155, p<0.01
	EH	r=0.49, N=160, p<0.01	r=0.64, N=174, p<0.01	r=0.39, N=181, p<0.01
Well-being	VH	r=0.53, N=147, p<0.01	r=0.56, N=151, p<0.01	r=0.29, N=154, p<0.01
	EH	r=0.47, N=160, p<0.01	r=0.67, N=174, p<0.01	r=0.43, N=181, p<0.01
Enjoyment at work	VH	r=0.48, N=148, p<0.01	r=0.56, N=152, p<0.01	r=0.34, N=155, p<0.01
	EH	r=0.47, N=159, p<0.01	r=0.67, N=173, p<0.01	r=0.44, N=180, p<0.01

3.2 Energy performance EH vs. VH

The annual electricity consumption at EH was measured to be 144kWh/m^{2,} which was 29.8% less than the total electricity consumption at VH in 2009 (205kWh/m^2). Gas consumption at EH in 2011 was found to be 98.4kWh/m^2, about 38% less than the 158.79kWh/m^2 gas consumption at VH in 2009. Figure 2 shows these results in more detail.

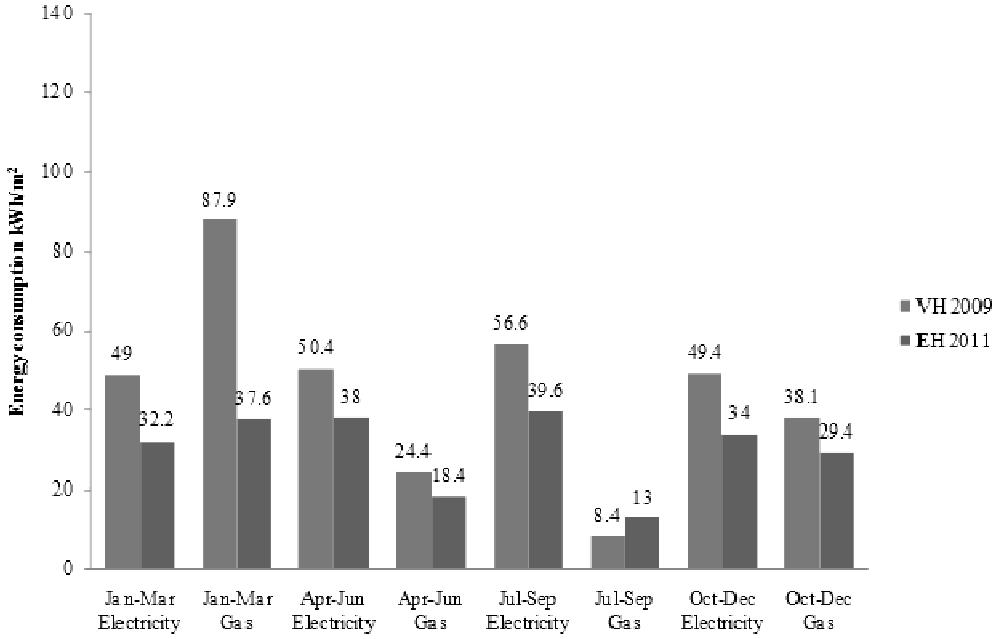

Figure 2: Electricity and gas consumption in VH and EH

The annual base-load for electricity (between 9.00pm and 7.00am) at EH was about 256,320kWh (21.9kWh/m^2) which accounted for 15% of the total electricity consumption. This figure, per m^2, was 65% less than the annual electricity base-load at VH which was measured to be 328,580kWh (63.16kWh/m^2), accounting for 31% of the total consumption. It was found that, during the study, the HVAC system at EH was in operation 24 hours a day, 7 days a week. So, the consumption at EH could be reduced further by reducing the hours of operation to 9 hours (e.g. between 8.00am to 5.00pm) on Saturdays and Sundays.

Figure 3, overleaf, shows the CO_2 emissions from electricity and gas consumption in VH (2009) and EH (2011). The total CO_2 emission at EH in 2011 was 93.6kgCO_2/m^2 which was 32% less than that measured at VH in 2009 (136.8kgCO_2/m^2). The design target at EH was predicted to be 30.5 kgCO_2/m^2. The actual emission, however, is about three times higher than what was predicted. This could be partly due to the unregulated loads (e.g. IT equipment, lifts and catering facilities) that were not considered in the design target. Compared to the benchmark (ECON 19), EH performance in 2011 was 23% better than 'good practice', while the performance of VH in 2009 was about 12% worse than 'good practice'.

Energy consumption per person, however, was higher at EH compared with VH. EH consumed 2831.11kWh/person electricity in 2011 which was 27% higher than that which was measured at VH in 2009 (2,229.59kWh/person). EH also consumed 12.3% more gas/person in 2011 compared with VH in 2009 (1936.51kWh/person at EH vs.1724.68kWh/person at VH). The main reason for this was ineffective use of space at EH. Observations showed that, at the time of the post-occupancy survey, on average, only 39% (263) of the workstations were in use. Observations also confirmed that, on the ground floor, contemplation and socialising areas (excluding the restaurant) were not being used effectively.

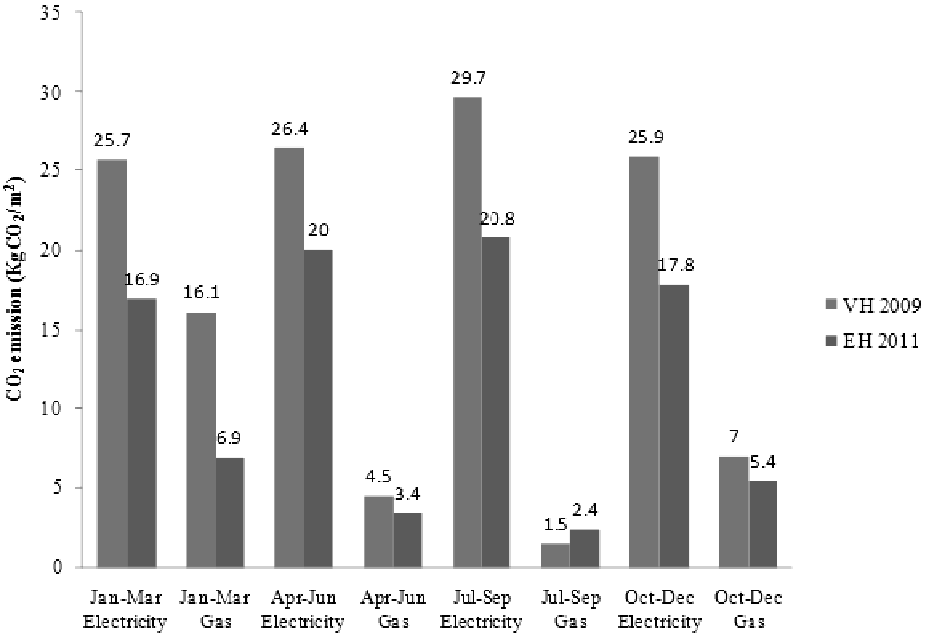

Figure 3: CO2 emission at EH and VH

4. Conclusion

Pre- and post-occupancy evaluation studies were carried out at Halcrow's previous headquarters and their newly refurbished headquarters adjacent to the site. The results showed that, after the move to the new headquarters, employees were more satisfied with their work environment (physical environment, interior use of space and indoor facilities). Employees' responses indicated that their perceived productivity also increased after they moved to the newly refurbished work environment.

EH showed better performance, in terms of electricity and gas consumption and CO_2 emissions per m^2, than VH. However, the CO_2 emissions at EH were more than 3 times higher than the design target. To reduce this gap, the facilities manager was advised to reduce the HVAC operation hours to 9 hours a day during the weekends. Occupants' behaviour and space utilisation should be also reviewed to detect further opportunities for more improvement.

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Benchmarking Saudi Public Schools Using a Safety Balanced Scorecard (BSC) Approach

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Abstract

Citizens in newly industrialized countries are demanding higher levels of safety in their built environments, particularly the education environments of their students. Saudi Arabia is an example of a country that is beginning to put a microscope on its current safety practices and performance in an attempt to reduce incident and accident rates. In the authors' prior research, a comprehensive safety performance evaluation framework was developed following the principles of the well-established balanced scorecard (BSC). The statistically formulated Saudi school safety performance BSC included 5 salient perspectives: P1: Safety Management and Leadership (5 factors); P2: Safety Learning and Training (3 factors); P3: Safety Policy, Procedures and Processes (3 factors); P4: Workforce Safety Culture (3 factors); and P5: Safety Performance (3 factors). This subsequent investigation applies the developed safety performance BSC in order to benchmark and compare 6 Saudi public schools. Comparisons were made between schools based on their gender (male and female schools), regions of Saudi Arabia, and school education level (i.e., primary, elementary and secondary). The developed safety performance BSC framework and associated benchmarking methodology applied in this study can aid Ministry of Education officers and school executives in better and more strategically monitoring and managing their respective schools by considering the influence of lead and lag indicators of safety performance.

Keywords: Safety, School, Balanced Scorecard (BSC), Saudi Arabia

1. Introduction

Education spending has risen dramatically in Saudi Arabia in the last decade, with a 12.8% increase in spending during the last year alone, from 121.9 billion to 137.6 billion Saudi riyals (SR) (Conway, 2010). There are about 25,000 schools, of which 16,000 operate out of rented buildings. The government has spent money acquiring land on which to build schools that will lead to the addition of new buildings (Conway, 2010). Currently, there are 33,000 schools (Ministry of Education in Saudi Arabia, 2012). Saudi public schools are free of tuition fees, and post-secondary students actually receive a stipend. With the increase in student

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numbers, there has been a growing concern for their safety in the school environment, particularly after catastrophic events such as the fire in a girls' school in 2002 that resulted in 15 deaths (Prokop, 2003). Moreover, in the last decade (2002-2012) there were 19 student and teacher fatalities and more than 150 students injuries of which 12 were serious (Ministry of Education in Saudi Arabia, 2012).

While concerns about school safety are growing in the wider community, there are still limited studies addressing the issue of school safety specifically targeted towards the Kingdom of Saudi Arabia. However, in many Western countries, there are numerous studies tackling this issue (Nansel et al., 2001; Pellegrini and Long, 2002; Pepler et al., 2006). Most studies examining school safety in the broader Asian region highlighted a poor safety record in these regions (Ando et al., 2005; Yang et al., 2006). Unfortunately, much of this existing literature focused on the Asian region presented findings that were often based on small data samples, and these findings are not reliable. Furthermore, existing studies focused on developed Western countries are not often transferable to the Middle East region, where an entirely different cultural context exists. Nisbett (2004) presented empirical evidence from social psychology that suggests that cultural, behavioural and perceptual differences exist between different world regions and even countries. On the other hand, Benbenishty and Astor (2005) stated that even though regions or countries may differ based on incident and accident rates, their research posited that many seemingly different cultures have similar patterns and structures of school safety. Therefore, in order to gain a clearer understanding of school safety in the Saudi context, as well as specific comparisons between school gender, type, and region, it is important that further studies are conducted in this specific context. This research study addresses this gap in the current body of knowledge.

In Saudi Arabia, a number of regulations have been introduced in recent years in a bold attempt to rapidly improve school safety performance. For instance, the Ministry of Education put in place regulations that enforce heightened expectations of student safety and ultimately reduced rates of accidents and incidents. These regulations included several aspects, such as compulsory first aid courses for teachers, laboratory safety guidelines and student supervision, to name a few (Bendak, 2006). However, while stricter regulations have now been implemented, safety performance has not improved to the expected degree because there still are no enforcement practices and no ongoing safety performance evaluation. To address this missing link, a safety performance BSC for Saudi schools was recently developed by Alolah et al. (2012). The BSC was first developed by Kaplan and Norton (1992). It was one of the first comprehensive business evaluation frameworks that considered both the lead (e.g. profit, market share, etc.) and lag indicators (e.g. staff learning and innovation) of business performance. This important feature of the BSC and its holistic and long-term evaluation of performance makes it highly suitable to the issue of safety which inherently is the slow build up bad practices that suddenly results in catastrophic events. For example, the BSC framework will be able to pick up a diminishing learning culture in an organisation even when profits are at a record, before its inevitable decline in subsequent years. The developed safety BSC is intended to pick up interconnected poor safety planning, leadership and culture before a school fatality occurs and enable executives to take action. This specially developed safety performance BSC will enable a comprehensive evaluation of safety performance considering both the lead (e.g., accident rates) and lag (e.g., safety

culture) indicators of school safety. Using exploratory factor analysis (EFA) and partial least square (PLS) analysis, a confirmed safety performance BSC consisting of 5 salient perspectives could be developed: (1) Safety Management and Leadership (SML); (2) Safety Learning and Training (SLT); (3) Safety Policy, Procedures and Processes (SPPP); (4) Workforce Safety Culture (WSC); and finally, (5) Safety Performance (SP) (Alolah, et al., 2012). Each perspective had several measurement items, namely: SML, 16 items; SLT, 12 items; SPPP, 15 items; WSC, 13 items; and SP, 8 items. Appendix A provides a full description of each perspective, factor and item in the developed safety performance BSC that has been applied in this paper for benchmarking the safety performance of 6 Saudi public schools.

2. Benchmarking study context

2.1 Saudi Arabian education environment

Like most Muslim countries, Saudis consider male and female roles to be complementary rather than equal (Esposjto, 1982; Keddie, 1979; Saleh, 1972). El Guindi (1981) stated that 'one basic feature of Arab sociocultural organization is the division of society into two separate and complementary worlds, the men's and the women's'. In Saudi Arabia, this division is relatively rigid and strict; sexes do not mix (El Guindi, 1981). Several studies have reported that safety in girls' schools was greater than that of boys' schools (Baldry, 2003; Bosworth et al. 1999; Chen and Astor, 2009; Hu and Lin, 2001; Kumpulainen et al., 1998; Nansel, et al., 2001; Rigby, 2005).

The Saudi Arabian education system has 3 main school types: primary (ages 6–11), elementary (ages 12–14) and secondary (ages 15–18) (Alshumaimeri, 1999; Sedgwick, 2001). Six schools (3 male and 3 female) were involved in this study. In fact, every school type has its own dynamics, mission and structure, and numerous practitioners have suggested that the prevalence of school safety is dissimilar from school to school due to their distinct characteristics and cultural dynamics (Astor et al., 2002; Benbenishty and Astor, 2005; Benbenishty et al., 2002). Also, Zeira et al. (2003) stated that the prevalence of school safety is highly dependent on the school type.

Another important aspect of school safety is the location of the school, due to the large differences between each region's distinct social and cultural context (Basu, 1992; Dyson and Moore, 1983; Jejeebhoy, 2000). The capital of Saudi Arabia is located in the central region, where there is an apparent concentration of funding and resources assigned to education in general and a greater emphasis on safety. Furthermore, large oil companies are located in the eastern region, where there are a number of expatriate staff who have higher expectations of safety performance in their schools.

2.2 Design and sampling frame

In September 2012, a questionnaire survey was distributed to 6 public schools in Saudi Arabia. The questionnaire contained a cover letter that explained the survey's purpose and benefits, notably the concept of a 'balanced scorecard' to measure the level of safety

performance in Saudi schools. The questionnaire was distributed to teachers, school executives and Ministry of Education officers in Saudi schools, so that they all could express their perceptions of safety performance in their schools. This study consisted of 67 respondents, including 47 teachers, 14 school executives and 6 Ministry of Education officers affiliated with particular schools. Those respondents worked in 3 different school levels (2 primary, 2 elementary and 2 secondary).

A 5-point Likert scale was used for rating the performance of each item in the questionnaire (i.e., 1 = Very Poor, 2 = Slightly Poor, 3 = Moderate, 4 = Good, and 5 = Very Good). The unit of analysis for this benchmarking study was the school, with the results averaged from the respondents according to each respondent type for each school. The following section investigates the benchmarking findings for the 6 schools (e.g., number of participants, their education and experience, and school size). More importantly, a comparative assessment is reported based on school level, gender and region.

3. Benchmarking 6 Saudi public schools

3.1 School 1 (S1)

This school is a male primary school located in the western region of Saudi Arabia. The respondents from this school were 1 Ministry of Education officer, 2 school executives and 7 teachers. The school had a student population of between 1,001 and 1,500 students. The two school executives had masters' degrees in education, while the other respondents had bachelor's degrees. The majority of respondents (*n*=7) had more than 11 years of experience, while 3 had fewer than 10 years.

Results indicated that the overall safety performance of S1 was poor. Individual perspectives about the school were all low, ranging from 1.88 (SPPP) to 2.12 (SP) (Figure 1). This result was due to several issues, including: the school's safety policy, procedures and processes were not reviewed during the last two years; safety didn't feature at all as a standing item at school staff meetings. Also, fire evacuation training was not routinely practiced. Additionally, this school appeared densely populated, meaning that there were too many students for the size of the campus, which could prove problematic for highly active male students.

3.2 School 2 (S2)

This school is a male elementary school in the central region of Saudi Arabia. The participants in this school were 1 Ministry of Education officer, 2 school executives and 8 teachers. It had between 501 and 1,000 students. All of the respondents had only a bachelor's degree. The majority (*n*=9) had fewer than 20 years of experience, while 2 had more than 20 years.

The school's overall safety performance was rated as poor to moderate. Perspective performance ratings were SML, 2.48; SLT, 2.17; SPPP, 2.47; WSC, 2.35; and SP, 2.37 (Figure 1). This result is due to a number of identified issues at this school, including: although the school staff had received a copy of the school safety policy and procedures,

they were not able to demonstrate that they understood its contents and how to implement it; the majority of staff had not completed basic first aid training.

3.3 School 3 (S3)

This school is a male secondary school in the eastern region of Saudi Arabia. The participants in this school were 1 Ministry of Education officer, 3 school executives and 10 teachers. It had between 501 and 1,000 students. Also, 3 teachers had master's degrees, while the rest had bachelor's degrees. The majority (*n*=10) had fewer than 20 years of experience, while 4 had more than 20 years.

Data recorded S3's safety performance as very good. All perspectives were rated very good: SML, 4.28; SLT, 4.40; SPPP, 4.34; WSC, 4.31; and SP, 4.43 (Figure 1). This school's score was 87%, which led us to consider the safety performance of this school to be very good. This result was for several reasons (Ministry of Education in Saudi Arabia, 2012), including: all staff had received safety policy, procedures, and processes and understood them; the majority of school staff participated regularly in first aid and safety training courses. Furthermore, the fire evacuation training had been done routinely. Finally, there was periodic communication between school management and the Ministry of Education.

3.4 School 4 (S4)

This school is a female primary school in the northern region of Saudi Arabia. The participants in this school were 1 Ministry of Education officer, 2 school executives and 7 teachers. It had between 201 and 500 students. Also, all of the participants had only bachelor's degrees. The majority (*n*=8) had fewer than 20 years of experience, while the Ministry of Education officer and one of the school executives had more than 20 years.

Data recorded S3 as having the worst safety performance. SLT was very poor (1.59), while the other perspectives were slightly poor: SML, 1.86; SPPP, 2.08; WSC, 2.18; and SP, 1.87 (Figure 1). The score of this school was 38%, which led us, in general, to consider the safety performance of this school to be slightly poor. This result is due to several issues (Ministry of Education in Saudi Arabia, 2012), including: the school's safety policy, procedures and processes were not reviewed during the last few years; no fire evacuation training has been done routinely; and the communication between school staff and the Ministry of Education was poor due to social customs.

3.5 School 5 (S5)

This school is a female elementary school in the southern region of Saudi Arabia. The participants in this school were 1 Ministry of Education officer, 2 school executives, and 6 teachers. It had fewer than 200 students. Also, a school executive had a master's degree, while the rest had bachelor's degrees. The majority (*n*=8) had fewer than 20 years of experience, while one of the school executives had more than 20 years.

Data recorded the safety performance for S4 as the most worst. SP was very poor (1.71), while the rest were slightly poor: SML, 1.86; SLT, 1.83; SPPP, 1.88; and WSC, 1.88 (Figure 1). The score of this school was 37%, which led us, in general, to consider the safety performance of this school to be slightly poor. This result is due to a few factors (Ministry of Education in Saudi Arabia, 2012), including: school staff haven't reviewed the school safety policy, procedures, and processes four years ago; the fire evacuation training wasn't done during the last two years. The communication between school staff and the Ministry of Education was very poor due to social customs and the school's location outside the city.

3.6 School 6 (S6)

This school is a female secondary school in the central region of Saudi Arabia. The participants in this school were 1 Ministry of Education officer, 3 school executives and 9 teachers. It had more than 1,500 students. Also, the Ministry of Education officer responsible for this school and 1 school executive had master's degrees, while the rest had bachelor's degrees. The majority (*n*=11) had fewer than 20 years of experience, while 2 (the Ministry of Education officer and a teacher) had more than 20 years.

Data recorded the safety performance for S6 as very good. Four perspectives were very good: SLT, 4.21; SPPP, 4.24; WSC, 4.38; and SP, 4.34. SML was good (4.16) (Figure 1). The score of this school was 85%, which led us, in general, to consider the safety performance of this school to be very good. This result is due to several aspects (Ministry of Education in Saudi Arabia, 2012), including: the safety policy, procedures and processes manual had been reviewed and understood by all the school staff; the school provided monthly first aid, safety and fire evacuation training. However, social customs led to poor communication, and school management communicated with the Ministry of Education, but they were in touch, specifically the school's Ministry officer, by phone/email at various times.

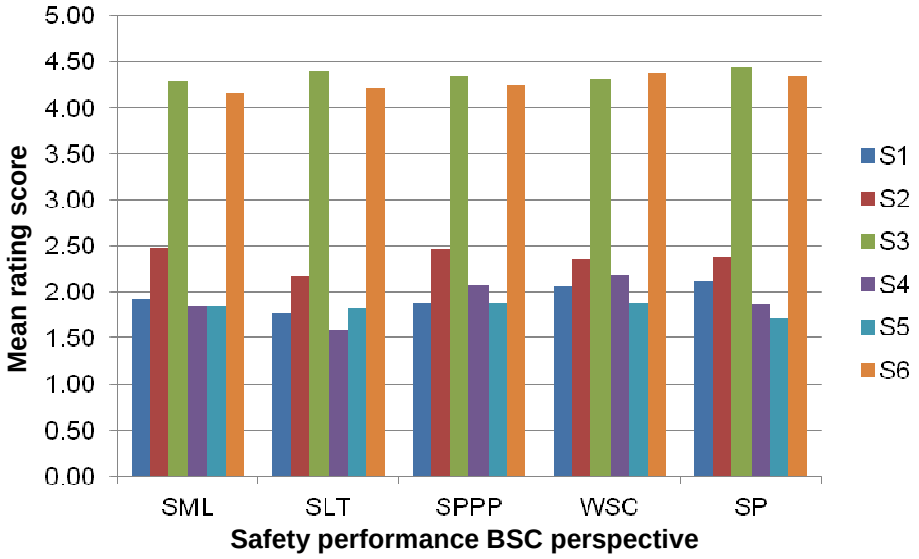

Figure 1: Perspectives rating for all schools

4. School comparative assessment

A comparative assessment of the above 6 schools was conducted based on clustered benchmark results for school gender, level and region. This enabled a comparison of these groupings in order to reveal whether they were critical factors contributing to safety performance across the 5 perspectives of the safety performance BSC framework.

4.1 School gender comparison

As described previously, schooling in Saudi Arabia is strictly divided by gender. Figure 2 illustrates the performance rating for the 6 schools across the 5 perspectives when clustered into gender categories. Surprisingly, even though males are viewed as being more active and more inclined towards partaking in riskier activities, this study indicated that male schools had a higher performance rating across all 5 perspectives. Some explanations have been provided in the previous section as to why the female schools examined had lower safety performance (e.g., social customs). This benchmarking study in the Saudi context had different results from those previously reported in the literature, where girls' schools generally had high safety performance (Baldry, 2003; Bosworth, et al., 1999; Chen & Astor, 2009; Hu & Lin, 2001; Kumpulainen, et al., 1998; Nansel, et al., 2001; Rigby, 2005). In fact, there is a belief that girls do not engage in risk-taking behaviour, so safety is given no attention at girls' schools. Furthermore, girls are valued less than boys are, so their safety is not valued as highly.

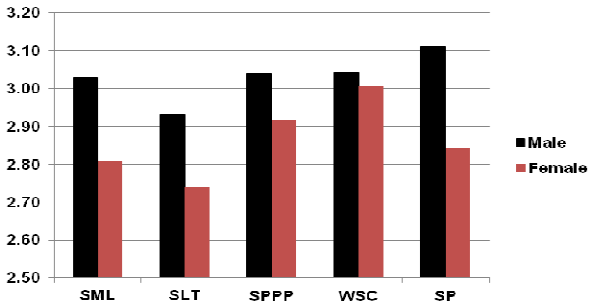

Figure 2: Comparing schools by gender

4.2 Schooling level

The Saudi Arabian schooling system is divided into 3 levels, namely, primary, elementary and secondary. Figure 3 illustrates the performance rating for all perspectives across the 3 levels. Findings indicated that the level of safety performance for all perspectives in secondary schools was higher than that in primary and elementary schools. Various safety studies and practitioners reported in the literature that the prevalence of school safety is dissimilar from school to school due to distinct dynamics in each individual school level and type (Astor, et al., 2002; Benbenishty & Astor, 2005; Benbenishty, et al., 2002). The predominant explanation for higher safety performance in secondary schools is that this age group (i.e., 15–18) is more mature and educated, is less prone to risky behaviour and tends to follow safety procedures.

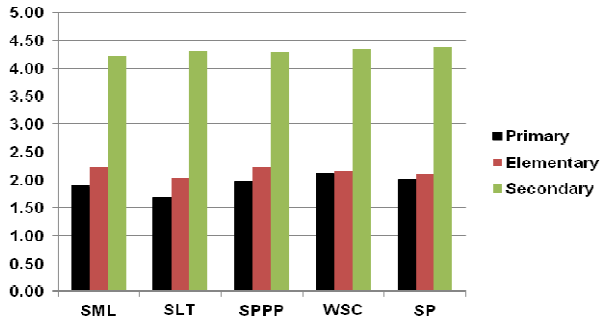

Figure 3: Comparing schools by schooling level

4.3 School region

As described previously, this study considered 5 regions in Saudi Arabia, namely, central, western, eastern, northern, and southern. Figure 4 illustrates the performance rating for all perspectives in the 5 regions. Results indicated that the safety performance for all perspectives in the eastern region was higher than that in other regions. As discussed earlier, the social systems that characterise a particular region will provide a macro framework for school safety performance in each region (Basu, 1992; Dyson & Moore, 1983; Jejeebhoy, 2000). Because the eastern region and its population are mostly affluent employees of the oil industry, and many are expatriates, they have a high regard for personal safety; this culture is also reflected in the schooling system in this region. Furthermore, the results showed that the safety performance of all perspectives in the central region was also moderately good. This is because the densely populated central region is where the capital is located and therefore may receive a higher degree of investment and concern than the more sparsely populated northern and southern regions do. Overall, the regional comparative analysis confirms expectations that the more educated and affluent central and eastern coastal region also have a higher regard for safety in their schooling systems. A challenge for the government will be to ensure a homogenous level of safety performance across the entire country.

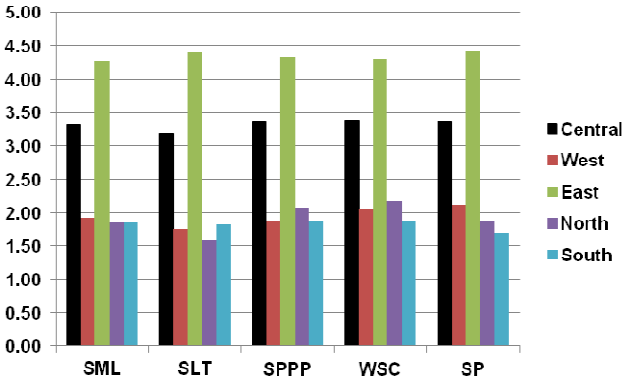

Figure 4: Comparing schools by region

5. Conclusion

Generally, Saudi Arabia has higher rates of school incidents and accidents than most other developed and newly industrialised countries have. In this study, the developed safety performance BSC was utilised to benchmark safety performance in 6 schools and confirmed that there is still considerable room for improvement in the country. The findings showed that male schools had a higher level of overall safety performance compared to that of female schools, which is contrary to prior reported studies. Primary schools had a poorer overall safety performance when compared to that of elementary and secondary schools; secondary schools had the highest safety performance. There might be a greater appreciation for safety by teachers and executives in secondary schools, and the cohort of older students might be more likely to engage in safer behaviours and better understand safety policies and procedures set by the school. Finally, the safety performance of the more affluent eastern and central regions was higher than that of the more densely populated and less affluent northern and southern regions.

6. Recommendations

The completed benchmarking study of safety performance in the Saudi public school system, using the developed safety performance BSC, shed light on a range of issues that need to be considered. To address school safety deficiencies in the Saudi context and create a culture of continuous safety performance improvement in the country, the following recommendations are provided:

1. Apply the developed comprehensive safety performance BSC to continuously evaluate and benchmark the safety performance of Saudi schools and to pinpoint areas for improvement in each school, region and school level and across the country.

2. Provide more attention to safety performance in the less affluent and more densely populated rural areas of Saudi Arabia where there appears to be a lower level of safety performance.

3. Conduct further studies to understand why there is a lower level of safety performance in female schools and invest in gender-focused safety strategies that heighten safety performance across the 5 safety BSC perspectives.

4. Invest in improved school facilities to ensure that the schools are not overpopulated and that the educational built environment is safe for all school activities.

5. Create [the government] a safety performance funding scheme that is linked to evaluation ratings established by the safety BSC, thereby creating incentive for school executives to promote a heightened level of safety performance in their schools.

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Appendix A

Table 1: Safety performance BSC perspectives, factors and items (Alolah, et al., 2012)

SML: Safety Management and Leadership (Perspective)
SML1: Management Commitment to Safety (Factor)
SML11: Management actions safety issues
SML12: Management provides adequate resources to safety
SML12: Management encourages employees to voice concerns and safety improvement proposals
SML14: Management provides adequate safety information (i.e. media, mission statements, accident statistics, etc.)
SML15: Management involves employees when setting safety objectives, decision making and improvement plans
SML2: Management's Active Participation in Safety (Factor)
SML21: Management promotes a safety culture
SML22: Management actively participates in risk assessments, consultative committee meetings and inspections
SML23: Management ensures that information (i.e. procedures) is visibly present in the workplace
SML3: Safety Communication and Relations (Factor)
SML31: Management and supervisors have an open door policy
SML32: Safety information is regularly brought to my attention by supervisors
SML33: Supervisors are more attentive to safety issues than the average employee
SML34: Supervisors are trusted and can relate with employees about safety

SML4: Safety Practice Incentives (Factor)
SML41: Monetary (e.g. bonuses) or recognition (e.g. safe employee of the month) incentives are provided for employees for good safety practices
SML42: There are punitive measures for the continued poor safety practices of employees (e.g. fines, demotions, etc.)
SML5: Perceived Supervisor Competence (Factor)
SML51: Supervisors have adequate skills and authority to tackle safety issues
SML52: Supervisors are committed to, and convinced of, the benefits of safety

SLT: Safety Learning and Training (Perspective)
SLT1: Safety Training, Seminar, and Promotional Strategies (Factor)
SLT11: Regular safety seminars and updates are provided to employees (e.g. short talks, group meetings, etc)
SLT12: Adequate provision of up-to-date safety training to all employees
SLT13: Adequate resources allocated to safety training
SLT14: Safety training adequately covers emergency response and provides first-aid competencies
SLT15: Enhanced safety awareness by clearly visible mission statements in the workplace (i.e. slogans and logos)
SLT16: Readily available published materials on safety in the workplace (i.e. library, statistics, and newsletters)
SLT2: Safety learning openness (Factor)
SLT21: Employees give tips to each other on how to work safely
SLT22: Accident/incident reports are used to improve safety
SLT23: Employees learn lessons from near misses, incident and accident reports
SLT24: Feedback is used to improve safety in the workplace
SLT3: Safety knowledge and competence (Factor)
SL31: Employees are competent in fulfilling their safety obligations
SLT32: School students are instilled with sufficient knowledge on safety management procedures

Safety Policy, Procedures, and Processes (Perspective)
SPPP1: Safety procedures, audits and reviews (Factor)
SPPP11: Safety inspections are regularly conducted
SPPP12: Employment of a safety officer and safety supervisors
SPPP13: The results of accident investigations are fed back to the supervisory level
SPPP14: Adequate emergency planning and procedures
SPPP15: Safety management systems include strong auditing requirements
SPPP16: Safety equipment, tools and other accessories are maintained and tested regularly
SPPP17: Sufficient training on the use of safety equipment is available to employees
SPPP18: Safety is viewed as an important consideration in the design process for new School buildings and facilities
SPPP2: Safety accountability and feedback (Factor)
SPPP21: Safety auditors are sufficiently familiar with the appropriate safety policy and procedures
SPPP22: Employee/parent satisfaction with the feedback given on accidents/incidents, near loss and injuries that occurred
SPPP23: Employee/parent satisfaction with the follow-up actions taken after incidents and accidents have taken place
SPPP24: Periodic maintenance of safety resources to reflect current best practices
SPPP25: Safety operations are conducted professionally and adequately governed by senior management
SPPP3: Built environment safety (Factor)
SPPP31: A safety checklist is regularly completed for School buildings/facilities to ensure that they are safe to use
SPPP32: Maintenance issues that are viewed as high safety risks are given high priority and addressed quickly

Workforce Safety Culture (Perspective)
WSC1: Individual responsibility to safety (Factor)
WSC11: Employee's at all levels generally have a personality that is conducive to good safety practices
WSC12: Value is placed on strong personal safety responsibility
WSC13: Employee's place a high priority on safety
WSC14: Employee's demonstrate 'Duty of Care' towards one another
WSC15: Employees safely utilise available machines and technical equipment
WSC2: Perceptions of work situation and pressure (Factor)
WSC21: There are enough employees to carry out required work in a safe manner
WSC22: Employee's have enough time to carry out their tasks in a safe manner
WSC23: A realistic amount of time is generally scheduled for completing assigned tasks in a safe manner
WSC24: Work procedures are presented clearly and logically
WSC25: Employee's feel comfortable to inform management of safety issues
WSC3: Propensity to report incidents and accidents (Factor)
WSC31: Employee perceive that the incident/accident reporting system is effective
WSC32: Employee's are willing to account for a co-worker's ongoing failure to report incidents/accidents
WSC33: Employee's have confidence in the ability of executives to correct safety issues and concerns

SP: Safety Performance (Perspective)
SP1: Safety accident and incident rates and appropriate responses (Factor)
SP11: There is a low frequency of incidents in our school
SP12: There is a low frequency of accidents in our school
SP13: Accident reports always result in a range of appropriate corrective and preventive actions
SP2: General safety behaviours of staff (Factor)
SP21: There are good safety attitudes and behaviours in the school environment
SP22: There is strong willingness to comply with safety policy, procedures and practices
SP23: Employees are always willing to assess incidents or accidents that occur and organise appropriate emergency care
SP3: Emergency response (Factor)
SP31: There is a quick emergency response to accidents
SP32: Emergency planning and response is effective

Time travellers: managers on the building site

Martine Buser[1]

Abstract

Efficiency is often described as the extent to which time, effort or cost is well used for executing an intended task or purpose: the shorter time between an investment and it return, the greater the profit. Organisational concepts and theories are here to help industries to perform as efficiently as possible. Management and planning tools are mobilised to frame and control work processes to be done on time. However studies on the building site usually show chaos and the proliferation of unexpected events. Interruptions are usually treated as disturbances which need to be reduced and avoided. Managers have to deal with these disturbances which create a rupture between what has been planned and what is actually happening at the building site. The present paper looks at how these interruptions appear during the workday and how the managers answer and reorganise their work consequently. The empirical material comes from a study carried at the building site of a public school. The methods used to collect data are frequency analysis and participant observation among others. The results show that these managers did not comply with the traditional picture of managing the building site. If their work is indeed fragmented with an average of 120 interruptions per day, they do not overwork to compensate the lack of time. Moreover instead of portraying these switching as interruptions affecting the work of managers it is argued that these switching in fact partly constitute their work.

Keywords: building site, fragmentation, time, work, managers

1. Introduction

In capitalist society “time is money” is more than a phrase. The ultimate goal of organisational studies is to maximise and optimise organisation efficiency and productivity. In that regards time is a precious resource which need to be carefully and scarily employed. Organisational time is often conceived as a linear measurement of chronology within which various activities can be aligned and organised in terms of duration, rate or intensity (Macey 1996). The construction sector is characterized by tight planning and strict deadline. Many concepts of management of construction such as Lean or Integrated Project Delivery are defining work as being a sequence of processes which can be ordered in time (Ladhenperä, 2012). Management and planning tools are mobilised to frame and control these processes. However many studies on the building site have shown chaotic organisations and the proliferation of unexpected events. These interruptions, as they often signalised unforeseen problems to be solved, are usually treated as disturbances which need to be reduced and avoided. The role of site managers is to deal with these disturbances signalising the mismatch between what has been planned and what is actually happening during the work.

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To capture what is happening in organisations, I have often used qualitative interviews, collecting organised narratives from the various actors I was talking to. These narratives were either mobilised from a pool of existing stories or created at the time of the interview to account for past and future events. But one thing was communally missing from all these accounts: the present time. So my gathering of what was happening in organisation was a collection of information about specific events but not the happening of events. The present paper tries to get closer to the work activities as they unfolded in real time.

2. Theoretical frame

Since Carlson study in 1951, giving a systematic report of the work of top managers, numerous researches have described what managers actually do at work. In listing a succession of events Minzberg (1973), Kotter (1982) and Stewart (1983) for examples, have identified different roles, functions and activities exercised by managers during their work. In doing so they also underlined the differences between what managers are supposed to do: strategy, planning, distribution of tasks, etc… and what they actually do: interacting with others and solving day to day problems (Hales 1986). Time is usually distributed in these activities, which in turn face many of what is described as interruptions or disturbances. It is often a consequence of these disturbances that managers need to work overtime to compensate the time lost (Mintzberg, 1973).

Another consequences identified by researchers regarding these interruptions is the fragmentation of work. In sectors as diverse as finance, IT, consulting companies, hospital or academia reports have insisted on the short amount of time spent for each activities and the high frequency of switching between these activities (Mark and al 2005). As previously identified for the top level management, other types of managers and workers are now involved in these multiple activities and collaborations which can be characterized by fast-paced activities, a frequent fragmentation of actions and a continuous flow of interactions with others (Gonzales and Mark 2005).

In sensitive areas, research has also focused on the danger associated with frequent interruptions, demonstrating how the increasing number of errors is linked to the increasing number of interruptions, especially in workplace such as emergency room, plane or nuclear plant (Chisholm and al. 2000). These studies underline the role played by interruptions as a stress factor, as well as responsible for slowing the process of completing the intended tasks (Carey and al. 2000) Related to these interruptions are the disruption costs, meaning the additional time to recall the task and reorient it back after an interrupted task.

Performing simultaneous activities in given time has been widely recognized in time-use research being differently termed: simultaneous activities, overlapping activities, concurrent activities, parallel activities, secondary activities, polychronic time use or multitasking (Keynon 2008). Theory about time divides and organizes time in different dimensions, intervals, sequences, tasks, and so on. In phase with the linear perception of time, these notions presupposed a beginning and an end to the activities they parallelised or superposed, they presupposed also a kind of rational organisation or hierarchies between them. The real challenge appears not so much to dismantle time into small pieces or

activities than to be able to account for the simultaneousness of these activities within a given time.

The use of IT tools and their proliferation at work have also been discussed as having a major role in increasing the number of interruptions. Mobile phones, portable computers and smart phones are providing a continuous stream of information whose receptions are signalised by different noises and icons. Many studies tend to portray these interruptions as disturbances which prevent workers to actually perform their tasks and therefore need to be reduced (Jett and Georges, 2005; Czerwinsky at al. 2004). By contrast a few authors have seen the role of information technology as included in the nature of work (Orlikowski, 2007). In this perspective, the constant connectivity enabled by the communication technologies is constituting of the work itself as would be all kind of other social interactions and therefore cannot be seen as exogenous and distinct from the day to day activities (Wacjman and Rose 2011).

To summarise, many of the notions describing time, interruptions and fragmentation of work assumes that time can be rationally divided and organised. The recognition of the possibilities of several activities sharing a given time implies then to be able to divide time into even smaller sequences and activities which once identified can then be superposed or parallelised. In doing so the researcher assumes an organisation and rationality between the different sequences or tasks as well as the ability for the worker to organise them. However the principle characteristic of an interruption is precisely to have the potential to reverse this order and hierarchies by introducing new demands and priorities and therefore forcing the worker to redefine and reorganise her/his priority.

3. Method

The empirical material used for this paper is taken mainly from two civil engineers students work, Nielsen & Apelgren (2003). Their master thesis or more precisely their 168 pages annexes documenting 15 full days of following work interruptions and their consequences on failures on the building site constitute the secondary data used here. The aim of their master was to count the number of disturbances during workday and related to these the number of failures during the construction of a building.

The empirical material concerns the work of building site managers. Work on the building site is often described as chaotic, full of interruptions and delays (Loosmore and al.2003). Managers on site are often said to be under stress and overloaded with work and therefore very vulnerable to interruptions. The data come from participant observation and frequency analysis of managers' workday on a building site done by the two students (Nielsen & Apelgren 2003). I have always been fascinated by these two students' frequency analysis and their meticulous dismantling of all activities, some of them lasting no longer than 15 or 20 seconds. So here I propose to revisit the material gathered by Nielsen and Apelgren in two steps. First to give an account on what working as managers on the building site looks like as extracted from their data and secondly to focus on how the multiple interruptions are dealt with.

In order to do so they observed the workday of eight middle managers and architects. The managers observed were working on the building of a new public school. The school project began in the late nineties. The conceptual phase lasted from October 2001 to May 2002, followed by a design phase. Production of the school commenced September 2002. The new school was finalized in August 2004. The field work was carried on at the building site from the beginning of the construction phase starting the last days of September and continued during 5 weeks to the end of October 2003. The engineers did welcome the students warmly and did not make restriction regarding access to their daily occupations. The architects though claimed they did not understand the interest of the students for their daily work and were a bit more restrictive regarding accessibility. Further studies of the same building site have shown that already at that time they were conflict between the engineering company and the architects who felt betrayed by the contractual conditions they were offered (Koch, Buser and Thuesen, 2004). The following lists the managers observed as well as the number of full days' observation per person, the observation days were not consecutive, all managers were male:

- Project coordinator (1 observation)
- Foreman (3 observations)
- Production manager (1 observation)
- Subcontract manager 1(2 observations)
- Subcontract manager 2 (2 observations)
- Overall project manager and controller (2 observations)
- Design manager (2 observations)
- Architects (2 observations)

The frequency analysis aimed at registering all the "stumbling stones" during a work day. The definition of "stumbling stones" is borrowed from Kjeldsen 1994 and describes "all the issues that prevents the actor in executing his work as effectively as possible and as correctly as possible the first time". Are included in this definition all the interruptions and disturbances encountered by the manager and the concrete failures on the work place necessitating adaptation or changes in the work processes. This definition and its interpretation by the two students present a methodological bias. What the observers perceived as interruptions may not been similar to what the observed person perceived as such. Besides by focussing on the rupture, there is a risk to overemphasise the interruptions and underestimated the symbolic and social part of the work place. Last but not least the frequency analysis does not allow recomposing a task or activity as carried in different sequences as the level of description announced the type of activities concerned but not the process as it developed.

In order to differentiate and trace the observed activities during the frequency analysis, the two students developed a schema stating 5 main categories of activities: 1. the actual school project divided in 22 sub-categories; 2. other projects divided following the same 22 sub-categories, 3. IT with 3 sub-categories, 4. diverse activities such as waiting time, transport, pause and cleaning, and 5. private. This categorisation presents also a bias as it divides the content of the workday between work and non-work and oversees the social and symbolic aspects of work related humans interactions.

To this frequency analysis, the two students added participant observation and they kept a diary of the manager activities. This diary accounted for the planning of the day and how activities took place during the day. These observations enriched the material by giving a context to the different disruptions as well as by tracing the reactions and attitudes of the observed person. Besides following workday, participant observation covered also three meetings on the site and one visit of the site with a delegation of the various companies involved. The observed managers took part to a qualitative interview In addition written documentation related to the project was referred to. All the observations were orally recorded on site and transcribed; they are the basis of the present paper.

Though the empirical material is extremely detailed, using other people's material has its limitation as it is not possible to enquire further on specific issues or to develop further the trustworthiness of methods used by then. The interruptions as defined by the students as well as their activities report is mirroring their own understanding of the notions which may not be shared similarly by others observers or participants; this limits the interpretation which can be extracted from the material. Another limitation resides in the fact that the master study was carried out in the context of operation management, focusing on prime processes and disturbances as causing failures.

4. The case study

The building site visited is the building of a new school. It was one the subprojects of a larger cooperation between a municipality and a network of construction actors. The overall project aimed at renewing and enlarging the public school services of the municipality (Koch and al. 2004). This sub project amounted to 12 million Euro for the contractor out of a total project budget at 26 million Euro. Whereas the architects and consulting engineers has a common budget for the entire project at 2,6 million Euro.

Operation during production was planned using traditional project planning tools (Microsoft project), meetings in the project group and in the steering group and evaluated by a key performance indicator scheme used in the steering group. It should be underlined that the project did not as a general feature demonstrated stress like tight budget frames or delays: it was finalized on time and with a small surplus compared to budget. The quality of the school was said to be good at the time of the completion of the project. The fact that, end-users later found number of problems which had not properly been dealt with is another story (Koch and al. 2004).

To the exception of the two architects, all the interviewees were employees at the design build contractor. One of the four managers worked predominantly with production issues and the three others worked predominantly with design issues, although these issues were interwoven. The site had 13 employed craftsmen and building workers in the beginning increasing to 79 at the end of the project. The next section presents first a general account of the workday based on the sequential frequency analysis.

The 15 workdays of the managers observed by Nielsen & Apelgren (2003) had an average length of 7 hours 45 minutes (the legal week work in Denmark is of 37 hours). While the 3 observations of the foreman did start rather early in the morning (6.05, 6.00 and 6.31), the rest of the observed managers began their day later between 7.25 and 9.47 with an average at 8.20. At the end of the day, the ones who arrived early left between 14.30 and 15.30 and the others stayed no longer than 16.45.

Taking a closer look at the work organisation, the managers had scheduled between 3 to 4 main tasks to be carried during the day usually including meetings with different actors related to the project both internal and external to the company but also sometimes external to the school project. Besides meetings, economy, planning, controlling and reporting were recurrent activities.

Looking at the actual unfolding of the day, the results of the study show very fragmented activity over time. As during the course of the 3-4 primary activities, an average of some 126 interruptions were observed. The highest number of interruptions is scored by the production manager in charge of concrete with a total of 284 interruptions which gives a rate of an interruption every 1 minute and 40 seconds. In term of length of the recorded activities, 3 activities are lasting more than 10 minutes; 135 have duration between 1 and 10 minutes and 146 are actually lasting less than a minute.

The three activities lasting over 10 minutes occurred first at 7.50, a 10 minutes of work with economy in the office; second at 8.36 a 11.25 minutes discussion on site with the carpenters about the tolerance of woods installation; and thirdly at 13.32 at 12 minutes telephone call with a consultant. During this call the manager was browsing through his computer screen and writing about something else on his computer during 22 seconds.

Under one minute length activities are listed activities such as questions and answers related to various issues during the walks on the building site; phones talks with the providers and the consultancy engineers as a problem occurred with the floor drain necessitating a quick and radical change in the work plan, as well as interruptions during these phone talks; events such as trials to join an interlocutor on the phone without success or looking at the display of a ringing phone even if the call is not answered are also registered as interruptions.

Most often during the observations, the managers don't take any specific pause for their lunch, but once a barbecue is organised with the carpenters.

Whenever there is a "temps mort" (dead time), meaning a moment in between to activities such as waiting for somebody to arrive at a meeting, time is used it for side or routine

activities such: making coffee during the loading time of the computer; listening to answer machine or calling divers interlocutors when driving their cars, discussing new projects when waiting for all the participants to join a meeting; typing e-mail when waiting for somebody to take their phones call; or even explaining things to the two students following them.

Out of the 15 days of observation there is only one mention of a manager not engaged in a specific activity with the following entrance: "*looking up in the air he looks like one who is thinking*" and this lasted 20 seconds.

The following table presents a limited example, about 22 minutes, of the recording of one of the managers' activities done by the students. The chosen moment is rather mundane and does not relate any specific crisis. It lasts 24 minutes and relates 18 activities.

Table 1. Extract form Nielsen & Apelgren (2003, page 19, document 4) translated in English by the author.

Main activity	**Sub categories**	**Start time**	**End time**	**Length**	**Comment**
School	On the site	08:42:55	08:43:42	00:00:47	Discussion with a sub-contractor
School	On the site	08:43:42	08:44:10	00:00:28	Walking on the site (wos)
School	Planning	08:44:10	08:44:26	00:00:16	(wos) Calculate concrete figures on his phone
School	On the site	08:44:26	08:48:22	00:03:56	(wos) walk back to the site office
School	On the site	08:44:22	08:48:24	00:00:02	Go in, take off his helmet and coat
School	Social discussion	08:48:24	08:50:00	00:01:36	
School	Office work	08:50:00	08:50:20	00:00:20	Check his computer and e-mails
School	Discussion about the project	08:50:20	08:54:08	00:03:48	With a collaborator about checking of ground quality
School	Discussion about the project	08:54:08	08:56:03	00:01:55	Interruption by the secretary about a file
School	Error	08:56:03	08:58:22	00:02:19	Try to find the file for the secretary, while still interacting with him
School	Discussion about error	08:58:22	08:58:43	00:00:21	Closing the discussion with the secretary
School	Office work	08:58:43	08:59:24	00:00:41	Working with computer finding at the end the document for the secretary
School	Phone call to a provider	08:59:24	09:00:53	00:01:28	Material
School	Call to another provider	09:01:30	09:05:15	00:03:45	Material
School	Social discussion with provider	09:02:25	09:02:50	00:00:25	
School	Discussion about the project with provider	09:02:50	09:05:15	00:03:25	Material
School	Internal discussion about the project	09:02:50	09:03:15	00:00:25	Another phone rings short communication internal of project, provider still online.
School	Planning	09:05:15	09:05:50	00:00:35	
	….				….

The succession of events shows how some of the activities were left aside when new ones popped up. Activities could also be superposed to each other's, before being successively closed

Aside for the human interruptions the managers are facing, the reliability of the tools they are using to support their daily work is also challenging: A digging machine is to stop the time to get more gasoline as the workers have forgotten the fill up the tank. The lamp in the workers hut has gone, as the workers cannot find a new bulb, the foreman is asked to search for one himself.

IT though representing a manifest benefit for the managers contributes also with its shares of problems. Computers are a frequent source of interruptions. They either crashed, during the observations several hours of work were actually lost, or required codes and accesses which were not accessible. Printers did not always resituate exactly what was expecting. Mobile phones could happened to be empty of batteries precisely at the time they where required.

5. Discussion

There is no doubt that the work of the observed site managers is fragmented and that compared to other studies consulted for this paper they hold a kind of record of the highest number of interruptions as none of the others reached the average of a new activity every 1 minute and 40 seconds. As discussed in the methods section the results could be relative to the manner the frequency analysis was performed and the units of analysis, the interruptions, defined. More than a change of activity, the frequency analysis reported all kind of changes it regarding space, media or interactions.

Since no overwork outside working hours was actually reported during the observations, one of the results is that these managers with an average of 7.45 hours' work per day are not working overtime. This is contrary to Mintzberg's point stating that managers need to balance the time lost in interruptions by overworking. Besides at the exception of the foreman who has to arrive early to decouple the site alarm, the meeting time in the morning are similar to office work and rather flexible at least within the sample of observations. This could be explained by the fact that the observations took place during the first months of this medium size construction building.

Most of the day managers during the observations sit in their offices. The walking around to look, discuss and control the work in progress is on the average only a small part of their work day. The majority of managers in this study have actually a rather office like type of job even if their tasks are of managing the building place.

Even of some of the incidents happening on the building site during the observations have required some quick handlings, the overall study does not report stress signals among the managers observed.

These 120 interruptions during the course of the workday are rarely of same context as the current task at-hand most often they are randomly related to other topics. Managers are

facing a continuous stream of activities where other people, events or things move in and out. They may switch between known and unknown expected and unexpected. They may be interruption within the interruptions, opening new windows of activities that need to be parallelised or closed before taking over the previous activities. In the example above, the manager needs to change an order after a problem has occurred on the building site. It takes 15 minutes between the moment he finds out how much concrete he needs and the time he can actually negotiate the order. First he has to physically move to his office, then meeting a colleague he is engaging in interaction of private character; as he is coming back in his office he is also quickly checking his e-mail for any kind of emergency. From his office he is discussing a ground quality issue with a colleague but is interrupted by the secretary who has other errands and needs him to provide specific documents straight away. After having used several minute in searching the document; he gives up and terminates his interaction with the secretary. He looks again at his e-mail, in doing so he finds by chance the document he was asked about. Then he calls a first provider who cannot deliver and then a second one. When making the second phone call, the manager has first a social interaction of 25 seconds with his correspondent before entering the professional discussion about the order. He is interrupting this discussion to be able to answer quickly another phone call from one of his colleague dealing with another issue before going back the previous call with the provider. The time needed to open and close the activities vary grandly between the type of tasks and emergency they represent. It is responsibility of the manager to ensure that these interruptions are taken care of so that the construction of building can carry on.

It would be difficult to distinguish between primary and secondary activities or parallel activities as the temporality as well the importance of these activities can vary strongly. The hierarchy of solving different tasks is often created by the context: delivering documents to the secretary may not be a priority for the manager but her insistence to obtain these documents modifies the previous planning of the manager. Similarly, the problem with the delivery of concrete is setting a new priority which importance varies during the morning as a solution is nearly found. To find a rational behind these actions in term of sequences or priority seems therefore difficult to achieve. The request of the secretary is linked to previous interactions with the manager, it would be difficult to trace its beginning and getting the document may not be the end.

Looking at how work develop during the day, during the observations, there are usually 3- or 4 planned main tasks or activities that need to be taken care. However at the exception of the meetings, there is a kind of inversion of priority as these tasks become what managers are doing when nothing else is asking for their attention. Most of these activities planning, controlling or reporting does not at the time of the observations required immediate fulfilling and can well be postponed without creating major delay.

The challenge is then not so much to liberate time in order to fulfil the planned tasks but to be able to collect, organise, prioritize and answer the different activities popping up during the day as well as constantly reorganising the already scheduled activities consequently.

6. Conclusion

By looking how time is spent by managers on the building site, the paper has shown some of the limits of assuming that time can be rationally divided and organised. As new situations occur continually, they forced the managers to react to a multiplicity of events. The temporality and hierarchy of these events can neither be predicted or fully organised as they are created by the interactions managers have with their surroundings and therefore do not only depend of their own will.

By looking closely at the daily work on managers on the building site, the present paper suggests that the flow of constant switching is not preventing managers to do their jobs but instead is co-shaping and co-organising their work. The task of managers is then to be able to deal and manage these changes of activities for the building process to continue.

A bias linked to the frequency analysis resides in the definition of interruption. What is seen by the observers as an interruption for example between informal private talk and formal worked related discussion, could be seen by the observed person as a totally linked activity where polite informal talk is the necessary warm up to a business discussion. So the apparent rupture between the two forms of interactions could be in fact a symbolic necessity before engaging into professional negotiations.

Moreover by fragmenting work into small pieces following a sequential time-line, the researcher is prevented to see that solving some tasks may require a number of different contacts, interactions and mediation. Even if these different actions don't always follow in an immediate sequence, they still represent effective practices.

15 days of works at the beginning of a construction site may not be enough to generalise on what constitutes the work of managers and the conditions under which this work is performed. But as time travellers, the managers of the study succeeded in being in different activities at the same time…

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Construction delivering transition -Danish and Swedish offshore wind farms

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Abstract

Construction activities are part of present societal transition towards a zero carbon society through several clean technologies' implementation and the construction sector is thereby possible either constraing and or enabling this current transition. Offshore wind turbine farms in Denmark and Sweden are one example of this. These projects encompass a high public profile, and might involve time delay, cost overruns and underperformance of their operations. The paper views offshore wind farms as socio technical undertakings of construction and draw on a combination of internal and external perspectives i.e. complex engineering projects and megaproject concepts and operation strategy and management. The aim of the paper is to investigate the phenomenon at Danish and Swedish offshore farms for strategic misrepresentation, overruns and underperformance or the opposite. Such projects tend to enact strategic misrepresentation understood as a combined practice of underestimating time and cost and overestimating the benefits of use of the completed product. The paper review other scholar's comments and criticism to strategic misrepresentation. The internal perspective focus on operation strategy is condensed into looking at contracts, planning, equipment and competences.

The results building on public accessible material show both successful and less successful projects, the less successful involving budget and time overrun, as well as under performance at a sample of 7 Danish and Swedish offshore wind farms. The paper discusses the particular elements of possible strategic misrepresentation but finds a contradictory pattern. Also experientally based competences are not clearly developing as later wind farms perform less than earlier. The insights provided offers alternative interpretations of overruns, relying on operations strategy elements.

Keywords: Transition, offshore wind farm, Denmark, Sweden, strategic misrepresentation

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1. Introduction

In the present contradictory societal situation strong forces push for transition towards a zero carbon society issuing demands for clean technology, yet the austere financial environment hampers the very same development. In these waters the wind industry continues to grow in terms of employment, conditioned by an uneven global development i.e. the light stagnation of number of new installed offshore wind turbines in Europe 2011 compared to 2010 (EWEA 2012), and the growth globally on markets like China, Asia and Latin America. And the impressive offshore wind plans presented in the EU members States energy renewal plans for 2020 alone represents investments in around 43 GW offshore (EWEA 2012). The installation of offshore wind farms, encompassing large power plants of wind turbines, as well as nearshore smaller farms are complex endeavours and the growth in demand for installations have generated a similar growth in operating companies, manufacturers, clients and interested citizens (BTM, 2010). Therefore the term “off shore wind farm” is used not only to denote the installations, but also the community of social players around them, adopting a sociotechnical viewpoint (Koch 2007). The technology involved encompasses installations from 5 MW and upward, usually consisting of a number of MW turbines, with an internal grid, a substation for transforming power, and an export cable connecting to a national grid (Gerdes et al., 2005; IEA, 2005; Snyder & Kaiser, 2009, Zhixin et al., 2009).

The aim of this paper is first to develop a combined social constructivist internal and external conceptualisation of the process of realising offshore wind farms; second, to investigate costs, time, delays and operational performance results of offshore wind farm power plant projects in Denmark and Sweden with a view to possible strategic misrepresentation.

The overarching theoretical perspective is thouroughgoing interpretivism (Grint and Woolgar 1997) appreciating the dynamic renegotiation of a sociotechnical community like offshore wind farms. This overarching perspective in turn features an external and internal perspective on offshore wind farms. The external perspective mobilised is Flyvbjergs constructs such as strategic misrepresentation as a combined practice that underestimates time and cost and overestimates the benefits from using the completed product (Flyvbjerg 2009).

The internal perspective builds on operations strategy (Slack And Lewis 2008), operations strategy (Slack et al 2007) and project management (Liu and Napier 2010, Love 2011). It focuses on contracts, planning, equipment and competences.

The empirical material encompasses data on seven offshore wind farms, six Danish and one Swedish, realised between 2001 and 2010. The farms are Horns Rev I, Horns Rev II, Lillgrund (SE), Middelgrunden, Nysted, Rødsand II, Samsø. Both the external and internal perspective is mobilised to scrutinize the process of realising those farms.

The paper is structured in a classical manner. Opening with a method, followed by theory, case description, discussion and conclusion.

2. Method

The research design behind this paper matches the two main aims of the paper. The first research question, the theoretical framework, is composed by combining an external and internal perspective. The external perspective contributions are critical studies of megaprojects (Flyvbjerg 2009, 2011)), complex engineering project management contributions (Davies and Hobday 2005, Miller and Lessard 2008) The internal perspective is covered by using operation strategy and operation management perspectices (Slack & Lewis 2008, Slack et al 2007). Finally Science, Technology, and Society (STS) approaches (Hughes 1983, Latour 1987, 2005, Grint and Woolgar 1997), acts as overall framework understanding of offshore wind farms as essentially being thoroughly negotiated and renegotiated, with inseparable social and technical aspects, operating in a semi-public environment, and involving a substantial amount of public performance. The second research question, the empirical, is answered by first investigating the external aspects of costs, time, delay and operational performance in relation to strategic misrepresentation, second the internal aspect of operational strategy. Both is done in an exploratory investigation manner with focus on a core data set from a selection of Danish and Swedish offshore wind farms. The selection of offshore wind farms has been done taking the largest in this geographical area, which also encompasses operational experience. These criteria lead to a sample of seven farms, six Danish and one Swedish; Horns Rev I, Horns Rev II, Lillgrund (SE), Middelgrunden, Nysted, Rødsand II, and Samsø. These farms also constitute a considerable basis of experience for a recurrent group of companies. The selection implies that some smaller Danish and Swedish wind farms have been disregarded, such as Frederikshavn (DK), Sprogø (DK), Vindeby (DK) and Yttre Stengrund (SE). The central tool for the first empirical work has been a desk study using internet sources. The analysis thus relies on publicly accessible sources, which is justified by the characteristics of engineering construction described above. Most of this material is not referenced as it is in Scandinavian language. It ranges from short newspaper announcements, articles in the business press and websites to reports and articles based on research from public wind industry associations and universities. For each of the figures and information given below, triangulation is used (Bryman and Bell, 2007), relying on several independent sources. The available public information has its strengths and weaknesses. Two examples of issues are currency conversion and difficulties in measuring the start and finish of a construction phase. The study is clearly limited in that it uses only desk research. If combined more systematically with other methods, it would be possible to detect internal phenomena, such as transfers of resources between projects, and capture details on labour and material costs.

3. Theory

The theoretical framework adopts an social constructivist approach drawing on STS (Latour 2005, Woolgar & Grint 1997). Within this frame two different perspective the external and the internal is combined. The external view draws on critical studies of megaprojects by Flyvbjerg and colleagues (Flyvbjerg 2009, 2011), and complex engineering approaches (Davies and Hobday 2005, Miller and Lessard 2008). The internal perspective combines operations strategy and management (Slack and Lewis 2008) project management contributions (Love 2011, Liu and Napier 2010). The social constructivist approach used

here, the thoroughgoing interpretive perspective (Grint & Woolgar 1997), appreciates the indeterminate features of cost, time, service provision, contracts and enterprise organisation and strategy, and viewing offshore wind farms as “texts” in an anti-essentialist manner (Grint & Woolgar 1997, Sismondo 2010). Throughout the project life time the figures and features characterising it are renegotiated over and over again both in the public sphere but also internally in the contributing companies. For example fixed sum contracts generate “backwards” controlling of expenses and/or attempts through various types of claims to enlarge the fixed sum. And project based accounting involves controlling hours spent using the portfolio of projects and activities rather than just one project, meaning the project costs are not necessarily allocated to the accounts where they belong. Texts on budget, time and cost figures thereby are renegotiated. Moreover the social constructivist approach implies that offshore wind farms should be understood as a socio-technical undertaking (Hughes 1983, Latour 1987, 2005) that operates in a semi-public environment (Hughes 1983). Hughes (1983) suggests ‘system’ as term, distinguishing between vertical systems, when the technical content varies between the different components, and horizontal when the same elements are repeated. Hughes (1983) views technical content and social aspects as inseperable, similar to Latour (2005). This is here taken to mean, that down to the detailed components of the technological constellation, they would encompass social issues such as cost, design approaches etc. Offshore wind farms can be understood as such socio-technical projects, which can be further defined using a complex engineering project definition: “high cost, technology intensive, customized capital goods, systems, networks, control units, software packages, constructs and services” (Davies and Hobday 2005). The strength of this definition is that it merges a business approach (capital goods) with a technical approach, underlining the scope and bundles of technologies associated with the product and appreciating the interconnection with the customer and the service aspect. The downside is however that the technology side tends to be described on a too abstract level and with too little appreciation of the intertwinedness of the technical and social. With a sociotechnical conceptualisation a cautious contextualisation in time and space of a study of socio technical phenomena is appreciated (Latour 2005). This approach emphasises an understanding of less stabilisation of the technology over time. Complex projects are often carried out under conditions of great risk and uncertainty, with a number of unforeseen aspects emerging as they develop (Davies and Hobday 2005, Hughes 1983, Millar and Lessard 2008). Decision-making regarding such aspects as budgeting and planning must thus cope with these conditions (Kahneman 1994). Offshore wind farms are essentially thoroughly negotiated and involve a substantial amount of public performance, and the project players are involved with the outer world.

Flyvbjerg (2009, 2011) represents a different, externalist approach, claiming that especially projects operating in a public-private interface would tend to be hampered by political mechanisms leading to a far more complex task for project management. The studies by Flyvbjerg (2009, 2011) on cost and time overruns within transport infrastructure (tunnels, roads, railroads, bridges) describe and document a long series of examples of heavy overruns. Also in later studies, Flyvbjerg and others have documented similar patterns (Flyvbjerg 2009). Flyvbjerg et al (2003) show that cost underestimation is a global and long-term phenomenon that does not diminish over time. Moreover, they document that cost underestimation cannot be explained by error, but rather by optimism bias and strategic

misrepresentation. Optimism bias occurs when planners of complex projects underestimate or are not fully aware of the time and costs necessary to realise the project. Estimations are often based on assumptions (Kahneman 1994). Strategic misrepresentation occurs when planners and other players who are active in preparing a project purposely reduce the required cost and time and increase the project's positive impacts in order to make the project attractive (Flyvbjerg 2011). Public and private players who join in alliance to launch a project often practice strategic misrepresentation. Project promoters may possess knowledge about how much a client for a complex engineering product can afford to pay, or at least the budgetary constraints that might exist (Flyvbjerg et al. 2003). Such knowledge can be used to fit budgets and schedules to these constraints rather than to present a realistic calculation of the project risks. Also, on a public-private arena, a "point of no return" is likely to exist; once a project is initiated, it cannot be stopped even if it runs out of funding (Flyvbjerg et al. 2003). The concept of strategic misrepresentation involves argumentation that combines underestimating time and cost and overestimating the value of the completed product to the customer (the benefit side, Flyvbjerg 2009). In relation to wind farm power plants, this would be equivalent to overestimating the actual power production based on unrealistically high expectations to production time and availability and underestimation of maintenance time and service costs. Flyvbjerg et al. (2009, 2011) argue that technical explanation cannot be found, whereas psychological and political-economic explanations are prevalent, which is contrary to the project management literature (see also Vanston and Vanston 2004). Political-economic explanations, however, explain inaccuracy in terms of strategic misrepresentation. Strategic misrepresentation is more likely to occur in wind farm projects than optimism bias, since these projects involve a series of reciprocal actions with public authorities, the press and the public. Flyvbjerg's critics, such as Love (2011), point out that the delimitation of Flyvbjerg's approach and concepts leaves a "chronological lacuna" between the initial event and the final outcome (Love 2011: 1202) since "intermediary conditions and events that lead to project overruns occurring are not examined or explained" (Love 2011: 1202). Moreover, Love (2011) characterises the reasoning of strategic misrepresentation and optimism bias as counterfactual causation (Love et al. 2011). Importantly, it can be added that Flyvbjerg, by adopting a focus on input and outcome measured in time and costs, overlooks the content of the project, which is rarely fixed as the project develops. Liu and Napier (2010) claim that optimism bias can be found widely within the construction industry. They contend that "it has been recognized that in preparing estimates, estimators are likely to make 'self-protective predictions', influenced by self-interest in securing contracts" (Liu and Napier 2010). Similarly, contractor's tender prices are often not only a product of the estimating department, but also managers may intervene reducing prices to lower levels in an attempt to win the contract (Liu and Napier 2010). Finally, clients may strategically underestimate costs to ensure that the project is launched and to obtain funding. Therefore there is a need for a more internal perspective.

3.1 The Internal perspective, operation strategy

Operation Strategy as a discipline and practice deals with

"the total pattern of decisions which shape the long term capabilities of any type of operation and their contribution to overall strategy, through the reconciliation of market requirements with operations resources" (Slack & Lewis 2008:18)

The main element of operations strategy according to Slack and Lewis (2008) are:

- Capacity Strategy
- Supply Network Strategy including purchasing and logistics
- Process Technology Strategy
- Development and Organisation

Capacity Strategy is concerned with how Capacity and facilities in general should be configured. In an offshore wind farm context contracts with windturbine manufacturers and a range of other suppliers is central. Windturbine manufacturer's capacity and quality of delivery are important and they normally do not directly do the installation, which is contracted. *Supply Network Strategy* including purchasing and logistics i s concerned with how operations relate to suppliers and customers. This is in the context of wind farms understood as the configuration of contracts with suppliers of products and processes for erecting the offshore wind farms, allowing the description and analysis to disregard the relation to the clients and customers. *Process Technology Strategy* concerns the choice and development of systems machines and processes. This is here simplified into looking at the equipment used. *Development and Organisation* is concerned with how the long term decision governing how the operations are run on a continuing basis. In the offshore wind farm context this occurs across projects and is here viewed as an issue of how project organisation is conceptualised as well as how competences develop. Competences as seen as a measure whether operational strategy are developing across projects. Also project management encompasses project planning. Literature on project management, often portray making time, cost and quality balance as a question of project management skills and tools (Atkinson 1999, Olewale and Sun 2010, Reichelt and Lyneis 1999) involving various budgeting, cost estimation and forecasting and planning techniques; however, the project management literature also explains how phenomena like 'scope creep' (increase in the number of project tasks) complicate this task. Love (2011) identifies a series of possible internal explanations for project overrun, which encompass practice, tasks, circumstances, organisation, system, industry and tools (including design errors and coordination problems). Similarly, Kaming et al. (1997), looking at high-rise projects, find "internal project" explanatory factors – such as inflationary increases in material costs, inaccurate material estimations and project complexity – to be the main causes of cost overruns. For time overruns, the main causes of delay are design changes, poor labour productivity and inadequate planning (Kaming et al. 1997).

Summarising the social constructivist framework, by combining an external and internal sociotechnical understanding of offshore wind farms provides an appropriate framework for evaluating both the external strategic misrepresentation and the internal operations strategy

for offshore wind parks here condensed into looking at contracts, planning, equipment and competences.

4. Cases: Selected Danish and Swedish offshore wind farms

The seven offshore wind farms investigated in this study are the following: Horns rev I, Horns Rev II, Lillgrund, Middelgrunden, Nysted, Rødsand II and Samsø. Lillgrund is the only placed in Swedish waters whereas the rest are placed in Danish waters. Middelgrunden is the oldest and was in operation in 2001. The youngest Rødsand II was operational in 2010.

Table 1 Technical features (M= monopole, G= Gravitation)

Wind farms	Power capacity	Turbine MW	Foun-dation	Water depth	Infield Cable kv/km	Export Cable kv/km	Offshore Sub-stations
Horns rev I	160	2	M	6-11	30/63	150/21	1
Horns rev II	209	2,3	M	9-17	33/70	150/42	1
Lillgrund SE	110	2,3	G	4-8	33/24	130/7	1
Middelgrunden	40	2	G	3-6	30/5	30/3.5	0
Nysted	166	2,3	G	6-10	33/48	132/11	1
Rødsand II	207	2,3	G	6-12	33/75	132/80	1
Samsø	23	2,3	M	10-13	30/3,5	30/4	0

Table 2 Cost

Wind farms	Power capacity	Initial Budget Mio. Euro	Actual Cost Mio Euro	Cost overrun %	Cost per MW Mio Eur
Horns rev I	160	229	278	21,4	1,74
Horns rev II	209	470	470	0	2,25
Lillgrund SE	110	167	197	18,0	1,79
Middelgrunden	40	46	49	6,5	1,23
Nysted	166	269	269	0	1,62
Rødsand II	207	450	446	-0.90	2,15
Samsø	23	33	32	-3,0	1,39

Table 2 shows that three out of seven wind farms exhibit a cost overrun. Two farms are completed using exactly the budget, whereas two farms have used less than budget (up to 10 %). Four can cautiously be considered as exhibiting acceptable performance for clients and contractors, also considering uncertainty connected with the calculation.

Table 3 Time

Wind farms	Power capacity	Initial time Month	Actual time Month	Time overrun %
Horns rev I	160	10	16	60

Horns rev II	209	21	17	-19,0
Lillgrund SE	110	20	23	15
Middelgrunden	40	4	6	50
Nysted	166	19	18	-5,3
Rødsand II	207	20	17	15
Samsø	23	7	9	28,6

Table 3 shows that four farms exhibit time overruns compared to the initial schedule, and that these overruns exceed 10 percent. Conversely three farm are completed before time even up to twenty percent. It derives that the small farms; Middelgrunden and Samsø will relatively short initial schedules are more vulnerable to unplanned events. Horns Rev 1 experienced very extensive problems with the turbine technology. The discussion presents an analysis of the reasons for compliance and overperformance respective underperformance and overrun.

4.1 Power production performance during operation

The planned production of wind farm power plants is often stated by an expected capacity factor, expressing the MW-hours one would expect out of the MW-capacity provided (Feng et al. 2010:4).The factor is around 35% for offshore (BWEA, 2008, Levitt et al 2011). Danish experiential figures show a “lifetime” capacity average of 37% for 12 long-term operational offshore farms (DEA, 2011) (lifetime meaning from installation some 20 years back to present date) including those examined here, see table 4. Four wind farms, have actual capacity factors lying above the average (BWEA 2008, Levitt et al 2011) and three wind farms, have actual capacity factors lying below. Only one, Middelgrunden is significantly lower (25,2% compares to 35%). The operational offshore wind farm power plants exhibit higher levels of maintenance time than planned. All offshore wind farms have scheduled service and maintenance, but there are many examples of unplanned extraordinary issues lowering the availability of the wind farm. These include unplanned replacement of generators, gearboxes, cabling, shafts and more. The owners of Samsø, had to carry out repair of the export cable in 2004. Vattenfall, owner of Horns Rev, announced in April 2010 that repair of transition pieces (between the monopile and the tower). Such extraordinary repair rounds affected British wind farms as well (Koch 2012).

Table 4 Actual Capacity factor (Source DEA 2011, LORC 2012)

Wind farms	Power capacity	Year In operation	Actual Capacity Factor %
Horns rev I	160	2003	39,9
Horns rev II	209	2009	46,7
Lillgrund SE	110	2008	33,79
Middelgrunden	40	2001	25,2
Nysted	166	2004	36,1
Rødsand II	207	2010	42,1
Samsø	23	2003	38,9

5. Discussion

The Danish and Swedish cases show an interesting mixture of some projects exhibiting compliance with articulated time and cost budgets and others with cost and time overrun. There is no difference between small and large projects in this small sample. Judged by budgets and schedule there is therefore not a clear picture of strategic misrepresentation. Lönker (2005)'s findings on the Nysted farm even indicates elements of proactive project scheduling, using two summers rather than one winter, and compliance with budget that can be said to demonstrate the opposite; a well exercised project management. Strategic misrepresentation also involves overestimating the benefits of the projects (Flyvbjerg 2009). By wind farms, this involves overestimating the power production based on unrealistically high expectations to production time, availability and underestimating maintenance and service costs. The present sample does not exhibit important deviances from planned capacity, with the exception of one, Middelgrunden. Two farms are even significantly higher than Danish average (DEA 2011). What the cases along with the UK cases demonstrate is, that the involved companies are involved in an developing the operations strategy gradually. This encompasses planning for the weather, using onshore assembly of either Siemens or Vestas turbines and barges and jack-up vessels as central equipment. And that competences develops as the projects are carried out, yet in a sometimes disruptive manner hampering experiential knowledge to be translated and carried on as the companies grow.

5.1 Contracts

It is clear that project management has to operate a complex set of contracts- Forexample Horns Rev 1, realised in 2003 had 69 contracts (4Coffshore 2012), and Horns Rev 2 had 91 (4Coffshore 2012). It is occasionally reported that contracts also involve the main contracting unit involve directly in the manufacturing at the wind turbine manufacturer and (for example) steel pipe manufacturers (Lönker 2005). It is equally clear that Danish, Swedish and UK wind farms built between 2000 and 2012 all encompasses a small group of recurrent firms. Siemens and Vestas share the installations between them and only in Holland and Germany one find other turbine suppliers present (Nordtank and RE power, 4coffshore 2012)

5.2 Planning

There is both examples of well exercised planning and less so. As Lönker (2005) finds Nysted appear to have benefitted from project manager recurrent from Horns rev I, and the planning works well here. The two small farms in the sample Middelgrunden and Samsø are different in terms on compliance with time, even they both feature short tight schedules, one complies with schedule and the other don't.

5.3 Equipment

Where the early farms tended to be erected using ad hoc equipment from the oil and gass offshore industry or from bridge building, the later uses a more and more advanced set of specially designed vessels. This also reflect the central placing of the A2SEA company both in Danish, Swedish and UK windfarms (Koch 2012). Another important feature is the

appropriation of harbour facilities such as the nearby harbour for Rødsand 2, also involving the possibility of onshore assembly of turbines

5.4 Competences

If one juxtaposes the development of Danish and Swedish windfarms with the UK ones developed over the same period (Koch 2012) it is less clear that the centrally placed and recurrent companies are learning and becoming more competent. There is even a tendency that some later wind farms involve more overrun and lower performance. It appears like the windturbine manufacturers have considerable problems with quality and defects when it comes to the UK deliveries, both impacting on the installation and operation phase. The worst example in a Danish context occurs at Horns rev I, which receives a heavy overrun because of quality problems at Vestas windturbines.

6. Conclusion

The aim of this paper was first to develop a combined social constructivist internal and external conceptualisation of the process of realising offshore wind farms; second, to investigate costs, time, delays and operational performance results of offshore wind farm power plant projects in Denmark and Sweden with a view to possible strategic misrepresentation. The results shows that combining the internal and external perspective gives a more precise understanding of why complex offshore wind farms come to operate well or less so. The investigated wind farm does not exhibit a clear pattern of strategic misrepresentation. Rather there are examples of project management that emerges into being successful even if the process is disruptive and full of complications. Even if there is a strong concentration of a few players on the Danish, Swedish and UK markets in the period investigated, learning effects and developed competences are less clear as late installed farms actually perform worse than earlier installed. The construction sector thus seem to contribute in an ambigious manner to societal transition towards zero carbon.

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Bringing the design team together: coordinating inter-organizational design work using an agile co-working method

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Abstract

Designing buildings requires efficient information exchange and knowledge co-creation between different disciplines to add value for the customer. The high of fragmentation of the AEC industry makes collaboration between disciplines difficult. New methods for increasing collaboration, knowledge co-creation, and customer involvement are needed. This paper presents a case study on developing and using an agile co-working method for coordinating inter-organizational BIM based design work during the conceptual design phase. Data was collected before, during and after the agile co-working sprint. The data includes discussions during four preparation meetings, the audio and video recordings of two-day co-working sprint, and nine interviews after the sprint. The co-working sprint necessitates planning: determining common ways of working, technology to be used, and the practicalities of the shared facility. Shared rules for conduct need to be agreed at the beginning of the sprint to ensure that members know how to exchange knowledge, what technology to use and in what way. The co-working sprint needs a team leader to facilitate the discussion and ensure coherent outcomes. Team members of the co-working sprint need to be motivated to work together. One of the most beneficial outcomes of the sprint was committing to goals that were defined together. The agile co-working sprint increased common understanding between team members about other disciplines' work tasks during conceptual design. The study sheds light on how to bring the design team together using an agile co-working method which enables the visualization of knowledge for customer's decision making.

Keywords: Coordination, knowledge integration, agile, co-working, BIM.

1. Introduction

The companies in the AEC (Architecture, Engineering, and Construction) industry are specialized into certain functional disciplines to design and build complex buildings. Due to this specialization, the industry is highly fragmented which challenges knowledge sharing and collaboration. (Brandon 2009, Dulaimi et al. 2002) Fragmentation can also be seen in

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the separation of design and construction, coordination issues between functional disciplines, and insufficient communication. Low productivity, cost and time overruns, and conflicts in the AEC industry are seen to be caused by this fragmentation. (Xue et al. 2005) New methods are required for collaborative and iterative development in the AEC industry. Owen et al. (2006, p. 63) discuss adopting agile management in the pre-design phases of construction.

The management of the design process is crucial because 80% of the costs of a construction project are determined in the front-end of the process (Tzortzopoulos 2006, p. 657). During the conceptual design of a new building, a number of issues are in constant flux and great uncertainty is involved which causes complexity (Owen et al. 2006, p. 61). For example, the structure, form and placement of the building affect the energy consumption and life-cycle costs. In practice, different disciplines', such as architectural, structural, and MEP (Mechanical, Electrical and Plumping), design decisions need to be made iteratively. Many design decisions produce requirements to other disciplines, affect design quality and investments, and pose requirements for the construction site planning. In addition, the customer is rarely able to specify all the requirements for a building during the conceptual design phase of a project. The designers of different disciplines can help the customer in the decision-making process by giving information and providing different solutions about what is possible and how it affects other design parameters such as energy consumption or building lifecycle costs. For this purpose, the different disciplines' knowledge needs to be integrated to achieve value to the customer within the constraints of time and cost. Value can be accomplished by first understanding customer's priorities and then by defining the requirements for the building through optimizing the different aspects of the building, e.g., life-cycle costs, energy usage, placement of the building on the site, to be designed by utilizing building information modelling (BIM). The customer needs to be involved in the value generating process to give priorities. BIM can help in simulating and visualising the alternative solutions to the customer.

The fragmentation of knowledge and high degree of specialization in the AEC industry creates "need for coordination between the various project participants." (Mitropoulos & Tatum 2000, p. 48) This paper studies the use of an agile co-working method for coordinating inter-organizational design work of a new school building during the conceptual design phase. The idea of an agile co-working method is to integrate the different disciplines' knowledge to provide the owner relevant information for the decision-making process. This study advances organization theory, specifically coordination theory, by understanding how the agile co-working method can act as a coordination method for managing collaborative design work between different organizations.

2. Literature study

2.1 Coordinating work between organizations

Poorly coordinated collaboration of different stakeholders results in decreased project quality, lower customer satisfaction, and information loss. In this study, coordination is defined as "the act of working together harmoniously" where the components of coordination

are goals, activities, actors, and interdependencies. (Malone & Crowston 1990, p. 358) First, the goals need to be identified and mapped to predefined activities. Then, activities need to be assigned to actors. Finally, activities have goal-relevant relationships, i.e., interdependencies which must be managed. (ibid.) Reciprocally interdependent activities provide input for each other in a mutually interdependent way. Actors executing reciprocally interdependent tasks need to communicate frequently and adjust mutually, which usually happens in small organizations or in complex operational environments such as projects. (Thompson 1967) Unscheduled meetings, ad hoc communication, cross-functional teams, and physical proximity represent mutual adjustment. (Mintzberg 1979)

According to Malone and Crowston (1990, pp. 364-365), there are three processes underlying coordination: group decision making, communication, and the perception of common objects. Coordination necessitates that some decisions are made and accepted by the group executing the coordination. Group decisions require communication about the goals between the parties. Finally, communication necessitates that messages are transported between senders and receivers in a language that is understandable to both parties. According to Malone and Crowston (1990, pp. 364-365), common language means that the parties perceive common objects, such as physical objects or information in a shared database. (See Table 1)

Table 1: Processes underlying coordination, components of coordination, and examples of coordination (Malone & Crowston 1990, p. 365)

Process level	**Components of coordination**	**Examples of coordination**
Coordination	Goals, activities, actors, resources, interdependencies	Identifying goals, ordering activities, assigning activities to actors, allocating and synchronizing resources
Group decision making	Goals, actors, activities, evaluations, choices	Proposing and evaluating alternatives, making choices
Communication	Senders, receivers, messages, languages	Establishing common languages, selecting receivers, transporting messages
Perception of common objects	Actors, objects	Seeing same physical objects, accessing shared databases

In the AEC industry, the work is executed in projects with several different companies and disciplines having their own language and knowledge, which challenges the codification and transfer of knowledge. (Bresnen et al. 2003, p. 157) The AEC industry lacks ways of working together in a way that would allow creation of common language and knowledge to enable knowledge integration from the customer's point of view and not from a single stakeholder's point of view.

2.2 Knowledge management through agile methods in construction

Knowledge management in the AEC industry is needed for innovation and improved efficiency through the use of different tools, processes and methods (Kamara et al. 2002, pp. 54-57). The AEC industry is organized in projects and the practice is guided by project management (Ballard 2000). As the industry has become highly fragmented and organizationally complex, the traditional project management methods are not adequate to

deal with challenges such as stakeholder management and iterative inter-organizational design. Mitropoulos and Tatum (2000, p. 52) discuss that integration during project's design phase is important for project performance and it requires the participation of contractor and customer in the design and joint decision making and "not only exchange of information and knowledge". In their study Mitropoulos and Tatum (2000) found three types of mechanisms to increase project integration: contractual (e.g., strategic alliances), organizational (e.g., cross-functional teams), and technological (e.g., electronic linkages between construction applications). The current focus in the AEC industry is on information and communication technology, although it should be more focused on finding "new ways of producing, collaborating, sharing knowledge and adding whole-life value." (Prins & Owen 2011, p. 231) Agile methods emphasizing lean thinking, flexibility and iterative development with the involvement of customers and end-users are one solution to these challenges. (Ribeiro & Fernandes 2010, p. 161)

Koskela (1992) started the discussion on applying lean to construction. According to Koskela, the construction industry was not paying enough attention to value creation but on transforming inputs to outputs which in the end leads to poor overall outcome and sub-optimization. (ibid.) Later Owen et al. (2006, p. 52) differentiate agile project management (APM) from lean methods such as lean construction or Ballard's (2000) 'Last Planner'. According to them, lean was developed "as a response to the competitive pressures with limited resources" while agile manufacturing is "a response to the complexity brought about by constant change". APM is based on "incremental and iterative development with continuous learning being essential to the evolution of the optimal value to the customer within the constraints of time and cost". (Owen et al. 2006, p. 57)

Ribeiro and Fernandes (2010, p. 162) state that "the number of scientific publications on the agile paradigm in construction is limited" which gives the authors of this paper a good reason to further study agile methods in construction. Owen et al. (2006, p. 63) conclude that adopting agile management in the pre-design and design phases of construction has considerable potential as the incremental and iterative development can "facilitate creative solutions, particularly to complex and uncertain requirements." Owen et al. (2006, p. 57) describe an agile project manager as "a facilitator who enables small, self-organizing multi-disciplinary teams to decide for themselves how they satisfy their value goals." This paper is studying agile methods as a way to manage knowledge of inter-organizational design work. We define the management of knowledge in inter-organizational work as the integration of different disciplines knowledge to add value for the customer.

3. Methodology

3.1 Case study on developing an agile co-working method

We examined a case study on the development and use of an agile co-working method that took place in spring 2012. The case study strategy allows studying a contemporary phenomenon which is difficult to separate from its context (Yin 1989). The development and use of the method is part of Model Nova (New Business Model based on Process Network and Building Information Modeling) work package of Built Environment Process Re-

engineering research program which is coordinated by the Strategic Centre for Science, Technology and Innovation of the built environment (RYM Ltd) in Finland. The idea behind the co-working method was that it would allow different disciplines to work intensively for a day or two in the same location, using BIM to integrate different participants' knowledge and thus create better design solutions for the customer, i.e., the owner and end-users. Mark (2002, p. 89) describes this type of design activity as extreme collaboration during which participants work in an electronic and social environment "to maximize communication and information flow".

The idea of testing an agile co-working method in the early stages, i.e., conceptual design, of a construction project arose in a workshop for Model Nova work package in January 2012. In another workshop in March 2012, a possible case including the object of co-design for testing the method was introduced and the interested companies and research institutes of the project to participate were identified. CRADLE (Center for Research on Activity, Development and Learning) research group within the University of Helsinki was named responsible for the practical arrangements of the development, such as organizing meetings to develop the concept of the agile co-working method. The authors of this paper from SimLab (Enterprise Simulation Laboratory) Aalto University and professionals from different disciplines and organizations participated in those concept development meetings.

The object of co-design was decided to be the planning of the conceptual design of a school and a day care building in a village next to the city of Kuopio, Finland. The building and design process had not been started, but the preliminary decisions of executing the project had been made. The spatial program had already been decided. The approximated number of students and children at the day care was about two hundred. The city of Kuopio represented the owner. The building to be built was to serve the inhabitants of an active village community, and the building itself should also provide possibilities for organizing events and past-time activities for the villagers. The inhabitants of the village, which were also the future users of the school, were eager to participate in the design process and share their ideas.

Two possible site locations were specified for the new building. In one location, the building would be a new building and in the other location, it would be renovated inside an old barn which at the time served as a summer theatre. The barn was considered as a historically relevant building and therefore the renovation should strive to preserve the old building and its style as much as possible. Model Nova work package agreed to provide the customer the conceptual design solutions for the building. The idea was that the customer could use them in decision making when choosing between the two site locations. The conceptual design was decided to be co-designed during a two-day agile co-working sprint where all the needed actors from different disciplines would work together in the same location. An important part of the sprint would be to hear the opinions of the customer as well as the end-users of the building and to pursue to fulfil these wishes in the conceptual design.

The development of the agile co-working method consisted of three steps: 1) preparation meetings together with different companies' individuals who attended the two-day sprint in the city of Kuopio, 2) the two-day agile co-working sprint in the city of Kuopio, 3) reflection

part that consisted of analysing the co-working together with participants. CRADLE organized four preparation meetings to determine the practicalities of the co-working sprint. In the meetings, the interested participants were divided into two teams, each of which independently planned the principles of their co-working sprint. We will refer to the two teams with names team New and team Reno. Team New focused on creating solutions for the new building on an empty site whereas the team Reno concentrated on creating solutions for renovating the old barn. The objectives and desirable outcomes of both teams were discussed together. After the teams had been decided, they were left to decide how they would proceed with preliminary tasks before the co-working sprint. Both teams comprised of two architects, a structural designer, a MEP designer, a life-cycle designer, a construction management consultant, and a cost accountant. In addition, in team New there were two participants, whose main focus was on creating a visual representation of the data collected that would help with communicating the results to the customer and end-users. In team Reno a person representing construction management consultant filled information in the forms (that would visually represent the information) created by the other team.

The two-day agile co-working sprint was conducted in the city of Kuopio and it started with a joint meeting where teams, researchers, owner representatives and end-users participated. During the meeting, the objectives of the sprint were discussed, as well as the hopes of both the owner and the end-users. The sprint continued with one and a half day of co-located work by each team. At the end of the second day, the results achieved were presented to the owner, end-users, other team, and the researchers. The results were discussed together. The success of the sprint itself was later analysed with both teams and researchers in a separate conclusion meeting a few weeks later.

3.2 Data collection and analysis

The empirical data was collected before, during and after the co-working sprint. The first and the second author of this paper participated in all the four preparation meetings before the co-working sprint. During the meetings participants from different companies planned on how to work together during the co-working sprint, e.g., which tools to use. During the two-day co-working sprint the authors observed and made field notes on the co-working and discussions that were also audio and video recorded. CRADLE researchers acted as action researchers, whereas SimLab researchers were mainly observers and had minor impact on the development and use of the agile co-working method.

After the sprint, the authors interviewed nine participants from different disciplines to understand how the co-working sprint could be developed and how the working methods during the sprint functioned. The interviewees represented an architect developing the information visualization, two architects, two MEP designers, two life-cycle consultants, a contractor and a construction management consultant. The interviews were semi-structured but open questions to get rich and detailed real-life descriptions from the interviewees. The interviews lasted from thirty minutes to an hour and were held either face to face or via Skype. Two researchers were present at each interview, one interviewing and the other taking notes. The interviews were also audio-recorded.

The analysis process of the interview data followed the analysis recommendations of Miles and Hubermann (1994). First, the interviews were transcribed word for word. Then they were read through to get a preliminary understanding of the data collected. After that, codes for interview data analysis were determined based on interview themes and raw interview data. Six codes were determined: preparation before agile co-working, customer involvement, IT and BIM software usage, working methods, management of co-working, and co-created results. These codes were used to analyse the interview transcriptions using a qualitative data analysis software Atlas.ti. Video data was once analysed and used to verify the notes made by the researchers on how participants communicated with each other and how they used information technology in their collaborative work.

4. Findings

Based on the analysis of the interview data, researchers' notes and discussions during the co-working sprint, three themes which were important to every participant were selected. These were preparing for the agile co-working sprint, customer involvement during and after the co-working sprint, and management and working methods during the co-working sprint.

4.1 Preparation for agile co-working sprint

The teams had prepared for the co-working sprint very differently. Team New held three meetings and planned their working routines, discussed their objectives, and started to develop a visual representation of the data to be produced for the customers before the two-day co-working sprint. Most of the members of team New knew each other because they had worked together before. According to interviews, team New was quite satisfied with the preparation before the sprint and they started working efficiently from the beginning. However, more preparation would still have been needed. Everyone knew their responsibilities and they worked towards them. Though, there was not much discussion during the first day as everyone was concentrating on their own tasks, which means that knowledge integration was minimal. During the second day, team members started to share their work with each other, integrated knowledge and learn from each other's work.

Team Reno had no preparation and consisted of members that had not been collaborating before the co-working sprint. At the beginning of the sprint team Reno used almost two hours for general discussion and decision making about the courses of action, how to work together and the goals of the co-working sprint. During the first day the architects had a lot of work to do with BIM modelling but some other disciplines such as structural engineer did not have lot to do. During the second day, team members started sharing their work more and discuss different design solutions and cost calculations.

4.2 Customer involvement during and after agile co-working sprint

Communication towards the owner and the end-users was different between the teams. Team New had no communication with the customers during their individual work. During the interviews, the members of team New expressed that the contact with the customers

would have been helpful in deciding what design issues to concentrate on. Team Reno made phone calls and exchanged emails with the representative of the owner. Team Reno requested information on details of the building to be renovated from the customer representative. However, neither team discussed their design solutions and the course of action to be taken in the design with the customers, even though the team members would have seen this useful afterwards. According to the interviews, the representative of the customer should be available, e.g. through phone or Skype, during the future co-working sprints to give comments and make decisions regarding financing and design solutions.

Both teams' design solutions and life-cycle cost analysis were presented to the customer in the end of the second day. The numbers in excel were visualized in order the customer to get a better understanding of different solutions. However, the design solutions of different teams were not comparable as the other team worked on the design for a new school building whereas the other focused on renovating an old building. If the case had been a competitive bidding, the results could not have been compared. However, if the purpose of the sprint would have been just to explore all possible solutions, this type of sprint would have pursued its case. The owner and end users were satisfied with the visual presentation of design solution information and encouraged to continue its development.

4.3 Management and working methods of the agile co-working sprint

Both teams had a team leader whose task was to make sure that the team delivers what is agreed with the customers. Both team leaders had their own work tasks to be completed during the sprint and thus they could not much focus on leading their team's work. During the first day, the team leaders made sure that everybody knew what to focus on but more guidance would have been needed especially during the second day to encourage communication and knowledge sharing.

The purpose of the sprint was to help the owner set the design requirements, e.g., design layout and life-cycle costs, for the school and day care project. However, some of the participants of the teams thought that they would have needed more information, in addition to the spatial program, from the owner to achieve that result. For example, the target price for the building was not set which challenged defining the life-cycle costs of the building.

Both teams faced some technical difficulties during the sprint. Neither team had agreed on a joint project database to save documents and such needed to be created during the co-working sprint. Both teams could also have benefited from larger or multiple screens, where information could have been shared between participants more efficiently. Team Reno had only two Internet cables to use during the sprint, which slowed information sharing significantly. In addition, BIM software used by different disciplines had interoperability issues to overcome. The software used by the architect used different kind of classification for spaces than the software used by the other designers. Therefore the information created by the architect could not be directly transferred to other software. Some of the data was transferred via excel, other needed to be manually entered. The cost calculator could not directly use any type of data created by others, but needed to manually enter all information received. Additionally, the cost calculator was last one in the information chain which in

practice meant that during the first day she did not have much to do but during the second day she had to work under constant time pressure.

5. Conclusion

The agile co-working sprint increased common understanding between team members about other disciplines' work tasks during conceptual design. For example, many participants reported having learned how cost calculations are done during the conceptual design and which software other participants use in their specific work tasks. The shared screens helped in integrating knowledge of different participants and focus on same issues. The exchange of information between team members was easy as people were co-located and focused on the same issue at the same time. Though, some reported that they were not sure when it was appropriate to interrupt others for information exchange as people were focusing on their individual work tasks. Bresnen and Marshall (2002, p. 500) found in their study that co-location of the design team permitted greater accessibility of participants and allowed timely and informal communications. In this study, participants focused mainly on formal communication as the co-location only happened for two days during the co-working sprint but still the informal communication may be an important ingredient for building trust between participants. Direct personal contact during co-working sprint and the socialization processes are ways of transferring knowledge (Nonaka & Takeuchi 1995).

A team facilitator's role is to ensure that different team members are motivated and know how to work together. In addition, the facilitator should aid in group decisions during the sprint. However, we argue that the success of the co-working method depends, among others, on the participants' capability and willingness to work together. Common rules for conduct need to be agreed at the beginning of the co-working sprint to ensure that members know how to exchange knowledge.

Most interviewed stakeholders thought that one of the most beneficial outcomes of the sprint was committing to goals that were defined together. All the big design decisions made during the sprint were based on the work of all stakeholders. Thus, the teams could choose an 'optimal' solution for the customer from all the stakeholders' points of view. Committing to these design decisions is believed to result in more compatible design solutions, which can also ease the workload during clash detection of BIM models. To add, since the decisions are made both on the basis of the different designers' as well as the customer's points of view, the end results are more likely to please the customer as well. These findings are in line with Mitropoulos and Tatum's (2000, p. 53) research results on interviews with managers: "Developing common norms, and understanding each other's culture and way of working enables better cooperation during projects." In addition to exchanging information and creating common understanding within the teams, one of the objectives of the sprint was also to communicate the results achieved to the customer. The visualization method created in team New was considered informative and useful for the customer's decision-making process. The visualization method was created during the sprint, and the participants believed that it could be used even more efficiently in a new sprint.

Malone and Crowston (1990) described the three processes underlying coordination: group decision making, communication, and the perception of common objects. The agile (i.e.,

iterative development) co-working method entails the three processes and thus can be described as a method for coordinating collaborative design work between different organizations. The agile co-working method allows group decision making and communication as participants are co-located. The participants should have the authority to make decisions and the customer should be available for timely decision making to advance group work. In addition, the facilitator ensures that every participant has the opportunity to express his/her ideas and encourages “goodwill” between the group members. The perception of common objects can be acquired through projecting the BIM models on a screen that every participant can see at the same time. The visualization of the object of common work on a screen helps participants to concentrate on the current collaborative work. Based on this study, the agile co-working method can be separated into three phases: before the sprint, during the sprint and after the sprint. The co-working method can be described as a process of following steps (See Figure 1):

Before the sprint:

1. Define together the **goals** for the sprint.
2. Determine the **common ways of working**, **technology** to be used, and the **practicalities of the common facility**.

During the sprint:

3. Make sure that **technology** and technical surrounding is working and supporting the sprint.
4. Choose a **team leader to facilitate** the discussion and ensure the outcomes.
5. Ensure team members are **motivated** to work together.

After the sprint:

6. **Communicate the visualized results** of the sprint to the owner and/or end-users.

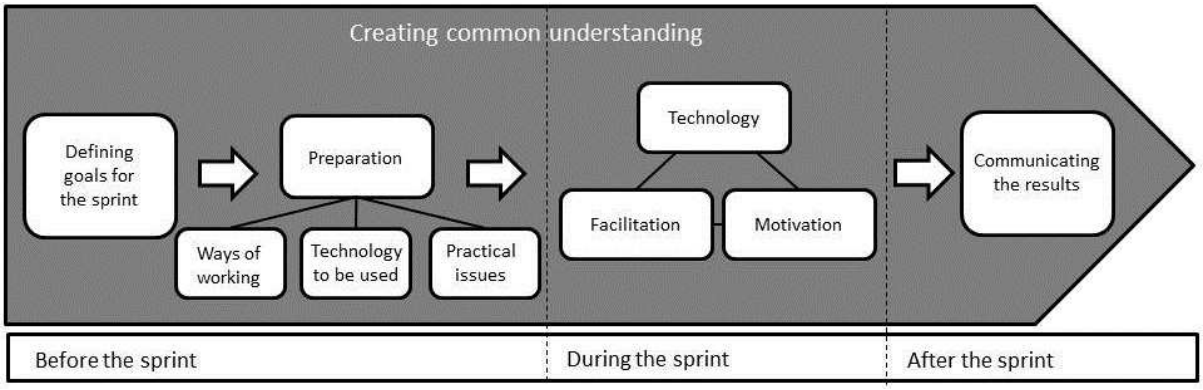

Figure 1: The process of the agile co-working method

6. Discussion

This paper presented a case study on developing and using an agile co-working method for coordinating inter-organizational BIM based design work during the conceptual design phase. The results show that the co-working sprint eases the exchange of information and learning between different disciplines during the conceptual design. The common working methods need to be specified in advance and a team leader appointed to make sure inter-organizational collaboration reaches its intended goals. The method seems to work as a

coordination method to manage the inter-organizational design work during the conceptual design. The method should also be tested in other phases of design and construction process to understand how it could be improved. In addition, the agile co-working method should be designed to allow both face-to-face and virtual collaboration optimally from the project's perspective. The next step could be to develop the co-working sprint to also include partial co-location, e.g., by using virtual collaboration tools such as GoToMeeting or Skype.

The study also sheds light on how to increase customer involvement during the conceptual design by integrating and visualizing knowledge for customer's decision making. The participants of different disciplines would have wanted the customer to be available during the co-working sprint to guide the decision making of different design solutions. The visualization of knowledge needs to be improved in order it to function also during the co-working sprint in communication between different disciplines and the customer.

We recommend the co-working sprint to be used during such design phases where the knowledge of different disciplines needs to be combined and thus availability of many disciplines is crucial. When important design solutions that affect many stakeholders are made, a co-working sprint can be a very effective coordination method for creating different design solutions and encouraging joint decision making. The sprints can either be planned well in advance or used as a problem solving tool when sudden difficulties arise. In the studied case, all the participants in the sprint were somehow involved in the Model Nova work package and therefore interested in developing and trying out new design and co-working methods. In reality, most participants in a traditional project may be more inclined to keep things the way they have always been. The co-working sprint method needs to be tested in a project where the participants are not motivated through previous commitments in participating in such methods in order to determinate how well it works in a traditional project.

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Managing Quality in Construction: Construction as Biological Cells

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Abstract

Construction is noted for handing over projects with defects with associated quality problems plaguing construction. Available models seem inadequate to ensure quality. Given this background, this study explores a new approach inspired by the high level of accuracy successfully achieved in the replication and proliferation of biological cells.

Construction operations are in many ways repetitive in nature. Hypothetically it can be broken down into basic repetitive units or 'cells' which undergo replication to constitute the 'whole' with similarities with biological cell. However, replication in construction is less error free when compared with the replication and proliferation of biological cells to produce a functional multicellular organ with an abnormally low error rate. As such, this study investigates this phenomenon with the aim of finding a better way for managing quality in construction by focussing on the replication of repetitive 'cells' (units) in construction.

A detailed study of the biological cell theory identified two new concepts relevant for construction (amongst others), namely, 'embedded design' and 'rate of proliferation' which impacts on cell-quality.

The relevance of these two concepts are explored further through the case study methodology: The first case study examines the impact of variation in the rate of poured concrete in a tunnel construction project whilst the second case study investigates the embedded design concept for planning and scheduling repetitive units in a multi-storey residential apartment complex providing two interim conclusions: Firstly, it is seen that variation in rate of production indicates presence of issues which have the potential for causing serious quality problems calling for closer attention whenever the rate of production changes. Secondly, the 'embedded design' concept is a relevant and viable concept for managing quality in construction which demands further exploration.

These two case studies have identified the need to examine the two concepts described herein further including other relevant concepts of the Biological Cell Theory with the

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intention of developing a new model for achieving an error free repeatability of construction units or cells.

Keywords: biological cell, embedded design, quality, repeatability, replication

1. Introduction: Quality in Construction

Despite the standard recipe of implementing quality management systems, experience shows that construction industry is saddled with projects with defects so much so that moneys due are held back for work performed lest something goes wrong with quality of work. Moreover, moneys are held during the defects liability period as well in what seems to be a defeatist and a punitive approach for achieving 'quality'.

The construction industry is characteristically chaotic in nature (Bertelsen Oct 2004), rendering it susceptible to quality issues. Historically, the principles of quality management have been developed in the relatively stable and controlled environment of production, which is in contrast to the chaotic nature of construction (Bertelsen Oct 2004), rendering it susceptible to quality issues. Thus the quest for better approaches for ensuring quality must therefore continue to change the status-quo.

This paper will present lessons learnt from biological cell theory relating to replication of cells to construct a functional multicellular unit in nearly error free manner to manage quality in construction. The construction operations are repetitive in nature and can be hypothetically broken down to basic units or cells which are replicated. However, unlike biological cell which achieves the replication with high level of accuracy, the same cannot be said for construction. The study of biological cell has led to two concepts relevant to construction. Firstly, the rate of cell proliferation and the detrimental impact of variation in cell proliferation rate variation on quality and secondly the concept of embedded design based on the DNA of the cell to achieve robust replication. Two case studies are examined with relation to the cell theory. In the first case, the variation in volume of concrete poured per day for slab in tunnel is considered and the number of quality issues during the duration of pour is examined while in the second case the effect of embedded design is examined and how it has assisted in delivering quality output for a building construction company.

2. Biological Cell Theory

The following description of the biological cell succinctly captures the essence of the cell and further reflection on it lays the foundation of the premise this study intends to explore.

> ***Cells*** *are the structural and functional units of all living organisms. Some organisms, such as bacteria, are* ***unicellular****, consisting of a single cell. Other organisms, such as humans, are* ***multicellular****, or have many cells—an estimated 100,000,000,000,000 cells! Each cell is an amazing world unto itself: it can take in nutrients, convert these nutrients into energy, carry out specialized functions, and reproduce as necessary. Even more amazing is that each cell stores its own set of instructions for carrying out each of these activities (http://www.ncbi.nlm.nih.gov/About/primer/genetics_cell.html)*

Implied in this quote is the functional efficiency of the cell not only to be self-sustaining, but the ability to replicate itself to develop into fully functional multi cellular and complex unit. To be able to evolve successfully into multi cellular entity, it appears that the basic building block, the cell, needs to be defined perfectly for it to function with instructions ingrained within the system for it to sustain and replicate, while maintaining the ability to faithfully transmit the instructions. This can be considered as an example of efficient process manageability to ensure successful repeatability based on well-defined cell to achieve a complex multi cellular pattern as if following an embedded design. This reminds of the call by Hinks et al. (1997) for construction industry to achieve repeatability and hence manageability.

2.1 DNA as Embedded Design in Cell

A cell can be considered as basic unit of life (Gerald 2010). Cells follow a programmed death but before that it will grow and replicate and in case of multicellular organism it replicates to produce a functioning unit. This self-elimination of cell is a result of an internal program that causes cells no longer needed or cells that pose risk of becoming cancerous to be eliminated. In construction, a cell can be considered as a basic unit for replication which will grow by drawing upon the resources and stop growing once it has reached its logical conclusion. However, to carry out such function there has to be a design and in case of cell this **design is embedded** within the nucleus of the cell in the form of (Deoxyribonucleic acid) DNA with chromosomes identified as the carrier of the genetic information (Gerald 2010).

Every cell of any living being interprets the DNA strand allocated in its nucleus to produce the proteins needed for the survival of the organism (Sanchez & Tyrell, 1998). Thus the manufactured proteins based on the deciphered instructions of DNA can be considered as basic life sustaining compound. According to Alberts (2012) these instruction are analogous to the blueprints that builder uses to construct the house. However in the case of cells with well-defined nucleus housing the DNA the blueprints themselves needs to be duplicated along with the cell before it divides so each daughter cell can retain the instructions required for its own replication and these instructions constitute the cell's heredity (Alberts 2012)..

2.2 Embedded Design and Replication Efficiency in Cell

Worth noting is the analogy of builder using blue prints to explain the working of the cell because the DNA contains the design according to which the life sustaining proteins are manufactured in the cell. It is complex operation which requires decoding the design, calling for assembling the right building blocks of protein and ensuring error free operation repeatedly. The order and consistency in handling such complexity has to be immense. Gerald (2010) has expressed that more complex a structure the greater the number of parts that must be in their place and, more regulation and control must be exerted to maintain the system to have less tolerance of errors in the nature and interaction of the parts.

The cell efficiency can be realised when we consider the rate of error in DNA duplication is of the order of less than one mistake every ten million nucleotide incorporated, and most of the errors are quickly corrected by an elaborate repair system that recognizes the defect

(Gerald 2010). The aim of six-sigma to achieve defect rate of 3.4 defects per million, or 99.99966% perfect according to Bounds et al (1994) appears inconsequential when compared with defect rate of one mistake every ten million achieved by the biological cell.

The cells are able to handle complexity effortlessly. The integrity the replication of process indicates the near perfection in the communication of the system, processes and procedures which are set out to accomplish this complex manoeuvre. For construction industry there is a likely lesson here in not only having a system to deliver the product but also the ease and effectiveness of communicating this system across the project team to replicate or produce the output as per the design.

2.3 Exploring Rate of Cell Proliferation

For a cell, growth by division during its life is the sole reason for its existence. This cell division process has been modelled mathematically establishing the rate of this process.(Bell 1967). Such mathematical models indicate that the cell growth rate can be determined. Koch (1962) has postulated that each cell grows with exactly the same growth rate constant as that of every other cell which has been justified based on the statistic of cell division for bacteria. Banks et al. (2011) have refined existing models depicting cell proliferation to compute average rates of proliferation in terms of the number of divisions undergone. This refined model has consistently estimated the average rates of proliferation (Banks et al. 2011). Mathematical models and application of statistics to understand cell division process highlights that the rate of cell growth can be determined, however it leads to question of the impact of changes in this rate, which is considered next.

The cell proliferation rate is at a **constant rate** leading to question if any acceleration or deceleration of the process has any impact. The increased cell division *per se* stimulated by external or internal factors is associated with the development of many human cancers (Martin et al. 1990). Further, Martin et al. (1990) clarifies that increased cell division may imply increase in process of cell division activity above the baseline rate or division of subset of cells that would ordinarily not be dividing. According to Lax and Thomas (2002) in-situ cell proliferation of transformed cell whose behaviour is no longer under normal regulatory pathway forms a small focus. It continues growth beyond its limited size by not only avoiding the surveillance of the immune system but redirecting the blood supply to continue its abnormal growth (Lax & Thomas 2002). It seems any deviation from the established rate of cell proliferation is considered abnormal and out of control leading to problem with faster rate leading to lack of repairs to DNA as per (Alberts) 2012 and slower rate leading to degenerative diseases and atrophy (Simon 1996).

Thus abnormal cell proliferation rate leading to harmful consequences can be considered as lack of the regulatory mechanism of cell. While there are quality control and repair system in place for the cell to ensure defect free replication and these are used to address the quality risk where the cell is most vulnerable, any uncontrolled changes in growth rate has harmful effect on organism.

2.4 Synthesised concepts

The above discussion leads to two concepts, viz. constant rate of cell proliferation, and embedded design. These two concepts form the basis for further examination in a construction setting.

3. Methodology

Construction operations are in many ways repetitive in nature as noted earlier. Hypothetically it can be broken down into basic repetitive units or 'cells' which undergo replication to constitute the 'whole' – a process biological cells handle with remarkable efficiency and accuracy when replicating cells to produce functional multicellular organs. In contrast, however, the replication and proliferation process in repetitive construction is error ridden when compared with processes adopted in a biological context where cells replicate to produce functional organs with abnormally low error rates.

An extensive study of the biological cell theory revealed a number of interesting concepts but only two concepts are examined in this study, namely, 'constant rate for cell replication and proliferation' and the use of an 'embedded design' – two concepts that seem to result in an abnormally low error rate when biological cells replicate and proliferate to produce multicellular functional units. Are such concepts used in construction? What implications do such concepts have for construction? How could such concepts be used in construction? These are some of the questions that this study attempts to answer in an attempt to develop new insights on how quality can be managed in a construction setting involving repetitive work. It was thought relevant that the case study methodology be used to explore answers to these questions.

A number of discussions were held with senior managers to elicit specific examples or case studies of practice which lead to the discovery of two interesting case studies with one involving the construction of concrete slabs in a tunnel project and the other involving the use of a set sequence for completing finishing work for a multi-story apartment complex. Details of these case studies are discussed in the next section with specific relevance to the two synthesised concepts.

4. Case studies

As mentioned, two cases are considered with first case relating to construction of slab. The production rate and associated quality issues are recorded and examined to determine impact of variation in production on quality. The second case considers how the concept of embedded design is used by a construction company in New Zealand for construction of apartment.

4.1 Case 1 Quality issues with slab construction and rate of work

This case examines the construction of slab in tunnel in Australia. During the construction of repetitive concrete slab there were 76 non-conformances recorded in terms of quality issues

of which 73 were product related and three were system related. The product non-conformances refer to issues like thickness of slab or finish which were out of specified tolerance and required corrective action, while system non-conformances refer to breach of documented procedures. Given that most of quality issues are not due to system issues, it seems to indicate it is production rate change that has led to quality problems

Please refer Figure 1 depicting the variation in the rate of concrete placed per pour during the project and the number of quality issues as measured in the recorded non-conformances related to slab production. The total volume of concrete placed was 3200m^3 over 86 pours with an average pour volume of 37m^3 per concrete pour.

This case will highlight the impact of variation of production rate when compared with uniform rate, which according to cell theory is an indication of activity which is out of control and has detrimental effect.

4.1.1 Analysis and Discussion-Slab construction

The figure 1 below captures the variation in production rate and recorded quality issues during the construction of slab in case study 1. The impact of variation in concrete pour rate is considered on the quality, keeping in mind the concept from cell theory in section 2.3 where variation in rate of proliferation of cells above a constant rate is considered an abnormality with activity outside the control of cellular mechanism and has detrimental effect.

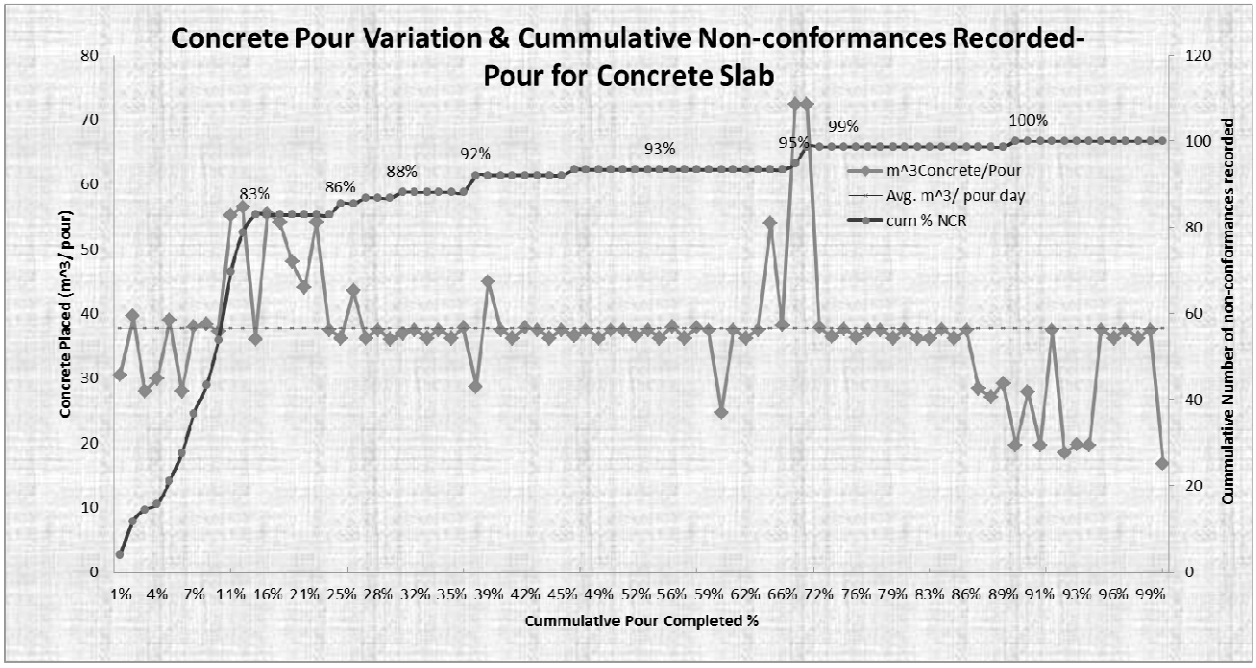

Figure 1: Variation in concrete poured per day and quality issues recorded

Depiction of variation in concrete pour volume and the quality issues recorded for the corresponding pour is presented below in Table 1.

From Table 1 it is clear that with variation in production rate there is associated quality issues related. However, when the pour rate is greater than the average rate, there are

higher numbers of quality issues recorded as there are 49% of such total pour which account for 51% of quality issues. Comparing with 45% of pour where the rate is lower than the average rate which have 36% of quality issues recoded is indicating that production rates with variation higher than average rate is more susceptible to quality problems. Remarkably, for 6% of pour which are at an average rate have recorded 13% of quality issues, which is the minimum for the project.

Table 1: Variation in Pour rate & Corresponding QA issues for slab construction

Variation in Pour Rate compared with Average Pour Rate	Number of pour as % of total number of pour for slab construction	No of QA Issues as % of total QA issues for slab construction	Remarks
Pour rate of less than average rate of $37m^3$ per day	45%	36%	With variation from average pour rate (or constant pour rate) on the lower side there are 36% quality issues recorded
Pour rate equal to average rate of $37m^3$ per day	6%	13%	With nil variation in the pour rate there is drastic reduction in quality issues recorded at 13%
Pour rate greater than average pour rate of $37m^{3/}$ per day	49%	51%	With variation in the pour rate on the higher side of average pour rate this is highest rate of quality issues recorded at 51%
Total	100%	100%	

Depiction of total number of pour and number of quality issues recorded during the project on progressive basis is presented in Table 2.

Table 2: Progressive Completion of job and quality issues recorded.

% Completion of job	Number of concrete pours	Number of Quality Issues or Non conformance	% QA Issues
First 25% of total concrete poured	19	65	86%
Between 26% and 50% of total concrete poured	22	6	8%
Between 51% and 74% of total concrete poured	19	4	5%
Final 26% of total concrete pour	26	1	1%
Total (3200 m^3 concrete)	86	76	100%

The Table 2 depicts how at the start the process is unstable with bulk of quality issues recorded during the first 25% of the job and progressively diminishing. This can be considered as representing the experience curve or learning curve with activities not yet under full control which is likely to lead to variations in production rate and by extension adverse quality issues.

The cell theory has established any variation either higher or lower than uniform rate is abnormal with activities beyond cellular control, similarly for construction the same can be concluded based on Table 1 as production variation has adverse effect on quality, indicating some out of control activity leading to such quality issues. When viewed together with the learning curve, this suggests the importance of controlling the activities especially at the start, as demonstrated in the first 25% of concrete pour which has more that lion's share of quality issues.

4.2 Case Study 2: Embedded Design for construction of apartment

One of the top tier contractors in New Zealand with construction portfolio which includes apartment building has developed what can be considered an example of building a construction cell based on what resembles an embedded methodology for construction of apartment. There is a methodology and planning, based on lesson learnt from past construction projects which has the sequence of activities and checkpoints before proceeding to next stage. One striking feature of this plan is requirement to construct a mock-up apartment 100% complete in every detail which is approved and meets the accepted quality level. This constructed cell is then used to make template which are used for each apartment construction to ensure consistency and uniformity.

This plan is strictly adhered to and relevant personnel involved informed about this. Those involved in critical areas of project undergo class room like training where the method and sequencing of job is reviewed in detail. Daily morning briefings are held to ensure all those involved know what they are doing, who else will be working in the same area and if any material delivery is scheduled. There are checkpoints and regular inspections carried out to ensure compliance as each trade progresses.

The company's manager in personal communication with one of the authors has confirmed that after various sequences the company has been able to identify an optimum sequence of work which is now embedded in the company's way of working. However, further work needs to be undertaken about its design, its impact and the implications reflecting further on the cell analogy described herein.

4.2.1 Discussion-Embedded Design and Construction

The approach this company has adopted is similar to the cell behaviour in many ways. Each cell has an embedded design in the form of DNA which is communicated in an error free way to ensure accurate replication. Further, according to Gerald (2010) the cells are evolving in response to the environment and this is an on-going process that continues to modify the properties of cells that will be present in organism that have yet to appear.

The construction company has refined their design and processes based on past experiences and refined the methodology of delivering the building project, so much so that the company has been able to identify, what it considers an optimum sequence of work. This is an example of evolving and preparing for projects that will be delivered in future. Importantly, it addressing the lament by Kransdorff (2006) regarding the lack of use of organisational memory to improve poor decision making by imbibing past lessons learnt, as this company has used the lessons from past experiences and made it part of its 'DNA' for delivering the projects.

Not only is there an embedded design which is evolving and communicated for proper execution, there is also a cell of acceptable quality created in the form of mock apartment, which is then replicated. This mock apartment is similar to cell behaviour where a cell is replicated in an error free manner with its design or DNA intact, ever evolving to meet the future challenges.

5. Cell-Theory and Quality in Construction

With lessons learnt from cell theory it is likely adverse quality issues can be avoided if there is a perfect cell developed for replication based on an embedded design in construction. Further, any unplanned change in rate of production is like a red flag which is indicating activities which are out of control and have the potential to cause quality issues. Changing the rate of production is quiet often the norm in construction as the crashing of activities with an associated increased cost is an accepted fact given the inherent relationship between the time and cost (Sears, Sears & Clough 2008). Thus increase in rate of production especially those on the critical path to shorten the project duration is a planned activity and may require additional resources for proper execution. But the cell theory clearly points out that any unplanned variation in production rate either on higher or lower side of the uniform rate is an indication of abnormal or uncontrolled activity, with potential to impact adversely the quality.

According to (Abeyesekera 1997) many projects are being planned with uniform rate of build with allocation of resources to create flow of work to achieve uniform rate of build. If this uniformity is not maintained and there if there is an acceleration of the work (i.e. the flow of work) or variation in production, particularly with the same resources, the cell theory clearly indicates the need to be alert as such variation in production rate has the potential to have impact on quality.

The implication of cell theory is that only planned variation in rate of build with appropriate allocation of resources are likely not to contribute adversely to quality. To further enhance quality of replication which is error free, the cell theory has suggested that embedded design which is evolving has the potential to deliver projects with an optimum sequencing of activities. While the focus of tools like six-sigma is to control variations to achieve quality consistently (Bounds et al. 1994), the cell theory has not only focussed on the variation as quality control too, but suggested an approach based on embedded design as one of the ways likely way to address such variations and the resulting quality issues.

The quality system of the cell allows for suspension of activities to fix the defect. In construction industry with the pressure to complete the job once started, the suspension of works for quality issues is rare. The general tendency is to complete the work and fix it later. It seems the defect liability period and retention mechanism to ensure quality issues are addressed later is a testimony to this fact and acceptance of such practice as normal in construction. By contrast, cell theory has indicated fixing the problem before proceeding to next step to ensure quality. This could be because the cost of failure of quality in cell replication can jeopardize the survival of the organism, and with life as the basic property of cell according to Gerald (2010) the cell has system to ensure high levels of accuracy of the order of less than one mistake in 10 million nucleotides incorporated. While in construction the penalty is in terms of cost of time and money, and sometimes the loss of reputation which the construction company has to endure in case of quality failures.

Achieving of quality in construction is indeed challenging which is characterized by its chaotic nature (Bertelsen Oct 2004). While Womack and Jones (2003) recommend implementation of Lean Principles to minimize waste to improve quality, Spear (2004) has warned that implementing Lean principles without proper understanding will only provide short term gains. Keeping this in mind, it is clear that for the construction industry a proper approach is the need of the time and the cell based approach to achieve quality is one of the promising and a refreshing ways as articulated in this study.

6. Conclusion

The cell behaviour indicates that unplanned variation in rate of production is abnormal and is an indication of out of control activities which has the potential to impact the quality. Such variations of production in construction can act as red flag for the project control team to be alert for any out of control activities, as uncontrolled activities is one of the least desired in construction, which are likely to have negative impact on quality.

There is potential in the concept of embedded design which holds promise for the construction industry. There is positive outcome in terms of quality when a perfect cell is constructed based on embedded design and then used for replication, however this needs further exploration in construction.

Two cases discussed here resonate with the findings from the cell behaviour but further research and validation of this approach is required. Meanwhile, it cannot be denied that such an approach is likely to lead to better understanding of the process to achieve quality and enhance the planning to control the variation of flow of work to achieve quality. This new approach to achieving quality holds promise and requires further investigation.

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Environmental Rating Tools and Residential Land Development in Australia

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Abstract

Numerous environmental rating tools have developed around the world over the past decade or so, in an attempt to increase awareness of the impact buildings have on the environment. Whilst many of these tools can be applied across a variety of building types, the majority focus mainly on the commercial building sector. Only recently have some of the better known environmental rating tools become adaptable to the land development sector, where arguably the most visible environmental impacts are made. EnviroDevelopment is one such tool that enables rating of residential land development in Australia. This paper seeks to quantify the environmental benefits achieved by the environmental rating tool EnviroDevelopment, using data from its certified residential projects across Australia. This research will identify the environmental gains achieved in the residential land development sector that can be attributed to developers aspiring to gain certification under this rating tool.

Key words: Residential land development, sustainability, environmental rating tool

1. Introduction

The purpose of this research is to identify the environmental gains that have been achieved in the residential land development sector attributable to sector specific rating tools. The need for sustainable urban growth has been acknowledged since the 1970's (Bryant and Eves, 2012, Xiaoping et al., 2009), with momentum increasing dramatically just in the last decade. Most developed countries have now introduced sustainability elements into their construction legislation and industry has developed a number of sustainability assessment and rating tools, such as LEED (Leadership in Energy and Environmental Design) in the United States, BREEAM (Building Research Establishment Environmental Assessment Method) in the United Kingdom, SBTool (Sustainable Building Tool) in Canada, CASBEE (Comprehensive Assessment System for Built Environment Efficiency) in Japan, ESGB (Evaluation Standard for Green Building) in China, BCA-GM (Building and Construction Authority – Green Mark) in Singapore and Green Star and NABERS (National Australian Built Environment Rating System) in Australia just to name a few (Ding, 2007, Reed et al., 2011, Xiaoping et al., 2009)[i]. As an indication of the explosion in the green building movement, the World Green Building Council lists 92 member countries (World Green Building Council, 2012).

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However the focus of much of this work has been on buildings, and particularly commercial buildings, given their large environmental footprint and high energy consumption due to their reliance on air conditioning and heating (Reed et al., 2009). Building impacts on the environment are reported to include 55 per cent of timber consumption, 27 per cent of plastics use, 12 per cent of iron and steel applications, 30 per cent of raw material consumption, 40 per cent of atmospheric pollution, 25 per cent of solid waste, 24 per cent of all water use, 20 per cent of effluent, substantial indoor air quality issues, 37 per cent of all energy, and 68 per cent of all electricity use (Bryant and Eves, 2012).

Whilst the statistics for buildings are alarming, the impacts of land clearing for development and the exacerbation of urban sprawl has not gained the same level of industry attention and self regulation. Development approval authorities administer the relevant Local, State and Federal environmental legislation, with little incentive for developers to outperform these minimum standards.

As indicated previously, there is a plethora of sustainability rating tools, and associated organisations promoting them. Xiaoping (2009) identifies three main purposes of environmental rating tools: *"(1) assessing the performance of the outcomes of the sustainable construction, (2) guiding the entire process of the sustainable construction to reach the three pillars of sustainability (economic growth, ecological balance, social progress and equity), (3) accelerating the evolution and transformation of the traditional construction industry."* (Xiaoping et al., 2009) Other objectives of green rating tools include: establishment of a common language; setting of a standard of measurement for green buildings; promotion of integrated, whole of building design; recognition of environmental leadership; identification of building life-cycle impacts; and the raising of awareness of green building benefits (Green Building Council of Australia (GBCA), 2012).

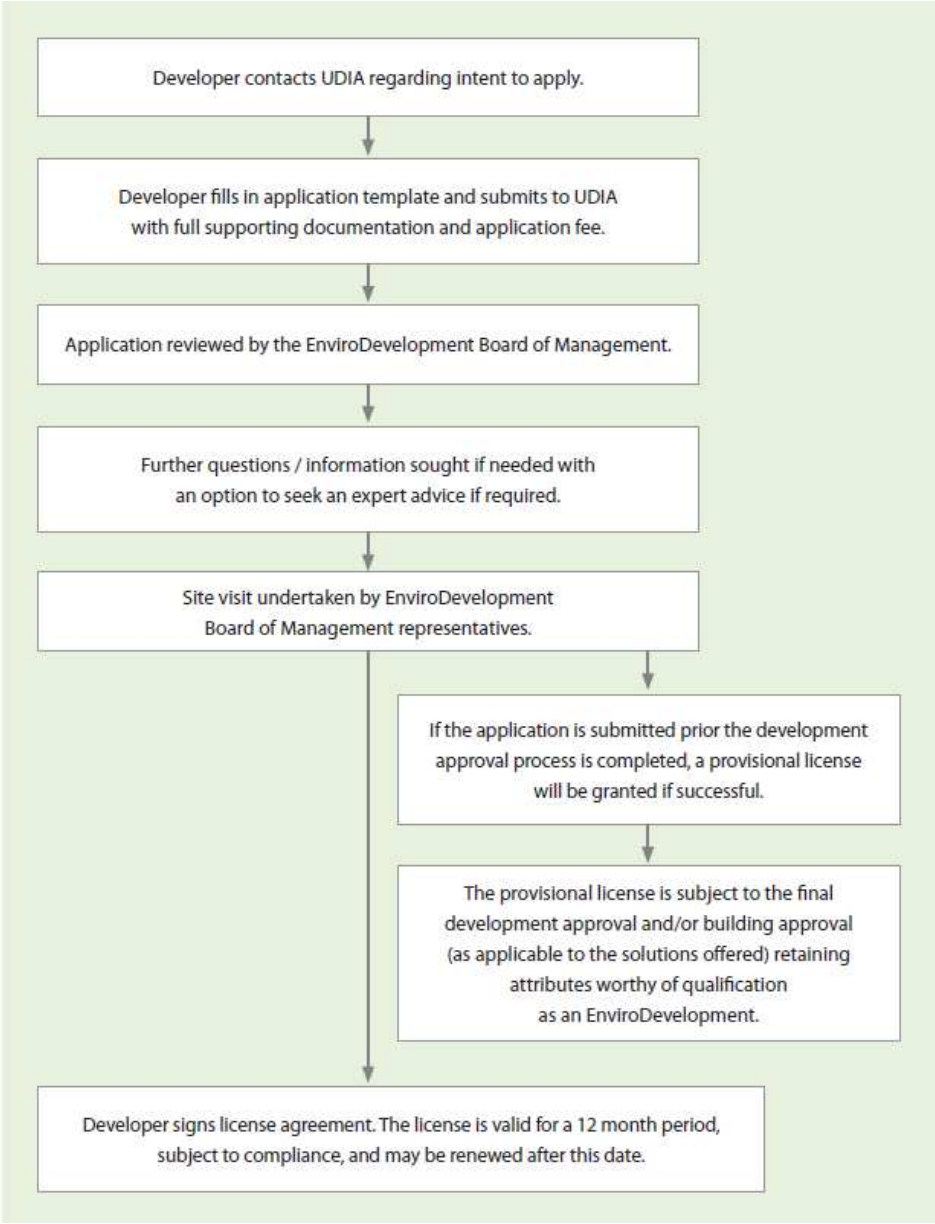
The purpose of this research is to identify if rating tools have a positive effect in achieving environmental outcomes, quantify the environmental benefits achieved by the environmental, using data from rating tool "EnviroDevelopment" and its first 50 certified projects across Australia. This research will identify the environmental gains achieved in the residential land development sector that can be attributed to developers aspiring to gain certification under this rating tool.

1.1 What is EnviroDevelopment

EnviroDevelopment is an industry generated, independent, national, sustainability accreditation scheme. Its purpose is to provide an incentive and recognition for an increase in the sustainability of property developments in excess of regulation, across a range of environmental and community aspects (EnviroDevelopment, 2011). The sustainability of a project is assessed across six elements: Water, Energy, Ecosystems, Community, Materials and Waste (Musgrave, 2010, EnviroDevelopment, 2012). For a project to obtain accreditation it must comply with the EnviroDevelopment Technical Standards National Version 1.0 which set sustainability criteria in each element that exceed minimum regulatory standards, as well as all Federal, State and Local legislative and regulatory requirements (EnviroDevelopment, 2011).

EnviroDevelopment's national standards can be applied across a range of property sectors including: commercial, industrial, retail, low and medium density residential and mixed use (EnviroDevelopment, 2012). Since its inception in 2006, EnviroDevelopment has accredited over 50 projects across a range of development types. The focus of this research is on the residential development sector.

The process by which developers apply for this rating tool is indicated in Figure 1 below.



Source: EnviroDevelopment National Technical Standards

Figure 1: EnviroDevelopment Certification Process Guidelines

It is appropriate to note that Green Star released a pilot Communities rating tool in Australia on 14 June 2012 (Green Building Council of Australia (GBCA), 2012). This rating tool assesses the sustainability performance of a project's planning, design and construction outcomes against six categories: governance, design, liveability, economic prosperity,

environment, and innovation. As at the time of writing, no accreditations have been made under the Green Star Communities rating tool.

1.2 Structure

This paper is arranged in the following sequence: this initial section has presented the background to the research problem and the EnviroDevelopment rating tool. The following section outlines the relevant literature associated with sustainable development. The third and fourth sections detail the methodology and findings respectively. The final section concludes and provides recommendations for future research.

2. Literature

The proliferation of rating tools, both internationally and domestically and the variances in metrics used, has lead to significant confusion in this crowded market (Warren, 2009, Reed et al., 2011). In recent years, a number of comparative studies have been undertaken to compare and contrast the leading brand name environmental assessment and rating tools. Ding (2007) in her paper on sustainable construction compared some 20 different international and domestic environmental building performance assessment methods. She argues that the available tools do little to encourage more sustainable designs during the project inception stage. She proposes an alternative sustainability index approach to address the "inflexibility, complexity and lack of consideration of a weighting system" (Ding, 2007, p463) which incorporates multiple criteria decision making processes.

Xiaping et al. (2009) identify the similarities and differences in six international green rating tools in the context of comparison with the emerging Chinese rating tool ESGB. These authors note that many of the leading rating tool brands focus primarily on the environmental criteria of sustainability's "triple bottom line" however more could be done to enhance the economic sustainability (growth) and social sustainability (progress and equity) aspects of such rating tools. Each of the tools identified list Residential within their scope, however it is unclear if this refers to low or higher density built form housing, or the actual residential land development activity itself.

Reed et al. (2009) provide an international comparison of eleven country's rating tools against fifteen sustainability criteria for commercial buildings. They noted a lack of consistency and transparency with the tools that limited the ability for meaningful comparisons to be made between buildings in different countries. It was recommended that a set of common metrics be developed for all building types, however allowing for regional (climatic) variations.

Reed et al. (2011) provide an update of their earlier 2009 works, acknowledging the rapidly changing market in both available tools and buildings seeking (and achieving) accreditations. A comparison between the take up of BREEAM in Europe and Green Star in Australia is made, concluding that the Australian market rates highly in the delivery of sustainable buildings, albeit off a lower set of benchmarks.

Hurley and Horne (2006) provide an initial framework for the assessment of sustainability rating tools for the built environment, arguing that whilst a building is a neat unit of activity for owners and developers to rate the performance of, the broader urban form also extends to the spaces between buildings, trunk infrastructure services and transport networks. This paper is unique in that it provides an overview of emerging sustainability assessment tools that address the suburb or precinct scale, rather than at a building scale as per the previously discussed works.

Hurley (2009) moves closer again to the issue at hand in this research, addressing the sustainability assessment of urban fringe residential estates, acknowledging the dominance of this form of development in the Australian residential sector. He specifically compares VicUrban's Sustainable Community Rating Tool and EnviroDevelopment as the primary tools available in this sector. He concludes that more rigour is required in the assessment of such tools to ensure they achieve more than "sustainability rhetoric".

Given the focus of this research is residential development, Hurley's (2009) critique is the most relevant. A number of positive and negative features of these tools are identified. The positives include:

- A strong focus on the sustainability issues associated with residential development
- An encouraging level of engagement from a peak industry body (being the Urban Development Institute of Australia (Qld))
- Capacity building within industry
- Facilitation of "best practice" urban development
- Improved understanding of sustainability in the community with potential flow on positive effects to increases in "green demand" and
- Potential to become the basis for future mandatory tools (Hurley, 2009).

Despite these positive attributes, Hurley dismissed these tools as little more than sustainability rhetoric "doing little more than dressing up the status-quo" (Hurley, 2009, p20) to divert attention away from the true underlying sustainability issues. The weaknesses identified include: a lack of rigour in defining what context "sustainability" was being addressed, little transparency in the interpretation of sustainability and limited accountability of the overseeing body. Hurley's view is that these tools are generally applied by only a few high-end developers that already target the green dollar, with no real impact on the majority of new housing stock. His view is that for such tools to have any real value (and therefore attraction for developers to use), sustainability rating tools need to provide significant incentives such as: a marketing advantage, planning/approval short-cuts and/or tradeoffs or else the introduction of a mandatory use system.

The purpose of this research is to challenge these findings and attempt to demonstrate that rating tools such as EnviroDevelopment are more than just a marketing ploy in a crowded market (Warren, 2009). This research seeks to quantify the sustainability gains achieved via the rating tool EnviroDevelopment since its inception in 2006.

3. Methodology

Data for this research was gathered primarily from documents submitted by developers seeking to attain EnviroDevelopment accreditation as well as from annual re-accreditation submissions. The author would like to thank EnviroDevelopment for access to this documentation. Data relating to the individual projects was obtained from the EnviroDevelopment web site (www.envirodevelopment.com.au) as well as individual project or developer web sites.

Given this research is specifically addressing residential developments only, submissions for EnviroDevelopment categories C1 and C2 only were examined where:

- Category 1 Development (C1): a development where the primary use is residential with a density of up to 30 dwellings per hectare (Low to Medium density); and

- Category 2 Development (C2): a development where the primary use is residential with a density of equal to or more than 30 dwellings per hectare (High density).

4. Data and Findings

This research seeks to identify the environmental gains achieved in the residential land development sector, over and above minimum statutory requirements as measured by the EnviroDevelopment rating tool. The data from this research is presented below in Tables 1 and 2 for C1 (low to medium density residential) and C2 (high density residential) development respectively. The data captured indicates the percentage above minimum regulatory development standards that the certified projects have achieved.

Preliminary analysis of the EnviroDevelopment certification data reveals that since inception in 2006, EnviroDevelopment has certified 46 residential developments across all Australian States and Territories excluding only the Northern Territory and Tasmania. Certified developers range from large publicly listed entities such as Delfin Lend Lease, Mirvac and Stockland, to government agencies such as the Urban Land Development Authority (Queensland) and affordable housing providers such as Horizon and Brisbane Housing Corporation (Queensland).

In relation to environmental gains achieved from this certification activity, Table 1 overleaf indicates the gains achieved over minimum government environmental regulations in EnviroDevelopment certified low to medium density developments since 2006. As indicated, significant gains across a range of environmental categories can be demonstrated in the low to medium density residential category. This category typically represents larger scale Greenfield developments where a change of use from lower intensity land uses to residential land uses is involved.

Table 2: Environmental Gains Achieved Over Regulatory Obligations (Category C1)

Item (n=49) / Element	Low %	High %	Median %	Mean %
Water	20	43.5	20	26.4
Ecosystems	4	25	9.6	10.45
Energy	20	27.5	20	21.8
Materials*	100	100	100	100
Waste*	100	100	100	100
Community	**	**	**	**

* There are no minimum regulatory requirements in these elements.

** The "Community" element is more qualitative in its measures than the other elements.

This research has found that in the areas of Water, Ecosystems and Energy, this rating tool has achieved average savings over and above minimum legislative standards of an additional 26.4% for Water, 10.45% for Ecosystems and 21.8% for Energy across a range of low to medium density residential developments throughout Australia. Given there are no minimum environmental regulations in relation to Materials or Waste for residential development, by meeting the certification standards, developers are providing significantly greater environmental benefits than required to by government. Developers may be utilising this rating tool particularly for these elements to gain third party recognition of its efforts in the absence any minimum regulatory standards.

Table 2 below indicates the same metrics for high density residential developments that have obtained EnviroDevelopment certification since 2006. This category typically represents infill or brownfield development where a change of use from non-residential land uses to high density residential is involved.

Table 2: Environmental Gains Achieved Over Regulatory Obligations (Category C2)

Item (n=5) / Element	Low %	High %	Median %	Mean %
Water	20	80	25	35.4
Ecosystems	4	25	9.6	10.45
Energy	20	75	37	41.2
Materials*	100	100	100	100
Waste*	100	100	100	100
Community	**	**	**	**

* There are no minimum regulatory requirements in these elements.

** The "Community" element is more qualitative in its measures than the other elements.

Again, this research is able to identify significant environmental gains achieved by developers aspiring to obtain certification under this rating tool. In the areas of Water, Ecosystems and Energy, this rating tool has achieved average savings over and above

minimum legislative standards of an additional 35.4% for Water, 10.45% for Ecosystems and 41.2% for Energy across a range of high density residential developments throughout Australia.

This research indicates that for high density development, even greater gains are achieved for Water and Energy as compared to low to medium density developments, being 36% higher for Water and 95% higher for Energy with high density compared to low/medium density projects. This finding may be due to nature of high density developments (apartment projects) which also comprise the construction element with the actual building of the apartment tower, whilst low to medium density developments (land subdivisions) typically comprise only the civil engineering and landscaping component, with individual lot purchasers building their homes thereupon. However, given the high density data is obtained from only 5 projects, whilst the low/medium density data is sourced from 49 projects, this finding may require further validation over the longer term.

1.3 Discussion

The data from this research challenges earlier claims that environmental rating tools are little more than sustainability rhetoric. It has been demonstrated that significant environmental gains over and above minimum planning requirements can be obtained through the application of such tools in a residential environment. The question then begs to be asked: why are residential developers are willingly providing green solutions over and above minimum requirements? As stated earlier, Hurley (2009) suggests that sustainability rating tools need to provide significant incentives such as: a marketing advantage; planning/approval short-cuts and/or tradeoffs; or else the introduction of a mandatory use system. Whilst a marketing advantage is likely to be a key driver of developer engagement with sustainability rating tools (EnviroDevelopment, 2011), in the absence of further evidence one could claim it is the only motivator, with neither access to planning credits nor mandatory disclosure currently in effect to motivate residential developers. The literature provides some insight into other possible motivators. Warren et al. (2009) have identified that larger corporate developers are using rating tools in order to obtain independent third party ratification of having met their environmental responsibilities. This may apply to the large publicly listed residential developers such as Delfin Lend Lease, Mirvac and Stockland, as well as government agency developers such as LandCorp and the Urban Land Development Authority that have sought this accreditation.

There is also the potential motivation of whether consumers are willing to pay more for greener projects. The literature to support findings on how a sustainability rating can contribute to the value of residential developments is sparse, however some parallels can be drawn from the commercial building sector rating tool literature. Earlier research identified the lack of transparency and inconsistency in rating tools as a key hurdle to the impact of sustainability features on the value of commercial properties is being recognised by the valuation profession (Warren et al., 2009) (Royal Institute of Chartered Surveyors (RICS), 2012). However, after many years of debate, it is now recognised that sustainable buildings benefit from increased demand as tenants prefer a sustainable building over a less sustainable alternative (Royal Institute of Chartered Surveyors (RICS), 2012). This is

now reportedly leading to greater evidence of capital value shifts associated with a building's sustainability features. This effect has been particularly observable since the introduction of the federal Building Energy Efficiency Disclosure Act 2010ii which introduced mandatory disclosure upon sale or lease of commercial offices from November 2011 (Australian Government, 2012a). This new level of consistency and transparency has now allowed both tenants and investors to readily understand and compare the sustainability features of buildings off a common index. If these findings can be transferred to other sectors, then it is not unreasonable to conclude that in time, and with greater understanding of the benefits of investing in accredited sustainable residential developments, capital value benefits may accrue to residential developers and home owners alike as demand for more sustainable residential properties increases.

5. Conclusion

There are a plethora of sustainability rating tools available around the world, however the vast majority are designed to rate the design and/or operation of single buildings, and most specifically commercial buildings, rather than the perhaps more visible ecological impacts associated with large scale residential development. EnviroDevelopment is one such rating tool that fills this gap in Australia.

Whilst criticised in some literature as providing little more than green rhetoric, this research confirms that environmental rating tools that require residential developers to perform in excess of minimum legislative requirements can have significant positive sustainability impacts. This research has found that in the areas of Water, Ecosystems and Energy, this rating tool has achieved savings of an additional 26-36% for Water, 10.45% for Ecosystems and 21.8 – 41.2% for Energy across a range of residential developments throughout Australia.

This research also dispels the view of earlier literature that only developers of high-end residential product (where prices may be more elastic) can afford to incorporate sustainability features in their developments. Accreditation has been sought and achieved by a number of government agencies and affordable housing providers.

Future research on this topic will examine the motivations behind developer engagement with sustainability rating tools in the residential sector, with a view to building on the body of knowledge on this emerging field.

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[i] For a comparison of these rating tools, refer to Reed et al 2009 and 2011, Xiaoping et al 2009 and Ding 2007.

[ii] In July 2009, the Council of Australian Governments (COAG) agreed to a 10-year national strategy on energy efficiency. The purpose of this strategy was to accelerate energy efficiency improvements and deliver cost-effective energy efficiency gains across all sectors of the Australian economy AUSTRALIAN GOVERNMENT. 2012b. *Department of Climate Change and Energy Efficiency* [Online]. Available: http://www.climatechange.gov.au/en/what-you-need-to-know/buildings.aspx [Accessed 27 November 2011.

"Information sharing problems among stakeholders in the construction industry at the inspection stage: A case study"

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Abstract

The paper reports the information management practices of the various key stakeholders during the inspection stage of a construction project. The data was collected through observations and shadowing of stakeholder exemplars, interviews and document analysis over a fourteen-week period. In the process of constructing a new and innovative academic building for an Australian University, vast amounts of information had to be effectively managed by various stakeholders in the construction process. This life cycle includes the creation, documentation, dissemination, utilisation, evaluation and archiving of the relevant information and knowledge across multiple domains and areas of practice and expertise. Without efficiency in these processes the effectiveness of construction project outcomes and contractual obligations could be challenged. This research evaluates the information life cycle through an Information Audit (IA) in the inspection stage of a large-scale construction project (the innovative academic building) through an evaluative lens integrating the concepts of Enterprise Content Management and Personal Information Management. The research shows that information auditing enables framework identification of iterative and problematic information reporting in the Construction process. The research shows the pivotal role of a key stakeholder involved in the process acting as an intermediary, translating and transferring information across different domains.

Keywords: Construction Inspection, Information Sharing, Information Audit, Information management, defects recording methods.

1. Introduction

The paper reports the information management practices of the various key stakeholders during the inspection stage of a construction project. The data was collected through a series of observations and shadowing of stakeholder exemplars, interviews and document analysis over an intensive fourteen-week period. In the process of constructing a new and innovative academic building for an Australian University, vast amounts of information had to be effectively managed by various stakeholders in the construction process through the use of an information life cycle (Persson, Malmgren, & Johnsson, 2009; Wenfa, 2008). This life

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cycle includes: the creation, documentation, dissemination, utilisation, evaluation and archiving of the relevant information and knowledge across multiple domains and areas of practice and expertise. Without efficiency in these processes the effectiveness of construction project outcomes and contractual obligations could be challenged. This research evaluates the information life cycle in the inspection stage of a large-scale construction project (the innovative academic building) through an evaluative lens integrating the concepts of Enterprise Content Management and Personal Information Management.

In all sorts of projects, including construction, the way people categorise documents is very personalised and most often linked to experience and domain knowledge. Both of these factors influence how we use information and this changes over time and from project to project (Arnorsson, 2012; Peansupap & Walker, 2006). This research clearly demonstrates how each of the stakeholders in the construction inspection phase process made use of differential means of collecting, storing and using their personalised information. An Enterprise Content Management System (ECM) managed the overall project, however, access to this was only for one set of stakeholders, the architects, and they admitted they rarely used it as it was seen as a repository rather than a system to manage active documents. Some stakeholders in this project made use of electronic devices such as tablets, whilst others relied on hand written notes. The project architects and some of the builder supervisors used annotations on plans and drawings. While the Principal Architect took minimal notes but, instead, relied on expertise in the domain and experience (Bartholomew, 2008; Cavieres, Gentry, & Al-Haddad, 2011) with the project from the beginning. Throughout the project, each of the stakeholders interacted with their Personal Information Management (PIM) systems to collectively create the construction process. In this construction project the outcomes were successful because of the key roles played by the Principal Architect and the Site Architects. Their combination of technology, memory and experience provided the substance for maintaining all of the requirements that needed to be completed during the inspection stage. At times, this process was confronting and argumentative as the personalised collections of information from each stakeholder's perspective was often different. Ultimately the ‘memory’ or ‘tacit knowledge’ of the Principal architect and the drawings agreed upon formed the basis of all decisions and the means to achieve all the requirements of inspection.

2. Research Context

2.1 Construction Process

The construction process is complex and contains vast number of sub-processes. The construction process is one where all stakeholders involved bring about their resources to put together the building/project and complete it within an agreed timeframe (Andrew et al 2006). The stakeholders in the construction process include clients, project managers, architects, consulting engineers, builders, contractors and sub-contractors, suppliers and users. The construction process can be viewed from different points of view and often can be explained differently. For example, from a business point of view the construction process includes a business case, conceptual designs, detailed designs, bidding preparations, bidding, awarding of contracts, build, handover and operations (Chinyio & Olomolaiye 2010).

The design process itself also contains large amounts of sub-processes such as requirements gathering, calculations, design layout and specifications determination. From the builder's point of view, the construction process includes pre-construction, shop drawing reviews, site setout marking, build, inspections and rectification. To enable a simplified example of the role of information auditing and tracking in the construction process, this study will focus only on the inspection stage during the build process.

The construction process is fragmented and differentiated via stakeholder role and the multiplicity of processes involved. These depend on the types of project delivery systems in use and notions of contracting (Chinyio & Olomolaiye 2010). Furthermore, the role of stakeholders involved and the scope of works in the construction process also vary as a result of the type of project delivery systems in place (Marco, 2011). The construction inspection phase is a process in which stakeholders carry out checking procedures to ensure that the building that is being constructed meets the project requirements (Ricketts 2001). These requirements include designs, specifications, contracts, documents, appearance, building codes, functionalities and happens within the agreed timeframe. The inspection process requires specific benchmarking or checklists that each stakeholder needs to inspect the building against. This benchmarking and checklists form part of the information captured as essential and needed for the project. This information has to be carefully managed to enable integration of the complex parts of the construction process. Much of the information is tacit (Shelbourn et al 2006, Tuuli et al 2010) and held within the domains of the various stakeholders.

2.2 Information embedded in the stage, stakeholders involved and the role of sharing

Information sharing is the process of exchanging information between two or more people (Ford & Staples 2010; Ling, Sandhu & Jain 2008). Information sharing is a process, in which an individual passes on their information. These include both tacit and explicit information (Ford & Staples 2010). This information includes both existing information and new information generated within information sharing processes. Most of the time this happens while employees or experts with domain knowledge in organizations are doing something together (Lilleoere & Hansen 2011; Lindsey 2006). Information sharing is important, as research has shown that it can be used to create competitive advantage for the organisation (Bryant 2005; Grant 1996; Porter 1993).

However, there are factors that impact the efficiency of information sharing. There include an individual's absorptive capacity (Reilly & Sharkey 2010) for additional or new information. Individual absorptive capacity is an ability of an individual to interpret received information and utilise it and turn in to action (Lilleoere & Hansen 2011). Nonaka (1994) mentions that to share tacit knowledge/information in the organization requires social interaction between an individual through human activity. Individuals in the group or in a "self-organizing team" perform this activity. The purpose of these activities is to pursue new problems and solutions. This interaction group can be within the organization or among individual formed inside and outside the organization (Nonaka 1994). Nonaka has listed factors that contribute to the success of information sharing. These are trust among individuals in the group, and

the existence of a common perspective that each individual has towards the group and towards dialog or individual communications. Holste and Fields (2010) have studied trust in information sharing in an international organization. The research found that warm relationships and respect are most likely to develop through face-to-face interaction among workers. This relationship among workers or trust has affected willingness to share tacit information. Van den Hooff and Huysman (2009) have found that organizational culture has an effect in organizational information sharing, the more interaction of employees in an organization, the higher the trust (Van den Hooff & Huysman 2009).

Kanjanabootra (2011) showed in a manufacturing construction process context that a process of information sharing could integrate multiple stakeholders in the process. In that research the catalyst was an external engineer with domain expertise in the process involved. The role of that engineer was to create a common language for the stakeholders to understand and enable the sharing process so that all understood all information elements of the project. This was collected and stored in an information system, which was made accessible to everyone in construction the role of catalyst, is often the project manager. However there are a multiplicity of domain expertise elements across all of the stakeholders and in construction the complexity of the tasks (Pan, Gibb, & Dainty, 2007) means that often not all elements of information understanding and completely understood by all stakeholders. One of the ways this might be overcome is the use of IT and an ontological-based structure to facilitate effective information sharing. One model that can be used to enable this is the use of the information life-cycle concept.

2.3 Information lifecycle

One of the most valuable assets an organisation can possess is its information. The ability to use it correctly and effectively may allow an organisation to gain insight to what is happening as well as, in many instances, speed up existing processes. This is no different within the construction industry. (Han, 2010)

Information within an organisation follows a lifecycle. Many have attempted create and define what is involved within an information life cycle, including the activities and processes. However, what is known is that many of these models represent anywhere between three to seven stages. At it's most basic level an information lifecycle will include: creation, dissemination, storage and disposal. The information lifecycle was selected and made use of in this particular project as it provided the researchers an evaluative lens in order to understand how information is made use of through the final inspection stage of a construction project.

2.4 Enterprise Content Management Systems

In recent times, we have seen a push towards Enterprise Content Management (ECM) within organisations. It has been successfully applied in many industries such as pharmaceuticals, finance and aviation. The use of ECM has allowed these industries to manage and integrate their structured, semi-structured and unstructured data in a meaningful way (Päivärinta & Munkvold 2005). Studies have also indicated that there is an

increasing amount of unstructured data being created and stored within organisations, with unstructured data accounting for 90 percent of all information created and stored (Jenkins, Glazier & Schaper 2004).

With the sheer abundance of this unstructured data, and the increasing amount of complex projects that organisations within the construction industry are faced with, many are finding it a real challenge to deal with all this information. Rogalski states that for an organisation to achieve high performance they should have in place an effective information management plan as well as taking into account other factors such as: the increase in data management cost, the difficulty of finding the right information and making use of information that has already been collected to yield useful new insights. Rogalski then also goes on and suggests that in order to solve these problems, many businesses and organisations are turning to ECM as it has the potential to streamline their business processes and increase collaboration within an organisation (2006).

3. The project case study

Although from the conception to practical completion of this multi-million dollar innovative academic building for a prominent Australian university took just a little over four years, this particular research project ran for a period of fourteen weeks.

Preliminary interviews showed that the case study project has unique characteristics when compared to total gross area within the construction time scale. The project was a challenging one because large amount of defects were both generated and handled during construction stage. “We found that there were fifteen something thousand preliminary defects found and in total over fifteen thousand defects generated for the whole building” said one research participant. The interest in this research was to investigate how the project team carried out such a complex and fast tracked project and managed to finish it within the time frame.

It investigated how various stakeholders in particular; architects (of which there were two) and builders (of which there were three) managed the information that was being produced during the inspection stage of a construction process. It studied the information management practices of the organisations in which the stakeholders were employed, their individual information management preferences and practices as well as the tools and technologies that were involved in successfully completing this task. In total, a Gross Floor Area (GFA) of 35,000 square meters, which totaled of eleven storeys, was checked for defects. Data was collected via various techniques, which included: observing, shadowing and interviewing the stakeholder participants.

4. Research Method

This research was developed in an interpretivist framework through the researchers using observation and shadowing of stakeholders involved in the inspection process of the single case construction project being studied. Yin (1994) has defined case study research as one which ‘investigates a contemporary phenomena within its real-life context, especially when

the boundaries between phenomena and context are not clearly evident' (Yin 1994, p. 13). Both Yin (1994) and Eisenhardt (1989) also suggested that a case study is a good technique to use to study social phenomena in a single setting. It can help researchers answer 'how' and 'why' questions in the situation that involves social behaviour through exploratory, descriptive or explanatory research (Barkley 2006; Blaxter, Hughes & Tight 2006; Eisenhardt 1989; Rowley 2002; Stake 1978, 1985, 1995; Yin 1994). The researchers also interviewed the stakeholders to try and understand not only the processes they were engaged in but also to try and understand how they collected information, how they stored information and organized it and how they shared and used this information during the inspection phase.

Qualitative researchers study things in their natural settings, attempting to make sense of, or interpret, phenomena in terms of the meanings people bring to them (Creswell 1997; Denzin 1994). Morgan and Smircich (1980) argued that the choice of research methods had to evolve out of the context of the research, not out of abstract reasoning (Morgan & Smircich 1980). The context of this research is embedded in the intricate interplay of numerous ways the various stakeholders in the construction project involved interacted with each other, with executives, with clients and with the design/build and testing process they were using on a daily basis. These interactions created a very complex environment where the adoption of simple tools of research would have produced little of any value. There was a need to address all of the processes in multiple ways to ensure that all of the detail in and nuances of, the data, information and knowledge were captured accurately. In this way, the researcher becomes much more experienced with the context of their research. The researchers were able to justify their understandings based on the detail of their observations, discussions and interviews. In this research, that complexity was addressed by the use of multiple qualitative research methods and techniques. Despite the increase in mixed method approaches (Mingers 2001), it is unusual for qualitative methods to be used in combination with each other (Frost et al. 2010). This is often a problem because of the multiple ideologies often embraced by qualitative researchers.

The researcher's perspective, in essence his own domain knowledge, can also play a key role in qualitative data analysis and the extent to which generalizations can be made. However, they are rarely undertaken as part of the one research project. Certainly, comparisons are being attempted within, (Frost et al. 2010) but those comparisons assume that each method is informed by different ideologies. In this research, the same interpretive structure (Walsham 1995) – based on the one researcher's domain knowledge and technical expertise in construction and the others in information sharing and auditing – forms the unifying framework through using a single interpretive case study, as a means of understanding the inspection process story. The research process involved an iterative set of interviews, discussions and observations of all stakeholders involved in the inspection phase of the academic building project. Each iteration involved feedback, re-discussion of observations and re-questioning of the participants to check observations and conclusions of the researchers throughout the process. The data collected was interpreted through a hermeneutic lens of feedback, interpretation, observation, interpretation and re-interpretation, leading to sets of conclusions.

5. Research Outcomes

This case study of a major construction project for education purposes has highlighted a number of conclusions that add to knowledge about information use, sharing and storage in the inspection phase of construction projects. Each of the outcomes derived from the analysis highlights issues that relate to process, issues that relate to domain knowledge problems, issues that potentially could derail the effectiveness of this part of the construction process.

5.1 Multiple stakeholder roles, which were not clearly defined

During the observations the researcher found that the role of the different stakeholders during the inspection stage was not clearly defined. In all, there were two stakeholders involved during the inspection process: the architects and builders. It was observed that it was mainly the Architect who primarily led the inspection process, whilst the builders took on a secondary role of recording the defects. However, these roles could switch depending on the situation and room they were in. On a number of occasions the defect list that both stakeholders made are out of alignment. Some defects appeared on the architect's defect list but have not been noted on the builder list and vise versa. The observations also showed that contractor who responsible for rectify the defects were excluded from the inspection process. In this project it was builder who had to transfer all of the defect details that they noted during the inspection process to the contractors.

5.2 Differences in access and availability of information management tools

The builder involved in this study made use of an in-house IT support tool to manage their information during the inspection process. The tool mentioned is a tablet computer, which ran a spreadsheet-like application. The inspector engineer who carries out the inspection process can select the inspection area (room number) and enter the defects details into the application. On many occasions there were multiple defects occurring in a single area. The engineer often had to add additional information into the system in order to distinguish the differences between them. Additional information often included; directional side of the room (west facing wall…) and take photos of those defects. However, the photo files and the tablet application were not integrated. The inspector engineer then had to sync and transfer details regarding the defects and photos onto the desktop computer located in the site office for internal documentation and to circulate to architect and contractors for further actions. However, the architects and contractors in this study did not have access to the same IT supporting tool as the builder. There were a number of occasions in which the defect lists were distributed to contractors so that they were able to rectify the defects, however; the contractor could not find the actual defects onsite due to the way the of the defect was described. As a consequence, the builders had to physically head onto site and point to the defects contractors.

5.3 Multiple methods of information recording, coding and storage

Throughout the inspection stage of this project there were multiple forms of information being recorded and stored. Different methods, criteria and tools were applied. For example, Architect A used the specifications and drawings to check issues during the inspection; whilst Architect B from the same company, relied on their tacit knowledge and expertise and did not record any information physically. In terms of process, the Architect A took pictures, wrote notes, and did drawings on paper and upon returning to the company's office he recoded all the information in the company's information systems and filled out the appropriate internal paperwork Whilst Architect B did not record either onsite or in the office. He verbally expressed the information and made sure that others were taken detailed notes. In shadowing Architect B in subsequent sessions in the inspection process, he demonstrated his use of memory and recall of issues without reference to stored or organised information. In terms of sense making Architect A made use visual representation through photographs. Architect B used memory and domain expertise for sense making.

5.4 Information incompleteness

It was observed that information gathering within the inspection phase of this project was invariably not systematic and happened in an 'ad hoc' manner. Stakeholders involved with these inspections would often switch from one space to another without adhering to the agreed plans. This was mainly due to the fact that, construction workers who were working on other aspects of the building, required instant clarification on certain issues in order to continue on with their tasks. This often distracted the builders and architects away from their primary duties and, in turn, meant that additional inspection times were required to be scheduled around their already busy work schedules. Another example of how information being collected in an ad-hoc manner included stakeholders switching the format in which they collected the data. One moment they would be noting the defects down the tablet and the next make use of pen and pad. After further clarification with the stakeholders, this was attributed to the amount of time available to them. The stakeholders stated that there was 'too much time spent wasted recording notes on the tablet versus hand written notes'.

5.5 Information gathering happens in an 'ac-hoc' manner

It was observed that information gathering within the inspection phase of this project was invariably not systematic and happened in an 'ad hoc' manner. Stakeholders involved with these inspections would often switch from one space to another without adhering to the agreed plans. This was mainly due to the fact that, construction workers who were working on other aspects of the building, required instant clarification on certain issues in order to continue on with their tasks. This often distracted the builders and architects away from their primary duties and, in turn, meant that additional inspection times were required to be scheduled around their already busy work schedules. Another example of how information being collected in an ad-hoc manner included stakeholders switching the format in which they collected the data. One moment they would be noting the defects down the tablet and the next make use of pen and pad. After further clarification with the stakeholders, this was

attributed to the amount of time available to them. The stakeholders stated that there was ‘too much time spent wasted recording notes on the tablet versus hand written notes’.

5.6 Shorten project timeline

The construction schedule is a very important element in construction project. The schedule determines the timeline for the building to be being constructed then and inspected for defects. For example, the project manager and construction manager needed to coordinate with contactors need to carry out their work to get material and workforce into the construction site in such an order to maximize construction workflow. In a ‘Design and Build’ type of contract especially as in this project the builder was offer an intensive program to finish the construction process as fast as they could. In the construction industry, it is not only the financial intensives that drive a builder to finish the project ahead of the schedule however, to finish the project ahead of time will also provides a good impression on their clients which, could, eventually assist the builder in winning additional projects.

Another observed factor, which contributed to the reduced timeline in this project, was the scheduling of multiple inspections at the same time. Both the builders and architects understood the importance of the timeframe in which they had to operate in, hence additional staff, were allocated so that defects list could be sent out to contractors to rectify their defects sooner.

5.7 Differences in: background, knowledge and experiences of participants

The research established that during the inspection process stakeholder’s experience, knowledge and backgrounds were also having impacts on the inspection process. There were a number of occasions when the architect spotted a defect and the rectification has been requested. However, the architect’s rectification request was not practical in a builder’s perspective. The builder offered an alternative solution that was often more practical, cost effective and still met the architect’s requirements. Sometimes the architect identified the defects to the builder. However, due to some physical characteristics of the equipment that limited their further actions. Therefore, both stakeholders had to come up with compromised solutions. On the other hand, one of the builders involved in the inspection process is also a qualified architect. This builder was able to understand the defect from an architectural and design perspective better than the other builders who have had limited or no architectural background. During the observations the researcher found that experience is a crucial elements for both architects and builders to come up with the solution to the spotted defects. Sometime both stakeholders have to delay the outcomes and seek further advice from their supervisors back at their respective offices.

6. Discussions

After the examination of the data collected through observations and shadowing of stakeholder exemplars, interviews and document analysis over a fourteen-week period, the figure below outlines the causes of information sharing problems that the stakeholders faced whilst attempting to conduct the final inspections for a construction project.

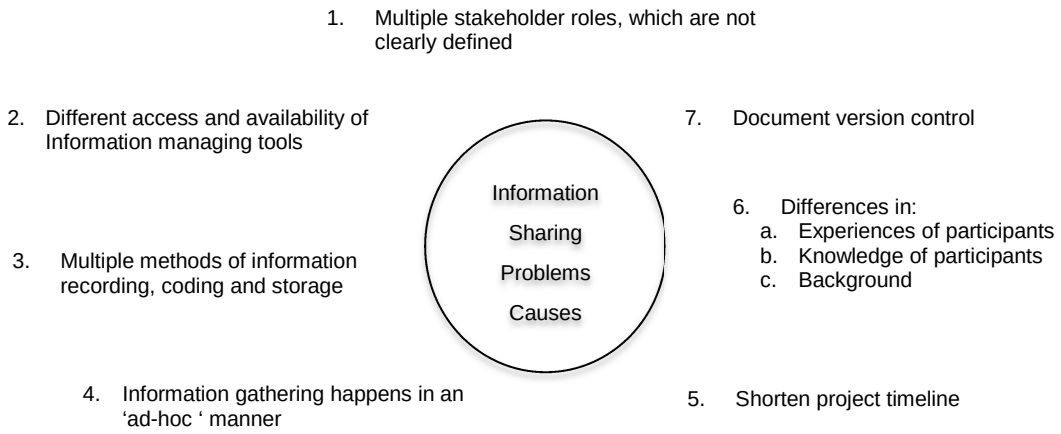

Figure 1: The causes of information sharing problems

The research shows that the various stakeholders involved made decisions and undertook their roles in the inspection process utilizing their differentiated knowledge domains. Ordinarily the interaction of differentiated knowledge domains results in poor decision-making and often leads to ineffective project management and sometimes project failure. In this project that potential for incompleteness was compounded by the multiplicity of methods used throughout the inspection processes. Use of different personal information management systems and different and incompatible technologies by each stakeholder, and the lack of attention of a project information management system created the conditions for significant failure. However the project was a success. The research showed that the solution only happened because of one key stakeholder, the Principal Architect, acting as an intermediary offering sense making of each knowledge domain across all other stakeholders. Information flows and information sharing centered on the pivotal role the architect played. He became both the conduit and interpreter of the existing differential knowledge and enable project success.

The information lifecycle tool used in the analysis of the case study data revealed that although all the stakeholders were working towards the same goal, they did so by making use of the information presented to each one of them differently. Each made sense of the situation through their own experiences, their organisation's restrictions and policies, the tools and technologies available as well as their own personal preferences. It also offered another evaluative lens to understanding the importance of information in the construction process and offers project managers and stakeholder-managers of construction projects a means to foreshadow information-sharing problems that may inhibit the effectiveness of projects. Information auditing as used here exposes inefficiencies and highlights iterative cycles in practice, differential levels of information sharing and information asymmetries, all of which can affect the efficiency of the construction process.

In conclusion, the findings of this study seem to indicate that there were a few lessons that the stakeholders in the construction industry needed to learn from each other. These included: the need to increase the effectiveness of information management practices during the inspection stages and the need to clearly define the roles and responsibilities for each stakeholder from the outset. Having a greater understanding of these lessons may facilitate a decrease in the number of defects and re-work that often occur in every construction

project. If the amount of re-work in construction projects can be reduced or eliminated, then the construction process effectiveness then can then be improved.

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Factors Influencing Construction Technology Adoption

Samad M E Sepasgozar[1], Leonhard E Bernold[2]

Abstract

History has shown that innovative new technologies are key contributors to improving productivity, quality and safety in construction. While the innovation process has been studied in the past, procedures that companies apply to make decisions on what technology to adopt, have received little attention. This paper presents the initial results of an on-going study to understand the processes, sources of information and the critical success factors that companies depend on when buying new technologies. It presents an adoption model that is being validated with an in-depth study of vendor strategies and visitor behaviour at two equipment exhibitions in Australia. Vendors displayed an array of products ranging from spirit levels to large hydraulic excavators and applied various methods to attract potential customers to their booths. The analysis presented below uses a wide range of measures to categorize each vendor booth to include the nature of the product, the area occupied and type of information offered. As was expected, the analysis reveals heavy clusters of vendors applying similar strategies strongly influenced by the size of the vendor company and the technology. The data also supports the adoption model as the vendors make use of specific techniques to serve the needs of novices as well as better informed customers with the aim of establishing a relationship that extends beyond the exhibit.

Key words: Technology, Adoption Decision, Construction industry, Marketing Strategies, Factors.

1. Introduction

Like every other industry, new technologies are constantly introduced to construction. Companies trying to improve their productivity, safety, and quality have to make a decision if and which technology should be adopted. However, surmounting the complexities facing this industry makes technology enormous challenging to adopt. Considerable research by, for example, Allmon et al. (2000), Goodrum and Haas (2004) and Astebro (2002) report that new technologies have a large beneficial effect on overall productivity in construction. Adding vibration to the rolling action of compactors exhibited a 260% increase in productivity during the mid 1980s when Caterpillar introduced this technology for example (HAAS et al., 1999). However, the whole industry continues to lag in technology adoption and is generally

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adverse to change (Nicolini (2001); Nikas et al. (2007); Harty (2008); Milliou and Petrakis (2010)). Data from the Melbourne Institute of Applied Economics and Social Research (2010) shows that the construction innovation index lags significantly behind other industries. This index even fell by 18.2% between 2005 and 2006. Averseness to risk and the adoption lag is due to many reasons such as the variability of a company's expertise, the uniqueness of the product (Munkvold, 1999) and the nature of industry itself (ABS, 2009). These reasons make the construction industry very different compared to other industries. Thus, the question is raised which factors critically influence the adoption decision in the construction industry.

The decision to deploy a technology is a function of a variety of influences. There is little known about the decision making process and the influencing factors. Deriving a clear benefit is a critical objective in construction projects and cost is often not the most important factor influencing the technology adoption decision. The TriComB2B (2011) survey reveals that total cost of ownership is considered 56% of the time in the construction purchasing decision, while it is 71% for purchasing in energy related industries. Technology exhibitors do reveal price of items in trade shows as the cost is not the first or main question of visitors. On the other hand, car exhibitors show price as one of first pieces of information to the visitors. Thus, other factors are likely to be critical in the adoption decision in construction industries which should be investigated.

Frambach and Schillewaert (2002) recommend future research should focus on the factors influencing different pre-adoption stages, rather than the adoption decision itself. They suggest the factors affecting the use of innovations should be studied in future. Linton (2002) concluded that there is still a need for theory building in how to implement decisions to purchase technology. At the same time, the technology adoption process in construction and also the influencing factors are not clearly understood. The research in this paper briefly introduces the technology adoption model and then investigates key factors likely to influence the decision. In order to support the main point of the study, two technology trade shows have been studied in Australia. Then, the study focuses on assessing the how vendors attract visitors to exhibitions on mining and construction equipment and what differences are discernible. Nineteen measured variables reduce to three main factors which vendors apply to attract potential adopters. The research attempts to clarify the adoption process in the construction industry and also addresses vendor business behaviour and customers' needs.

2. Theoretical Adoption Frameworks

Howard and Moore (1988, p. 34) found that the decision making path to a purchase consists of a series of mental or behavioural steps that potential adopters pass through. Here, adoption description reveals the necessary steps to introduce a product into the daily operations of an organization (Damanpour and Schneider, 2006). The Theory of Reasoned Action (TRA) by Ajzen and Fishbein (1975) is concerned with the determinants of conscious intention and attitude towards a behaviour defined by "salient beliefs (b_i) about the consequences of performing the behaviour multiplied by the evaluation (e_i) of those consequences" (Davis et al., 1989):

The Reasoned Action function: $A = \sum b_i e_i$

Extending the Reasoned Action function as a general psychological theory, Davis et al. (1989) established the well publicized Technology Acceptance Model (TAM), presented in Figure 1, to predict individual behaviour applied to the field of Information Systems (IS). TAM, as a predictor of the adoption of new IS and ITs, is psychometrically impacted by two external constructs shown in Figure 1 below. They are "Usefulness" and "Ease of Use" in accepting new technology. Since the mid 1990s, many authors such as Amoako-Gyampah and Salam (2004), Venkatesh and Bala (2008, p. 276) and Park et al. (2012) have provided theoretical underpinnings for the relative importance of the TAM in IT and IS disciplines. TAM has been extended by adding more construct determinates for actionable guidance and a complete nomological network of the determinants. However, this is not a theory or model which is able to predict construction equipment adoption.

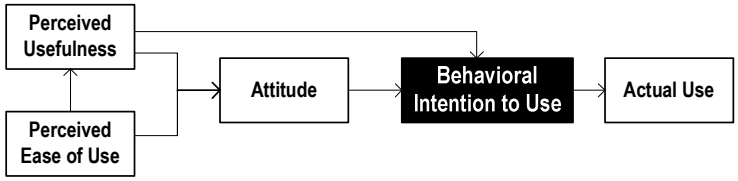


Figure 1: Technology Acceptance Model (Source: Davis 1989)

Similar to any decision-making process, the collection and processing of information is a key stage in the adoption process. Frambach and Schillewaert (2002) defined the initial stage as awareness of what is available that could respond to a need or improve the present situation. For example, Graaff et al (2008) studied factors influencing the adoption of soil and water conservation measures. They subdivided the adoption process as: 1) Acceptance, 2) Actual adoption and 3) Continued use. In contrast, Rankin and Luther (2006) proposed that acceptance followed a phase they called implementation. In practice, there does not seem to be a uniform adoption process applicable to different domains, in particular construction. The following section proposes an adoption model for construction as a hypothesis to be validated with data.

3. Research Methodology

In order to study vendors' business behaviour and identify factors influencing the adoption decision two trade shows were visited. The first was the Construction and Mining Expo (CME) 2012 in Perth and the second, Asia-Pacific's International Mining and Construction Exhibition (AIMEX) in Sydney. The data obtained includes brochures, catalogues, questionnaires and photos. The visits to the construction trade shows resulted in 1,812 photos and pre and post-show reports which the research used to identify critical factors. The photos directly provide in an independent way of acquiring data from the business area covering individuals' business behaviour and technology know-how. Morse and Richards (2002) explain that photos record directly "how much" or "how many" and provides illustrations for researchers. The collected data shows how vendors try to capture attention in the trade show and how they try to diffuse their technologies. Ethnographic techniques and a Likert scale were used to identify and measure vendors' activities in the trade show.

In the next stage of this research, testing CTAM, five groups of proposed decision variables are categorized in Table 1 such as maturity and after sale services. These variables were applied and measured at the shows based on the vendors' business behaviour. The codification of data permitted the subsequent factor analysis on nineteen variables which vendors use in their effort to support construction companies' decisions. Factor analysis was used to reduce variables to reach a better understanding of the crucial variables and reduce them from nineteen to three factors. According to Hayton et al. (2004), factor analysis can be broadly characterized as a set of multivariate statistical methods applied to determine the number and nature of common factors needed to account for the patterns of observed correlations.

4. Theoretical Concept of Technology Adoption in Construction

Understanding the process of technology adoption including the decision making process and influencing factors is critical for vendors. It assists them in successful marketing and improves the innovation process. Meanwhile it is important for construction companies to get better solutions and services. Companies are looking for a solution when they perceive a need such as contractual obligations, owner or consultant requirements, or government green regulations. In contrast, according to Rogers (2003) some customers of IS may accept a technology and then start to create a need. Construction companies want claims made by vendors about improved productivity, safety and/or reduction of muda-waste tested, while they prefer to "buy into" a technology only after it has already been successfully used by another company, especially a competitor. Furthermore, vendors try to provide "convincing" information and support each node of a decision making process leading from the recognition of a need to an "in the field" assessment of an adopted technology.

The construction company goes through three phases from solution to technology implementation, while vendors proceed from diffusion to after-sale services as the second side of the process. The vendor side could be replaced by a manufacturing representative, innovator, dealer, supplier or sale persons. Technology adoption occurs in an environment with two main players such as vendors and construction companies. Holt and Edwards (2012) state that machinery sales analysis ultimately support business decisions and the sale occurs in an environment characterised with both supply and demand influences. Therefore, the interaction between the two sides - vendors and contractors - is considered in modelling.

Building on work by other researchers, Figure 2 presents the Construction Technology Adoption Model (CTAM), consisting of three distinct phases:

1) The solution phase initiated by a need or desire,

2) Decision or purchase decision, and

3) Implementation.

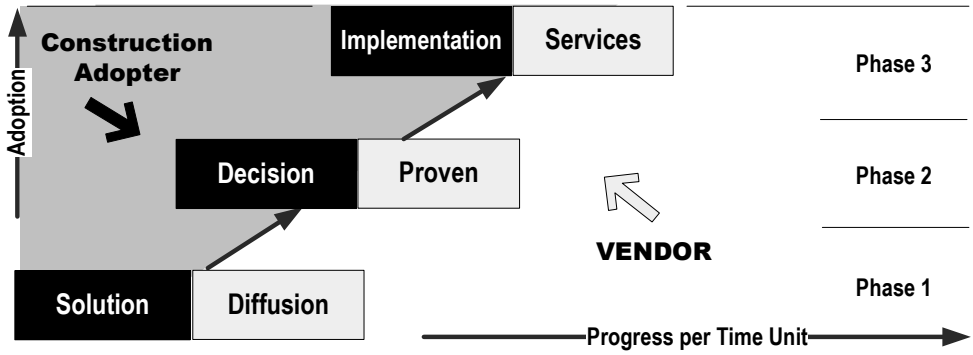


Figure 2: Construction Technology Adoption Model (CTAM)

From the vendor side, the three corresponding phases are namely Diffusion, Proven Technology and Services in this research. The phases cover eight stages from the perspective of the consumer and the vendors. The first phase including three first stages mostly focused on the identification of solutions and information gathering which will be explained below. The information collected in this phase is followed by an in-depth analysis which is consistently refining and tightening the decision criteria applied by the construction company. Vendor representatives offer a trial or actively demonstrate the technology to complement this evaluation, and then construction companies are approach with three options: adopt, reject or gather more information. Following CTAM, factors influencing the decision are discussed in the following section focusing on vendor and technology attributes.

5. Factors Influencing the Decision

The technology adoption process is influenced by different factors in each phase of CTAM. Proposed factors are classified in five categories which ultimately influence consumer intentions towards the adoption of new technology as shown in Figure 3.

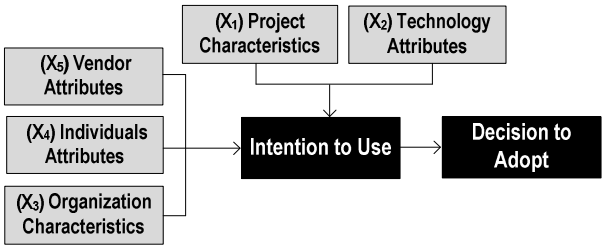


Figure 3: Decision Making Categories of Factors

According to CTAM, this overall decision tree is modelled as a sequence of decision nodes. At each level, the following generic function can be established:

$$V_A = f(aX_{A1} + bX_{A2} + \cdots) = \sum_{i=1}^{n} cX_{ci}$$

Where, A, B, C … = Decision nodes (e.g., Examination of Potential); Y_A= 1 if the decision is made at node A technology; Y= 0 if the individual is a non-adopter of new technology; and c is the coefficient related to each node of the decision path.

Table 1: Categories of Variables

Project characteristics	Technology attributes	Organization characteristics	Individual attributes	Vendors' attributes
Task	Maturity	Need	Relationship with a vendor	After sales service
Productivity	Brand	Goal	Response to risk	Guaranty
Quality	Reliability	Cost reduction	Culture	Warranty
Project cost	Versatility	Technology policy	Innovativeness	Training service
Time	Capacity	Formalization/ centralization	Subjective norms	Maintenance service
Safety	Power	Company culture	Personal response to motivation	Financial offer
Project condition	Durability	Company size		Relationship & Motivation program
Geography and location of the project	Site performance			Vendor: size of organization

6. Construction Technology at CME and AIMEX

Construction technology trade shows are critical for the early adopters and adopters in early stages. The TriComB2B (2011) survey reveals that 24% of respondents in the construction industry acknowledge the importance of trade shows (above the average of all industries), while respondents in Information Technologies and energy related industries rate them at 10% and 17% respectively.

Potential adaptors from different stages of the process visit construction technology shows as shown in Figure 4. The stages are called "*Identification of potential, Study of the technology, Examination of potential*" from the construction side. The TriComB2B (2011) data indicates *identification*, *criteria creation*, and *search stages* of the purchase decision at trade shows are 17%, 25% and 42% respectively important. Thus, tradeshows are considered as a critical environment for technology adoption in construction and assist potential adopters to gather more information to progress the situation to the next phase.

Construction companies are informed about new technologies from different sources mostly from innovative companies and suppliers' representatives. For 60% of respondents, "*informal contacts to colleagues"* for gathering information is important in at least 60% of the purchasing decision *in the construction industry*. "*Distributors* and *manufacturing trade representatives"* are also important for 46% and 52% of respondents respectively. Surprisingly, the data from 448 respondents reveals that the scores for the construction industry are more than in other industries such as IT and Manufacturing. Thus, "informal contacts with colleagues, *distributors* and *manufacturing trade representatives*" are important sources for construction customers associated with the first phase of CTAM, as shown in Figure 4. The opportunity to gather information using the above sources is facilitated at trade shows. Visitors at different stages of the adoption process attend the shows and proceed to

making purchase decisions In order to analyse vendors' support along the decision path, the data from construction trade shows are gathered and presented in the following.

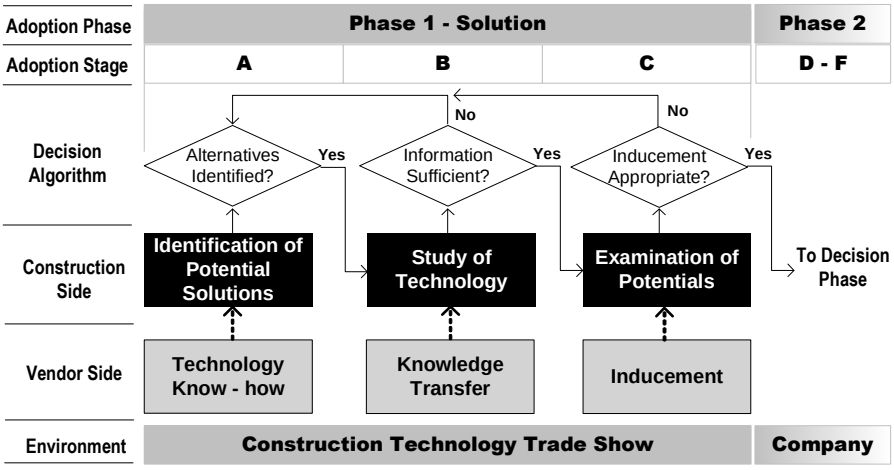


Figure 4: First Stages of CTAM at the Show

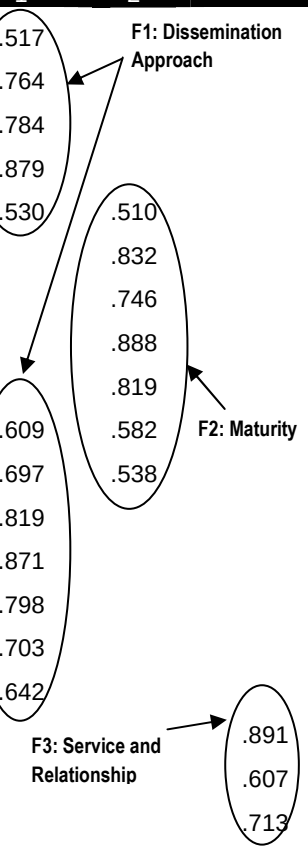
Both AIMEX (2011) and CME (2012) provided rich information about their technology such as maturity, brand, power and capacity as mentioned in the group decision variables. In contrast to other exhibitions such as electronic mini-devices, software or ordinary tools, AIMEX and CME do not immediately generate transactional information such as price, terms, discounts, promotions or other financial information. Furthermore, the survey at CME Perth showed that vendors extensively support the decision maker using strategies through meetings and exchange contacts. In turn, vendors inform potential consumers, who are in the third decision node, about hire rental or trial offers for further practice evaluation. As an example, in the interview a vendor said that they were willing to loan the equipment for a while to a potentially serious buyer for testing its reliability. Different factors related to vendor and technology attributes are analysed in the following section.

7. Analysis and Results

In the first part of the analysis the relationship between observed variables is discussed. The Exploratory Factor Analysis (EFA) is used to identify the key factors that vendors use to support visitors in the purchase decision process. EFA is used to reduce the number of variables (Tipping and Bishop, 1999), pattern recognition, explaining co-variational factors (Haig, 2005). EFA has an important role in theory generation. The analysis reveals that there is strong relationship between stand feature and design, vendors' representatives and exposed technologies. For example, the variable "number of sales persons at booth" has a strong relation with booth feature (correlation is 0.863), Conversation room (0.879), Visual Learning Tools (0.835) and real exposed technologies (0.823). Furthermore, exposing capability and compatibility of the technology in real samples has strong relationships with booth characteristics (0.601-0.786); number of sale persons (0.823); function of staff (0.772), knowledge and informative posters (0.838) and written knowledge (0.811) as shown in Table 2.

Table 2: Rotated Component Matrix and the Results

No	Variables	Component		
		Factor 1	Factor 2	Factor 3
1	Vendor's exhibit area (EXA)	.517		
2	Closed stand area (CST)	.764		
3	Media type (MDA)	.784		
4	Stand feature and design (STD)	.879		
5	Exhibited technology worth (WRT)	.530	.510	
6	Maturity of the technology (MTC)		.832	
7	Number of exhibited technology line (ETL)		.746	
8	Number of vendor's technology line (VTL)		.888	
9	Brand (BRD)		.819	
10	Product exposure (PDE)	.609	.582	
11	Number of personnel at booth (PRB)	.697	.538	
12	Learning tool (LTL)	.819		
13	Knowledge (KND)	.871		
14	Persuasion (PRB)	.798		
15	Socialization (SCL)	.703		
16	Demonstration (DMN)	.642		
17	Trial (TRL)			.891
18	After sale support (ASS)			.607
19	Relationship (RLN)			.713
	Factor Loading (Rotation sums)	12.485	1.563	1.087
	Rotation Sums % of Variance	37.006	25.372	17.276
	Rotation Sums Cumulative %	37.006	62.378	79.654



The use of EFA is suitable for this data set as correlation coefficients of all variables are more than 0.7 (well above 0.3). The result of the EFA in Rotated Component Matrix using Varimax with Kaiser Normalisation shows that the observed nineteen variables were grouped into three main factors.

Analysis of the data indicates that those variables revolving around technology and vendor attributes, respectively called X5 and X2, were the two main groups of decision variables of the model shown in Figure 3. As shown in Table 2, 12 variables grouped as the F1 Dissemination Approach, account for 37% of variance. F1 includes elements such as the vendor's exhibit area, closed stand area (CST), stand design and features (STD), media type (MDA) for generating awareness and presentation and also demonstration of the technology (DMN). As shown in Figure 5, visitors pause in front of the booth which is the potential start point for communication with Caterpillar at AIMEX 2011. Experts and technicians from high technologies or heavy equipment such as Caterpillar or supplier companies are ready to identify the best solution.



Figure 5: Social Activities and Live Performance at Caterpillar's Booth

Another factor – F2 Services and Relationship includes trial, after sales support and making relationships with the consumer. It accounts for 25.3% of variance. Three other variables - the number of product lines, brand and product maturity which vendors stressed at the show - are grouped as F3 and account for 17.2% of variance. The variables and factors influencing the two main categories (X5) and (X2) are shown in Figure 6 which is supposed to positively impact on the intention to use.

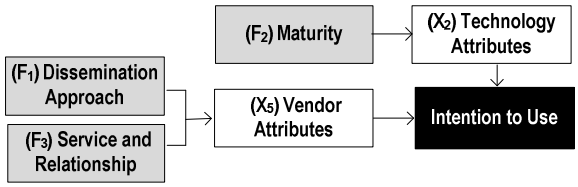


Figure 6: Factors Influencing Two Main Constructs of CTAM

8. Conclusion

The decision making process to purchase and deploy new construction-related technology introduces a variety of factors and functions. Good communication between vendors and interested customers companies as well as between "early "and "late adopters" is one of them. This paper presents the preliminary results of a study on the marketing strategies applied by vendors of various technologies modelled as part of the initial phase of the adoption process. Here, both vendor and potential customers interact and communicate with each other to find the best solution for the customer. In fact, the paper offers the Construction Technology Adoption Model (CTAM) where vendor and potential adopter pass through three stages: "Solution Finding, Decision Making, and Implementation".

The work focused on assessing the difference of how vendors attract visitors to an exhibition on mining and construction equipment. It was quickly found that several key features cluster the vendor companies: 1) stand design, 2) use of electronic communication media, 3) paper based information, 4) brand advertising, and 5) integrated marketing levels. A factor analysis classified nineteen variables such as Media Type (MDA) and Vendors Exhibit Area (EXA) in three main factors called "Dissemination, Maturity, Services and Relationship."

Heavy equipment vendors such as Caterpillar, Toshiba and Hyundai use a wide range of (expensive) marketing activities. For example, they use attractive booths overseen by professionals and staffed by welcoming marketing staff ready to take interested visitors into a special meeting room. They prefer face-to-face exposure, advanced audio-visual programmes, hands-on activities, food, live performance and live entertainment.

As the solution finding phase is completed, future work will focus on validating the model concerning Decision Making, and Implementation. This work will investigate the decision making process and procedures followed by companies related to the construction industry.

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Delphi Study for Improving Sustainable Construction Project Management in Universities

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Abstract

As sustainability becomes an important principle guiding various human activities around the globe, the higher education sector is being asked to take an active part in educating and promoting sustainability due to its moral responsibility, social obligation and its own needs to adapt to new circumstances. There is a global trend of higher education institutions embarking on responses to the sustainability challenge. On-campus building performance is one of the most important indicators for "sustainable universities", because buildings carry substantially environmental burden such as considerable consumption of raw materials and energy as well as huge amount of waste generation and greenhouse gas emission. Plus, much research proves that building performance can impact on students and staff's awareness about and behaviours related to sustainability.

The past studies rarely discussed about sustainable construction projects in universities' unique context. Universities are labelled with distinct characteristics such as complex governance, multiple cultures and juggling missions and so on. It is necessary and meaningful to examine the project management system in terms of universities' organizational environment. Thus, this research project applies Delphi study to identify primary barriers to green technology application in on-campus buildings, critical factors for sustainable project success, key actions in project phases and strategies for project improvement. Through three rounds of questionnaires among panel experts, the authors obtain a profound understanding of project delivery system in universities. The research results are expected to provide sustainability practitioners with holistic understanding and generic information about sustainable construction project performance on campus as an assistance tool.

Keywords: sustainability, high education, on-campus building, project management, Delphi study

1. Introduction

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Sustainability, acknowledged as the heated topic over decades, provides universities an opportunity to confront their core values, their practices, their entrenched pedagogies, the way they program for students' learning, the way they think about resources and allocate these resources and their relationship with the broader community (Wals & Jickling, 2002). Universities have the greatest capacity to define, analyse and examine sustainability issues while taking a leadership role in developing creative ways to respond to them (Newman & Abrams, 2005). In the modern society universities are able to better catalyse the necessary transition to a sustainable world because they have access to the leaders of tomorrow and the leaders of today so that what they do matters to the wider public (Orr, 1992).

The conversation of sustainability in the institutes of higher education has evolved from statements and declarations to implementation of sustainable practices in colleges and universities. Solely relying on lectures, discussions and experiments are inadequate to change students' attitudes or awareness about sustainability even though these methods can increase students' knowledge about the environment to an extent (Tung et al., 2002). Higgs and MacMillan (2006) stated that sustainable facilities and operations promote sustainability education by modelling sustainable practices, and providing hands-on opportunities to try sustainable practices, increasing students' ownership and stewardship of their environment. The most visible sustainability initiative is growing interest in green buildings, where facility construction and renovation seeks to match some definitions of sustainable practices (Kovac, 2009). Green buildings have accumulated significant motivation for universities because of environmental benefits, cost savings (Wilson, 2005), improvement in students' test scores (Pelletier, 2006), reduction in staff turnover (Kats, 2006), and increasing student health and attendance rates (USGBC, 2008).

Few studies reveal details about sustainable project delivery of green buildings in universities. The inadequacy of deep and specific discussion about construction projects on campus has a negative impact on actual project performance. In order to rectify this problem, it is necessary to investigate project management process in universities to equip practitioners with action plans and optimal strategies. This research expects to obtain a full understanding of project management system in universities. By means of exploring barriers to sustainable construction project, critical factors for project success and key actions in project stages, the author finally identifies a set of strategies for project improvement. The research findings will be used as a guidance manual for universities to remedy their project delivery process to achieve the target of "green building" on campus.

2. Literature Review

2.1 Sustainability in Higher Education

Sustainability has been recognized and gaining popularity over the past few decades due to the challenge of environmental degradation, economic recession and social disparity. As a guiding paradigm to instruct the human being's activities in every field, the mostly quoted definition of sustainability is "development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs" (WCED, 1987). The Chapter 36 of Agenda 21 clearly pointed it out that "education is critical for

promoting sustainable development and improving the capacity of people to address environment and development issues, and it is also critical for achieving environmental and ethical awareness, values and attitudes, skills and behaviour consistent with sustainable development and for effective public participation in decision-making" (Agenda 21, 1992). The United Nations proclaimed the decade from 2005 to 2014 as "Decade of Education for Sustainable Development" (DESD) to emphasize that education is an indispensable element for achieving sustainable development (United Nations, 2002).

Universities are placed in the best position to provide the most significant educational resources about environmental sustainability (Creighton & Rappaport, 2007). Both in the classroom and by the example of its physical plant, a university can give students an understanding of the interrelationship between making decisions and the natural environment, and thereby model their behaviours and attitudes that encourage environmental responsibility (Creighton, 1998). With the historical tradition of universities, they have responsibility for analysing and challenging ideas and conventions, conducting research, developing new technologies and educating future leaders and citizens (Bakker, 1998). Universities represent one the most powerful tools when approaching sustainable development, due to the academic freedom, diversity of skills and knowledge for developing new ideas, ability to comment on society and its challenges, and engagement in experimentation regarding sustainable living (Cortese, 2003). Therefore, universities are being asked to become leaders and role models in the adoption and communication of sustainable practices (Mcnamara, 2008).

2.2 Green Campus and Building Performance

The four main areas of greening universities are grouped into categories of research, education, campus operations and external community (Cortese, 2003). Of the four areas of practice with respect to delivering sustainability in universities, building a green campus is always top on universities' sustainability agenda and seems to gain the most attention. A sustainable university should have a healthy campus environment, with a prosperous economy through energy and resource conservation, waste reduction and an efficient environment management, and promotes equity and social justice in its affairs and export these values at community, national and global levels (Habib & Ismaila, 2007). Universities campuses are the place where various activities happen every day and connected with green initiatives to impact on the community and society fundamentally. The connection between the educational mission and social role of the university, particularly related to the physical environment, has been used as a rationale for campus greening (Bakker, 1998). The campus environment is a growing concern as it doesn't just affect how students live but also what they learn and how they will change workplaces and neighbourhoods as graduates (Kinzie, 2008).

The ways implementing green initiatives in campus environment vary from one university to another. Among these initiatives, the green building is gaining momentum and universities and colleges globally are nowadays using it to promote campus sustainability. The document titled Blueprint for a Green Campus in 1995, pointed it out that one of requirements for sustainable universities is that to make environmental sustainability a top priority in campus

land-use; transportation, and building planning. The Australian Tertiary Education Facilities Management Association (TEFMA) published an annual benchmark report on environmentally sustainable development which highlighted then enhancement of ecological values and construction projects incorporating principles of “green buildings”. Buildings in the education sector have the potential to offer highly productive, green environments that utilize converged and integrated technology to deliver high quality learning experience for students (Everett, 2008). A research used to prove that green building initiative was enacted with the hope of influencing people’s perceptions about sustainable technologies in buildings and homes and also revealed how behaviour was impacted by sustainability initiatives: specially, how the project influenced student and faculty’s attitudes, information levels and behaviours (Owens & Halfacre-Hitchcock, 2006).

2.3 Campus Facility Implementation and Management

In universities, facility departments directly manage the planning for, construction or leasing of, operations and maintenance of, and disposal of the physical assets of the institution (Adams, 2010). Facilities management units in universities are responsible for the stewardship of all physical assets owned by the institution (Ancarani & Capaldo, 2005). The overarching concept of sustainable development helped develop the concept of sustainable facility management (Shah, 2007). Facility management is on the agenda for change to develop practical sustainability goals (Elmualim et al., 2008). Although the FM profession has been evolving towards sustainability goals, it is not easy at present to make this reality (Elmualim et al., 2009). As a result, there is an urgent need to do research in sustainability issues within FM, and develop tools to enable and facilitate sustainability (Elmualim et al., 2008). In order to meet the challenge of applying sustainability criteria to facility management, there is a need of change management approach to the relationships evolving organizations, employees and facilities (Grimshaw, 1999).

3. Research Method

3.1 Justification for Delphi study

The Delphi technique is a widely used and accepted method for gathering data from respondents. Without physically meeting, Delphi study is a systematic, interactive method which relies on a panel of experts to answer questionnaires in two or more rounds, finally to converge towards the “consensus”. Using the Delphi technique, a reliable expert consensus can be obtained because the technique relies on anonymity, controlled feedback, and statistical group response and is thus structured to avoid the influence of dominant individuals on group discussion or group pressure for conformity (Fischer, 1978).

One major advantage of Delphi study is that it can provide in-depth information about the complex problem or issue under consideration (Kalian, 2012). Plus, Delphi study is very suitable for situations when no or limited historical data is available (Gupta & Clarke, 1996). In this case, the research is relatively new in terms of inspecting project management system in universities’ unique organizational context. Delphi study employs group decision-making techniques which carry greater validity than those made by an individual (Brooks,

1979). Among other group discussion methods, the Delphi technique is beneficial because the characteristic of avoiding physically bringing experts together can save travelling cost. This group communication method also avoids the pitfalls of face-to-face interaction such as group conflict and individual dominance (Gupta & Clarke, 1996). The whole anonymous and confidential process with controlled feedbacks enhances the validity of consensus-based findings from experts. Above all, Delphi study is desirable for this research for the purpose of obtaining huge amount of objective information on a new topic.

3.2 Sample Criteria

Contrary to a traditional survey, which would use a random sample to estimate the views held by separate individuals in a target population, the Delphi method uses interactions by a panel with relevant expertise to arrive at a consensus, because the validity of a Delphi study depends not on the number of participants polled, but rather on the expertise of the panel who participate (Armstrong, 1985). The Delphi participants should meet four "expertise" requirements: (1) knowledge and experience with the issues under investigation; (2) capacity and willingness to participate; (3) sufficient time to participate in the Delphi; and (4) effective communication skills (Adler & Ziglio, 1996). In this study, experts are required to have deep understanding of sustainable project management in universities.

With reference to the potential participants' academic qualification, professional expertise and working experience, 29 potential experts were targeted and invited to participate in the Delphi study. Sixteen of these expressed their interest and agreed to participate – a total of 55.2% participation rate. Ludwig (1997) addressed that "the majority of Delphi studies have used between 15 and 20 respondents". The participants were senior practitioners in the area of sustainable activities at universities. They were comprised of Deputy Vice Chancellors, professors, president and regional directors of a leading organisation dealing with sustainability in Australian universities, consultants from government, directors or managers in various departments dealing with sustainable projects. This laid a solid foundation for the validity and reliability of the Delphi data. The various constitution of this panel structure (e.g. academics, practitioners, policy makers, consultants) enables the Delphi study to obtain different perspectives as well. In addition, the panel members have international backgrounds, 3 of whom are from U.K. and 2 from New Zealand. This helps the researcher to have reference to other commonwealth countries' experiences.

Table 1: Profiles of panel members

Participant	Position	Organisation	Professional Area
H1	Professor	University	Research on sustainability and innovation
H2	Deputy Vice Chancellor	University	Leadership
H3	President of a leading organisation	Peak Association	Sustainability in higher education
H4	Vice President of a leading organisation	Peak Association	Sustainability in higher education
H5	Vice President of a leading organisation	Peak Association	Sustainability in higher education
H6	Member of a leading organisation	Peek Association	Sustainability in higher education

Participant	Position	Organisation	Professional Area
H7	Associate Head of school	University	Teaching and research, leadership
H8	Government Consultant	Government	Sustainability policy
H9	Member of Green Roof organisation	University	Green Roof design and engineering
H10	Sustainability consultant in state government	Government	Sustainability consultancy
H11	Deputy Vice Chancellor	University	Leadership
H12	Principal Policy Advisor	University	Policy advice
H13	Executive Director Sustainability	University	Sustainable project management and environmental planning
H14	Executive Director, Finance and Resource Planning	University	Financial management
H15	Associate Director of Operations, Facilities Management	University	Engineering and Maintenance
H16	President of Green Roof organisation	Peak Association	Green Roof and Living Wall's design and consultation

3.3 Process and Data Collection

The three rounds of Delphi surveys were conducted during the period from March to June 2012. These questionnaires will be distributed by email to participants. All the participants will be asked to rate the factors on a Likert-type scale to establish preliminary priorities among the items (Hsu & Sandford, 2007) for both desirability and feasibility. Ratings scale from 1 to 7, with 1 being "disagree" or "insignificant" and 7 being "agree" or "significant". The result of first-round questionnaire will be reviewed by the researcher to design the second questionnaire and summarise items based on the investigation. In Round 2, each Delphi panel member will receive the second questionnaire with summarised items. They will be asked to revise their ratings or specify the reason why he or she wants to remain the same rating. In this round, consensus begins forming and the actual outcomes can be presented among the participants' responses (Jacobs, 1996), as shifts in rating items are allowed. Round 3 is the same process repeating previous rounds.

3.4 Data Analysis and Results

In the Delphi process, qualitative and quantitative analysis can be both involved. Open-ended questions used in the first round to solicit panel members' opinions were analysed in a qualitative way, while the quantitative data was calculated using descriptive statistics, as the detailed description below.

Qualitative data was analysed by content analysis (Burnard, 1991) which involves coding, categorising and theming. In the meanwhile, One of the prominent characteristics of a Delphi study is being able to use statistical analysis which ensures the opinions generated by each panel member are well presented and reduces the potential of group pressure for conformity (Dalkey, 1972), because statistical analysis allows for an objective and impartial analysis.

The major statistics used in the Delphi questionnaire are measures of central tendency (mean, median and mode) and level of dispersion (standard deviation and inter-quartile range) (Hasson et al., 2000). The mean value is the arithmetic average of a set of values which points to the central location of the data; the median is described as the numerical value separating the higher half of a sample from the lower half; and the mode is the value

that occurs most frequently in a dataset (median, 2012). Based on Likert-type scales, the use of the median value is strongly favoured (Hill & Fowles, 1975). The median can inherently reflect the resultant convergence of opinion given that the anticipated consensus of opinion and the skewed expectation of responses are compiled (Jacobs, 1996).

Although the uses of median and mode are favoured generally, the mean is also workable in some cases (Murray & Jarman, 1987). In this study, mean and median were chosen to present the rating factors to the panel members. Standard deviation and Interquatile Range (IQR) were also computed as they are closely linked with mean and median to demonstrate the trend towards group consensus. Standard deviation measures the spread of a dataset. The larger the standard deviation is, the more spread the various data is. The IQR is made robust through comparing the difference between the upper and the lower quartiles. 25% of the measurements are less than the lower quartile and 75% of the measurements are less than upper quartile. Upper quartile minus lower quartile equals the inter-quartile range, with smaller values indicating higher degrees of consensus. According to Linstone and Turoff (2002), an IQR of 1.00 or less can be considered to reach a good consensus on a seven-point Likert scale. An IQR≤1 means that more than 50% of all opinions falls within one point on the scale. In order to achieve a statistically rigorous consensus, this research also looked at the degree of consensus. Accordingly, Kendall's coefficient of concordance (W) was applied to measure the agreement in the ratings. A strong consensus exists for W >=0.7; moderate consensus for W=0.5; and weak consensus for W<0.3 (Schmidt, 1997). The tables below list the final results of Delphi study after three rounds: all items of which IQR <= 1.

Table 2: Rating of barriers to sustainable construction projects in universities

Barriers to Sustainable Project Delivery in Universities					
NO.	Barrier	Average Score	Standard Deviation	Median	Interquatile Range
1	Lack of commitment to sustainability from top management	6.23	0.832	6.00	1
2	Funding and cost	5.77	0.927	6.00	1
3	Split budgets between capital and maintenance	5.69	1.032	6.00	1
4	Lack of human resources in sustainability profession and expertise	5.54	1.127	6.00	1
4	Bureaucratic barriers inertia from academic staff	5.54	0.877	5.00	1
6	A challenge of fitting new untried technology into current capital work program	5.46	1.127	6.00	1.5
7	Ownership and control of various components of infrastructure	5.38	0.870	5.00	1
8	Complexity of organisational environment (e.g. large size, frequent turnover)	5.15	0.987	5.00	2
9	Difficulties in communicating with key stakeholders	5.00	0.817	5.00	0.5
9	Lack of well established cooperation between academic staff and project team	5.00	0.817	5.00	2
9	Exiting gaps between different management levels	5.00	0.913	5.00	1.5
12	Lack of client demand	4.92	0.760	5.00	1.5
12	Lack of understanding about priorities and directions and universities don't have to regard for councils' development control plans	4.92	1.320	5.00	2.5
14	State wide planning controls/ regulations don't require sustainability to be addressed	4.77	1.301	5.00	2.5

15	Lack of assessment framework specific to universities' context	4.62	1.198	4.00	2
16	Ever-changing management system	4.54	0.877	4.00	1

"Lack of commitment to sustainability from top management" is ranked in the first place with a high rating of 6.23, which is closely followed by "funding and finance". The items of "split budgets between capital and maintenance" and "lack of human resources in sustainability profession and expertise" are rank the third and fourth significant barriers respectively. The average rating of all barriers is relatively high, all above 4.5. Overall, consensus is obtained on 8 items (IQR ≤ 1) resulting in an agreement rate of 50 %. In this section, the Kendall's W is 0.335, which belongs to weak-to-moderate range. It is also discovered that most barriers to sustainable project delivery are fundamentally related with organisational issues such as bureaucracy, poor communication and authority gaps.

Table 3: Rating of critical factors for sustainable construction project success

Critical Factors for Sustainable Project Success					
NO.	Factor	Average Score	Standard Deviation	Median	Interquatile Range
1	Top management commitment/support to project	6.69	0.480	6.00	1
2	Clear objective and scope	6.38	0.650	6.00	1
3	Clear project performance criteria regarding sustainability	6.30	0.855	6.00	1
4	Integrated-sustainability planning and design	6.15	0.555	6.00	0.5
4	Project's integration with teaching and research	6.15	1.144	6.00	1
6	Availability of resources (financial, human and technical)	6.08	0.641	6.00	0.5
7	Effective communication/information sharing channels	5.92	0.862	6.00	1
7	Post-occupancy evaluation	5. 92	1.038	6.00	1.5
9	Key stakeholders' participation	5.85	0.555	6.00	0
10	Multidisciplinary/competent project team	5.77	0.439	6.00	0.5
10	Risk management	5.77	0.725	6.00	1
12	Comprehensive contract documentation	5.69	0.751	6.00	1
13	Accurate cost-effectiveness analysis	5.69	0.855	6.00	1
14	Proof and clarity of innovative concepts	5.54	0.519	6.00	1
14	Allocation of these deliverables/accountabilities to individuals	5.54	0.967	6.00	1
16	Absence of bureaucracy	5.46	0.660	5.00	1
16	Cooperation and coordination between academic staff and project team	5.46	1.050	6.00	1
16	Sustainability projects need themselves to be sustainable – e.g. maintenance of green roofs	5.46	1.266	6.00	2
19	Wide community involvement	5.38	0.870	6.00	1
20	Substantial demonstration cases and proper emphasis on past experiences	5.38	0.770	6.00	1
21	Awarding bids to the right designer/contractor	5.15	0.987	5.00	1
22	Up-to-date technology utilization	5.15	0.899	5.00	1
23	Apply to Green Star rating system of GBCA (Green Building Council of Australia)	4.62	1.325	4.00	2.5
24	Run a trial case under controlled condition	4.62	1.044	5.00	1.5
25	Engage environmental/sustainability consultants during all the life cycle	4.38	0.961	4.00	1

Most factors (22 out of 25) are rated high (5 and above). Among them, 6 factors are above 6 representing the “significant” opinion, which are the same items from Round 2. Plus the ranking of these six most significant factors doesn’t change much except that “seeking for integration with teaching and research” is upgraded from No. 5 to No. 4 which is equal to the ranking of “integrated-sustainability planning and design”. Most of critical factors belong to organisational categories which were commented by interviewees. In relation to the obstacle “lack of commitment from top management”, the most critical factor was identified to be “top management’s commitment”. It can be concluded that the importance of “top management’s commitment” was emphasised throughout the study. Similarly, interviewees often mentioned the insufficient human resource in sustainability team constrains the progress of sustainability implementation in such a large organisation. In response, experts ranked “available resources” the sixth most important factor. The same rule also applies to “absence of bureaucracy” “accurate cost-effectiveness analysis” “corporation between academic staff and operational staff” and “wide community involvement” and so on. A high consensus level is reached in this group. 21 out of 25 items reached an IQR ≤ 1 (percentage is 84%). Responding to the large number of items meeting the criterion of IQR≤ 1, the Kendall’s W is 0.599 which indicates a moderate – to – strong consensus.

Table 4: Rating of Key Actions for Each Stage of Sustainable Construction Project

Key Actions for Each Stage of Project Implementation					
NO.	Action	Average Score	Standard Deviation	Median	Interquatile Deviation
Conceptual Stage					
1	Obtain vision and commitment from the top management	6.67	0.779	7.00	0
2	Set clear and well understood goals and metrics	6.58	0.793	7.00	1
3	Clarify budget	6.33	0.651	6.00	1
4	Identify number and range of idea and stakeholders	6.31	0.855	6.00	1
5	Consult sustainability professionals and experts, integrate sustainability with conceptual planning	5.58	0.996	6.00	1
Planning and Design Stage					
1	Consult sustainability professionals and experts, integrate sustainability issues with planning and design	5.92	0.996	6.00	1
2	Thorough analysis and simulation of different alternatives	5.75	0.866	6.00	1
3	Ensure resources are commensurate	5.67	0.651	6.00	1
4	Clarify time framework and cost	5.50	0.905	6.00	1
5	Monitor planning and design, open discussions and get input	5.67	0.985	6.00	1
6	Low impact score for environmental and social factors	5.58	0.793	6.00	1
Pre-tending Stage					
1	Verification of the design solutions against target	6.17	0.937	6.00	1
1	Specify clear deliverables, cost and budget in detailed proposals	6.17	0.835	6.00	0.75
1	Monitor implementation, consider ongoing operational issues	6.17	0.718	6.00	1

4	Identify contractors which have sustainability credentials with track record of delivering sustainable projects	5.67	0.888	6.00	1
4	Consult sustainability professionals and experts	5.58	0.996	6.00	1
6	Have Expression of Interest to assess the companies that are available to build the project	5.50	0.905	6.00	1
	Contracting Stage				
1	Including clear requirements and metrics into contracts	6.08	0.900	6.00	1
2	Ensure costs are manageable and risks covered	6.08	0.900	6.00	1
3	Bidders have experience in building sustainable development teams	6.00	1.128	6.00	1
4	Understand expectations of contractors	5.58	0.996	6.00	1
	Project Preparing Stage				
1	Ensure sustainability fits with broader use	6.17	0.937	6.50	1
2	Communication with all teams	6.08	0.900	6.00	1
3	Establish communication protocols, reporting lines	5.83	0.835	6.00	0.75
4	Contractor engagement	5.67	0.887	6.00	1
5	Procedures and processes developed and committed to sustainability	5.58	0.900	6.00	1
	Execution and Operation Stage				
1	Monitor and report against plan	6.17	0.835	6.00	1
2	Low environmental and social impact	6.08	0.900	6.00	1
3	Clarity of project performance	6.08	1.084	6.00	1
4	Partnering, extensive stakeholder input	5.42	0.996	6.00	1
5	Procedures and processes being allowed (audit)	5.42	0.996	5.00	1
	Project Close Out Stage				
1	Confirm sustainability objectives met	6.50	0.905	7.00	1
2	Conduct “lesson learnt” session, monitor and report project process against sustainability plan	6.08	1.084	6.00	1
3	Monitor implementation	6.00	1.279	6.00	1
3	Review what went well and what did not. Reflect what would be done differently	6.00	1.279	6.00	1
5	Certification of key deliverables provided to required standard	5.92	0.996	6.00	0.75
6	Optimum operational instructions clear to user	5.75	0.866	6.00	1
7	Verification of the systems against requirements, continuous project commissioning documentation	5.67	0.985	6.00	1
	Maintenance Stage				
1	Compile post-construction review against sustainability targets	6.42	0.996	7.00	1
2	Continuous comparison of the real behaviour of the building against the targets	6.33	0.779	6.50	1
3	Serviceability and access to skills	5.58	0.996	6.00	1

In terms of rating result of key actions in project delivery, the action indicators in each stage are rated very high above 5. All the action indicators in each stage were rated very high (above 5). There was a huge increase in the number of items reaching consensus. Overall, the consensus was obtained on 41 items of IQR ≤ 1 (the total number of rating items was 58), representing an agreement rate of 70.7%. However, there were differences of consensus achievement between the different phases of project implementation. For example, all the key actions in the “conceptual stage” and “pre-tendering” stage obtained IQR ≤ 1. In contrast, only three key actions in the “maintenance stage” met this standard. For the whole section, the Kendall W is 0.490 which suggested that the degree of consensus for “key actions in each phase of project delivery” was close to moderately strong.

Overall, the consensus level of the whole rating items didn't reach very high. This result echoes the finding from existing literature that it is very difficult to obtain agreement on general issues about "sustainability in universities" due to the complexity of universities and breadth of debates. The discovery from the Delphi study provided a solid proof that the effectiveness of sustainable project implementation is grounded on a desirable organisational environment. The barriers to sustainable construction projects in universities as well as the critical factors for project success highlighted the organisational issues such as leadership, structural inertia and communication more than once. The panel experts also achieved consensus on key performance indicators for each stage of sustainable construction projects' delivery, which specifically take universities' unique characteristics into account. For example, the coordination between academia and project team should be specifically considered when endeavouring to deliver sustainable construction projects.

4. Conclusion

Realising their social responsibility, universities are assuming a lead role in creating a sustainable future for our societies. However, their commitments to date seem confined with research and development. Opportunities to showcase the potential and achievements have not been sufficiently explored, especially in the development and utilisation of built environment on campuses, which are often regarded as microcosms yet influential part of the society. Green building, as a significant indicator for "sustainable university", has been gaining universities' interests. The lack of in-depth understanding of sustainable construction delivery in universities drives the researcher to investigate project management system on campus. The three-round Delphi surveys help to identify 8 main barriers to sustainable construction project and 22 critical factors for project success. The findings reflect that organizational issues are the most significant impediment to sustainable construction project, such as lack of top management's commitments and solid support, funding models, bureaucracy and so on. In response, the critical factors for success address the organizational remedies combined with management improvement. In addition, the key actions identified in each stage of sustainable construction project process in universities offer project team a clear guidance. The synthesized strategies for project improvement are concluded as well. The research findings expect to provide sustainability facilitators in universities with holistic information about sustainable project management process in universities.

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Issues of breadth and depth in Facilities Management - Reflections of 30 years of educational development

Danny Shiem-Shin Then[1]

Abstract

Facilities Management (FM) has been around for almost three decades. As a profession, FM is now recognized in all six continents with recent movements of international collaborations between national institutions in Europe, North America, Asia and Australia. This paper will trace the development of FM and critically examine issues relating to the breadth and depth of FM from an educational perspective against the backdrop of a dynamic business environment and changing corporate demands for facilities provision and facilities services. The paper advocates that education in FM must balance theory with practice with emphasis on identification of context and culture, hard and soft skills, procurement and administrative processes, appropriate application of tools, and increasingly in a regional and global scale. In particular, issues relating to the role of FM, scope of functions, strategic and operational support to business units have been considered, with a view of justifying the contributing role of this rapidly growing profession. A focus of the paper is to provide a framework for postgraduate education and training in Facilities Management. The framework has been evolved out of the author's experience as program leader in developing and teaching postgraduate FM courses in three universities in three countries – i.e. United Kingdom, Australia and Hong Kong.

Keywords: facilities management, educational development, trend.

1. Why FM is needed in a dynamic business environment

In a recent white paper by i-FM (www.i-fm.net UK, 2012) "*Facilities Management – New needs. New solutions?* it is stated that "…Facilities Management is an essential management discipline, and a multi-billion pound business sector employing hundreds of thousands of people. ……" This is generally true for most countries; the differences are perhaps in the perception of facilities management (FM) as a distinct economic activity or an industry sector. There is also a consensus that while FM are tactical in its day-to-day operations, it is nevertheless closely related to, and should be involved in the corporate strategic planning and decision-making processes in both private and public sector organizations. There is greater corporate management acknowledgement that in realizing an organization's business objectives, the provision of facilities and support services is an integral part of strategic business planning. The recent global financial crisis have brought home to many organizations, the need to seriously consider the facilities dimensions of

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business planning – a resource which commonly constitutes 20-40% of total corporate asset value and consumes 10-15% of corporate expenses. The unique characteristics of facilities assets in terms of modes of ownership, functional adequacies, essential support services and long-term asset care demand management competencies that are often underestimated by corporate managers.(Apgar 2009) More recently, the growing awareness of impact of climate change has added the agenda of sustainability and corporate social responsibility on shoulders of facilities managers.

Over the last two decades, the discipline of facilities management and the FM industry that had developed to support it have both grown in complexity and maturity in response to the ever-shifting social, economic and technological trends. As the nature of work itself changes, so does the design and operation of the workplace, as do the drivers behind an organization's facilities strategy in relation to facilities design, provision and on-going management. The impact of globalization and the growing trend towards outsourcing of non-core functions, have also led to the transformation of client-service provider relationships within large multi-national corporations which are promulgating long-term, bundled or total FM contracts on a national or regional basis.

1.1 Key trends and influences and their impact on FM practice

FM delivers critical business services that underpin the day-to-day operations of major and minor operations within any economies. A scan of learned papers in facilities management journals over the last two decades will reveal that the general development of FM thinking has evolved over four distinct phases (Jensen , et al. 2012):

1. FM merely considered as an overhead to be managed for minimum cost rather than optimum value.
2. FM as in integrated continuous process in relation to the organization's core business.
3. FM as resource management concentrating on managing supply chain issues associated with the FM functions.
4. FM as strategic management to ensure alignment between organizational structure, work processes and the enabling physical environment according to the organization's strategic intent.

A key theme across the four phases of change is a shift from pre-occupation with tactical concerns to addressing strategic concerns as illustrated in Figure 1. (Then 1998)

Key factors that drive the changing focus in facilities management include:

- Dynamics of business environment – need to cater for the speed of change.
- Demand for flexibility – need to incorporate built-in exit strategies in facilities provision.
- Demand for global connectivity – impact of technology and communication network on nature of work and business delivery
- Changes in work and workplaces – need to cater for employees' diversity and mobility.

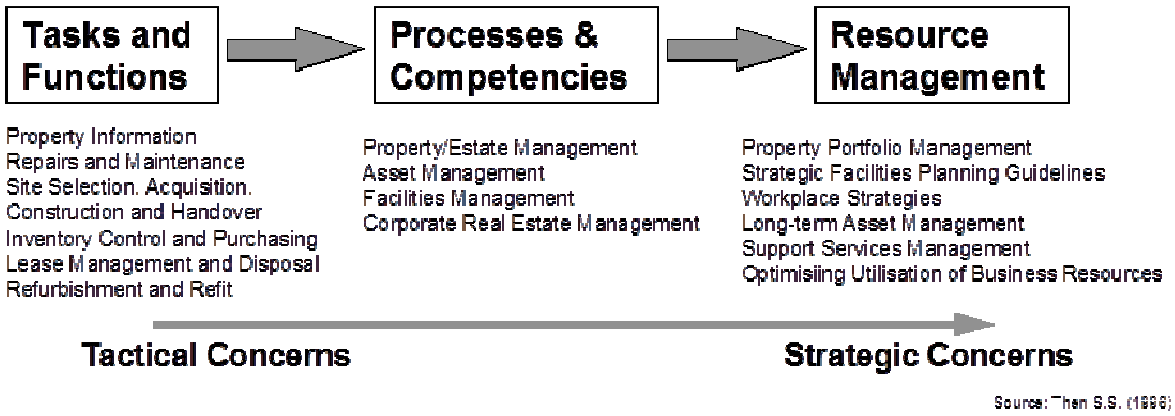

Figure 1: Changing focus in Facilities Management

It can be surmised from the above that the role definition of facilities managers is predicated on change which necessitates abilities to respond to organizational change, to predict and manage facilities changes and changing service delivery models. Facilities managers should regard this as an opportunity to promote themselves as a catalyst of change within their organization as any change in the corporate strategic business direction are likely to impact on some facilities dimensions of facilities management.

1.2 Review of FM Practice in Corporate Organisations

Facilities management is now a recognized component of the business delivery supply chain but its mantra has been associated with 'reduced costs' and 'improved efficiency'. This tired proposition is in danger of becoming irrelevant since cutting cost and process efficiency are a means to an end, and not the end itself. The massive economic and societal changes the world is currently experiencing require a more fundamental rethink of how the provision and management of real estate and facilities services can add value to businesses by taking a more strategic view of organizations' operational needs.

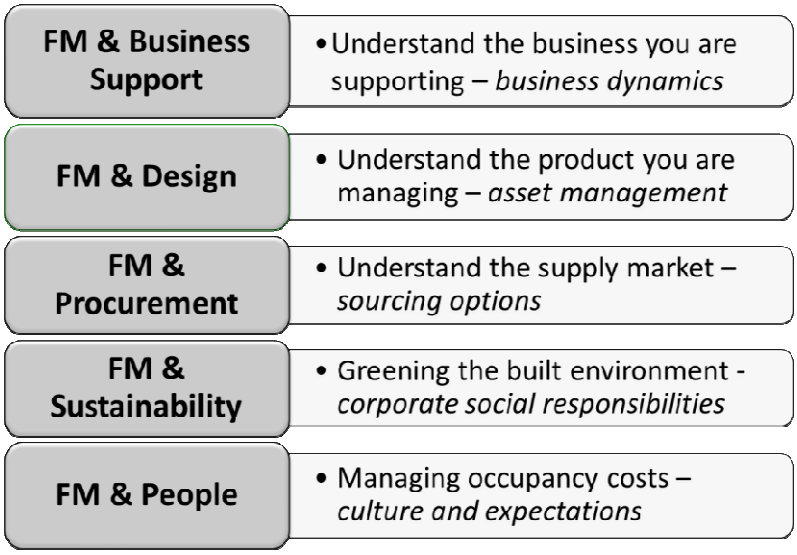

Figure 2: What businesses expect from Facilities Management? (Then 2012)

The above 4-phase change in FM development described in the last section clearly reflects a change from the initial dominating focus on cost reduction towards stronger strategic focus on actively supporting the core business. However, such a shift in focus and approach must be accompanied by a conscious attempt to understand the various facets of facilities management and their demands, as illustrated in Figure 2.

Ultimately, the justification for FM professionalism to corporate management demands a proactive integrated management system with ability to:

- Provide strategic facilities options and advice to corporate business planners.
- Demonstrate to corporate senior managers that facilities managers possess the ability and competences to provide facilities solutions to business challenges by leveraging facilities resources and services at a strategic level.
- Demonstrate the contributions of real estate and facilities services interventions to human resources productivity, business profitability and competitive advantage, through innovative facilities solutions – whether they be sustainable design and operations, branding, portfolio rationalization, high performance facilities, continuous improvements through technology, innovative procurement, etc.

2. Educational provision in Facilities Management

This paper represents an overview of my involvement in facilities management as an academic in three universities: Heriot-Watt University in Edinburgh; Queensland University of Technology in Brisbane and the last decade at Hong Kong Polytechnic University. As an academic offering high level education to practicing professionals from various disciplines, a primary challenge is to provide a credible knowledge framework from which the content of the program remains relevant and attractive to potential students. In this respect, I am constantly challenged to keep up-to-date on the latest pressures from the realities of economic and social shifts in an increasingly competitive, globalized and networked world. The aim has always been to develop a framework for postgraduate education in FM that is relevant, logical and credible. In this respect, I was particularly conscious of a comment by Adrain Leaman in an article in *Facilities* in 1992, which I shall quote:

> "..At present, the agenda of facilities courses sometimes appears as unco-ordinated or illogically-formed lists, with no one quite knowing what to put in or what to leave out and with items sometimes included on the basis of staff availability or enthusiasms rather than on a clear idea of overall course structure…" (Leaman, 1992, p.20).

Formal university courses in FM (including variants of it) at certificate, undergraduate and postgraduate levels are now available in many countries in North and South America, UK, Western and Eastern Europe, Scandinavia, Asia and Africa. A scan of course content of existing programs in the internet confirmed a wide mix of subject topics. It would be fair to say that Leaman's statement still holds true for some programs. A critical examination of the breadth and depth of FM may provide a basis for differentiating different product offerings.

2.1 Issues of breadth and depth in defining Facilities Management

Professional institutions' definitions of FM tend to focus only on competencies – with an emphasis on getting the job done. Educational development in FM, on the other hand, focuses on personal development and extending knowledge acquisition. For the continuous development of facilities managers, both knowledge (theory) and competencies (practice) are essential.

Given the potential scope of functions/services that could be included under the umbrella of facilities management, in practical terms, the unit of analysis has to be the business entity per se – i.e. it is the nature of business and the structure of business organization which provide the context within which the FM role has to operate. In an organizational context, 'breadth' can be taken to be synonymous with the scope of FM services needed to support the core business deliverables and how they are procured and managed. In terms of 'depth' this is a reflection of how the FM role is perceived at corporate management level and actually reflected in organizational positioning, in level of resourcing and in value adding potential to the core business – i.e. the current FM practice in the business entity.

From an education and training viewpoint, issues of breadth and depth in FM take on a different perspective in that they are a by-product of the program's or course's intent and the target population.

The breadth of FM has been variously described by a range of functions in relation to competences required to get the job done, much in line with the approach taken by FM professional institutions like IFMA, BIFM and FMAA. Similarly, FM has also been described in relation to the range of services needed to support the core business, particularly in decisions relating to procurement and outsourcing strategies. However, In terms of the knowledge areas, decisions relating to FM actions often rely on understanding and application of theories and principles that underpin:

- Economics and finance – e.g. financial control, budgeting, asset life-cycle cost evaluations;
- Human relationships and people management – e.g. working with service provider(s);
- Technology – e.g. its role and impact on work and workplace design, technology as a management tool;
- Physical asset management – asset life-functional, technical and economic, maintenance and component renewals, long-term care.

There are inherent tools and processes for each of the above knowledge areas that must somehow be incorporated in the individual subject content of FM programs.

As depth in FM is embedded in current practice within a business entity, the approach to learning is to assess and understand the context of actual practice. The learning outcomes rely essentially on soft skills in terms of understanding the determining variables (factors) that had influenced the current practice. These factors may be cultural, organizational,

political, internally or externally driven, and can only be abstracted through knowledge in soft skills.

In my opinion, it is the delicate balance in choice that has to be struck between the appropriate breadth and depth in FM that underpins the core of a well-structured course in FM. This has been the governing principle that has guided my program design.

3 A framework for postgraduate education in Facilities Management

It has taken me a greater part of three decades to complete the development what I consider to be a dedicated FM program that is comprehensive in coverage of FM functions that may be found in most business organizational settings. In the three universities that I have had the privilege of serving, I have sought to adopt a path of integrating the activities associated within the realm of FM as part of business resource management, albeit with a biased towards the effective management of the provision, servicing and management of physical assets within business settings, be there private or public sector organisations.

My initial thoughts of FM as a discipline started at Heriot-Watt University when I started my research career in public sector housing maintenance management in the early 1980s when FM first 'arrived' in UK with much confusion as to its role and content. Having spent a year discussing with FM consultants and professionals, I came to the conclusion not to attempt to seek a definitive definition for facilities management, but resolved to chart a course that attempts to map its context within business settings. Over the last 30 years or so, I have continued to explore what I consider to be essential facets of the practice of FM from a strategic management perspective. (Then, 1992, 2003, 2004) The emphasis on 'strategic' is both deliberate and critical, especially for post-degree programs with an emphasis on broadening an individual's knowledge horizon in a managerial role within an organizational setting.

3.1 Key facets of Facilities Management

In the more mature markets like in North America, Western Europe and U.K. the market for facilities management services appears to have developed to cater for three interrelated areas associated with the management of operational property assets. The search for value for money has had one important implication for the whole spectrum of industries selling products and services of all kinds - the need to describe (specify), to measure (performance criteria) and to quantify (price) the outputs (end products). In terms of facilities management, the response for more effective utilisation of operational property assets has been on three main areas: (1) strategic evaluation of the real estate portfolio which has led to the development of strategic facilities planning in many of the larger organisations; (2) space management and post occupancy evaluations which have been driven by the need to maximise utilisation of the workspace but with considerations on the well-being of occupiers; and (3) premises audits and condition assessments which have raised the awareness and need for cost effective long-term asset management. (Then 1994)

The above developments have reinforced my personal view of the scoping of facilities management. There are many definitions of facilities management that have been proposed by professional institutions around the world. Personally, I have found them to be unhelpful from the business point of view, especially from the perspective of corporate management, as their focus tended to be on required competences rather than what corporate management should focus on. From my experience, the core of facilities management can be considered as management relating to three key aspects of corporate facilities - assets, workspace and support services – all three are impacted by technological developments. (Figure 3)

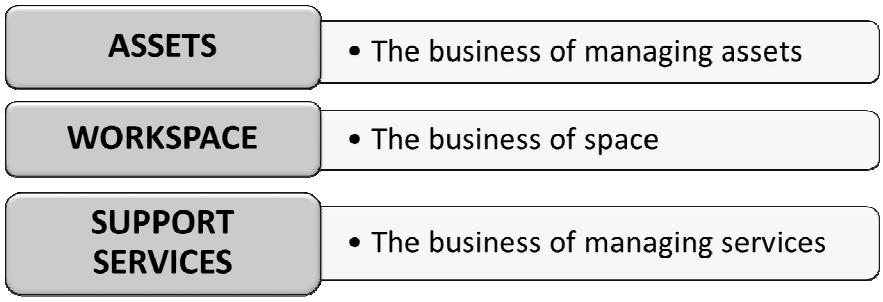

Figure 3: Management Aspects in Facilities Management (Then 2012)

The scoping of facilities management under assets, workspace and support services also conveniently define the distinct sectors of the FM services market that have evolved in the more mature economies. This categorization also defines the specific competencies relevant to facilities asset management, workplace management and service management respectively.

Corresponding to the three facilities management facets, the last two decades have seen major fundamental changes on the demand side and supply side of the facilities management market that has resulted in shifts in the management approach and focus as illustrated in Figure 4.

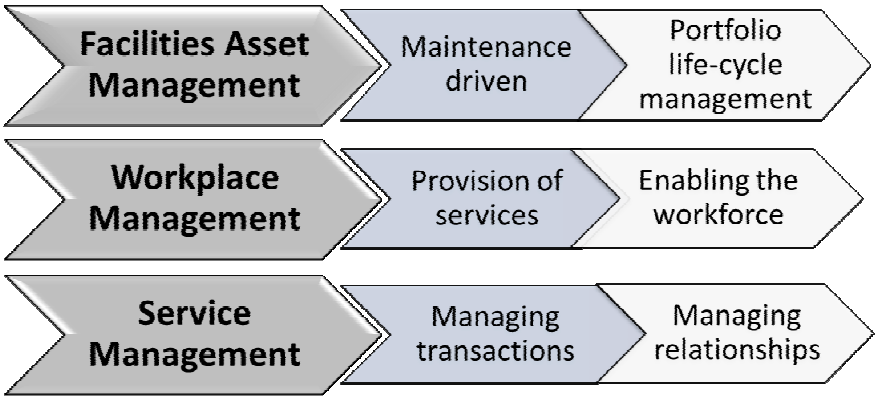

Figure 4: Changing Management Focus (Then 2012)

The adoption of the above scoping necessitates fundamental shifts in the current conceptualization of facilities management in terms of:

- FM beyond transactions – *about people, investments, assets and space.*
- FM beyond buildings – *about effective deployment and utilization of functional space.*
- FM beyond cost – *about alignment of supply to demand, value contribution to core business, affordable and appropriate services, and whole-life asset management.*

3.2 Main components within each facet of FM

In terms of implications on competencies, the four core components of FM become apparent covering strategic, tactical and operational aspects of facilities management activities:

- Strategic Facilities Planning – *responding to business dynamics.*
- Space Planning and Workplace Strategies – *workplace location, workspace design and space utilisation.*
- Asset Management and Maintenance – *asset value, asset care and performance.*
- Facilities Support Services Management – *defining services, procurement and monitoring delivery.*

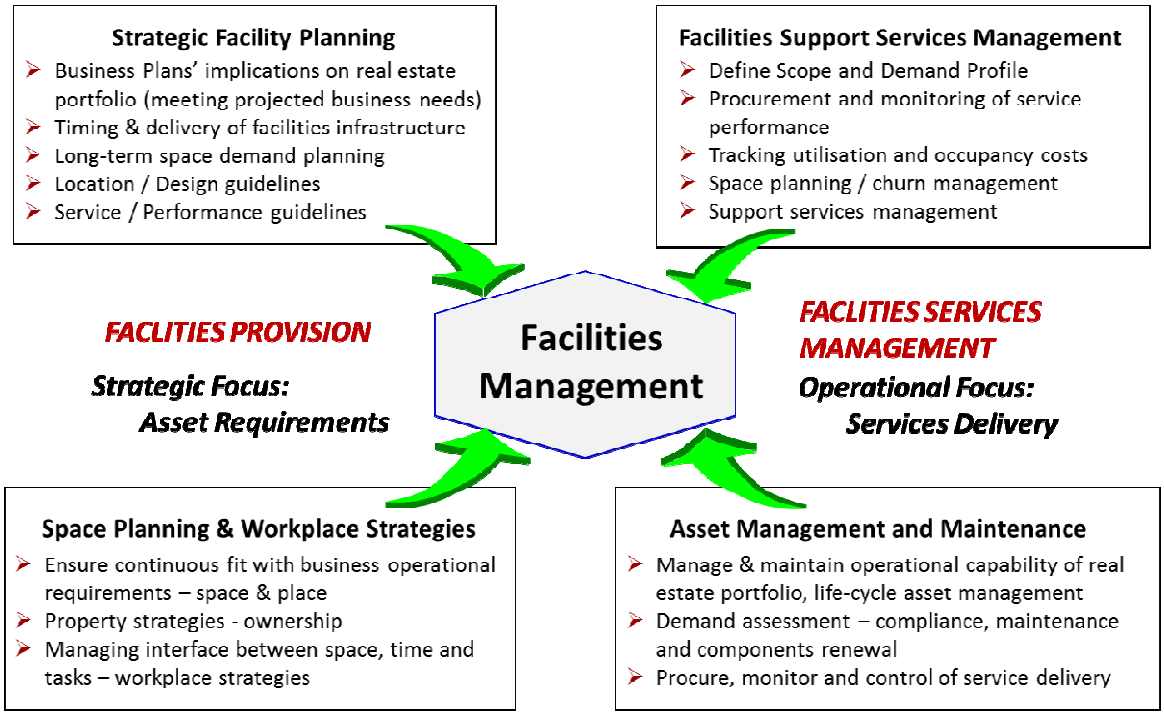

Figure 5: Integrated Facilities Management – Main components (Then, 2004)

The need for an integrated management approach is critical in that the prevailing business strategic direction will drive strategic facilities planning, the outcome being an agreed workplace strategy which in turn feeds into the needs for facilities support services and asset management and maintenance. It is within such an integrated management approach that the need for corporate management to consider their operational assets as a business

resource and integrates facility-related considerations within the strategic business planning processes. Figure 5 proposes a model that sees facilities managers' involvement spanning from facilities provision (strategic components) to facilities services management (operational components). The four components of *Strategic Facilities Planning, Space Planning and Workplace Strategies, Facilities Support Services Management* and *Asset Management and Maintenance*, reflect a broad, but inter-related resources base (people, place, process and technology) that the practice of FM must manage effectively to bring about favourable outcomes to business demands. The inter-relationships of the four components within an integrated management framework are illustrated in Figure 5.

The growing acceptance that an optimum facilities solution must be a by-product of considerations of the business operational needs (for space), the users (people) of the facility in performing their work tasks (process), and the necessary support infrastructure (technology and support services) to carry out their tasks efficiently and effectively; has had the impact of promoting this integrative view of managing business resources. The integrated components of FM in Figure 5 above points to a need to understand the business needs for space (demand) as the driver of facility provision (supply) – the start of the building development cycle. The use of new procurement methods has led to the integration of design-build-operate necessitating a partnership approach between traditional professions and taking a whole-life view of buildings as functional, durable assets.

From the above review, three features of the 'professional core' for FM are apparent:

- A broad framework of competencies for facilities management is identifiable; its coverage spans from facilities provision to facilities services delivery;
- Facilities management is multi-disciplinary embracing a blend of generic management skills with a range of facility-related technical knowledge that are specific to the asset portfolio needed to support the core business; and
- FM education and training must cater for career development from different traditional disciplines and at different entry levels.

3.3 A working model for postgraduate education and training

In my opinion, the theming of a program is critical in differentiating one from other competition in the marketplace. The reality will always be – the customer's choice. My journey to aspire to develop a dedicated FM graduate program started at Heriot-Watt University, Department of Building Engineering and Surveying, in Scotland where I initiated the MSc. in Facilities Management and Asset Maintenance in 1992. In 1997, at the Queensland University of Technology, School of Construction Management and Property, the first Graduate Program in Facilities Management (offering certificate, diploma and masters level qualifications) was jointly developed with the Graduate School of Business. I joined the Department of Building Services Engineering at the Hong Kong Polytechnic University in late 2001 where an existing MSc program in Facility Management already existed. As program leader since 2003, I am fortunate to have the opportunity to guide the development of the MSc program in FM in terms of its subject content, pedagogy and international accreditations. The development of each program's content progressed in

stages as I was fortunate to move from one university to the next which all wanted FM as a discipline.

The current working model of the MSc in Facility Management offered by the Hong Kong Polytechnic University is based on the conceptualization articulated above (3.1 and 3.2). Perhaps, a point of departure in the approach I have taken is to view the requirements of FM from the business perspective, rather than, from a professional viewpoint, whatever the bias may be; i.e. from a surveyor's, engineer's or real estate/facilities manager's viewpoint.

I am also fortunate to have colleagues who share my view of FM and contributed by developing specialist subjects in legal aspects and sustainability. Figure 6 illustrate the subject headings of the current program. The program is currently on its 17th year of self-funded existence with a consistent applicant-intake ratio of 2 to 3 for the last decade. It is perhaps worth mentioning that all the subjects on the program are specifically designed with the FM perspective in mind. In terms of pedagogy, almost all the subjects have a workshop component aimed at applying theory into practice via real-life case scenarios developed with experienced practitioners from the FM industry. The aim of incorporating the workshop (lasting 11 formal scheduled hours) for each subject is to provide a business context, via a case study scenario. Students (working in teams of 4) are required to generate realistic solutions against issues raised in the particular scenario based on knowledge, concepts, processes and tools covered during lectures and prescribed readings. The workshop scenario sessions also provided valuable opportunities in role playing and in considering realities of soft issues relating to organization culture and politics in terms of managing change through facilities-related initiatives and projects. This approach to pedagogy has proven to be effective, with positive feedback from students, who are all working professionals.

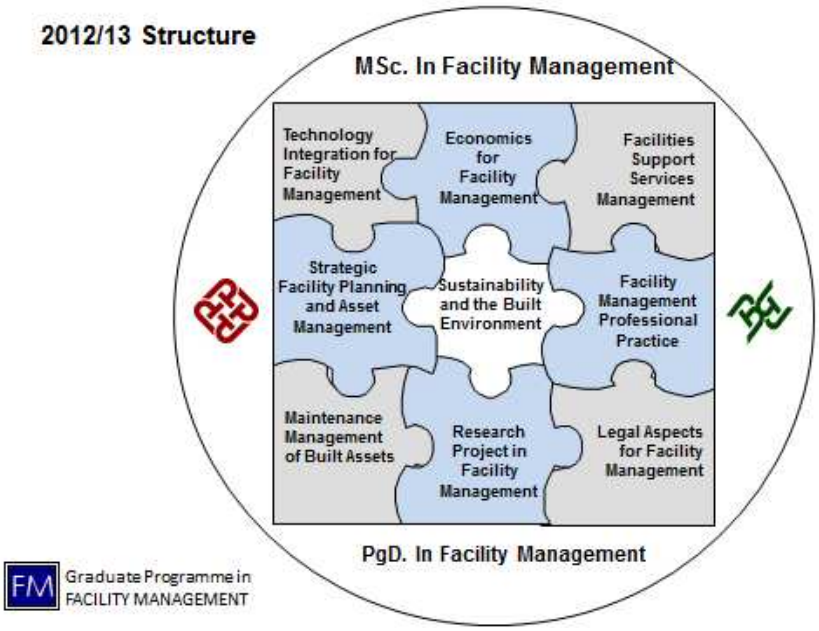

Figure 6: MSc in Facility Management - Course Structure

4 Reflections

As an academic, I have been very fortunate to have been given the opportunities and support in the three universities that I have the privilege of serving. I have the luxury of realizing a postgraduate program that was conceptualized during my doctoral research – even though the fruition of the complete package took a greater part of the last three decades and over three continents.

Over the same period, facilities management, as a recognized profession, has grown in strength, in numbers and in countries around the world. However, its recognition as an academic discipline is still somewhat patchy, due mainly to a perceived lack of its own knowledge base when compared to the more traditional disciplines. Nevertheless, healthy discourse amongst academics have already emerged in recent years that points to possible avenues of research to redress the knowledge or theoretical gap that beset it recognition as a valid discipline. (Jensen, et al 2012; Drion and Melissen 2012; Then 2004a; Price 2001, Wagenberg 1997). On the other hand, there are some practitioners in FM who argue that its lack of a clear definition is a source of FM's strengths rather than weakness.

Personally, I subscribe to the view that there is a growing consensus that acknowledges FM as potentially central to an organisation's core business processes. My view of FM comprising essentially of the management of *assets, workspace and services*, testifies to the potential breadth of FM within an organisational context. Issues of depth are manifested in the practice of FM within an organisation and is a consequent of knowledge, awareness of the potential role of facilities design in changing human behavior and hence, organisational performance. Ultimately, I believe, the pressures to remain competitive, coupled with the need to cope with rapid changes, driven by technological, social, environment and political developments, will drive the need to optimize all business resources, The management of physical assets and the facilities and services within them, being one of the most under-managed business resources, offers ample opportunities to add value to business by being more effectively matched to business requirements. (Apgar 2009, de Valence 2004; Ward and Holtham 2000, Then 1998). I concur with Wagenberg's assertion that 'development of FM theory has to take place in the practical context of FM… Theory proofs itself in the reality of management of facilities.' (Wagenberg 1997; 6).

5 Conclusion

Educational offerings in FM education and training will continue to evolve worldwide, but the nature and content of programs offered in each country will be influenced by the level of maturity of the local FM industry in terms of developments in the demand side by clients' organisations, and supply side by FM service providers, FM professionalism and awareness of the need to better manage the built environment in a more sustainable manner. Given the broad scope of facilities management as a professional practice and field of research, it is hoped that this paper goes some way to provide considerations of potential avenues of specialisation in courses offering by institutes of higher learning in different countries in relation to their respective level of development in facilities management.

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Roadmap enabling ICT to improve energy efficiency in the built environment

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Abstract

Information and Communication Technologies (ICTs) are today pervasive to all industrial sectors which are faced with a sustainability paradox in maintaining economic growth while consuming fewer resources. ICTs have proven central to the performance driven development of modern industry in supporting production systems at all levels. ICTs have a unique opportunity to address the sustainability paradox by enabling Energy Efficient (EE) viable operations. However, often the issue is not a lack of technological options, but rather it is the understanding of what choices will lead to the greatest impact. This paper summarises the outcome of the research work undertaken within REViSITE (Roadmap Enabling Vision and Strategy for ICT-enabled EE), an EU funded project covering migration pathways from the current state of the art to the common vision for ICT-enabled EE. These pathways are based on research and technology development (RTD) topics for short, medium and long term delivery in terms of industrial take-up. The developed multi-disciplinary strategic research agenda (SRA) suggested research priorities in the domain of ICTs for EE, especially considered for the built environment, and its interaction with energy grids, manufacturing and lighting. The corresponding Implementation Action Plan (IAP) is given in the form of recommendations and suggestions for research development and other actions (for policy makers and regulators, RTD funding organisations, industry, education and training institutes) in the domain of ICT for EE. It is also expected that the identified RTD topics will be relevant also to many other sectors which contribute to improving the impact of ICTs on EE.

Keywords: ICT4EE, Energy Efficiency, smart Building

1. Introduction

Energy efficiency is paramount in ensuring the energy security and sustainability of Europe, and Information and Communication Technology (ICT) has a fundamental role to play in

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delivering that energy efficiency (Barroso, 2008; Barroso, 2011; EU commission, 2009). However, while the enabling role of ICT is clear, understanding which technologies are best positioned to deliver meaningful impact and where future research and associated funding should be directed is less clear.

The goal of the research work described here was to develop the REViSITE (Roadmap Enabling Vision and Strategy for ICT-enabled EE), it is a roadmap that identifies common research priorities in the domain of ICT for Energy Efficiency (ICT4EE). The whole project focused on four target sectors—Grids, Manufacturing, Buildings, and Lighting—and sought to develop a generic mean of assessing the impact of ICT across these sectors, however in this paper, a particular view point for the building sector perspective is drawn, discussed and recommendation for implementation are proposed. By leveraging the heuristic and domain expertise of different stakeholders, the project sought to: i) outline a common vision for multidisciplinary, ICT-enabled energy efficiency; ii) identify a strategic research agenda (SRA) focused on critical, cross-sectoral research pathways; and iii) develop the associated implementation action plan (IAP) to address those research trajectories. This was achieved through the involvement and contribution of many stakeholders across the four sectors, drawing on the combined expertise of the Expert Group, the direct contributors to this report and the ICT4EE community at large.

2. Methodology

This section summarises the methodology used in developing such cross-sectoral ICT4EE trajectories for tools and systems that are generic and can serve different industry sectors with no or reasonable adaptation.

2.1 Life Cycle Thinking

Assessment of best practice (Ellis, 2010; VDI Directive 4499, 2008; Stark, 2010) suggests that the capacity to quantitatively assess ICT impact, while desirable, is in practice an arduous task. Situations where an existing system and a replacement ICT-enabled system can be directly measured are not very common. Where this does arise, the task is often complicated by the fact that the replacement system frequently differs from the old in more ways than just the ICT element. For this reason, it can be difficult to apportion energy savings as being ICT-enabled or otherwise. Abstracting this information further to the sector level is an even more onerous process. In short, determining if the energy savings are solely attributable to a change in ICT is difficult.

In scenarios where the opportunity for direct quantitative comparison is limited, some form of heuristics-based approach is typically used for estimating. In such situations, part-measurement, secondary data, specialist knowledge, etc., all play a part. Consistent with that approach REViSITE developed a qualitative-based framework to identify the RTD strategies and ICT implementations most likely to have a positive impact on energy efficiency.

The REViSITE framework, shown in Figure 1, was based on a combination of 'Life Cycle Thinking' and on an adapted 'Capability Maturity Framework' (CMF). It used a 'triangulation' approach to assess the impact of ICT by combining heuristics obtained from domain experts with data available from quantitative and qualitative sources. (Ellis, 2011; Web 1, 2012)

2.1 Adapted Capability Maturity Framework / REViSITE Framework

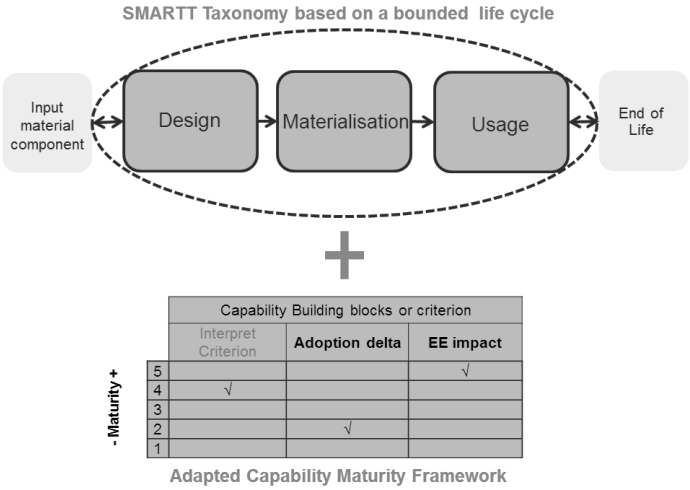

Figure 1: REViSITE framework

2.2 SMARTT Taxonomy

But, before the building sector and the other three target sectors could begin to make comparisons across their respective domains, it was essential to first speak a common technical language (Hesselbach, 2008). The first stage of framework development focused therefore on developing a common taxonomy. The output was the SMARTT taxonomy, which comprised six high-level categories (the dashed lines in Figure 2) and 23 sub-categories (as shown in Figure 3), which together were deemed to cover the scope of the ICT4EE domain. The high-level categories were aligned to the generic, bounded life cycle shown in Figure 1. Both the categories and the sub-categories were fixed, allowing for common categorisation of ICT and RTD strategies across sectors. Sector RTD/ICT topics, defined by the partners, and were nested within the sub-categories.

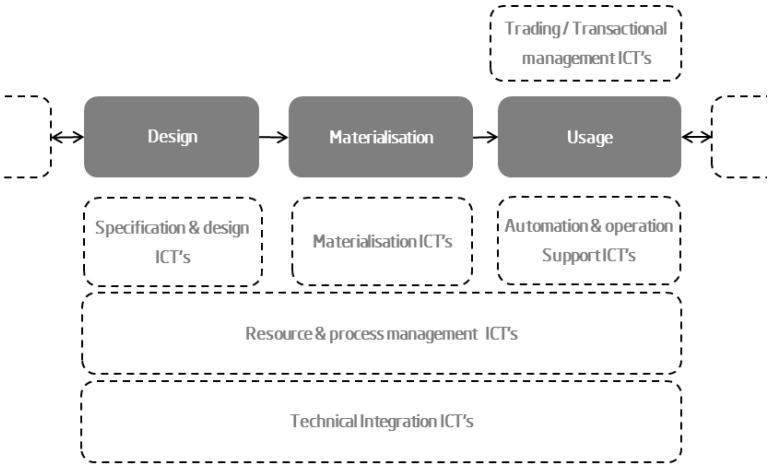

Figure 2: SMARTT taxonomy categories mapped to life cycle phases

The full SMARTT taxonomy is shown in Figure 3. The SMARTT taxonomy was used throughout the investigation as an integrative classification system and as an aid to cross-sector ICT4EE assessment. (Web:1 , 2012)

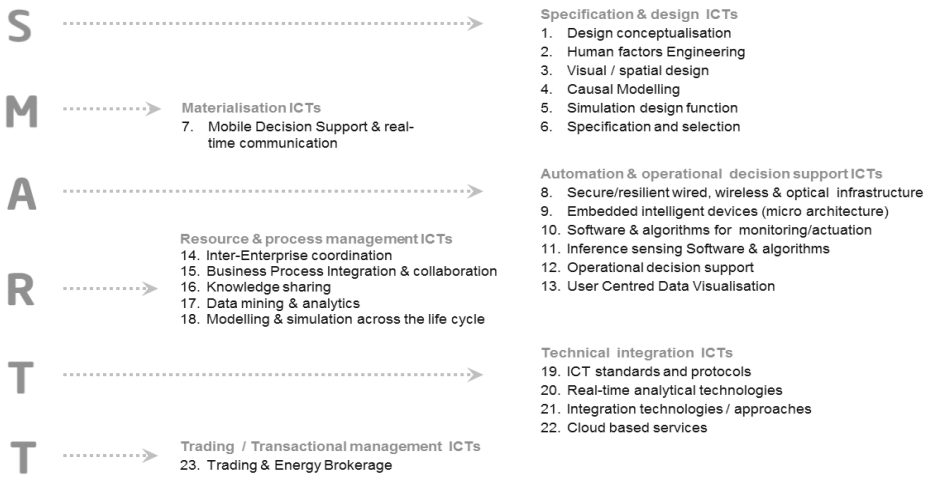

Figure 3: SMARTT taxonomy categories and sub-categories

2.3 REViSITE Framework and SMARTT Taxonomy to Identify Research Themes

The adapted CMF was used to assess how relevant each theme was in terms of defining a strategic research agenda (SRA). An online questionnaire was distributed to individual respondents (which corresponds to 23 valid respondents), who assessed the 23 ICT themes based on a combination of heuristics and domain expertise. During the subsequent analysis, each theme was mapped to a score based on the CMF-derived impact and adoption maturity scale shown in Figure 4. This enabled us to build sector-specific views about the theme's relevance to a strategic research agenda, where 'relevance' was determined using the formula:

Potential Impact Score * [Potential Adoption Score – Current Adoption Score]

2.4 Strategic Research Agenda (SRA) development

Based on the relevance of the themes as explained in the previous section, the Strategic Research Agenda suggest research priorities in the domain of ICT for Energy Efficiency across the building sector and the other three sectors. It should be noted that different sectors will invariably represent different maturity levels with respect to the technologies outlined, however the aim is to produce a holistic cross-sectorial view. 6 'roadmap' tables based on the 6 main categories and 21 sub-categories of the REViSITE SMARTT taxonomy were provided and summarised in the following section, these include: (i) State of the art; (ii) Short-term research priorities (~3 years to industrial usage; adaptation, testing and take up of new technologies, etc.); (iii) Medium-term research priorities (~6 years to industrial usage; development of new applications and incremental technologies, etc.); (iv) Long-term research priorities (~9 years to industrial usage; radical technical developments, etc.) and (v) Vision (~desirable future situation based on currently foreseen developments). Figure 4 shows a table summarising these information.

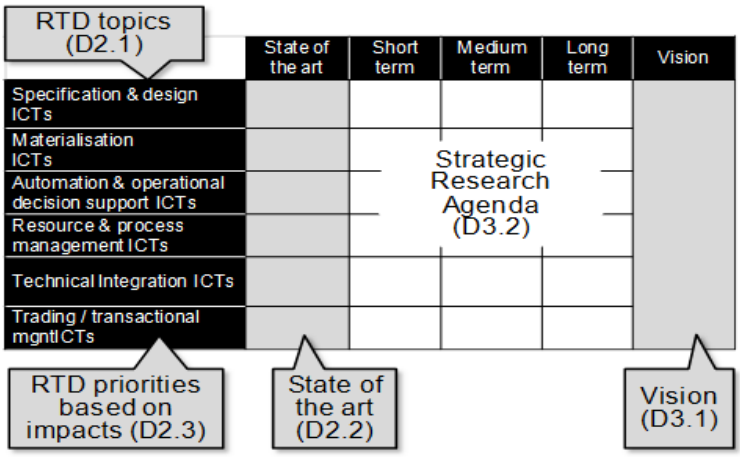

Figure 4 – Development of the Strategic Research Agenda

The SRA presented in this paper which is essentially based on the RTD topics (taxonomy) was exposed to comments by external experts in several iterations.

3. Outputs

The main body of the survey was based on rating the 'potential impact', 'potential adoption' and 'current adoption' of the 23 themes relative to energy efficiency or energy consumption reduction in each sector. The 23 themes are based on the SMARTT taxonomy. It was necessary to separate out some ICT themes for the purpose of the survey.

The survey data was extracted into matrix format, the pattern/trend analysis utilised standard mathematics, conditional formatting and re-orderable matrices [6]. This technique allowed us to separate out overall trends while also allowing for identification of difference across themes.

The output which corresponds for the built environment is outlined in the sections below. Not reported in this paper, similar work was undertaken to present the output for the other three sectors [7]. This task is followed by a trend analysis of common patterns between the sectors. The analysis is based on responses from a total of ninety-five respondents, who were surveyed and the valid response rate was 24%, making a total of valid responses equal to 23 (Building =10, Manufacturing =5, Grids = 4, and Lighting = 4).

The analysis was considered useful for SRA development and discussion. The following sub-section begins with a sector specific trend graph (see Figure 5). In all other cases (not reported here for the other sectors) the following applies:

- Column 1 – is the SMARTT taxonomy category identifier
- Column 2 – is the associated sub-category ICT theme no.
- Column 3 – is the potential impact score 'P imp',
- Column 4 – is the potential adoption score 'P Adopt',
- Column 5 – is the current adoption score 'C Adopt'
- Column 6 – is the Potential SRA Relevance score 'P SRA Relevance'.

To calculate 'P SRA Relevance' for each theme 'P imp' was multiplied by 'P Adopt' minus 'C Adopt' i.e. P SRA = P Imp * (P Adopt- C Adopt).

3.1 Key RTD/ICTs for Buildings

		Maturity Scores			
		P Imp	P adopt	C Adopt	P SRA Relevance
TE	20	4.25	4.25	1.50	11.69
TE	23	4.00	4.25	1.38	11.50
R	17	4.75	4.13	1.75	11.28
A	12	4.25	4.00	1.75	9.56
S	2	4.38	3.88	1.88	8.75
A	9	4.25	3.63	1.75	7.97
R	18	4.13	3.88	2.00	7.73
S	5	4.63	4.13	2.50	7.52
S	6	4.00	4.25	2.50	7.00
A	11	3.63	3.63	1.75	6.80
M	7	4.00	3.50	1.88	6.50
A	8	4.00	3.88	2.25	6.50
A	10	4.00	3.75	2.13	6.50
S	3	4.25	4.50	3.13	5.84
A	13	3.75	3.63	2.13	5.63
TE	21	3.00	3.25	1.50	5.25
R	14	3.50	3.13	1.63	5.25
TR	19	3.50	3.25	1.75	5.25
TE	22	3.38	3.25	1.75	5.06
S	4	3.50	3.13	2.00	3.94
R	15	3.25	3.63	2.63	3.25
R	16	3.25	3.00	2.25	2.44
S	1	3.13	2.75	2.00	2.34

SRA [Relevance] = P Imp * (P Adopt - C Adopt)

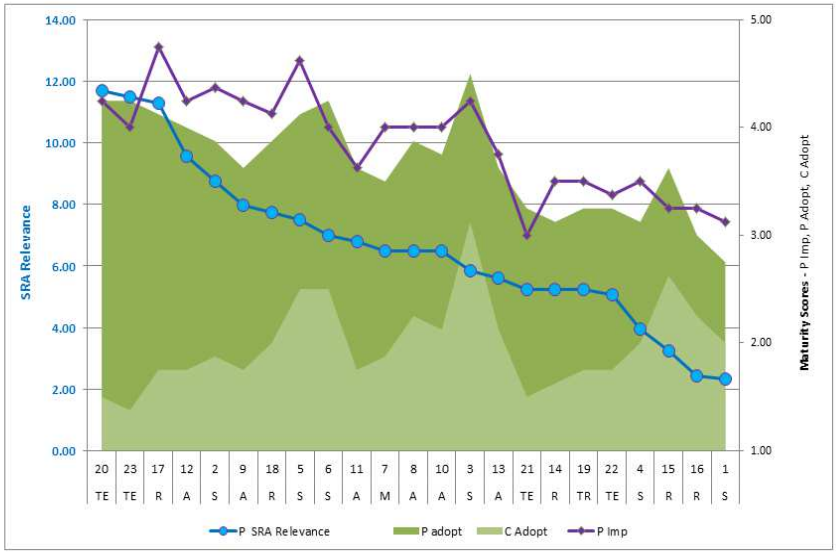

Figure 5 – Built environment ranking table and graph [10 respondents]

In figures 5 the blue (lower) line graph helps to visualise the importance of the x-axis which is relevance ranking in the context of SRA development. The purple (higher up) line indicates the specific 'P Impact' scores for each of those themes. The area graphed backdrop indicates the delta between current and potential adoption.

The 23 ICT themes are ranked in terms of greatest SRA Relevance to lowest. The top 11 themes are highlighted. Highlighting the top 11 scores is not to say other themes are to be ignored and is merely to guide conversation in terms of prioritisation. The column furthest right indicates the sector with the highest current adoption of each theme. This may be useful as a reference point for any research into that specific theme by the scoring sector.

The delta between current adoption and potential adoption is indicated in the column immediately to the left. While this is an obvious influencer of the overall 'P SRA relevance' calculation it is useful as a visual clue to the potential appropriateness of individual themes is in terms of SRA development.

4. Analysis and discussion

Having established individual sector trends we set about trying to understand common patterns amongst the sectors and try to inform on how building sector can learn from best practice of ICT applications in other sectors.

Using the re-orderable matrix technique we developed the matrices and corresponding graphs of figures 6, 7 and 8. Again the benefit of this technique is that it enables identification of overall trends while allowing for identification of variation within individual themes. ICT theme numbers together with the corresponding SMARTT category indicators [i.e. the first two columns of the table of figure] were hidden during this process to minimise influencing pattern generation.

		Light Potential Impact	Grids Potential Impact	MFG Potential Impact	Built E Potential Impact
R	15	2.67	2.75	2.75	3.25
S	1	3.33	2.25	2.75	3.13
S	3	2.33	2.25	3.50	4.25
TE	21	2.33	3.25	4.00	3.00
TE	23	2.00	3.50	3.25	4.00
TE	22	2.67	3.25	3.50	3.38
R	16	3.00	3.00	3.75	3.25
TR	19	2.33	3.75	3.50	3.50
S	4	3.00	3.00	4.00	3.50
A	13	3.00	3.50	3.75	3.75
M	7	2.33	4.25	3.25	4.00
R	14	2.33	4.25	3.75	3.50
TE	20	3.33	3.25	3.50	4.25
S	6	3.33	3.00	4.50	4.00
A	11	3.00	4.00	4.50	3.63
S	2	3.67	4.00	3.25	4.38
R	18	3.33	4.00	4.25	4.13
S	5	3.00	3.75	4.50	4.63
A	8	4.33	3.75	4.00	4.00
A	10	3.67	4.00	4.50	4.00
R	17	3.67	3.50	4.50	4.75
A	12	4.33	4.00	4.00	4.25
A	9	4.33	3.75	4.75	4.25

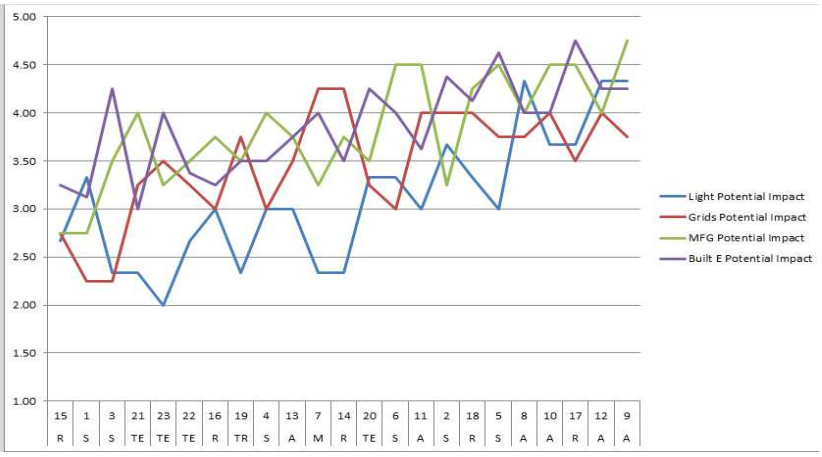

Figure 6 – Potential impact trend all 4 sectors

		Light Potential Adoption	Grids Potential Adoption	Built E Potential Adoption	MFG Potential Adoption
S	1	3.33	3.00	2.75	3.75
M	7	2.00	4.00	3.50	3.50
TR	19	2.33	4.00	3.25	3.75
R	16	3.33	3.00	3.00	4.00
TE	22	2.67	3.50	3.25	4.00
TE	21	3.00	3.25	3.25	4.00
R	14	2.67	3.50	3.13	4.25
R	15	2.67	3.50	3.63	4.25
S	4	3.67	3.50	3.13	4.00
S	6	3.33	2.75	4.25	4.00
TE	23	2.67	3.75	4.25	3.75
S	3	3.33	2.75	4.50	4.00
S	2	3.33	4.25	3.88	3.75
A	11	3.00	4.00	3.63	4.75
R	18	3.33	3.75	3.88	4.50
R	17	3.67	3.50	4.13	4.25
TE	20	3.67	3.75	4.25	4.00
S	5	3.33	4.25	4.13	4.00
A	13	3.33	4.50	3.63	4.25
A	8	3.67	4.00	3.88	4.25
A	12	4.00	4.00	4.00	4.25
A	9	4.33	4.00	3.63	4.50
A	10	4.33	4.25	3.75	4.50

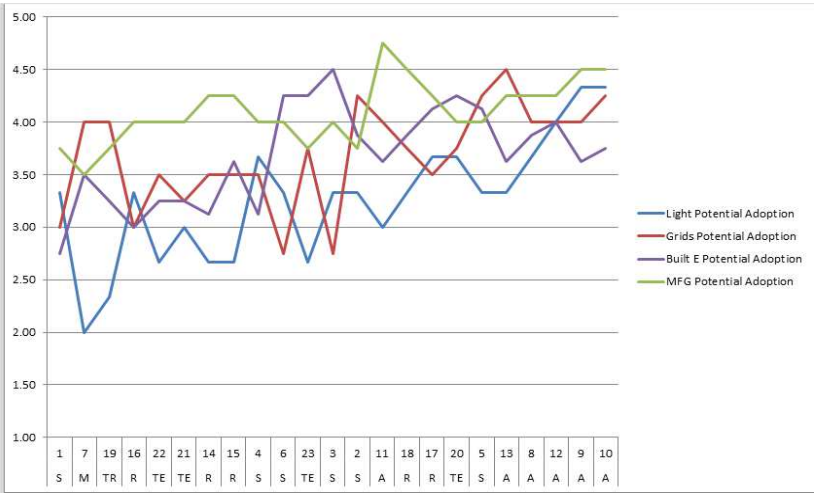

Figure 7 – Potential adoption trend all 4 sectors

		Light Current Adoption	Built E Current Adoption	MFG Current Adoption	Grids Current Adoption
TE	23	1.33	1.38	1.50	2.50
A	12	1.33	1.75	1.75	2.50
S	2	1.33	1.88	2.00	2.25
TR	19	1.00	1.75	1.25	3.50
TE	22	1.00	1.75	2.50	2.25
A	11	1.33	1.75	1.75	3.00
A	13	1.33	2.13	2.25	2.50
R	14	2.33	1.63	2.25	2.25
TE	21	2.00	1.50	2.00	3.00
R	16	1.33	2.25	2.50	2.50
M	7	2.00	1.88	2.00	2.75
R	17	2.33	1.75	2.00	2.75
A	9	2.00	1.75	2.50	2.75
S	1	2.00	2.00	3.25	2.25
S	4	2.00	2.00	3.00	2.50
S	6	2.33	2.50	2.25	2.50
A	10	2.33	2.13	2.25	3.00
TE	20	3.00	1.50	2.75	3.00
R	18	2.67	2.00	3.25	2.50
A	8	3.00	2.25	2.50	3.25
S	5	2.67	2.50	3.00	3.00
R	15	2.67	2.63	3.25	3.00
S	3	3.00	3.13	3.75	2.25

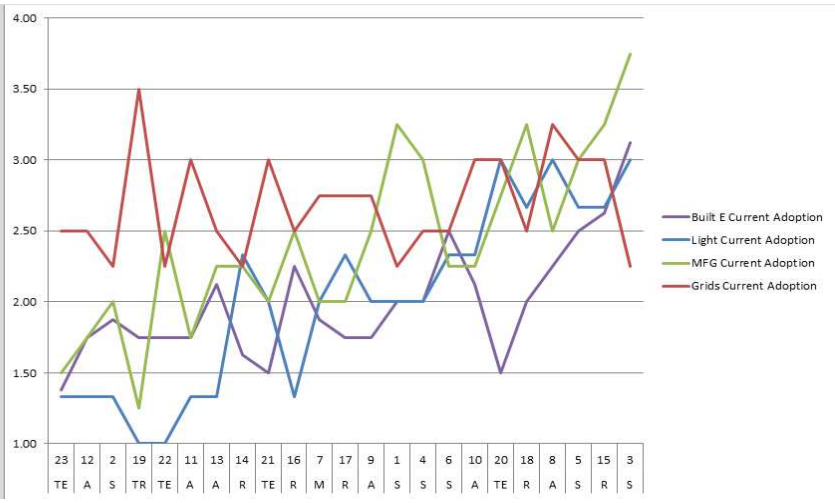

Figure 8 – Current adoption trend all 4 sectors

Based on the interpretation of the cross-sector themes ranked in terms of 'P SRA relevance'. figure 9 is the overall resulting output from the exercise and offers a prioritised list of ICT themes to be considered, while figure 10 is a an un-sorted histogram comparing SRA relevance across the sectors.

SMARTT cat.	ICT Theme no.	ICT Theme description	adoption delta
A	**12**	Operational decision support ICTs that integrate high level diverse systems such as safety, security, weather and energy etc. at individual, building or district level for near real-time decision making	2.23
A	**9**	Embedded intelligent devices (micro architecture)for operational control, sensing & actuation at machine, plant or building level	1.86
S	**2**	Human factors Engineering ICTs to gather and model data describing the behaviour of end users/energy consumers	1.94
A	**11**	Inference sensing Software & algorithms for pattern & signal identification at machine, plant or building level	1.89
A	**10**	Software & algorithms for operational monitoring & actuation of devices at machine, plant or building level	1.78
R	**17**	ICTs for data mining & analytics in terms of energy consumption & optimisation, pattern identification, predictive diagnostics & analytics at enterprise or network level	1.68
A	**13**	User Centred Data Visualisation ICTs to support system state awareness by human operators / users	1.88
Te	23	Use of cloud based services for tasks such as data management, monitoring and analysis	1.93
Te	**20**	ICT standards and protocols for interoperability across heterogeneous devices at an enterprise, network or environmental level	1.35
R	**18**	Modelling & simulation ICTs e.g. What-if scenario planning continuous improvement across a sectors life cycle	1.26
A	**8**	Secure/resilient wired, wireless and optical infrastructure for operational communication, monitoring & control	1.20
Tr	19	Trading & Energy Brokerage ICTs e.g. Consumer/Producer forecasting algorithms, energy source tracking, consumption/price negotiation	1.46
S	6	Product/component specification and selection ICTs E.G. material characteristic database specifying embedded energy, recyclability, thermal performance etc.	1.19
R	14	Inter-Enterprise ICTs for supporting coordination e.g. contract & supply-network management in the context of reduced energy consumption	1.27
Te	22	Integration technologies / approaches such as service orientation and event driven architectures to facilitate heterogeneous device data interoperability at enterprise, network and environment level	1.48
S	**5**	Simulation ICTs for predicting/estimating the dynamic behaviour of a system as part of the design function E.G. Computational Fluid dynamics, Finite element mode analysis, power system simulation etc.	1.14
M	7	Mobile Decision Support ICTs that utilise real-time communication to facilitate in the field decision making particularly in construction or civil engineering tasks	1.09
Te	21	Real-time analytical technologies such as Complex Event Processing and in-memory databases for enhanced operational control and awareness	1.25
S	4	Causal Modelling ICTs used to describe / predict relationships in physical systems E.G. computer-aided diagramming (e.g. Sankey, Cause and effect, influence diagrams etc.), Life cycle modelling, statistical packages such as JMP & MatLab etc.	1.20
R	16	Knowledge sharing ICTs, knowledge management, knowledge repositories, knowledge mining and semantic search, linked data, long-term data archival and recovery at enterprise or inter-enterprise level	1.19
S	1	Design conceptualisation ICTs for requirement engineering & ideation. E.G. Quality Function Deployment, Mind maps etc.	0.83
S	3	Visual / spatial design ICTs E.G. CAD (Autodesk, 3D studio max), Multimedia (e.g. Flash, Silverlight), Graphics (e.g. Photoshop, Illustrator) for digital mock-up etc.	0.61
R	15	Business Process Integration & collaboration ICTs E.g. collaboration support, groupware tools, electronic conferencing, social-media, etc.	0.63

Figure 9 – Cross-Sectorial SRA themes ranked in terms of potential relevance

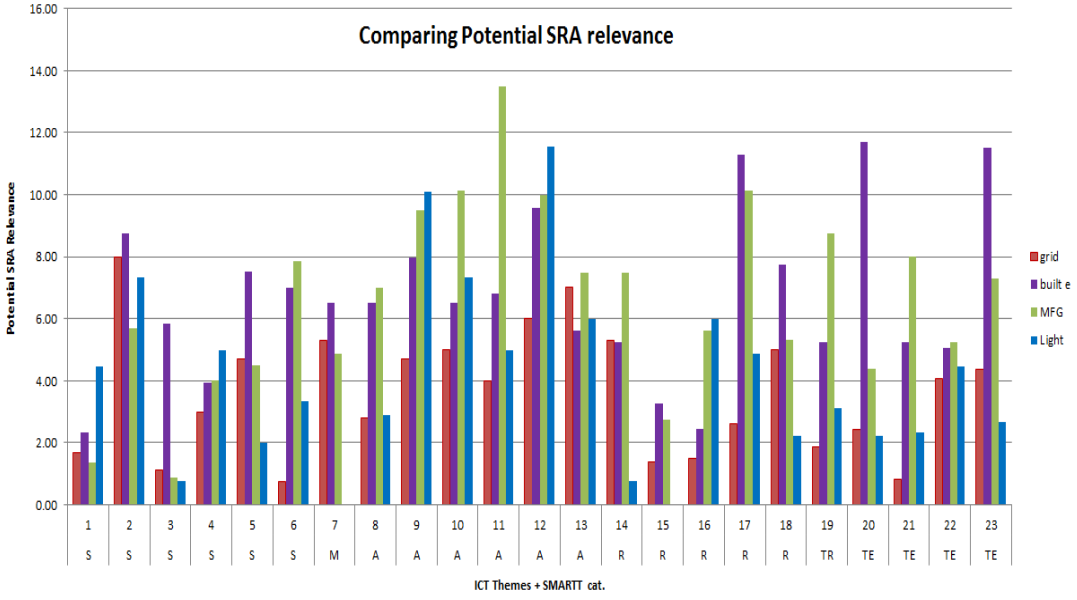

Figure 10 – Comparing Potential SRA relevance between sectors [unsorted]

The impacts of ICT on energy efficiency are subject to complex causal interdependencies of many different systems over several life cycle stages. This fact in itself calls for research to model and quantify ICT impacts for decision making about investments in ICT research and use.

The findings discussed so far were ultimately formulated into the Strategic Research Agenda which is based on the taxonomy categorisation and also follows the trends summarised in figure 9 and 10. The high level synthesis of the SRA findings are given in the following under the six SMARTT taxonomy categories, while details of the full SRA is available at (Web: 1, 2012)

4.1 The Strategic Research agenda

Specification and design ICTs: Design is central given estimates that a major share *(indicatively ~80%)* of a products *(e.g. buildings)* life time environmental impact is determined in the design phase. This is especially the case when new products/systems are designed. However, design for retrofitting of existing systems is also crucial as many products/systems are renewed several times throughout their life time. The degree, to which the designed energy efficiency potential will be actually materialised, depends on the downstream life cycle stages *(materialisation, operation).* Therefore integration between different stakeholders and stages is of fundamental importance for design. The main trend in this area is "integrated design" implying interoperability of various ICT applications and sharing of information at high semantic level between stakeholders over all life cycle stages.

Materialisation ICTs: 'Materialisation' follows the design phase and is a non-sector specific term understood within REViSITE to encompass construction, grid infrastructure and production-system development i.e. realisation of the physical. ICTs in this space are similar, identical in most cases to decision support ICTs in the operational phase. What is different is the context, which undoubtedly has greater significance for, but is not limited to, the construction sector.

Automation and operational decision support ICTs: This category, given its direct relationship to the operational phase of the respective sector life cycles, is probably the most obvious in considering impact on energy efficiency, especially in the context of existing buildings, production systems and grid infrastructure.

Resource and process management ICTs: This category focuses on supporting holistic EE management and decision making regarding processes/resources that span LC phases, organisational functions and indeed organisations.

Technical Integration ICTs: Semantic interoperability and technical integration are central to a holistic energy management strategy and arguable links to all categories and subcategories of ICTs. Semantic interoperability is equally as important as technical integration, but the main focus from a technical perspective is integration technologies / ICTs.

The trading/transactional management ICTs: This category relates to technologies and practices required to support an economic negotiation driven relationship between energy grids (both regulated operators and competitive market parties) and prosumers in both the manufacturing and building/lighting domains. The topic has been divided and described in terms of four energy management levels. The SRA table for the "The trading/transactional management ICTs" which includes the detailed result is given in Appendix 1 (see table 6).

4.2 Recommendations - Implementation Action Plan

The SRA was extended to much more tangible recommendations given into the form of an Implementation Action Plan. A menu of 23 potential ICT4EE research trajectories established, from the themes descried above. Attention in the following is turned to formulating the work into a format that clearly identified the 'target outcomes', 'expected impacts', and potential 'actionable items'. The interim output of the IAP work was 23 succinct tables [9] that detailed:

- The scope of each RTD topic
- The target outcomes pertaining to any future research funding call
- Expected impacts of achieving the identified target outcomes
- Specific recommendations for various stakeholders

While any of the 23 could potentially inform a research call, the research team supported by the expert group, based on their own expertise and inputs from the wider community, consolidated the 23 themes into 11 proposed call themes. The following section outlines the 11 research themes identified.

Integrated Design: Complex systems need to be optimised based on multiple and often conflicting criteria. The degree of energy efficiency potential that can be achieved through integrated design depends on the downstream life cycle stages (materialisation, operation). Integration between different information sources, stakeholders, and stages is, therefore, of fundamental importance for design.

The main targets for integrated design are the interoperability of various ICT applications and the ability to share information at a high semantic level between stakeholders throughout all life cycle stages; integrated design has a direct impact on both the design process itself and on the subsequent life-cycle stages which depend on design information. The energy performance of the target system depends ultimately on the combined impact of design, materialisation, and operation.

Component Catalogues: Catalogues of materials and components are needed to support the design of products/systems, as well as procurement for materialisation. These catalogues should provide access to various commercial and technical information (including, e.g., properties relating to energy efficiency). The catalogue content should be at an abstract/semantic level to meet the requirements of increasingly model-based design tools.

Data Models: Achieving energy efficiency requires holistic management of information from many stakeholders over the product's lifetime. Common concepts and language are prerequisites for communication, both between humans and ICT systems. Agreed data models (ontologies) are needed to bridge the gaps and to enable information-sharing and re-use without error-prone interpretation, manual data re-entry, and loss of data.

Application Tools: The main research needs are related to issues such as early-stage design and decision-making, enhancing the scope of existing tools to support design for energy efficiency, increased utilisation of existing good design solutions, information-sharing between various ICT tools through interoperability, and reducing the gap between predicted and actual energy performance of systems.

Life-Cycle Energy Modelling and Estimation: In early design, there is a need for planning and testing, as this has a high impact on the system's overall energy consumption. Later stages require performance indication, data processing, and visualisation, as a foundation for

management, decision-making, and control. A holistic (cross-sectoral) perspective needs new ways of integrating the different energy efficiency evaluation methodologies used across the respective sectors. Multiple new approaches are, therefore, needed to address energy efficiency metrics, measurement and analysis methods, systems integration, and knowledge repositories. Using a central hub to measure/monitor energy efficiency in buildings will help conserve energy and improve efficiency, based on market options and incentives.

Metrics and Methods for Assessing Energy Efficiency and the Impact of ICT:As discussed in previous sections, one of the primary barriers to adopting ICT for energy efficiency is assessing which solutions will have the greatest impact. Much has been done already in developing a common framework for understanding the direct impact of ICT on energy efficiency. However, while somewhat addressed in this new methodology, there is still a requirement for research to identify a) a common means of assessing the impact of ICT on energy efficiency and b) a common means of assessing energy efficiency in the first instance, as an accepted, common method does not currently exist.

Common metrics and measurement methods are required for comparison. Proposed methodologies for measurement, such as those used in residential buildings, are a good starting point, but continued research is required into ICT-enabled measurement, common assessment, verification/certification, best-practice sharing, and knowledge generation.

Data Visualisation and Decision-Support:

Compelling data visualisation and decision-support ICT will be paramount in navigating the increased volume and complexity of data, including energy and resource efficiency data at the individual, home, enterprise, and district level. In the context of future sustainable cities, there will be a need for novel data visualisation and decision-support solutions in coping with diverse, complex data and in ensuring sustained user interest/engagement. Greater volumes of heterogeneous data will require dynamically-adaptable visualisations. A basic requirement of this call theme is the expanded use of cognitive data visualisation principles. The scope of ICT solutions includes, but is not limited to, the integration of diverse systems (safety, security, weather, energy, etc.) at different levels of abstraction, SCADA, business activity modelling, management dashboards, and methodologies for analysing situation awareness in complex systems.

ICT for New Business Models and Work Practices for Improved Energy Efficiency:

There is a need for new business models and work practices to support the paradigm shift towards energy-efficient delivery of products and services throughout the whole life cycle. These may include (but are not limited to):

- New types of contractual relationships, such as performance-based contracts.
- E-commerce tools and collaborative working environments that facilitate remote working.
- Incentives for environmentally-friendly, low-carbon/energy-efficient design.
- Methods of modelling and simulation to estimate the appropriate incentive, and deliver transparent energy consumption data.

Cloud Computing and Network-Enabled Energy Services:

'Cloud computing', which encompasses Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS), is transforming the software and service

industry, and will have a profound impact on the ICT strategies of multiple sectors. Much in terms of augmentation with regard to cloud computing and future networks is essentially independent of a 'sustainability [1] context. However, if not addressed, more generic issues, such as those related to adoption5 identified below, will negatively impact on cloud-based energy and resource management services, which are highly pertinent to sustainability.

The top four actions that are important to most groups (from small- and medium-sized enterprises to large enterprises) in terms of cloud computing adoption are:

- Greater accountability and liability for security by providers of cloud-based services.
- Ensuring portability between cloud services.
- Improving internet connections.
- Security certification of vendors of cloud-based services.

Add to this the important role data privacy will have for the adoption of energy-related offerings and one begins to understand the immense role context-independent issues, such as dependability, scalability, flexibility, and privacy of data, will have for energy- and resource-related services.

ICT for Nodal Energy Management: To describe the different nodes of the smart grid, a common model, known as a Virtual Power Plant (VPP), is used. The VPP model contains a generic set of characteristics to allow connection and interaction between the building blocks of the smart grid. The objectives of this call for research are, therefore, to investigate the different facets of the VPP model and to prepare for migration towards open platforms, which will enable energy to be managed on different scales, such as at the building level, at the district level, and at the city level, etc.

Integrated Monitoring and Control for Improved Energy Efficiency:

ICT solutions supporting intelligent sensing/control with respect to energy-efficient building, industrial, and grid resource automation are required. The scope of this research call includes sensing/control software and hardware, control and optimisation algorithms, embedded microcontrollers, etc.

5. Conclusions

Given the arduous nature in quantitatively assessing the impact of ICT on energy efficiency, we have posited the utilisation of an adapted capability maturity framework coupled with Life cycle thinking in leveraging the heuristics of sector experts. As a result a model outlining key ICTs with respect to energy efficiency for SRA development, and a suitable implementation action plan was devised. We believe we have achieved this aim offering a more in-depth analysis of ICT themes identified. The survey and trend analysis offers, in the opinion of the consortium, trajectories for SRA discussion. However, it must be noted that this paper does not do justice to the body of knowledge compiled during this project or to the level of effort expended by the various contributors. Altogether, the conclusion is that the target research domain consists of complementary areas that need to proceed in a balanced way in order to achieve sustainable long term impacts. The overall expectation is that ICTs will contribute to applications with higher level of semantics, knowledge sharing, system integration and interoperability. It was perceived from the analysis of the received feedback that the SRA covers the target domain with sufficient width and depth, all listed topics are regarded as

relevant and important, and there is no basis for pointing out specific topics with exceptionally high or low priority.

To learn more about the REViSITE project, or to view full versions of the deliverables produced during each phase of the project, please see the project website: http://www.revisite.eu.

6. Acknowledgements

The REViSITE Coordination Action (Grant Agreement no. 248705) is co-funded by the European Commission, Information Society and Media Directorate-General, under the Seventh Framework Programme (FP7), Cooperation theme three, 'Information and Communication Technologies'. The authors wish to acknowledge the Commission for their support, the efforts of the partners, the REViSITE Expert Group, and the contributions of all those involved in REViSITE

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Determining the magnitude of transaction costs in construction procurement systems: An exploratory study

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Abstract

Transaction cost economics (TCE) has traditionally examined customer-supplier relationships in the context of contractual arrangements. This enables the development of appropriate strategies, such as long-term agreements and alliances, to eliminate the risk associated with contracting uncertainty, limiting the number of instances of bargaining or opportunism and asset specificity. In the context of construction procurement decisions, TCE could generate a valuable understanding of the costs associated with coordination, inspection, translation, incentives, transactions, and other interactions. This paper therefore reports on an exploratory effort to capture the transaction costs (TCs) of different procurement systems used in construction projects. Specifically determining the relative values of TCs for Traditional and Design - Build systems for the purpose of comparison.

The paper involves a meta-study of construction procurement systems and TCE. It reviews the approach to the development of a conceptual framework that could enable the selection of appropriate procurement systems and/or make-or-buy decisions that could minimise TCs and therefore enhance the performance of the construction industry.

The study is an aspect of a doctoral research study on determining appropriate construction procurement systems based on rational evaluative tools (TCE being one such tool). An outline of the larger study programme that forms the basis of the current paper is presented to demonstrate the benefits of the research investigation to construction clients and the construction industry as a whole.

Keywords: Transaction costs, Procurement systems, Construction.

1. Introduction

Operational performance continues to generate interest in construction. For example the procurement process provides opportunities for cost reduction and value enhancement to project owners. The selection of appropriate procurement systems for a construction project may influence its success or failure. Merrow (2011) contends that procurement systems make a difference in project execution, while poorly managed project relationships

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negatively impact project performance (Meng et al. 2012, Merrow 2011). In fact Meng et al. (2012) has shown that poor supply chain relationships significantly impact the occurrence of cost overruns than time delays.

Relationships in the form of buyer-supplier relationships have been the object of several investigations in construction (Al-Najjar 1995, Artz 1999, Bajari et al. 2009, Kajewski et al. 2010, Eriksson 2007, Hughes et al. 2006, Love et al. 2009). However for the purpose of this paper, the costs associated with customer-supplier relationship in the context of contractual arrangements is the primary focus. TCE focuses on economic actors' behavioural assumptions (opportunism and bounded rationality) and transaction characteristics; i.e. asset specificity, uncertainty, frequency, complexity, and contestability (Williamson 1985, Williamson 2005, Williamson 2010b). Heide and John (1990) contend that TCE provides a useful framework for the selection of the most suitable procurement system for projects.

Eriksson (2007) argue that the procurement selection decisions are always judgmental, subject to bias, and heavily affected by individual experiences of a particular procurement system. Given that TCE is such a significant component of construction procurement, and that the procurement decision is highly cost sensitive, it seems apparent that there is a need to better evaluate TCs in construction. As early as 1985, Williamson (1985) suggested that the comparative costs of planning, adapting, and monitoring task completion under alternative procurement systems should be examined. Moreover, Turner (1997) expanded the notion to contemplate other important factors such as engineering, economic, environmental, and social factors, in the procurement selection process (Turner 1997). Therefore, theoretical elucidation is required to enhance the development of practical concepts and techniques, and to assess the circumstances under which they are suitable for a certain purpose (Cox et al. 1998). Theoretical concepts of TCE are supported by several empirical studies (Artz 1999, Heide and Stump 1995, Melese and Franck 2005) and will be discussed later in this paper. Researchers within the TCE field suggest the applicability of transaction costs theory (TCT) although some have employed imperfect proxies for key variables. TCT contends that there are costs to conducting transactions through the market, which can be reduced through certain mechanisms (Coase 1988, Williamson 1971). Specifically, these costs relate to drafting, negotiating, and safeguarding and exchange that could impede smooth transactions (Williamson 1985). Further, changes in design and information requirements for procurement are significant to TCs in construction (Wenan and Mengjun 2010).

This paper aims to investigate the linkage between procurement systems selection and TCs, using TCE methodologies. The paper presents a conceptual model that is developed, for the selection of the most economic procurement system that could achieve project success. The model of procurement selection so informed could help to reduce costs, enhance productivity, and increase quality performance and customer satisfaction.

2. Literature Review

2.1 Transaction cost

Ronald Coase first introduced the concept of TCs in 1937 (Jacobides 2008). He subsequently further investigated pricing mechanisms and concluded that there are costs related to searching for relevant prices, negotiating, and making a contract (Coase 1992, Coase 1988, Coase 1960). Williamson (1985) developed the theory of TCE by focusing on the economic actors' behavioral assumptions (opportunism and bounded rationality) and transaction characteristics; i.e. asset specificity, uncertainty, frequency, complexity, and contestability (Williamson 2005, Williamson 2010a, Williamson 1985). Economic actors behaving opportunistically with bounded rationality and uncertainties dominate contracts, which partially accounts for contingencies. Importantly TCE has traditionally examined the customer-supplier relationship in the context of a contractual arrangement. This relationship is associated with TCs including; costs of information, negotiation, competitive advantage, contract administration and management, market structure, enforcement, and measuring/monitoring performance (Melese and Franck 2005, Artz 1999, Heide and Stump 1995).

TCs perspective has received considerable attention by researchers and academics and has been applied to a variety of construction topics. The rationale behind applying TCs in construction is to understand the cooperation and motivation among project stakeholders. Eccles (1981) conducted an investigation on the impact of asset specificity and uncertainty in the governance form of construction firms (Eccles 1981). Eccles adopted the hybrid contract (the quasi-firm) for examining the relationship between contractor and sub-contractor. Winch (1989, 2008) investigated the relationship of socio-technical systems, organization and environment, and project management in construction. Winch believes that the three perspectives do not fully elucidate the differentiation and integration of market governance. This means the transaction between firms in using the market governance model does not fully examine the relationships between firms (Winch 1989, 2008). Hence, Winch adopted the TCs perspective as an alternative approach in systematically handling the relationships within and between firms. The significance of his study was in specifying the sources of uncertainty, complexity, and number of these situations facing construction firms.

Reve and Levitt (1984) examined the effect of applying transaction cost framework in explaining contractual uncertainties in construction using the project as a unit of analysis in determining resource allocation uncertainties. However, construction project does not of itself allocate resources. Resources (land, labour, and capital) are allocated by individual firm involved in the delivery of the project. This in turn is dictated by the requirements of the client. Alsagoff and McDermott (1994) discussed applying TCE theory to explore the causes of disputes between clients, contractors, and subcontractors in the construction industry (Alsagoff and McDermott 1994). They concluded that contractual incompleteness and opportunism are the root causes of conflicts and disputes between firms. Therefore, they introduced the relational contracts as alternative contractual approach in resolving conflicts among contractual parties.

Walker and Wing (1999) developed a framework that explains the possibility of integrating project management theory (PMT) and TCE theory (Walker and Wing 1999). They tried to delineate the relationship between these approaches and the benefits of merging the two approaches in improving construction management theory. Therefore, they made a comparison of a traditional organization structure and a design-build structure to illustrate this relationship. By doing so they tried to answer why design and construction processes are separated in the traditional system. Walker believes TCE theory is providing an alternative theoretical basis, which can be integrated with the project management perspective and correlated models of organization. The strength of this study in underpinning the behavioural assumptions of TCE theory, such as opportunism, moral hazard, and shirking that the management theory could not cover.

Chang and Ive (2000, 2007) in their study proposed modifications to TCE methodology to make it applicable in dealing with construction (Chang and Ive 2000, 2007). They developed the direct measurement approach (DMA) and indirect measure approach (IMA) to predict theoretically the amount of TCs incurred. The DMA based on the identification and measurement of TCs elements, while, the IMA explained the relative effectiveness of governance structures in terms of TCs. Moreover, they tried to quantitatively analyze TCs elements to explore the link between these costs and procurement routes during construction. The weakness of this study is in dealing with theory for measuring TCs. Thus, the distinction between production costs and TCs became less clear.

Jin and Zhang (2011) developed a framework for risk allocation strategy for public private partnership (PPP) based on TCs characters. In this framework, the determinants of efficient risk allocation were identified based on TCE theory. As a result, the buy-or-make decision can be taken based on the risk response evaluation for adopting certain strategy. Using a proper risk allocation strategy can significantly reduce TCs. This is because risk allocation has been judged on a cost benefit basis. Therefore, improper risk allocated strategy might incurred costs such as; higher contingency costs, more resources to monitor risk, quality costs, safeguarding costs, enforcement costs, and legal costs.

In General studies applying TCs perspective in construction are not fully reliable with the suggestions of TCT; others employed imperfect proxies for key variables. Moreover some developed models have not directly tested the parameters of TCT. Nevertheless four key characteristics of transactions can make them more costly: complexity, uncertainty, frequency, and asset specificity (Williamson 2010a). Therefore, understanding the key characteristics of a transaction can help decision-makers improve the design of contracts, organizations, and other governance structures that could reduce TCs and improve the gains from an exchange between buyers and sellers (Williamson 2008). This research contemplates the gaps of these researches through developing a model that sets the mechanisms in selecting the most appropriate procurement system based on TCs. Further, a comparison of the results will be shown in a graph that illustrates the amount of different TCs for two procurement systems; the Traditional and Design – Build.

2.2 The linkage between Procurement system and TCs

The relationships between procurement strategies, contractual arrangements, and tendering procedures are not well articulated in the construction industry, whereas contractual arrangements are often dictated by the procurement strategy (Hackett et al. 2007, Hughes et al. 2006, Murdoch and Hughes 2008). Dudkin and Valila's (2006) study in the UK construction industry shows that the private/public partnership projects (PPPs) in the UK are continually affected by significant costs related to the procurement phase of PPPs. Currently this amounts to an average 10% of the capital value of the projects that erodes the potential savings achieved within partnership projects (Dudkin and Valila 2005). There are other TCs that affect the performance of PPPs that are not easily assessed, for example the opportunity costs as a result of renegotiation and delays to the completion of the project (Ho and Tsui 2009), which may significantly undermine expected benefits. Frank et al. (2007) also found that outsourcing relationships could involve extra TCs such as negotiation, measuring, and monitoring costs that can quickly overwhelm a 10% production cost advantage (Frank et al. 2007). It would therefore seem that TCs are highly significant in the overall cost of construction on any project.

There is a current and pressing need to examine the relationship between the procurement system and TCs in the New Zealand construction industry. Recent studies have shown generally that the New Zealand construction industry has poor productivity (Tran and Tookey 2011). More broadly, this recognition has led to extensive efforts to achieve a 20% increase in productivity by 2020 (see www.buildingvalue.co.nz). Since productivity is a function of cost versus revenues, developing and improved the understanding of the basis of costs offers significant potential to affect construction productivity.

With an appropriate TCE-based framework, acquisition management practices could be improved by evaluating the largely hidden costs of managing contractual relationships. TCE offers useful insights on appropriate contract types, provides useful predictions about how contracting relationships evolve over the project's life, and highlights the crucial issue of resource ownership and the associated problem of asset specificity. The procurement selection process is associated with the degree of defined contract specifications and the value of transactions. With TC analysis, emphasis could be placed on developing formalized governance mechanisms (i.e. formal contracts, rules and regulations, reputation mechanisms, termination agreements, warranties, etc.) and suitable strategies, such as long-term agreements and alliances. This way it would be possible to eliminate the risk associated with procurement uncertainties, limiting the number of instances of bargaining or opportunism and any asset specificity issues. According to Angelis et al. (2008) the reasoning behind such strategies is the elimination of coordination and motivation cost which ultimately reduces TCs (Angelis et al. 2008). Thus a TCE perspective could improve the procurement phase through: firstly, developing a service strategy by improving risk profile; secondly, identifying the service goals, objectives, and priorities through better contractual agreements; thirdly, identifying the capacity development requirements through enhanced long-term strategies; fourthly, ensuring adequate funding through improved cost estimation, and finally, defining the most feasible contractual approach.

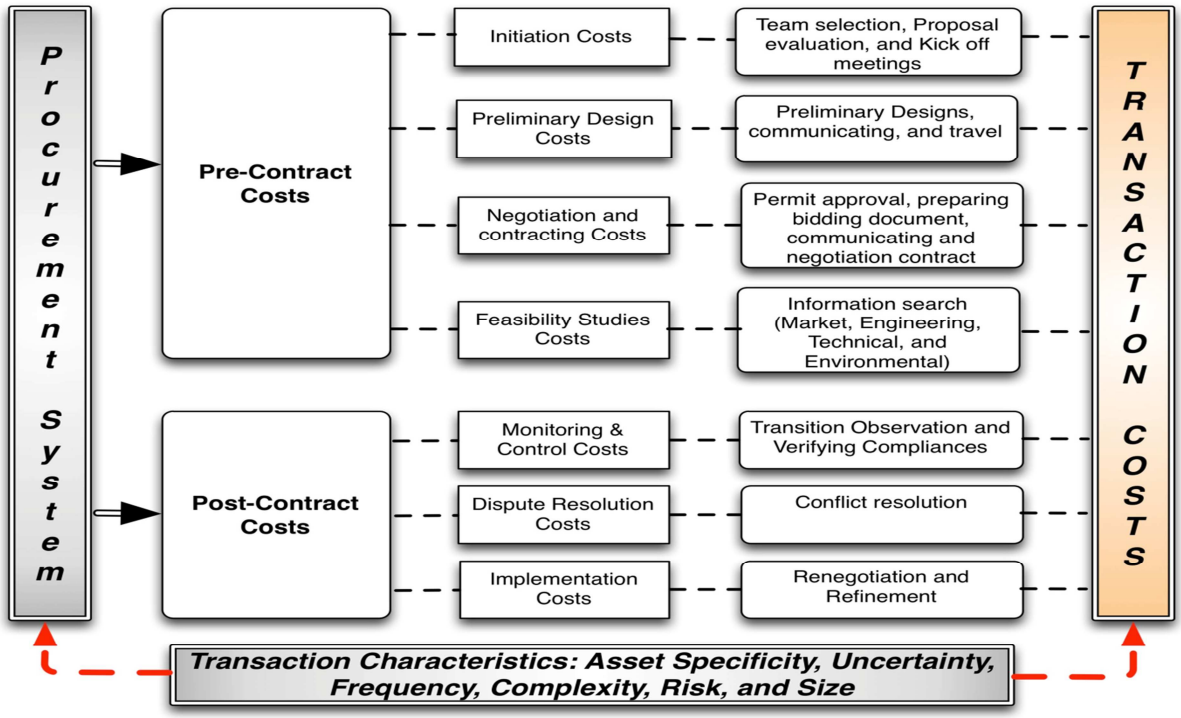

Figure 1: Delineation of TC activities in construction procurement systems

The larger study on which this paper is based determines the magnitude of TCs associated with procurement processes, for Traditional and Design - Build systems. Relative cost centers such as coordination, inspection, translation, incentives, transactions, and elimination of interactions are captured. In addition, the study attempts to define processes and identify the time and cost importance of procurement activities and processes. The study posits that any mechanism that can determine the magnitude of TCs will allow contractors to make more appropriate procurement decisions. Figure 1 illustrates the key cost elements within procurement systems that the TCE-based framework could focus on. Procurement systems implemented on any project have a significant impact on the TCs associated with the pre-contract and post-contract phases. Pre-contract costs relate to activities carried out during initiation, preliminary design, negotiation and contracting, and feasibility studies; while post-contract costs are commonly associated with monitoring and control, dispute resolution, and implementation activities for projects. These costs could be measured by evaluating the time- spent daily by professionals on these respective procurement activities relative to other project activities.

Common procurement systems are the Traditional, Design - Build (DB), Management, Alliance, Build Operate and Transfer (BOT), and PPP (Brook 2008, Murdoch and Hughes 2008). In the traditional procurement system the design is very often completed (or near completion) before construction begins, thus the certainty of a tender price is higher because the project scope is defined. In terms of TCs one could hypothesize that relative to other procurement systems its pre-contract costs are likely to be higher because of the time spent in defining the project scope before construction begins. With systems such as DB, BOT, and Management, it is more usual to commence construction before designs are completed. According to Brook (2008) such systems (DB, BOT, and Management) could benefit from speedy construction because the design and construction phases have been integrated,

although incomplete documentation is often a source of uncertainty and could pose difficulties to cost prediction and estimation, TCs for these integrated systems may be comparatively lower at the pre-contract phase but higher if and when implementation problems occur as a consequence of incomplete designs. Conversely with Alliance procurement systems, TCs at the pre-contract phase could comparatively be the highest because of the level of preparatory activities involved in setting up alliances.

2.3 Procurement selection: the model

Researchers have developed several theoretical models for the procurement selection process in construction (Skitmore and Marsden 1988, Chan et al. 2001, Kumaraswamy and Dissanayaka 1998, NEDO 1985, Singh 1990, Cheung et al. 2001, Alhazmi and McCaffer 2000, Franks 1990). However, these models generally do not address the environmental factors (internal and external) affecting firms in the procurement selection process. As mentioned previously, procurement system selection is very often subjective. This paper aims to address these weaknesses by adopting a more strategic approach that combines cost evaluation criteria with environmental (contextual) factors. Figure 2 depicts a comprehensive framework of criteria for procurement selection. The figure depicts a combination of project constraints, objectives, and environmental forces that could influence procurement system decisions. The framework is developed in line with Williamson (1991, 1998) wherein human and environmental forces were considered the most important contributory factors to TCs. In this case, environmental forces represent external forces (i.e. threats and opportunities) and internal forces (i.e. weaknesses and strengths) of the procuring party (project owner).

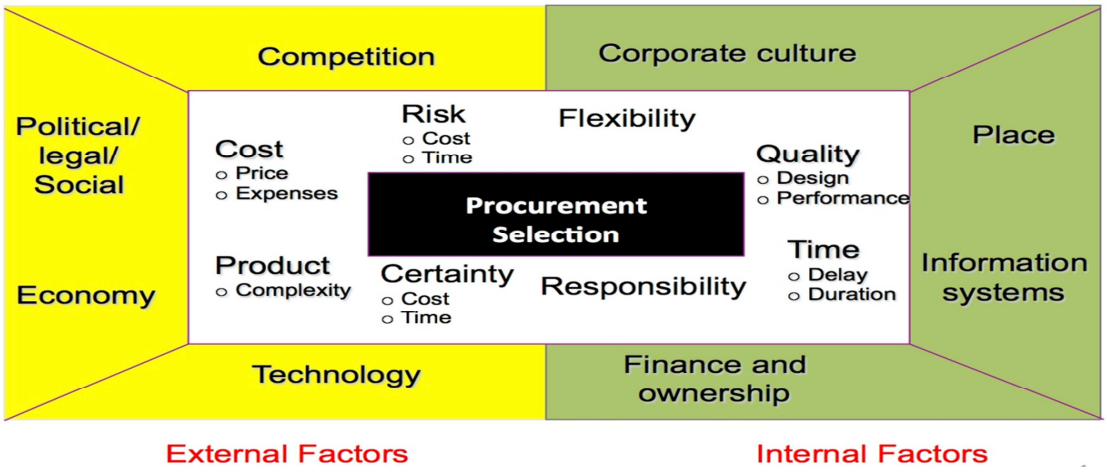

Figure 2: The determinants of procurement systems

Political, legal, and social factors play a crucial role in procurement selection decisions. For example Duncan (Duncan 2009) posits that lump-sum competitive tendering and cost reimbursement systems was the procurement trend in the era of post-war regeneration (1946-1969). During the 1970-1979 period of high inflation in much of the developed world, an increasing preponderance of clients started to use management contracting in the hope of saving some money by ‘smart’ letting of contracts. That said, it is well documented that the management form of contract should be kept in the preserve of ‘experienced clients’ (Masterman and Gameson 1994). Indeed the management route has been cited as a

significant contributor to the cost escalation of such projects as the Scottish Parliament building in the UK (Fraser 2004). Meanwhile the sub-prime mortgage market collapse in 2009 was reported to have caused a shift in procurement trend to design and build (Duncan 2009). Brochner (1990) suggested that procurement selection could be influenced by the level of information system (IT) usage and availability. IT improves coordination between team members, quality control/product inspection, and translation of client needs. Other determinants of procurement systems include: corporate culture (Wright and Race 2004), market competition (Duncan 2009), technology (Duncan 2009, Schermerhorn et al. 2002), project location (Hughes et al. 2006), finance situations and project ownership. These factors are depicted in Figure 2.

3. The research

As earlier alluded to, the current study is a part of a larger research (doctoral) programme that determines suitable construction procurement systems based on TCE tools. Key information in this larger study is outlined under the following subheadings.

3.1 The research questions

The research questions were developed based on the literature reviewed. Clearly there is a current need to investigate the linkage between procurement systems and TCs and to determine how this information could be useful in the procurement selection process. The study therefore will attempt to answer the following key questions:

1. What is the linkage between procurement systems adopted and the magnitude of TCs?

2. How could TCs evaluation help in the selection of appropriate procurement systems for construction projects?

3. How could client's procurement selection procedures be improved?

Addressing these research questions could help to improve procurement selection practices in the construction industry, and subsequently reduce the costs associated with the project administration.

3.2 The research objectives

1. To identify and categorize TCs for two procurement systems, the Traditional and Design-Build in New Zealand construction projects during the pre-contract phase and post-contract phase.

2. To investigate the linkage between the procurement systems adopted and the TCs incurred with this adoption. This objective could be achieved by evaluating the cost of search and information, procurement, and monitoring and control cost.

3. To develop a model for the procurement selection process based on TCs.

4. To provide guidance for the client undertaking the construction and procurement selection process.

3.3 The research design

In pursuit of the goals and objectives of this research, a framework was developed and this is presented in figure 3. This framework contains four sequential phases. The first phase covers problem recognition and research scope. This will be achieved by an extensive review of relevant literature to articulate the research questions and objectives.

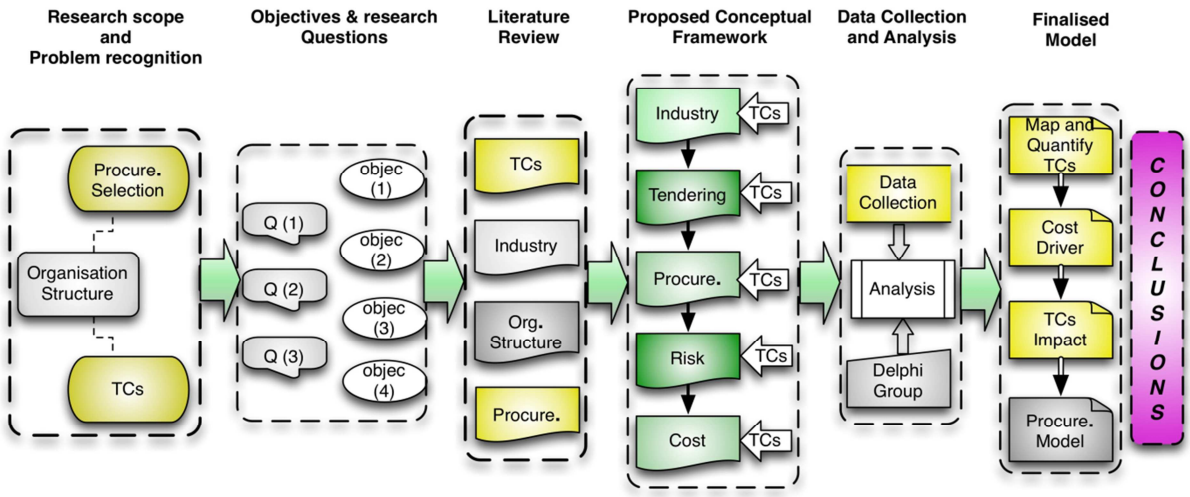

Figure 3: The research design

The second phase involves data collection and analysis. Two data collection tools will be developed to collect information from two key research participants. The first set of information will be obtained through the administration of a pilot questionnaire (using Delphi techniques) to an expert group, to validate the proposed survey questions. The second set of information will be procured through the administration of a semi-structured questionnaire to key construction professionals (at both managerial and operational levels). These professionals (project design consultants, contractors, suppliers) involved in project procurement activities would define processes and identify the time and cost importance of activities within respective processes. Data will be analyzed using structured data analysis techniques. It is envisaged that a verification exercise involving subject matter experts will be conducted to validate the results emerging from these analyses.

The third phase will involve the synthesis of the research findings. This will include a comparison among alternative procurement processes to evaluate the TCs associated with each one. Simple interpretive and descriptive methods of presentation will be adopted so that the findings will be communicative and understandable. This could be achieved using matrices that will indicate the variability of time, resource and technology sensitive costs across the range of activities involved in different procurement systems.

The final phase will conclude the research and proffer necessary recommendations based on the TCE of different procurement systems. It will provide decision makers with guidelines

for the selection of the most applicable procurement systems under a range of project circumstances.

At present the design of the study is largely evolved and the next step will be the collection of data. This is anticipated to be well advanced by mid-2013, with preliminary findings anticipated to be available from that time.

3.4 Potential benefits of the research

Generally, this research will benefit the wider construction industry through enhanced performance by eliminating non-adding value activities throughout project procurement processes. Some other direct benefits include:

1. Enhanced project performance - TCs are very often borne by the construction client as contractors (through submitted bids) and other project parties (through service invoices) pass this on. Eliminating TCs associated with non-value adding procurement activities would ultimately improve construction project performance.

2. Improved operational practice - In construction risks are generated at different levels of the supply-chain such as design and construction risk, financial risk, and market risk. The decision to outsource construction activity is made to reduce TCs through offsetting and/or mitigating risks and reducing capital employed in specialized sub-trades. Therefore improve operational practice, for example procurement practice will improve risk mitigation that inherently improves performance.

3. Reduced coordination and motivation costs - This could be achieved by applying proper strategies such as long-term agreements and alliances, which reduce TCs of writing formal contracts, termination agreements, warranties, etc. These strategies also reduce the risk associated with uncertainty, bargaining and opportunism, and asset specificity.

4. Conclusion

This paper introduced the potential for the use of TCE for determining the magnitude of TCs for different procurement systems in construction. It reviewed TCE, procurement systems and the linkages between them to show how procurement systems selection could benefit from this rational deterministic exercise. It is anticipated that these mechanisms may contribute to a reduction in TCs that may in turn reduce construction prices and/or increase profitability and productivity on construction projects. Further TCE could help to improve the procurement phase through: firstly, developing a service strategy by improving risk profile; secondly, identifying the service goals, objectives and priorities through better contractual agreements; thirdly, identifying capacity development requirements through enhanced long-term strategic procurement approaches; fourthly, ensuring adequate funding through improved cost estimation; and finally, defining the most feasible contractual approach under certain circumstances. This is achievable through discerning the costs associated with activities such as: coordination, inspection, translation, incentivising, and elimination of wasteful interactions.

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Failure and documentation of building structures

Dr. Niels-Jørgen Aagaard[1], Erik Steen Pedersen[2]

Abstract

In recent years, a number of structural failures have occurred in buildings in Denmark, trigging a debate on safety and reliability in the built environment in general. In this context, the quality of the documentation of the capacity and functionality of building structures has been criticised and a common understanding of content and quality assurance of the documentation of load-bearing building structures has been identified.

Based on experience from the Danish building industry as well as guidelines published by the Danish Building Research Institute, the paper discusses the outline and control of documentation of load-bearing building structures. The qualitative analysis includes the content of individual parts of the documentation. A distinction between the documentation of the physical structures and the documentation of the design process is introduced. Furthermore, the organisation of the design process and tasks related to the individual parts of the documentation are discussed both regarding the engineer in charge of the main design and for the individual engineering tasks for all elements of the structure, including drawings and structural calculations.

Finally, the paper discusses a set of information and document management issues of critical importance for the resulting safety of the documented load-bearing structures; e.g. how to administer, document, identify and draw up the individual parts of the documentation; especially how to incorporate results from digital modelling and simulation of structural behaviour into the documentation. It is concluded that an industry standard is necessary in order to maintain the safety levels of load-bearing building structures in the future.

Keywords: Structural failure, defects, safety, quality assurance, documentation

1. Introduction

1.1 Recent incidents

In recent years, a number of structural failures have occurred in buildings in Denmark. In 1999, a storm caused severe damage for approximately 2 billion euros (Andersen & Buhelt, 2000). In 2003, a relatively light snowfall caused the roof of a Sports Arena in Ballerup, Copenhagen, to collapse in 3 sections (Nielsen, 2004a), Figure 1. In 2007, a heavy snowfall

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in central Jutland caused damage to a large number of warehouses, stadiums and commercial buildings (Nielsen & Pedersen, 2008).

In early 2009, a steel-concrete structure of a new skating arena in Copenhagen, collapsed during construction (Pedersen et al. 2009), Figure 2. In February and March 2010, snow accumulating over a period of 2 months caused damage to some 5000 buildings mainly located in northern Jutland, around 300 of which suffered damage of structural significance; they were mainly agricultural buildings (Hansen & Tølløse, 2010). Later the same year, the apse of 'Club Denmark Sports Center' in Valby, Copenhagen, with a span of approx. 80 m. collapsed under the weight of local snowdrifts in what was expected to have been a harmless light snowfall (Pedersen et al. 2011), Figure 3.

Figure 1 Sports Arena, Ballerup, (Nielsen, 2004), Photo: Jørgen Munch Andersen



Figure 2 Skating Arena, Rødovre, (Pedersen et al. 2009), Photo: Niels-Jørgen Aagaard



Figure 3 Agricultural building (Hansen & Tølløse 2010), Photo: John Dalsgaard Sørensen



Figure 4 Club Denmark Sports Centre, (Pedersen et al. 2010)), Photo: Erik Steen Pedersen



In most of the reported cases, failures were caused by defects or omissions in the design phase or in the construction execution. In a small number of cases, failures where caused by unexpected natural loads or load-combinations as prescribed in applying design codes (CEN 2002a, 2003, 2005). In none of the reported cases, failures where caused by unexpected imposed loads on the buildings (CEN 2002b).

1.2 Causalities

Based on an analysis made in (Nielsen, de Place Hansen, & Aagaard, 2009), the following terminology for causality of failures is used: Situation → Cause → Defect → Failure, being a simplified version of the schematic pathway from defects to rework suggested by (Sommerville 2007).

Failure is regarded as the physical loss of functionality; e.g. collapse or major deflection. Defect is the physical relation(s) in the structure that might lead to a failure; e.g. an omission, wrong dimensions or placements of structural elements or unintended modes of operation. Cause is the underlying incident(s) leading to the defect(s); e.g. miscalculations, design errors, gaps in rules of actions, execution errors or inappropriate maintenance. Finally, the situation as such may imply the cause(s) in the first hand. The situation might refer to circumstances in the project, e.g. contracts, organisational matters or staffs competences, or circumstances in the industry in a broader sense, e.g. building regulation, strong competition or 'safety culture' in general.

In a significant number of the reported instances, several circumstances in combination leads to a set of causes that leads to one or more defects that eventually – if the structure is tested by loads at limit level – may cause failure. Consequently, we very seldom observe deterministic relationships between causes and failure; usually a mix of circumstances creates causes that act together, se discussion below.

Causes of defects leading to failures in the above mentioned incidents are grouped into Basis (e.g. regulation and requirements), Design (e.g. inconsistencies and mis-calculations), Construction (e.g. omissions and non-compliance with design) and Maintenance (e.g. deterioration and misuse) in Table 1 corresponding to the generic phases of almost any construction projects. Causes are mainly rooted in design and construction activities and initiatives should respond to this pattern.

Table 1. Causes for defects leading to failures in 6 reported incidents

Incident of failure	Causes for defects			
	Basis	Design	Construction	Maintenance
1. Wind storm 1999		x	X	
2. Sports Arena, Ballerup 2003		x		
3. Snow fall 2007		x	x	x
4. Skating Arena, Rødovre 2009			x	
5. Snow fall 2010	x	x	x	x
6. Club Denmark Sports Centre, 2010	(x)	x		

The reported incidents have triggered a debate on safety and reliability in the built environment in general, and focus has turned towards the culture of quality management in engineering design companies as well as contractors' handling of errors, omissions and rework. It is assumed that the incidents are only 'the top of the iceberg', since many defects will only emerge and show up when loads in rare cases approach the design limit loads. Consequently, the building stock may in general have a lower safety level than intended in codes and regulations (Nielsen, de Place Hansen, & Aagaard, 2009).

1.3 Cost of defects

Analysis indicates that costs correlated to rework due to defects in construction are at a magnitude of 10% of the production value for Danish conditions, not including costs due to delays and rework during construction, (Nielsen, 2004b), (Reenberg et al., 2010), (Erhvervs- og Byggestyrelsen 2011). Research in the English construction industry indicates a magnitude of costs for rework during construction at 15-16% (Barber, Graves, Hall, Sheath, & Tomkins, 2000), while similar case studies in the Swedish construction industry (Josephson & Hammarlund, 1999) indicate some 2-6% of the production value. Reports from Australian case studies indicate costs for rework during construction at a level of 2-3% (Love & Heng, 2000). It is difficult, if not impossible, to compare these figures as the referred investigations define defects in different ways and consequently may include different magnitudes of costs. Nevertheless, it seems obvious that an effort to reduce defects and failures may be necessary both in terms of reducing costs for rework and to ensure the safety level in the built environment.

1.4 Causes of defects

Many causes may contribute to defects and a strict classification scheme for defects is needed in order to analyse the underlying circumstances and causes. Defects are rooted in an array of causes that may act interdependently. A State of the art for classification of design errors are given in (Lopez et al. 2010).

Through seminars and network-based discussions, a handful of possible causes has emerged as being important in a Danish context:

- New ways of organising construction projects
- Fewer competent structural engineers available in the construction industry
- Use of new and advanced structures
- Use of new and advanced materials
- Uncertain or inexperienced use of Engineering Information and Communication Tools (EICT)
- Missing or weak control of design basis and documentation
- Missing or weak supervision of construction execution
- Loss of good workmanship
- Constant demand for productivity enhancements, i.e. reduced costs for design and execution

Each one of these factors, or several of them in combination, may cause defects, which in the end trigger a structural failure. Evidently, the listed causes are not independent of one another, and it one cause might trigger one or more other causes. Obviously, it would be an interesting and important but immense scientific task to reveal the inner causalities and correlations of causes behind defects in general, but some causes seem particularly important for the Danish construction industry: Project organisation, use of ICT and quality assurance, i.e. control of design and supervision of execution.

1.5 Project organisation

For some years, the organisation in the construction industry in Denmark has been undergoing significant changes, and new models for the organisation of a construction project have been tried out. In many cases, structural elements are delivered and documented by many different manufacturers, and the delivery system becomes very complex. Consequently, the design and documentation activities as such are distributed on many subcontractors; and manufacturers leaving the coordination task to the main contractor or consulting engineers (Busby, 2001).

1.6 Use of ICT

The use of Information and Communication Technology (ICT) for static calculations has enabled the construction of more sophisticated and complex structures and made it difficult to ensure the correctness of calculations and documentation. It is often due to the fact that content and formats of output from various ICT systems are defined by the system vendors, who are rarely familiar with the building regulations in specific countries and the design process. ICT systems are seldom fitted to suit the phases of a construction project and the demands for documentation from building authorities.

1.7 Quality assurance

Today management systems for quality assurance or their elements are common in the construction industry and among design companies as well as manufacturers and contractors. In Denmark, the Danish Society of Engineers runs - on behalf of the Danish Energy Agency - a certification scheme for structural engineers that aims to ensure the quality of the design and execution process for load-bearing structures, and allows only certified engineers to perform design and documentation of structures where the consequences of failure would be severe. Unfortunately, these elements of quality assurance differ in structure and content, and expectations to their use may be somewhat uneven among actors in the construction industry. It has been suggested that a major cause of defects has to do with the quality of design documentation produced by consultants and that higher fees would result in improved quality of contract documentation. However, no such significant relationship could be established (Love, Edwards, & Smith, 2006).

Traditionally, designers have browsed or checked each other’s calculations and drawings and made notes on the documents directly. Only in rare circumstances do they distinguish between ‘control’ and ‘acceptance’ and generally, separate documentation of the control and

findings has not been prepared. As the above-mentioned changes have taken place in the construction industry's delivering system, this means that the documentation of load-bearing structures is distributed among many parties, and such ways of control becomes inadequate and insufficient.

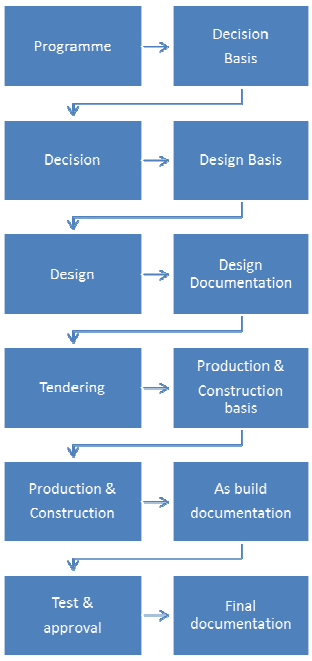
Furthermore, in the traditional way of controlling the execution and ensuring that the construction work is in accordance with the design and intention of designers, designers have supervised the construction work on site. The supervision has often been documented in minutes of meeting or separate memos. Following the more fragmented design processes as mentioned above, each manufacturer has to some extent supervised his own deliveries. Consequently, the extent and level of supervision has faded.

1.8 Structural Documentation

The common focal point for distributed responsibility for quality assurance, uncertain or inexperienced use of ICT and weak quality assurance is the documentation of load-bearing structures, or 'structural documentation' for short. Consequently, building authorities, trade organisations, major design companies and technical universities have joined efforts to develop a common understanding of form and content of structural documentation.

2. Basics on Structural Documentation

It is claimed that a common understanding of form and content of documentation of load-bearing structures may increase the level of safety in the built environment. The assumption is that demands from building authorities concerning documentation will force designers to more careful preparation and calculation of building structures, manufacturers of building parts to document their product in a project-specific way and finally contractors to follow prescriptions more carefully in the execution of the project.



The design, production and execution of building structures may be understood as an ideally serial process; an interpretation of this is illustrated in Figure 5. In the real world, there will be lots of loops and feedbacks that make the picture a lot more complicated, and the process will probably have its unique character for each construction project.

Figure 5 Activities (left column) and documentation (right column). From each activity in the left column, a part of the total documentation is produced.

Internationally, an early attempt to guide the structuring of building related documents is presented in (CIB 1972) and (CIB 1993), while later, the guidelines has bifurcated into separate systems for industrial systems and technical documentation of products, e.g. (CENELEC 2001), and principles for structuring BIM, leaving us today with no international standard for documentation of buildings.

In several countries, national attempts have been made to enhance the project documentation in general. In Spain, an XML-based system has been developed including a new set of taxonomies to support the processes of elaboration, control, verification, digital stamping and compulsory registration and storage of the project documentation by public authorities (Mena, Lopez, Framinan, Flores, & Gallego, 2010). In the UK, benefits and elements of a process documentation system for industrialised housing has been suggested (Roy, Low, & Waller, 2005), and through case studies (Laryea, 2011) shows that the quality of tender documentation is still a problem in construction in the UK despite newly developed standards and best practices. Based on the assumption that there has been a decrease in the level of quality of design and documentation to or from contractors in Australia (Tilley, McFallen, & Tucker, 1999), (Tilley, Wyatt, & Mohamed, 2004) analyse the 'Request for Information' (RFI) process with focus on deficiencies in the overall project performance.

In Denmark, several initiatives address the matter of structural documentation like textbooks outlining design methodology and engineering reporting in general (Mosegaard & Broch, 2008), (Behnke, 2009) as well as methods for structural calculations (Jensen & Hansen, 2012; Jensen, 2003). Specific textbooks address structural calculations of structural elements of specific construction materials like concrete (Jensen, 2012) or steel (Jensen, Bonnerup, & Plum, 2009).

bips (translated from Danish: Construction, Information Technology, Productivity and Corporation), is a non-profit trade organisation specialising in tools for productivity improvements in the construction industry. bips has prepared several systems and best practices on digital description of building components classification systems and BIM, but none of them covered technical calculations and documentation.

The above mentioned works cover general aspects of information and documentation in the construction industry. Only little research has been reported internationally on the importance of quality of documentation for structural safety, although it seems obvious that preparation and control will inevitably catch errors. (Kangari, 1995) reports the importance of having updated and full documentation on arbitration. (Lopez, Love, Edwards, & Davis, 2010) find that no single strategy may handle the problem of design errors, but rather a multitude of strategies needs to be adopted (abstract, p. 399) in construction engineering. They distinguish between three categories of design error: (1) Skill- or performance-based errors, e.g., the plan is acceptable, yet the actions are not performed as planned, (2) Rule- or knowledge-based errors, e.g., the actions are performed as planned, yet the plan did not achieve the outcome intended; and (3) Violations or non-compliances, e.g., to industry or organisation imposed norms and standards." (p.400).

The following proposed framework deals with all 3 types of errors, in the sense that the framework outlines both the planning of the documentation and the preparation of the documentation.

3. Framework

3.1 Documentation of objects and processes

In (Aagaard & Feddersen, 2009), a distinction is introduced between documenting the physical objects/structures and documenting the design process as such. The documentation of the physical objects/structures may be regarded as product documentation, while documentation of the design and execution process may be regarded as documentation of legal responsibilities of the involved parties.

The enhanced framework in Table 2a and Table 2b is proposed for the documentation of load-bearing building structures and design and execution process respectively, and is by the Danish Building Regulation implemented as mandatory structure for documentation of any load-bearing building structures; except those with low consequences of failure according to (CEN 1990).

Table 2a: Documentation of structure

Document	**Part**	**Issues**
A1 Design basis	Building	Building type and use; Type of structure and main elements; Structural sections; Execution, descriptions, models and drawings
	Basics	Codes and Standards; Safety level and factors; ICT-tools, references
	Pre-investigations	Site, soil and local conditions, geotechnical parameters, environmental parameters, environmental and climate conditions on site
	Structures	Structural system and models, functional requirements, service life, robustness, fire, execution
	Materials	Soil, concrete, steel …
	Actions	Combination of actions; Loads: permanent, imposed, climatic, accidental, seismic
A2 Structural analysis	A2.1 Structural analysis of the building	Main structural system; Robustness;, General structural analysis and calculations
	A2.2 Structural Analysis of sections	Design basis for structural sections; Main structural system for sections, verification of structural components
A3 Drawings and models	A3.1 Drawings and models for the building	Plans, sections, elevations, details and 3D models of the building
	A3.2 Drawings and models for the sections	Plans, sections, elevations, details and 3D models of structural sections
A4 Design changes	A4.1 Design changes to the building	Description and verification of design changes to the building
	A4.2 Design changes to the sections	Description and verification of design changes to the structural sections

Table 2b: Documentation of design process

Document	Part	Issues
B1 Report on design process	Building	Type and use of building, situation and context; Overall layout of the building, definition of structural sections
	Organisation	Organisational layout, parties involved, distribution and responsibilities for tasks
	Quality assurance, design	Plan for quality control of design documentation, Documentation of design review Coordination of design review
	Quality assurance, execution	Plan for supervision Documentation of supervision Coordination of supervision
	Design changes	Plan for handling design changes
	Content of documentation	Required list of content for the documentation
B2 Report on quality control	B2.1 Report on review, building	Plan for quality control: type, level and extent of quality control, building Results of quality control and conformity assessment, building
	B2.2 Report on control, sections	Plan for quality control, type, level and extent of quality control, sections Results of quality control and conformity assessment, sections
B3 Report on supervision	B2.1 Report on supervision, building	Plan for supervision, types and level of supervision, extent of supervision, building Results of supervision and conformity assessment, building
	B2.2 Report on supervision, sections	Plan for supervision, types and level of supervision, extent of supervision, sections Results of supervision and conformity assessment, sections

Four important characteristics of the framework deserve special attention: design basis, division of the building structure into sections, report on design process and finally the request for documenting QA.

3.2 Characteristics of the Framework

3.2.1 Sectioning of Building Structures

In modern construction industry, structures are – as many other building components - delivered not by one single supplier but by a wide array of designers, manufacturers, contractors and service providers. Except for rare occasions of total deliveries by one single system supplier, the usual project calls for a massive coordination effort, to ensure that deliveries from one manufacturer fits with requirements as well as connected structural elements. This coordination must also cover the associated documentation. This ‘division of deliverables’ leads to a ‘division of responsibilities’ and finally a ‘division of documentation’ that was unknown in classic previous construction projects, dominated by a strong design team. In a dominating share of the reported incidents, issues of importance for the structural consistency and safety remain unsolved or solutions are based on wrong prerequisites or inadequate assumptions.

It is suggested to overcome this division of responsibilities by a strict division of documentation corresponding to strict sectioning of the building structures each having one and only one responsible supplier. As a consequence of the proposed sectioning, a person responsible for coordination of the documentation should be appointed and tasks relating to the individual parts of the documentation should be outlined both for the engineer in charge of the main design and for the individual engineering tasks for all elements of the structure including drawings and structural calculations.

3.2.2 Design Basis

A comprehensive design basis is necessary for all involved suppliers to relate to and it should ensure that all contributions to the documentation are in accordance with the same prerequisites. The design basis must comprise references to all relevant regulations and requirements necessary to perform adequate drawings, models and calculations. It is suggested that a design basis is constituted as a separate document - with a formal and standardised structure - and kept updated continuously throughout the entire project period.

3.2.3 Documenting control and review

It is crucial to emphasise planning, execution and documentation of control and review activities related to the documentation of the building structures. The framework contains definitions for control, review and inspection, including types and levels of control, planning and execution of control and finally inspection and alteration under construction in order to finish with an ‘as-built-documentation’.

Finally, the framework in (Aagaard & Feddersen 2009) is supplemented with a set of check lists and advice on document management in practice, including how to administer, document, identify and draw up the individual parts of the documentation including principles for handling the digital parts of the documentation and how these parts are incorporated into the documentation.

Conclusion

Strengthening of the culture for quality assurance in the construction industry is necessary in order to maintain the safety levels of load-bearing building structures in the future. Initiatives must take the increased division of labour and responsibilities into consideration, and in practice this calls – among other things - for standardisation of structure of documentation of load-bearing structures as well as project processes; preferably on an international level.

Emphasis must be on review and control of documentation as integrated tasks in the design and construction phases. Special attention is required on review and control of use of ICT and modelling in structural design.

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Affordances of Building Information Modeling in Construction: A Sequential Analysis

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Abstract

Introducing Building Information Modeling (BIM) systems in construction workplaces requires changes to well-established design routines and practices. This paper analyzes BIM-based design activities in a contemporary construction project in order to identify how design professionals have adjusted their practices and what users can accomplish with the new technology. Based on interviews with members from different design professions, a sequential analysis technique was applied to study design routines based on BIM artifacts. The findings indicate that BIM's cooperative affordances, such as its embedded work sharing functionality, were not enacted in practice. Moreover, the systems used did not provide support functionality to inform users in which context the production and coordination technology should be applied. In addition, infrastructure functionality allowing users to transfer knowledge, skills or methods to other projects or planning situations could not be identified. Last, the systems applied in our case did not afford users to store or house information within a device. We found that actors at early project stages had a greater degree of freedom when it came to making use of their design tool affordances than actors working at later project stages. Thus, we argue for the need to focus managerial attention at the choice of design technologies and the enactment of affordances at early project stages. Our findings illustrate weaknesses in existing practice and highlight possible improvements.

Keywords: affordances, sequential analysis, digital design, inter-organizational collaboration, building information modeling

1. Introduction

In recent years, the construction industry has embraced the use of information and communication technology (ICT) in its operations. Construction firms adopt technological innovations because they seek competitive advantage, want to resolve process related problems, are forced by their external environment to implement new technologies, or seek to improve collaboration and knowledge exchange with others (Bossink, 2004). Virtual modeling technologies, frequently referred to as Building Information Modeling (BIM), constitute core technologies for improving the process of construction. Examples of these technologies include applications for surface and solid geometry modeling, model-based drawing generation, 3D visualization, 3D animation and 3D schematic design. Anticipated benefits of BIM include performance gains, increased clarity in information sharing and

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reduction of errors in construction design (Baxter and Berente, 2010). Motivated by these prospective benefits many design offices have replaced their traditional two-dimensional design systems by BIM technology (Rivard, 2004). However, despite an increasing uptake of BIM, scholars report that the industry still misses out on many crucial advantages the technology has to offer (Ahmad and Sein, 2008, Neff et al., 2010). The industry focus on enhancing existing processes rather than changing the way of doing business hinders them from taking advantage of BIM technology. In this respect, construction professionals would need to improve the management of ICT and use technological innovations such as BIM as strategic organizational assets (Ahmad and Sein, 2008). A recent literature review recommended further research into the relationship of BIM's functional affordance and its human agency (Merschbrock and Munkvold, 2012). Functional affordances are defined as "the possibilities for goal-oriented action afforded to specified user groups by technical objects" (Markus and Silver, 2008, p.622). White (2011) argues for the need to conduct further theoretical and empirical work to understand digital infrastructure in practice by focusing on how different professions structure their interaction with the integrated software. Our research follows up on these calls by exploring how BIM is currently used and what BIM technology affords its users in construction projects. Based on our findings we identify areas in need for managerial attention. Thus, our research is guided by the following question: *How can we explore BIM's current use and affordances in construction design, to identify challenges and suggest improvements?*

To address this question we present the results of a case study conducted of a building construction project in Norway. To analyze our data we conduct a sequential analysis (Gaskin et al., 2010) of the design activities in the project. Based on this analysis we develop an understanding of the areas in need for further managerial attention. The intended contribution of this paper is twofold: First, we argue that research based on a sequential analysis can broaden the theoretical understanding of activities and their variations in digital construction design. Second, the practical contribution of the study is to showcase how sequential analysis can be of use to identify required changes to ICT management useful to improve current design practice. The organization of the paper is as follows: Section two presents the sequential analysis perspective, section three presents the research methodology, section four presents the data analysis, followed by the discussion and conclusion.

2. Analytical Perspective

The study reported in this article can be positioned within the current research stream on BIM's impact on social and organizational practices in construction projects (e.g., Gal et al., 2008, Harty and Whyte, 2010, Whyte and Lobo, 2010). This work reports persistent challenges to the successful deployment of BIM rooted in the industry and its established way of working (the projects' mode of organizing, contracts, fees and delays, etc.). Our study is based on the perspective of sequential analysis. Sequential analysis can be defined as an effort in which sequences of human activity, such as work processes are analyzed using time series (Gaskin et al., 2010). Sequential analysis is an analytical perspective widely used in disciplines such as engineering, economics and medicine (Lai, 2001). Further, this perspective has been deployed to analyze sequences of human activity in urban

transportation (Wilson, 2001). Sequential analysis has also received attention by researchers interested in understanding routines and activity in digital design (Gaskin et al., 2010). Sequential analysis is a fruitful lens to identify variations and compositions of routines in design. For example, Gaskin et al. (2011) studied and compared digital design routines across several industries, i.e. a car manufacturer, a semiconductor manufacturer, a mechanical, engineering and plumbing contractor (MEP) and a manufacturing company producing hoses. They found that organizational context has an effect on digital design routines and their variation. Gaskin et al. (2010) suggested a specific methodology for encoding and analyzing routine composition in digital design, based on three steps: (1) determine sample and collect field data; (2) encode data into a lexical model of routine which serves as "…*an 'alphabet' to characterize elements of each design task*" (ibid. p.3); (3) analyze data. Thus far, Gaskin's work draws from a rather limited empirical base and he recommends researchers to analyze design practice in further contexts.

Gaskin et al. (2010) suggest a lexical model consisting of five key elements useful to encode design routines in project based organizations. These elements are: "**activities** [which] are comprised of **actors** engaged with **tools** that **afford** those actors the opportunity to produce design **objects**" (ibid, p.2). Gaskin et al. here adopt Markus and Silver's (2008) definition of functional affordance, as presented in section 1. An overview of the lexical model is presented in Table 1.

Table 1: Lexical model of design routines (adopted from Gaskin et al., 2010)

Routine element	**Definition**
Activities	Specific design task undertaken by actors
Actors	Individual or organization performing the task in question
Tools	Digital or physical tool used to perform an activity
Affordances (1-8):	Defines what an actor can perform with the tools used
(1) representation	functionality enabling users to define or change a description of a design object
(2) analysis	functionality enabling users to explore, simulate, or evaluate alternate representations or models of objects
(3) transformation	functionality to execute a significant planning or design task
(4) control	functionality enabling the user to plan for or enforce rules, priorities or policies governing or restricting the design process
(5) cooperative	enables users to exchange information with others
(6) support	functionality to inform users in which context production and coordination technology will be applied
(7) infrastructure	functionality to transport knowledge, skills or methods to other projects or planning situations
(8) store	functionality allowing information to be housed within a device
Object	The digital or physical outcome of the design activity

Gaskin et al. (2010) developed their view on affordances including eight sub categories based on typologies reported in literature (e.g. Leonardi and Barley, 2008; Henderson and Cooprider, 1994), except for the 'store' affordance which they introduced themselves. Gaskin et al. (2010) argue that their framework is limited in that it's "*more concerned with composition of design routines then their exact sequence* (p. 6)". We address this challenge by classifying the identified routines based on a sequential typology for construction design activities proposed by Evuomwan and Anumba (1998). The eight affordances proposed by Gaskin et al. (2010) are considered a good fit to address the research aim of our study, as they are designed to describe the different ways in which digital design tools such as BIM are applied by industry actors.

3. Methodology

The case study methodology was deployed since it allows the investigation of *"…sticky, practice based problems where the experiences of the actors are important and the context of action is critical*" (Benbasat et al., 1987, p.370). The case project was selected based on three criteria 1) the project participants had to resemble a typical project constellation in the industry (clients, architects, engineers, contractors); 2) the design had to be completed at the time of data collection; 3) BIM technology had to be deployed to some extent in construction design. The setting of our case study is the design and construction of a library and cultural center in southern Norway. The project comprises the construction of a library including a café, meeting places and administrative areas. The building's gross floor area is 1938 m2. The building's wooden structure consists of 27 ribs made of prefabricated glue-laminated timber elements and computer numerical control (CNC) cut plywood boards. In the period from April to May 2012, we conducted nine semi-structured interviews with professionals involved in the design and construction of the project. Semi-structured interviews were chosen as means for data collection as they allow for understanding the experiences from various practitioners using modeling technology in their daily work practice. Three of the interviews were conducted via Skype due to the firms' geographical locations in distant regions of Norway, while the rest of the interviews were conducted face-to-face at the companies. Each interview lasted for about one hour. The interview strategy chosen allowed us to capture the whole design interaction in depth. The interviewees had the following professional roles: design manager (engineering); structural engineer; electrical engineer; fire-protection designer; massive-wood builder (project manager); glue-lime builder (project manager); client's representative (municipality); architect and general contractor (project manager). The author's civil engineering background comprising both university level education and work experience helped to minimize potential social dissonance between interviewer and respondents. The interviews were recorded, transcribed and coded in NVivo 9™ in order to identify activities, actors, tools, affordances and design objects comprising the design routines under study (Table 1).

4. Analysis

The analysis in this paper is guided by the lexical model introduced in Table 1. We present our aggregated data on the case project's design routines and discuss how these were composed. An overview of our findings is presented in Table 2. The routines presented in Table 2 and in the following paragraphs are arranged in a temporal sequence taking into account their occurrences in the process chain. The proposed sequential stages are defined based on Evbuomwan and Anumba's (1998) typology:

- *Negotiation*: client requirements processing; preliminary conceptual design; design of schematics
- *Generation*: analysis and detailed design; design documentation
- *Execution*: construction planning

Routines labeled as 'negotiation' took place at initial project stages, activities labeled 'generation' took place in the mid-stages, and all activities labeled with 'execution' took place in the late stages of the project's design.

Table 2: BIM design routines in the Library Case

Activity	Actor	Tool	Affordance	Object
Negotiation Early-stage design	Architect Client	Architectural BIM software	Transformation Representation Cooperative*	3D BIM model 2D paper drawing set
		Sketching software	Transformation Representation	3D "snapshots" taken of the BIM model
		Rendering software	Transformation Representation	3D "photo realistic" rendered surface model
Generation Architectural design	Architect	Architectural BIM software	Transformation Representation Cooperative*	3D architectural BIM model 3D open standard IFC model 2D paper drawings
		Model viewer software	Cooperative	View of 3D open IFC files
Generation Structural design	Structural Engineer	Structural BIM software	Transformation Representation Cooperative*	3D structural BIM model 3D open standard IFC model 2D paper drawings
		Structural calculation software	Analysis	Structural strength simulations
		Model viewer software	Cooperative	View of 3D open IFC files
		Model checker software	Control	Combination of 3D open IFC files for clash detection
Generation Fire-protection design	Fire-protection engineer	2D CAD software	Transformation Representation	2D paper drawing set
		Computational Fluid Dynamics (CFD) software	Analysis	Fire growth simulation
Generation HVAC design	HVAC designer	Mechanical engineering BIM software	Transformation Representation	3D HVAC BIM model 3D open IFC model 2D paper drawings
Generation Electrical design	Electrical engineer	Electrical engineering BIM software	Transformation Representation Cooperative*	3D electrical BIM model 3D open IFC model 2D paper drawings
		Electrical dimensioning software	Analysis	Electrical dimensioning simulation
Execution Workshop design	Glue lime manufacturer	2D CAD software	Transformation Representation Cooperative	2D paper shop drawings (glue-lime beams)
		3D CAD / CAM solution for timber building	Cooperative	View of full-fledged 3D files
Execution Workshop design	Massive wood manufacturer	3D CAD / CAM solution for timber building	Transformation Representation Cooperative	2D shop drawings Bill of materials Computer Numerical Control (CNC)-data View of full-fledged 3D files
Execution Assembly planning	General contractor	2D CAD software	Transformation Representation Cooperative	2D Site-layout drawings 2D assembly drawings
		Model viewer software	Cooperative	View of 3D open IFC files
*functional affordance has not been enacted				

Early-stage design (Negotiation) was the first in a sequence of activities undertaken to accomplish the design. In close collaboration with the client, the architect developed an understanding of what the future building should be like. The architect visualized his ideas and presented them in digital and physical models, drawings and sketches. The digital design tools used in this routine were architectural BIM software, sketching software and rendering software. The architectural BIM software had the functional affordance to *transform, represent* and *cooperate* based on virtual BIM models. The architect used BIM software to develop the building's outer shape and the building's conceptual layout, thus, he made use of BIM's transformational affordance. Further, he deployed the system to represent his design ideas in form of 3D models and 2D paper drawings to the client. The 3D

models, projected on a screen, served as a basis for discussion at meetings and the 2D paper drawings were handed over to the client. The architect did not deploy BIM's embedded *cooperative* "work sharing" functionality at this stage of the project. The second ICT tool deployed in early stage design was sketching software. This software served as a complimentary tool to the main BIM system in that it allowed the architect to quickly create "snapshots" and sketches depicting certain details of the building, thus it's transformational and representational affordances were enacted in practice. In addition, the architect deployed advanced rendering software to create "photo-realistic" surface models of the building. The surface models made it possible for the architect to create 3D geometric elements signifying the "skin" of the building. Thus, the architect created several different architectural models by using three digital modeling applications in early design.

Architectural design (Generation) was the next activity studied. The main ICT tools deployed by the architect to develop the detailed architectural design were architectural BIM software and Model viewer software. The BIM software served as a tool to create 3D architectural models and at the same time to produce 2D paper drawing sets ergo BIM's *transformational* affordance to create a significant planning task and its *representational* affordance to define design objects were enacted. In addition, the software was used to create open standard IFC files of the architectural model which were used to exchange modeling data with other project partners. The model viewer software provided a *cooperative* affordance, serving as a common environment in which the IFC files created by other designers could be viewed.

We continue by discussing four engineering design activities namely: **Structural, Fire-protection, HVAC and Electrical design (Generation)**. The reason for discussing these activities together is that all these engineering services were provided by the same firm. In terms of sequence all of these activities took place concurrently. First of all, we found that the structural, electrical and fire protection engineers all used engineering systems having *analytical* affordances alongside with their main design systems. These were: structural calculation, Computational Fluid Dynamics (CFD) and electrical dimensioning software. These systems allowed for several analytical operations such as to simulate fire growth, calculate structural stability and electrical dimensions. With the exception of the fire protection designer, all engineers deployed BIM modeling systems to create 3D virtual models and 2D paper drawings of their designs, thus enacting BIM's *transformational* and *representational* affordances. These BIM systems were domain specific, e.g. for mechanical, structural or electrical design, and differed for instance by the availability of certain parametric objects (e.g. electrical designers require cable-trusses and structural engineers require parametric objects signifying reinforcement bars). The fire-protection engineer, however, created his design by using a 2D CAD system to generate 2D paper drawings of his design. The engineers made their designs match by simply discussing relevant issues in their office, for instance, the HVAC and electrical designers shared office and all other designers had their offices on the same floor in the same building. Thus, they did not use the *collaborative* functionality embedded in their BIM systems. However, the engineers had a system in place to align their designs with external parties such as the architect. This system consisted of a model viewer and a model checker, which allowed assembling individually created domain specific BIM models based on open standard IFC files into a common

building model, thus this system was used for its *cooperative* affordance. Throughout the design stages they met with the architect and client in bi-weekly meetings in which all designs were matched and discussed based on a shared IFC model. The engineers and the architect together conducted virtual “walkthroughs” to detect clashes and conflicts between their models in building design.

The activities related to the **Workshop design (Execution)** took place after the architectural and engineering designs were more or less finalized. These activities included the creation of detailed workshop designs required for manufacturing of the wooden building components as well as the detailed planning of their on-site assembly. These services were provided by a general contractor, a massive wood manufacturer and a glue-laminated timber beam manufacturer. The general contractor had a mediating role in that he gathered design information provided by the architect and the engineers and distributed this information further to the massive-wood and the glue-lime beam manufacturer. The general contractor used a 2D CAD system to execute his design tasks ergo he made use of its *transformational* and *representational* affordance. The design objects distributed further were 2D CAD files and 2D paper drawings. In addition he deployed a 3D model viewer affording him the opportunity for “one way” *cooperation* where he could view models created by others but not share any models since no such were created. The general contractor used the model viewer application to view IFC files provided by the structural engineer and the architect as an information source for their on-site assembly crews. The glue-lime manufacturer used a 2D CAD application to create their shop drawings based on 2D drawings provided by the general contractor, thus they made use of 2D CAD’s *transformational, representational* and *cooperative* affordances. Alongside their 2D CAD system they deployed a 3D Computer Aided Design and Manufacturing CAD/CAM solution for wood design to view the architectural 3D model in order to understand the complicated roof shape of the building, thus utilizing this system’s *cooperative* affordance. They opted for using 2D CAD instead of their 3D CAD/CAM solution in design due to the fact that they did not have CNC production machinery large enough to produce the components required for the library. The massive wood contractor deployed an end to end 3D CAD/CAM solution to create their workshop design. The outcomes of their design activity were 2D shop drawings, an Excel bill-of-quantity and CNC data used to control their production machinery. They based their design on the 2D CAD drawings and a 3D virtual model provided by the general contractor and the structural engineer.

5. Discussion

Our findings make it possible to understand the range of affordances BIM technology offered its users at project level and the degree to which these were enacted in practice. While most of the project’s designers made use of BIM’s transformational affordance to create their individual disciplinary 3D models, BIM’s embedded cooperative affordance was only enacted to a very limited degree. Today’s systems such as Autodesk’s Revit® have the affordance to serve as cooperative design spaces allowing for multiple designers from different disciplines to create shared virtual BIM models in collaborative dialogue. Scholars have argued that concurrent design based on a central, shared 3D model is difficult to accomplish with current “packaged [BIM] software solutions” (Whyte, 2011). Instead of collaborating based on a

central model in their BIM systems, the actors collaborated based on a variety of improvised practices. In our case study we observed, for instance, that collocated actors such as the engineers matched their model based designs by simply discussing them in their office. Others collaborated based on paper drawings created in 2D CAD. In addition, several actors exchanged and matched replicas of their individually created project models based on standard IFC file format, shared by deploying model viewers and checkers. However, presuming that BIM's embedded work sharing solutions are technically adequate for cooperative design, we can only speculate why actors opted for not making use of its cooperative functionality.

Literature reports that "*systems promoting teamwork may be rejected by people that usually work alone",* and refer to this phenomenon as "cultural misfit" of technology (Markus, 2004). It could be that BIM's embedded "work-sharing" functionality was rejected due to the fact that construction designers are not used to create designs in concurrent collaboration, but rather like to finalize designs individually before sharing them with others. A second possible explanation for not enacting BIM's inbuilt cooperative affordance could be that it simply does not fit the way in which people work in the construction industry, a phenomenon referred to as "task or business process misfit" (ibid.). If BIM's embedded cooperative functionality is unfit or counterintuitive to people's way of working then it becomes understandable why this functionality has not been enacted in practice, and why the actors deployed other solutions (model viewers or 2D paper drawings) for collaboration.

Further, none of the systems used at project level had the affordance to inform its users about the context in which the design and coordination technology was to be applied. An example for such technology could be a "communication web tool where individuals exchange and organize files as nodes in information dependency maps" (Senescu et al., 2011, p. 3) This finding does not come as a surprise since systems having these affordances are not yet commercially available. Currently, research efforts are underway exploring ways how to develop BIM into a communication facilitating software and an example for this work is the development of the "Design Process Communication Methodology" (DPCM) which has been developed based on ideas stemming from Business Process Modeling (BPM), Human Computer Interaction (HCI) and Organizational sciences (Senescu et al., 2011). In addition to the absence of systems having support affordance at project level, we found no systems having an "infrastructure" affordance useful to transfer knowledge, skills or methods to other projects or planning situations. Moreover, we could not identify systems useful to serve as a central repository providing "storage" affordances to its users. These findings are somewhat surprising as for instance shared BIM model severs or online repositories useful to exchange model drawings and information surrounding the BIM model, which have both storage and infrastructure affordances, have been commercially available to the construction industry for some time.

Apparently, the design practices of several project actors, such as the general contractor and the fire-protection engineer were based on 2D CAD technology. Other project actors interested in communicating with these two parties were required to convert their model based designs back and forth into 2D CAD drawings. Researchers argue that "the conversion of the model […] into 2D drawings" is a common phenomenon in today's

construction projects as industrial practice is still in transition from 2D to 3D design (Whyte 2011). However, having two types of design objects is problematic as "…it takes extra work to get 2D plans and is not just a slice through the model" (ibid., p. 165). Moreover, our findings support that when central project actors, such as the general contractor, do not deploy 3D tools affording them to collaborate with others then the project partners begin to improvise and "bypass" these actors in their communication. In our case project, for instance, the subcontractors (massive-wood contractor and the glue-lime builder) approached either the structural engineer or the architect to establish a direct access to 3D modeling data. Thus, the general contractor's traditional role as information hub for the subcontractors was undermined by him not deploying 3D modeling technology. The fire-protection engineer's inability to participate in modeling had less severe consequences, since he was collocated with the other engineers who readily incorporated his 2D design in their 3D models.

There is high task interdependence between the designers participating in the different design stages of negotiation, generation and execution. Engineers depend on prior work provided by the architects and so forth. This fact is owed to the sequential nature of construction design in which design is gradually accumulated over time. We found that actors' possibilities to use their design systems for goal-oriented action or their "freedom of enactment" depended on when in the design process they contributed. We define freedom of enactment as the degree of flexibility which an actor has to act in a given structure such as BIM information systems (Weick, 1988). While actors working in early project stages (e.g. architect) enjoyed relative freedom in enacting their design tool affordances (in our case the architect used three different modeling systems), actors in later project stages are constrained in their ability to make goal-oriented use of their technology. These constraints stem from the necessity to work with design data previously created by others.

Examples of project actors being less fortunate than the architect regarding the freedom of enacting their tool affordances were subcontractors such as the massive wood and glue-lime entrepreneurs who were dependent on design created by their predecessors. They needed to incorporate previously created 2D CAD files or 3D models from a variety of systems into their design. Thus their capability to deploy their own systems effectively for goal-oriented action was reduced. A graphical illustration depicting that an actors' position in the design process relates to the freedom of tool affordance enactment can be found in Figure 1. We argue that choices made at an early stage of a project with regards to which tools and affordances are enacted in practice may have a profound effect on the opportunities for goal-oriented ICT mediated action at later project stages. Thus, we argue for the need to direct managerial attention at decisions made in early design stages, foreseeing their potential consequences which may constrain actors in later project stages in using their systems effectively. In addition, it seems that the case study results could be partly explained due to a lack of explicit agreement on software to be used and on the strategic management of the BIM implementation (Merschbrock, 2012). Moreover, the results may be attributed to a lack of client commitment to using BIM at project level, and the varying maturity in using advanced systems such as BIM among the individual project participants.

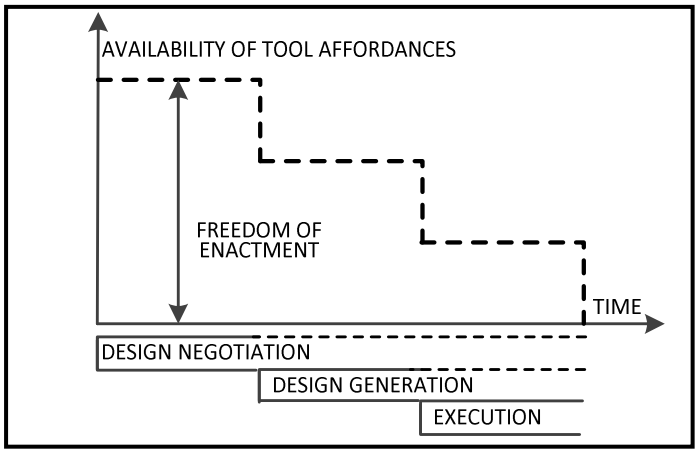

Figure 1: Freedom to enact tool affordances in construction design

We believe to have provided some practical insights helping to understand some of the weaknesses in current practice and some of the hurdles preventing practitioners from reaping the benefits of BIM technology and we have presented suggestions for how these hurdles could be overcome. Gaskin et al. (2010) provided a list of research avenues worthwhile pursuing, e.g. to study the extent to which "design routines within in a single project […] are similar and different, in what ways, and how do they mutate over time?" (p.12). We have contributed to their work by an in depth discussion of the similarities and differences of the design routines within our construction project, however, our work is limited in that we did not provide a longitudinal perspective identifying if and how these design routines mutate over time. Deploying a longitudinal perspective explaining how actors' routines vary beyond the project studied could be a worthwhile avenue for further research.

6. Conclusion

By deploying a sequential analysis it was possible to develop an understanding of the use and affordances of BIM technology in digital construction design. Despite heavy investment by most project actors in new modeling technology, several organizational and technical challenges prevail. On the technical side, the tools deployed at project level had several shortcomings in their functionality, lacking support, infrastructure and store affordances. Moreover, the cooperative affordance embedded in the BIM systems had not been enacted in practice. In addition, we found a central project actor still deploying 2D CAD instead of 3D modeling technology in design, requiring frequent transition of model based designs into 2D CAD drawings. Thus, it may be questioned if the tools used at project level were "good, complete, aligned and used and appropriately managed for benefits" (Markus, 2004). On the organizational side, we could identify many practices surrounding the modeling activity which were merely improvised "workarounds" that emerged in response to the affordances of the tools used at project level. These workarounds, in combination with the lacking tool affordances, resulted in the designers missing out on the radical improvements often attributed to BIM technology. We argue that some of the identified weaknesses can be attributed to a lack of managerial attention directed at the early stages of the project. However, our view on design routines is developed based on a single case study and interviews with a selected number of practitioners. Even though we argue that our findings

have relevance beyond the case project studied, additional research studying multiple projects and contexts is needed to further validate our findings.

Acknowledgements

Bjørn Erik Munkvold provided helpful feedback. This work is supported by grants from the Competence Development Fund of Southern Norway and Vest-Agder County Municipality.

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Optimising Building Affordability and Operational Costs – A Case Study of the Parallel Design Philosophies in the Use of Cool roofs in Australia.

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Abstract

In 2006, the Building Code of Australia (BCA) introduced energy efficiency requirements for new Class 2 to 9 buildings. Over time, the regulatory approach has been to increase the energy efficiency requirements. This has led to the development of products designed to improve the thermal performance of the building envelope. This paper examines one of these products, cool roofing.

In considering the design philosophies in the use of cool roof technology, two alternate frameworks are possible; to improve a building's energy efficiency or to deliver construction cost benefits. Particularly at a time when building costs are achieving great focus, understanding these frameworks provides additional options for optimising the design of the roof to deliver the best combination of energy efficiency, operating and capital costs of a building.

It is shown that, for the case study building, the cool roof is able to deliver economic benefit in most environments in Australia. The philosophy of improved energy efficiency is shown to have an attractive economic pay back in most climates, while the philosophy of efficient building construction leads to immediate capital savings. In both cases, there is the additional benefit of reducing the urban heat island effect.

Keywords: cool roofing, solar reflectance, energy efficiency, construction cost.

1. Introduction

Cool roofs are characterised by having high solar reflectance and high thermal emittance (Akbari and Levinson, 2008). The coolest roofs are typically white; however technology has been developed to provide high solar reflectance products where colour is required, referred to as cool colours. Cool roofs provide a range of benefits, including energy efficiency of buildings, human comfort and reduction in the urban heat island effect (VanCuren, 2012). Whilst cool roofs are also often promoted on the basis of reducing urban heat, including through credits in green rating tools (LEEDUser, 2012) the principle focus of this paper is upon energy efficiency of buildings.

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A primary benefit of cool roofing is its ability to reduce the heat transferred to the building below, and as a consequence reducing the building's cooling load. Many factors influence the savings from cool roofing, however high savings are typically achieved for single or 2 storey buildings that have high cooling demand. High cooling demand is typical of buildings in either a warm climate, predominant daytime only occupation or a high internal load. Retail buildings, which are the focus of this study, can provide all three of these situations in combination, and therefore have some of the highest levels of cooling demand of any building typology.

The major design philosophy of using a cool roof has been to improve building energy efficiency. An alternative approach is the philosophy of using a cool roof to deliver equivalent energy efficiency to a nominal roof design, and deliver construction cost benefits. These two distinct design philosophies are considered for a case study retail building.

2. Literature on potential of cool roofing

Numerous studies demonstrate that cool roofs can significantly reduce energy costs, particularly for single storey buildings in warm climates. For example, Akbari et al. (2004) documented that 72Wh/m^2/day (52%) air conditioning energy saving was achieved by replacing an existing dark roof (solar absorptance, α=0.79) with a cool roof (α=0.2) for a retail building located in Sacramento California during summer. Bhatia et al. (2011) demonstrated, based on a calibrated simulation, that an office building (663 m^2) in a cold climate in India (Shillong) can still achieve valuable savings from a cool roof, with annual savings of 4586 kWh or an average saving of 19 Wh/m^2/day. Parker et al. (1998) reported average mid-summer cooling energy savings of 19% in Florida by lowering the roof's solar absorptance by painting them white based on measurement of 11 homes. Similar results have also been found in other residential building studies where white metal roofing has been used (Parker et al., 2002, Chasar, 2005).

A cool roof primarily saves cooling energy by reducing solar heat gain into a building (Mechanism 1 and 2 in Figure 1). For some buildings further savings are achieved due to reduced heating of the cooling system (Mechanism 3 in Figure 1). This is true for buildings where the duct system is located in the attic, upon or just beneath the roof and/or has a roof-mounted Heating Ventilation and Air Conditioning (HVAC) system. Further, for cool roofs where the HVAC inlet is on the roof, the air intake temperature is lower than for standard roofs (Mechanism 4 in Figure 1). Carter (2011) proposed that this is a key factor in explaining why current simulation software underestimates the energy saving potential of cool roofs. Whilst the impact of solar heat gain transferred to the building below is usually accounted for (Mechanism 1 and 2), other factors associated with a cool roof's impact upon a cooling system are not (Mechanism 3 and 4).

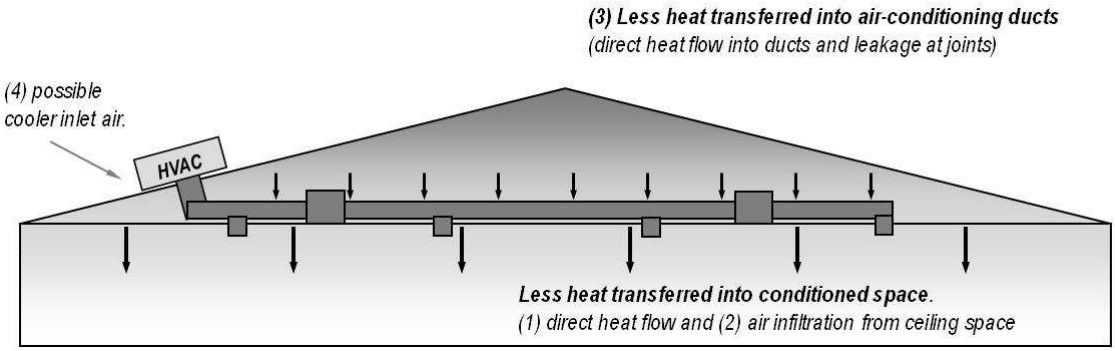


Figure 1: Cool roof impacts upon a building and its cooling system.

Gentle, Aguilar and Smith (2011) demonstrated that for certain buildings, where a cool roof is used, an optimum level of insulation can be determined. Similarly, Carter (2011) showed that the air temperatures around cool roofs lead to an improvement in the operation of the conditioning equipment in warm climates.

Given the current software limitations, this paper only considers the primary saving potential of a cool roof as a result of solar heat gain transferred to the building below (Mechanism 1 and 2). Further investigation is required to better understand the value of other factors influencing cool roof savings, in particular the impact of a cooler roof upon cooling systems (Mechanisms 3 and 4).

3. Modelling methodology

3.1 Simulation software

The building simulation conducted for this paper uses the DesignBuilder interface, which uses EnergyPlus simulation software.

3.2 Building constuction

The building modelled in this paper is a rectangular store with flat roof of size 40m×50m×5m (W×L×H) and set with its 50m side facing to the north (Figure 2). The glazing ratio of the north façade is 12% and the other three facades have no glazing. The building geometry was chosen to resemble a medium sized retail building, such as a supermarket.

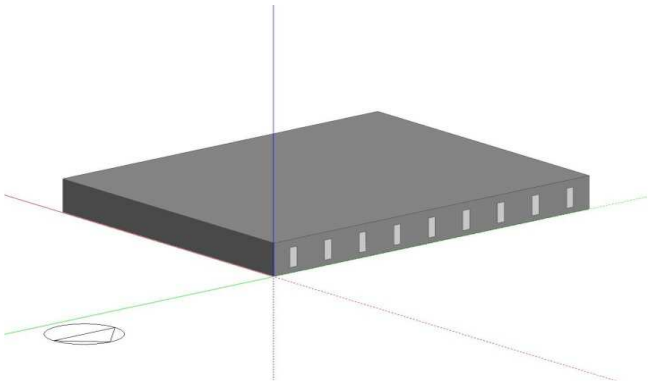


Figure 2: Overview of the building modelled.

The reference building fabric wall and roof layers used in the building model and corresponding total R-value are shown in Table 1. The insulation levels and surface properties are based on the National Construction Code (NCC) BCA 2012 Volume 1 Section JV3 (Australian Building Codes Board, 2012).

The study includes comparison of two forms of roofing against the reference roof, a white prepainted steel roof and a resin coated aluminium/zinc (AZ150) roof, referred herein as a cool roof and a bare metal roof. The assumed cool roof and bare metal roof solar absorptance are 0.23 and 0.35, respectively, and thermal emittance are 0.87 and 0.3, respectively. The Cool Roof Rating Council (2009) contains typical values for cool roof and bare metal roof products. The solar absorptance used in modelling were increased by 0.05 to 0.28 and 0.40, respectively, to allow for weathering as required by Section JV3 (Australian Building Codes Board, 2012).

Table 1: Reference building construction

Construction	Wall	Roof
Layer 1	BRICKWORK outer leaf (100mm, k=0.84)	Metal Deck (0.42mm, k=48)
Layer 2	Concrete Block Medium (100mm, k=1.35)	Air Gap (30mm, R=0.18)
Layer 3	Glass Wool (84mm, k=0.037)	Glass Wool (20mm, k=0.007)
Layer 4	Air Gap (10mm, R=0.18)	Plasterboard (10mm, k=0.4)
Layer 5	Plasterboard (10mm, k=0.4)	N/A
Base Solar Absorptance	0.6	0.7
Thermal Emittance	0.9	0.85
Total R-Value	2.838 $m^2.^oK/W$	3.202 $m^2.^oK/W$

Note: k is thermal conductivity in $W/m.^oK$,
R-Value is thermal resistance in $m^2.^oK/W$.

3.3 Internal loads

Internal loads heat a building, which can be beneficial in cold climates and deleterious in warm or hot climates. Internal loads in retail buildings include occupancy, lighting and equipment. This paper includes consideration of a high and a mid range internal load case.

The high internal load case is in line with the Green Star Retail Centre Energy Modelling Guidelines (Green Building Council of Australia, 2009), and is summarised in Table 2. Such high internal loads may exist in a supermarket as a result of refrigeration equipment within the building. The equipment load in these Guidelines is higher than the default value in Specification JV for a retail building of $5W/m^2$ (Australian Building Codes Board, 2012). A set of lower internal loads was also modelled (as shown in Table 2) with reduced loads for both equipment and lighting. A daytime building operation schedule was assumed for both internal load cases based on the Green Star Retail Building Guidelines (Green Building Council of Australia, 2009).

Table 2: Assumed internal loads

	High Internal Load	Mid Range Internal Load
Occupancy m^2/person	4	4
Metabolic Rate (Sensible) W/person	70	70
Metabolic Rate (latent) W/person	60	60
Total Lighting Load (W/m^2)	20	14
Equipment Load (W/m^2)	40	5

Note: As EnergyPlus/DesignBuilder defines metabolic rate based on human behaviour, light office work/standing/walking was selected instead of defining it as W/person.

3.4 HVAC assumptions

The following assumptions were made for modelling of the HVAC system and based on default software values and BCA Sec J5.4 (Australian Building Codes Board, 2012): a Co-efficient of Performance of 2.7; a 5% distribution loss; cooling and heating setpoint of 22ºC and 24ºC respectively; and mechanical ventilation of 2.5 l/s.m^2.

3.5 Scope

The variables considered in this paper were chosen to allow investigation of the influence of insulation levels when cool and non-cool roofs are used for a typical retail building located in different climate regions of Australia.

The variables considered include:

- Roof type: Comparisons between the reference building roof (Table 1), with a cool roof and a bare metal roof.
- Climate: Seven locations (Darwin, Brisbane, Tenant Creek, Kalgoorlie–Boulder, Perth, Melbourne and Hobart) representing all of Australia's BCA climate zones except for alpine (Zones 1 to 7).
- Internal load: A high and a mid range internal load case.
- Roof insulation level: Roof insulation total R-Values ranging from R0.18 for an uninsulated roof up to R4.2. A total R-Value of R4.2 is the highest BCA minimum requirement for climate zones 1 to 7 (Table 3).

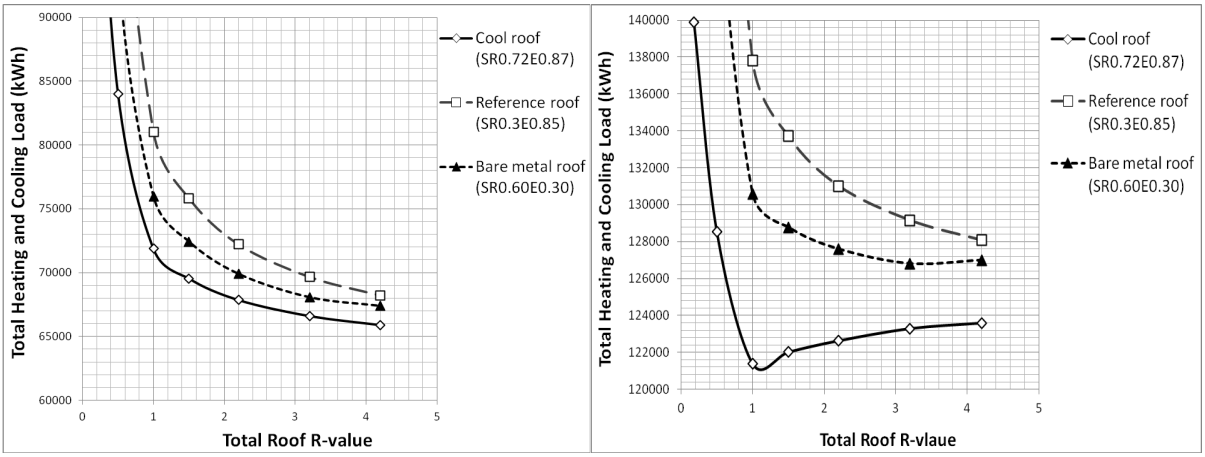
Table 3: BCA minimum prescriptive roof Total R-Value requirements (Australian Building Codes Board, 2012)

Climate Zone	1 to 5	6	7	8
Direction of Heat Flow	Downwards		Upwards	
Roof solar absorptance value of not more than 0.4	3.2	3.2	3.7	4.8
Roof solar absorptance value of more than 0.4 but not more than 0.6	3.7	3.2	3.7	4.8
Roof solar absorptance value of more than 0.6	4.2	3.2	3.7	4.8

4. Results and discussion

4.1 General

Modelling was completed to determine the annual heating and cooling energy demand (thermal load) for each climate, roof type, insulation and internal load. The data was plotted comparing the thermal load for different roofing products at different insulation levels. An example is shown in Figure 3, which charts the results for Perth (climate zone 5) for mid range (Figure 3a) and high (Figure 3b) internal load cases. It is clear from this that increasing insulation creates a diminishing benefit, and in the case of a high internal load, the increased insulation can increase rather than decrease the building's thermal load.

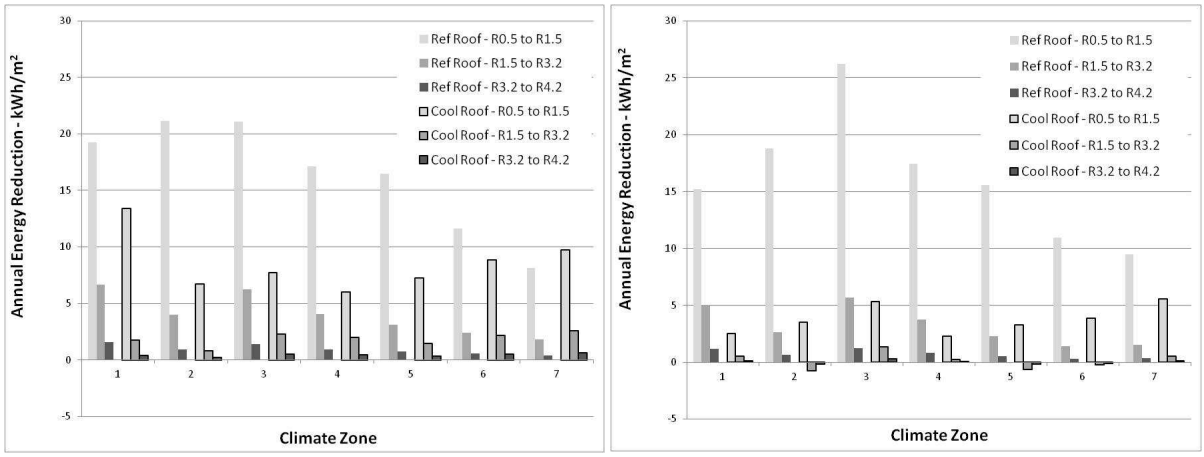


(a) mid range internal load ***b) high internal load***

Figure 3 Annual thermal load – Perth (Zone 5)

This type of thermal load curve applied in all seven climate regions modelled. For all climates the building's thermal loads were found to reduce dramatically up to an insulation level of about R1 to R1.5, highlighting the significant benefit of modest insulation (see Figure 4). There is less incremental benefit from greater levels of insulation. Under certain conditions additional insulation reduces the energy efficiency of a cool roof building (Figures 3b and 4b). Insulation acts to slow heat moving through the building fabric. There is a trade-off in the value of additional insulation between reducing the solar load coming in through the roof, and impeding the ability for the heat (due to internal loads or gains through the façade) to escape the building. The results show that for cool roofs on buildings with high internal loads and in temperate climates that have high night cooling potential (zones 2, 5 and 6) that an optimum level of insulation exists. For each of these climate zones, Figure 4b shows a decrease in annual energy reduction as insulation is increased from R1.5 to R3.2, i.e. the higher level of insulation led to greater energy load.

For more thermally absorbent roofs, the results show there is still a benefit in additional insulation, albeit smaller, as its value in limiting the solar load through the fabric is greater than the negative impact of impeding the ability for heat to escape the building.



(a) mid range internal load ***b) high internal load***

Figure 4 Value of insulation to reduce thermal load

This finding that, in certain circumstances, a minima in thermal load can occur at an optimum rather than maximum level of insulation is in agreement with the work of other researchers. A number of studies have found that under certain conditions insulation did not improve walling performance (Johnson, 1997, Barkaszi and Parker, 1995, Masoso and Grobler, 2008), whilst research at UTS has shown that for certain buildings, where a cool roof is used, an optimum level of roof insulation can be determined (Gentle, Aguilar and Smith, 2011).

4.2 Financial consideration of the cool roof benefits

This section examines the modelled outcomes of two distinct design philosophies, using a cool roof to either increase a building's energy efficiency or deliver construction cost benefits. The merits of bare metal roofing are also considered.

4.2.1 Using a cool roof to increase energy efficiency

As already discussed, the traditional approach to use of cool roof technology in buildings has been to reduce the heat transmitted into the building, improving building comfort or when conditioned create operational savings. Whilst not considered here, improved energy efficiency can also lead to higher building ratings, such as NABERS, that may improve capital values and or rental yields.

For R3.2 roof insulation, the maximum saving was 13 Wh/m^2/d or 6.5% (and a peak cooling load reduction of 8 W/m^2) in changing from a roof solar absorptance of 0.70 to 0.28. This is lower than savings discussed in the real building studies (19 and 72 Wh/m^2/d) in Section 2, again indicating that modelled cool roof savings may be underestimated relative to real world performance.

The operational financial savings from a cool roof can often provide payback of the extra cost for appropriate buildings. However, this will depend on several factors:

- Cool roofing costs can vary widely from around \$2/m^2 for cool pre-finished roofing products to more than \$20/m^2 for some post applied solutions (US EPA, 2012).

- Energy tariffs also vary widely, and can include combination of cost components of consumption, peak demand, time of use and fixed daily charges.

Cool roofs can provide benefit through reduced consumption, reduced peak demand and savings tend to coincide with the higher time of use tariffs. For simplicity assuming a single consumption tariff of 28 c/kWh with the conservative modelling results, the cool roof saving is predicted to be up to \$1.33/m^2/year.[3] In addition, potential also exist to scale down the size of the cooling equipment creating an additional upfront saving of around \$2.40/m^2 assuming equipment cost at \$300/kW (The Centre for International Economics, 2009).

These predicted savings are based on the change in solar absorptance of 0.42 in this study. Linear interpolation of the relative solar absorptance of similar products will provide a reasonable estimate to assess the operational saving and payback period for alternative solar absorptance products.

4.2.2 Using a cool roof to deliver construction cost benefits

A cool roof can be used to deliver construction cost benefits for a new building required to meet BCA energy efficiency requirements. This approach involves the use of BCA Section JV3 (Australian Building Codes Board, 2012), which recognises that comparable energy efficiency of a reference roof can be achieved at a lower insulation level with a cool roof.

In the cases of high internal loads, it is possible that the cool roof may deliver an improved energy efficiency outcome (and lower operating costs) as well as lower capital costs, for those situations where there is a minima in the thermal load curve for cool roofs (see Figure 3(b) and climate zones 2, 5 and 6 in Figure 4(b)).

BCA Section JV3 allows verification of a 'proposed building' by modelling that shows the performance to be as good as, or better than, a 'reference building'. The 'reference building' is required to be equivalent in most respects to the 'proposed building' but include some mandatory prescriptive features. The 'reference building' must have a roof solar absorptance of 0.7 and prescriptive insulation levels as per Table 3. For the building modelled in this study, an insulation level for the cool roof was determined that provides equivalent performance to the building as the reference roof with prescriptive insulation levels, thereby meeting the BCA Section JV3 performance requirement. The equivalent R-value for each climate zone and internal load case is contained in Table 4. Again, this is solely based on Mechanisms 1 and 2 in Figure 1, and does not take into account the additional unmodelled benefits of Mechanisms 3 and 4.

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[3] A \$1.33/m^2 saving is determined on the basis of 28 c/kWh with an average daily saving of 13 Wh/m^2 (365x0.013x0.28). Example electricity rates for small to medium business can be found at:
http://www.originenergy.com.au/976/Energy-Price-Fact-Sheets?
http://www.qenergy.com.au/docs/default-document-library/ausgrid_price-fact-sheet_nsw_freedom-biz.pdf?
http://www.momentumenergy.com.au/system/files/documents/PPIS/01102012-PPIS-SmilePower-SME-NSW.pdf

Table 4: Cool roof Total R-Value required for equivalence to reference building

Zone	Location	Reference Roof	Cool Roof	
			Internal Load	
			High	Mid Range
1	Darwin	4.2	0.50	0.93
2	Brisbane	4.2	0.50	0.95
3	Tenant Creek	4.2	1.00	1.56
4	Kalgoorlie–Boulder	4.2	0.50	2.12
5	Perth	4.2	0.53	2.06
6	Melbourne	3.2	0.74	3.12
7	Hobart	3.7	1.14	>3.7

Table 4 indicates that replacing the reference roof with a cool roof on the modelled building leads to the potential to:

- In all high internal load cases, reduce the total insulation requirement to under R1.5.
- For mid range internal loads,
  - in climate zones 1-5, reduce the total insulation requirement to around R1.5 to R2, and
  - for the cooler climates of zones 6 and 7 (Melbourne and Hobart), the cool roof does not substantially alter the insulation requirement[4].

The simulation results highlight that many retail buildings can reduce roof insulation levels when cool roofing is used, by using the verification method of BCA JV3, rather than using the prescriptive deemed to satisfy approach. The reduced insulation requirement has the potential to drive construction cost savings through thinner insulation and avoiding the need for roof raiser systems that are often used for commercial roofing to limit squashing of insulation between the roof and safety mesh. The construction cost savings attributable to being able to use thinner blanket and foil insulation is about $\$2/m^2$ for a 25mm reduction (≈R0.5 reduction) in thickness (Cordell, 2012). The removal of the need for a roof raiser system has the potential to save significantly more than the insulation saving ($>\$10/m^2$)[5].

4.3 Relative performance of bare metal roofing

Bare metal roofing, which is often used for commercial roofing, was modelled to understand its relative performance. The results of this study have shown that the heating and cooling energy load of the building with a bare metal roof lies typically between the cool roof and the reference roof, although closer to the reference roof for the warmer climate zones and high internal loads (Figure 3). The exceptions are for the cooler climates of Melbourne and Hobart with mid range internal load.

[4] Had the model been capable of incorporating the benefit created by cool roofs, as discussed in Section 2, a reduced insulation requirement may have also been achieved for these cooler climates.

[5] Cost estimate from unpublished industry survey.

The insulation required using a bare metal roof to provide equivalent performance to the reference building in accordance with BCA Section JV3 is provided in Table 5. These results show that the ability to significantly reduce insulation using a bare metal roof is likely to be quite limited. Further, bare metallic coated steel is known to weather more than pre-painted steel (Cool Roof Rating Council, 2012) leading to poorer relative long term performance of the bare metal roof than considered here.

Table 5: Bare metal roof Total R-Value required for equivalence to reference building

Zone	Location	Reference Roof	Cool Roof	
			Internal Load	
			High	Mid Range
1	Darwin	4.2	3.77	3.43
2	Brisbane	4.2	2.13	2.88
3	Tenant Creek	4.2	3.60	3.68
4	Kalgoorlie–Boulder	4.2	3.18	3.53
5	Perth	4.2	1.93	3.12
6	Melbourne	3.2	2.05	2.81
7	Hobart	3.7	2.61	3.43

5. Conclusion

This case study has modelled the impact of cool roofing on heating and cooling a retail building with different levels of insulation and internal load, based on the two first two mechanisms for cool roof performance articulated in Figure 1. The results demonstrate the value of the two distinct design philosophies aimed at creating energy efficiency improvements or construction cost benefits of using cool roofing for a retail building.

The results show that, for the building modelled, a cool roof increases the energy efficiency of the building. Noting that the additional benefits of Mechanisms 3 and 4 are not included, for the retail building considered an operational saving of up to \$1.33/m^2/year was determined on the basis of a solar absorptance change of 0.42. The operational financial savings provided economic payback of the extra cost of cool roofing products.

The alternative approach in this paper has shown that in most climates of Australia for the retail building considered, a cool roof can allow thinner roof insulation creating reduced need for roof raisers, potentially providing a lower total construction cost. Where the retail building also has high internal loads, in some climates, both reduced insulation was possible with an increase in energy efficiency thereby also delivering operational savings.

The case study has highlighted the importance of the relationship between internal loads in buildings and insulation, particularly for cool roofs. For high internal loads in the retail building studied, for some climates, there was an optimal insulation level beyond which additional insulation increased energy loads for cool roofing.

This paper has considered the savings attributable to cool roofing from models rather than real building studies, and notes the reasons that modelling often under predicts the observed benefits. This risks underselling the appreciable benefits of cool roofs and the benefits to the carbon footprint and energy efficiency they can deliver to the built environment. Further investigation is required to address these inadequacies and ensure that models more accurately account for the full range of benefits. The final set of benefits around the mitigation of urban heat island at a precinct level needs additional quantification, though this is more readily dealt with in precinct models rather than individual building models.

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Development of SCM competencies in construction: Lessons learned from New Zealand

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Abstract

The construction industry, which contributes around 5 percent to gross domestic product, is a vitally important industry in New Zealand. With over 50,000 businesses, the construction industry is the third largest industry by business count in New Zealand's economy (Statistics New Zealand 2009). Although it is widely accepted that productivity can be improved by adoption effective supply chain management (SCM), no studies have investigated this in the New Zealand context. The purpose of this paper is to understand the nature and extent of current practice of Construction Supply Chain Management (CSCM) in NZ construction. Consequently to examine whether current SCM practice exemplified in NZ could be considered to be international 'Best Practice'. A case study approach is used for probing SCM practice on a NZ$75m commercial project located in Auckland Central Business District (CBD. The supply chain network of the principal ground works and superstructure construction stages was studied. The key findings of the case study suggest that the flow of materials remains the main focus of CSCM practice. It was found that essential skills training for CSCM was extremely limited and largely ill-defined in terms of its nature and content. Finally it was identified that as the NZ construction industry moves towards a significantly more collaborative framework, the efficacy of CSCM operations is expected to substantially improve. However this last point did not negate the requirement to expand and improve skills training in CSCM. This indicates that there is room for improving CSCM to reduce construction project costs and increase productivity.

Keywords: construction supply chain management, logistics, skills, training, collaboration, New Zealand

1. Introduction

The construction industry is regularly described as suffering from poor performance (Cox and Ireland 2002), such as time and schedule overruns, quality defects and poor health and safety performance. Similarly, findings from numerous studies have categorised the problems facing construction into five broad areas: industry's fragmented nature, adversarial relationships between participants, project uniqueness, separation of design and production,

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and competitive tendering. Supply chain management (SCM) and related concepts (i.e. partnering, alliancing and PPP) have been proposed as solutions to these issues.

As a result these 'post modern' contracting frameworks have received increasing interest in construction research and practice (Bankvall et al. 2010; Briscoe and Dainty 2005; Bygballe et al. 2010; L??nngren et al. 2010). In NZ there have been numerous studies and discussions related to the implementation of such high level strategic approaches on the behaviour of the NZ construction sector (Liu and Wilkinson 2011; Masurier et al. 2006) which is very much in line with 'rest of the world' thinking. This is an interesting observation since the understandings of the principles of SCM in NZ are much less well documented from the literature.

As the scale of the discussion is brought down to focus on tactical issues around construction and site operations, SCM literature is quite substantial. However, as the scope of discussion area has reduced, the amount of work specifically related to the NZ experience of CSCM has reduced. This is a key finding since at present there seems to be an oversupply of NZ research targeted at the high level, strategic aspects of CSCM, but is unsupported by research dealing with the low level capabilities necessary for its effectiveness. The main conclusion to date is that the construction industry worldwide seems to be facing problems in managing supply chains and is lagging behind in terms of supply chain practices (Bankvall et al. 2010), and specifically in NZ there are many deficits in the knowledge of best CSCM practice. This paper illustrates the initial results of an ongoing research project which aims to map construction supply chain structure in the Auckland region. The aim of this paper is to investigate the adoption of SCM to date in the NZ construction industry. There has been little research on the understanding of the nature and extent of CSCM current practice in NZ. The research described in the paper begins to fill this current gap in New Zealand SCM knowledge. It also seeks to establish current best practice elsewhere, before proposing how the NZ industry can improve its performance to achieve higher efficiency and productivity.

The paper starts with a preliminary inquiry into how SCM is viewed in NZ construction. This is conducted through a review of construction literature with regard to various flows of construction supply chains occurring at a construction site. Thereafter, barriers in implementing SCM in constructions are examined. The case study methodology and key findings are described subsequently. In the concluding section, the principal insights and suggested directions for future research are discussed.

2. Construction supply chains: barriers and contributors to 'Best Practice'

2.1 Construction: An Industry Unique?

Compared to other industries, such as manufacturing, the construction industry is a highly project-centric industry. As we have indicated previously it operates in an environment of extreme complexity and uncertainty. This is largely due to the fragmented structure of its supply chain, short term trading relationships, poor information flows and a high degree of

dependency between tasks and activities (Briscoe and Dainty 2005; Wegelius-Lehtonen 2001). This is particularly difficult to deal with since the supply chain is constantly evolving as the project develops through its constituent phases. As a result creating the conditions whereby construction operations achieve the same level of certainty and consistency as a manufacturing facility are next to impossible.

The two most important aspects of the construction industry are customer specificity of the final product, the essential mobility of the production process and the involvement of numerous value-adding organisations (Cherns and Bryant 1983). The construction industry is customarily viewed as having a high degree of fragmentation, low productivity, cost and time overruns, and conflicts and disputes. Certain characteristics of construction, such as one-of-a-kind products, temporary management team and site production (i.e. weather dependent), are major causes of performance-related problems facing the industry and prevent the attainment of flows as efficient as in manufacturing (Segerstedt and Olofsson 2010; Xue et al. 2007).

Expert estimates and historical data analysis indicate that materials costs amount to circa 50-60% of project cost and control 80% of its schedule (Ibn-Homaid 2002). This demonstrates the importance of the material logistics tasks and shows that they comprise a large segment of the construction industry. Material logistic management is "the system for planning and controlling all the necessary efforts to ensure that the right quality and quantity of materials and equipment are appropriately specified in a timely manner, are obtained at a reasonable cost, and are available at the point of used when needed" (Business Roundtable 1983). Furthermore, in a construction project, any delay of the materials deliver may have knock-on effects on delaying works. If the material supply is on the critical path, the project will likely be delayed as a consequence. Nevertheless, research suggests that the biggest risk factor impacting on projects was delays in material flow, followed by labour flow, information flow and 'plant, equipment and temporary work' flow (Hatmoko and Scott 2010).

2.2 NZ Construction: A unique case in a unique industry?

These fundamental problems that are observed and reported upon in the literature appear to be extant everywhere in the world to greater or lesser degrees – the main problems summarised neatly by Dainty et al (2001) in Table 1. In New Zealand, these problems are exacerbated as a result of significant local issues. The economy is small for a developed nation, however as a developed nation we collectively have very high expectations of all industrial performance. The combination of high expectations, low economic size and physical isolation from other key markets reduces the purchasing power of local industry. Consequently materials and commodities in NZ are noticeably more expensive than in the next 'nearby' economy (Australia – some 4500km distant). This is made more contentious yet in NZ as a result of up to the minute media and communications which allow local consumers to know exactly how expensive things are in NZ compared to elsewhere. This in turn has driven extensive efforts to drive up productivity in construction through the Productivity Partnership (more details see http://www.buildingvalue.co.nz/).

Key issues	Barrier to subcontractor integration into the supply chain	Change required to alleviate barrier
Financial	Late and incorrect payments Tendering process Retention	Fair payments from main contractors Main contractors need to focus on value rather than price Trust needs to exist between parties
Programming	Unrealistic programme times	Parties should be involved in construction projects earlier
Contractual	Traditional contracts do not engender good working relationships	New contractual documents or less reliance on contracts
Main contractor's staff	QSs do not encourage subcontract integration Estimators are too demanding on small organisations	QS training in communication skills Educate estimators into the demands of these businesses
Knowledge and information	Companies do not understand other businesses within the supply chain	Time needs to be taken to learn from partner organisations
Partnering	Some partnering relationships are executed for the wrong reasons Many partnering relationships were one sided Some subcontractors lack skills relating to design, legislation and costing that may be required for partnering	All employees should be educated in the benefits of partnering Main contractors need to offer subcontractors benefits if they are to enter into such relationships Subcontractor training for those lacking skills
Miscellaneous	Main contractors do not treat subcontractors fairly	Educate main contractors into the business needs of smaller organisations

Table 1: Barriers to supply chain integration (adapted for Dainty et al. 2001)

The New Zealand construction industry contains a relatively high proportion of micro enterprises as well as small to medium enterprises (SMEs) (Building and Construction Sector Productivity Partnership 2012). The labour force working for the sector has a relatively lower skill level/education level than those in other sectors. For example new concept introduction is generally late in NZ compared to the rest of the world. At present BIM is being used widely in the US, UK and Europe (Azhar 2011). BIM compliance is a prerequisite of governmental contract/tendering in US/UK (Tran et al. 2012). Historically, NZ initiatives mimic UK initiatives, delayed by around 8 years. The counterpart of Egan report (1998) is not published in NZ until 2006 by the New Zealand Construction Industry Council (2006). In NZ discussion and debate still rages as far as whether BIM, as well as many other initiatives, are worthwhile to undertake and who should bear the cost of introducing new ways of doing business.

What can be said without fear of contradiction is that CSCM has significant problems in all construction sectors around the world, including NZ. However there are some unique factors that make the NZ case even more challenging for developing excellence in CSCM. Therefore the situation in NZ is both by degrees unique and generic. Consequently is the first instance to establish correct NZ SCM practice in the context of the wider global "Best Practice". Once this has been achieved it should be possible to propose opportunities for further development and improvement in the capability of the construction industry.

3. Research methodology

The objective of the research reported in this paper was to investigate the nature of current "close to best" practice in CSCM in New Zealand. The full study was very wide ranging and recovered substantial amounts of operational data related to vehicle movements and the logistics of construction supply. The findings reported in this paper concentrate on the specific issues related to management of logistics and SCM processes as they occurred on site. From the literature review reported earlier, it was established that the main areas of

interest for this aspect of research revolved around understanding of SCM, training in SCM skills and the relationships between supply chain protagonists.

To this end, a case study research method was adopted, with 'Elite Interviewing' selected as the principal method of data collection (Davies 2001; Tansey 2007). The method of case study research was chosen for this initial probing into the local situation for two main reasons. The first reason was that there was a need to recognise the importance of the changing dynamics of CSCM as projects develop through time. This, it was felt, did not allow for a 'snapshot' type of interview in order to make meaningful observations. Consequently a strategy of speaking to the project 'Elites' on a regular basis was adopted to gain a longitudinal insight into the processes being undertaken.

Secondly, there was a need to be able to engage with these 'Elites' in their real-life context, as well as using multiple sources of evidence to support the research observations (Yin 2003). The research team took the position that the best way in which both practice and context could be reported upon was through an action oriented "Genba Genbutsu Genjitsu" (3G) approach. Genba Genbutsu and Genjitsu, means actual place, actual thing and actual situation, is a special technique developed Honda Motor Company (Hartley 1992). This "seeing in operation" approach allowed the principal researcher to gain a much deeper understanding of what was happening and what were the implications of the research problem.

It is important to select a critical case that can explicitly demonstrate the "how-problem" (Yin 2003). The first criterion was that the main contractor must have extensive experience and a high reputation in the New Zealand construction industry. The firm acting as main contractor in the case study is the leading contracting organisation by company capitalisation and volume of work in New Zealand. Maintaining a dominant position in the construction industry implies either cost advantage or technical advantage over the remainder of the market. As such it may be deduced that this contractor must therefore represent NZ "Best Practice". It was anticipated that this practice may approximate World Class, but may not actually achieve it. However, it is reasonable to assume that the company represents the best competitiveness that NZ has to offer in this area. The second criterion was that the construction project represented a commercial building being constructed in the strategically important Auckland region.

Auckland is the largest city by population and area in New Zealand – indeed it is the city that continues to grow more rapidly than any other in NZ. Regional planning wants to direct part of this growth towards more intensified land-use and higher building densities (SGS Economics and Planning Pty. Ltd 2007). Auckland's growth results in mounting pressure on existing transport networks which suffer under frequent congestion problems that also impact on construction processes (Sankaran et al. 2005). A commercial project normally has more complicated concerns in SCM than other types of construction projects, such as residential and infrastructure. Therefore, the construction project located in Auckland downtown reflects typical problematic issues for SCM in NZ.

Boundary issues, such as what is and what is not part of the case, are important to address in all case studies (Dubois and Gadde 2002). In this case study, since the construction project is still ongoing we focus on the ground works, frame and envelope stage of the project only - covering about 18 months of the total build. In designing the case study we have included the supply chain from the main contractor to subcontractors and their suppliers. The main reason for this is the construction industry is deeply dependent on subcontractors and suppliers of building materials (Agapiou et al. 1998). Indeed it is widely accepted in construction to subcontract extensive portions of any project (Eccles 1981). Main contractors largely purchase labour and materials from their subcontractors, rather than maintaining contract staff themselves. This process of outsourcing reduces staffing "cost risk" as well overheads. Consequently such main contractors have become increasingly reliant on other actors in the construction supply chain (Vrijhoef and Koskela 1999). In spite of significant research on CSCM, little attention has been paid to upstream relationships from the construction site, such as between contractors and sub-contractors or material suppliers (Bankvall et al. 2010).

The data from the study reported in this paper were gathered by interviews, supplemented with site observation and documentary information. A face-to-face interview technique was used because it allows an in-depth understanding of the research topic and the use of intensive probing questions to gain more insight into the research problem. A semi-structured questionnaire was adopted as the data collection instrument, since it allows for structure, spontaneous discussion and follow-up questions on the research topic (Harris and Brown 2010; Polonsky and Waller 2005). However, the 'main' questionnaire interview was followed up with a number of subsequent contacts and discussions with respondents on points of clarification, as well as to gain the 'through process' longitudinal insights.

The interviews captured similarities and dissimilarities of experience on a project compared with other projects in which the subcontractors were, or had been, involved. This approach made it possible to discuss and evaluate different views of SCM implementation in NZ more broadly. Each interview session was recorded electronically (with interviewee permission) to ensure all relevant issues were captured. Once complete, the entire interview session was transcribed and analysed using qualitative data analysis techniques. Multiple sources of evidence, such as site observation and access to project documentation and reports (i.e. truck delivery documents, progress reports, minutes of meetings and proposals) were utilised and collected in a project diary (Yin 2003).

The case study described in this paper has been developed from a commercial project hosted by AUT University. The construction site was located in central Auckland, implying special requirements in terms of logistics and physical distribution. The $75million project consists of a 13 level tower block with roof top plant room surrounded by a lecture theatre wing with roof level at level 6 of the tower. The new construction ties into existing buildings on campus. The construction has three stages: ground works, structure, and fit-out. The contract was fixed price, with the client being allowed certain flexibility in the scope without extra charge. The general contractor had a total of 21 subcontractors working in the construction project for the ground work and structure stages.

4. Case study findings

4.1 Understanding of SCM – Material flow focused

Respondents were asked to relate their understanding of some of the key concepts in SCM/CSCM. The first question asked about their current understanding of SCM in terms of operating requirements and objectives. All participants mentioned optimisation of material ordering and material delivery as principal operation objectives. Over and above, three participants indicated that subcontractor selection is also a significant part of SCM as well.

This is a highly significant observation. Whilst it is not surprising that material logistics is a predominant emphasis in understanding of SCM, it was a surprise to see it as the overarching or main consideration. The simple fact is that the order versus delivery dynamic expected in the relationships place the onus exclusively on the supplier. However few of respondents recognised the duality of that position. If a supplier fails to perform, this is regrettable. However there was limited recognition of the fact that the supplier whose performance was being lamented upon was placed on a list of approved suppliers. In that case what is at fault, the poor supplier or the poor supplier selection process? The fact that only three respondents identified supplier selection being a substantial part of the SCM process is indicative of a failure to grasp the basics of SCM.

Given the complex nature of project characterised by a vast network of inter-related dependant tasks, and delays in material flow have the biggest impact on a construction project schedule (Hatmoko and Scott 2010), there is evidence to support the notion that material logistics management is worth practitioner attention. A further observation from the research was that at no point was logistics management capability mentioned either explicitly, or as a price / non-price attribute associated with the selection of subcontractors. This is again highly significant as a finding in the context of the broader project currently undertaken in conjunction with Building Research Association New Zealand (BRANZ). Logistics embodies the management of ordering, transportation and delivery for any production process. Consequently in construction it has a substantial input on costs, material management, waste and productivity. However it is not addressed as a performance criteria explicitly. Logistics is an “implied competency” – both here in NZ and apparently worldwide.

Construction is fundamentally a manufacturing operation consuming materials that are generally low value with high volume, transporting to geographically mobile points of distribution on demand. Therefore logistics costs of the material accounts for a significant proportion of the material costs. In general, transportation costs represent approximately 39 to 58% of total logistics costs and up to 4 to 10% of the product selling price for many firms (Coyle et al. 2003). Due to Auckland’s geographical location, all the construction materials have to be transported from a considerable distance. Thus, the logistics costs are assumed to be at the high end of approximate average.

Compared to other industries, such as fast moving consumer goods and retail industries, construction lags behind in terms of both logistics and SCM. During the study, the

researcher was able to observe many truck deliveries for construction materials for the project moving around the road network either empty or half full. It is (and was) not uncommon for delivery trucks to wait on city roads to gain access to the site or be unloaded. Skilled tradesmen were often involved in unloading and moving materials around site, which significantly reduced their productivity. Thus, the consequences of poor construction logistics are apparent not only with unnecessary costs incurred, but also with negative impacts on environment and society, congestion and pollution.

4.2 Limited training

Only one of the interviewed firms indicated that formal training in SCM skills is given to key staff. This particular company provided perishable materials (i.e. ready mix concrete) that has strict delivery time windows, therefore logistics competency is 'mission critical' for the firm to carry out daily business. This is an interesting observation for the body of construction logistics knowledge. Prior to relatively recently the only construction logistics research undertaken has been dealing with the issue of concrete deliveries to site (Proverbs et al. 1999). This understanding and recognition of the relevancy of logistics planning seems to have appeared indigenously in NZ. Although the respondent reported that his company was looking more widely overseas for 'best practice'. He reported that logistics management techniques were the 'the way things were going around the [the ready mix concrete industry]'.

For this concrete firm, as well for SCM training around the world (ref), training in SCM has a principal emphasis on logistics. The main topics include 'Just in Time' (JIT) delivery, inventory management, stock control techniques, demand forecasting and monitoring as well as lean operations. Four other firms on the studied project mentioned that there was "some sort of training" in SCM techniques for their staff involved. This more broad training ranged from project programming to communications with clients, and normally are part of a package of staff development. However, there is no training regarding the body of knowledge for SCM for either the management level or operational level personnel. It can be seen that the reported 'some sort of training' in SCM was actually very much more general management methods with little specific relevance to SCM *per se*.

Workshops in construction logistics or SCM are not available in New Zealand through professional engineer organisations, such as Institution of Professionals Engineers New Zealand (IPENZ), at the time of writing. Although IPENZ deliver many professional development courses in professional and technical skills national wide, there is no SCM course available for professionals in construction. Indeed, there are few universities providing SCM course at tertiary and postgraduate level in construction disciplines. The personnel involved at middle and senior management level among NZ construction firms are therefore generally strong in technical expertise in specific engineering areas, however they generally do not have strong background management generally. In SCM discipline knowledge specifically, these engineers are largely very weak. It has been reported in the past that in order to implement SCM successfully, senior management commitment is one of the critical factors (Burgess 1998). Without even a basic understanding of SCM competencies, this commitment seems unattainable.

Commenting more broadly on the current situation in NZ, the survey respondents were somewhat disappointed with educational levels in the industry. This was a uniform observation from all respondents in the sample. At the operational level, a wide range of generic skills, including writing and reading skills, numerical and financial skills, client and contractor relationships, design communication, supplier communication, teamwork, planning and problem solving and manual skills, are required for effective SCM (Briscoe et al. 2001). However, employees in NZ construction have low levels of basic qualification attainment compared to the NZ norms of literacy and numeracy. Although Specialised Managers within the sector have the highest portion of employees holding bachelor degrees or higher, other trades at the operational level have much lower qualifications. The respondents reported that much of the skill acquisition of the construction sector is through "learning-by-doing", but it may not remain sufficient to equip operatives in construction firms with the range of skills necessary for enhancing supply chain performance. In short there is a pressing need to significantly enhance the general (i.e. transferable skills of literacy, numeracy etc) skills of workers in advance of developing the specific skill sets necessary for 'best practice' SCM. This in line with the findings of Saad et al. (2002) that formal training is a necessity to initiate the shared learning required for effective SCM implementation.

4.3 Partnering in the Supply Chain

All respondents were questioned as to their current working relationships within the supply chain and particularly in relation to the main contractor. All participants considered that they have a "close and trusting relationship" with the main contractor. One of the participants even made a remarkable comment: "We will do anything for the main contractor. This is how good our relationship is." Arguably this could imply that the subcontractor was outstandingly loyal. However in the context of the interview the implication was that of total dependency, and therefore weakness.

Most of the subcontractors interviewed had an extensive experience working with the main contractor. All of the respondents had a minimum of five year's relationship with the main contractor and were considered to be 'trusted' contractors. Simply put the view was taken that, 'If [the main contractor] did not have faith in our ability to get the job done we would not [be on the job]'. All of the firms had been working in the past on a variety of projects with this main contractor. Whilst there was no way of suggesting that these firms were working in a consortium or alliance form of contract on this project, the behaviours of the protagonists was very close to that which may be expected on such a contract. Practically, in the relatively small market that New Zealand represents, along with the smaller subset represented by the Auckland construction market, the firms represented by the respondents will always have to work together at some point in the future. The anticipated requirement for follow on work emanating from this project tended to therefore moderate behaviours on the contract. Anecdotally it can be reported that there is a very high rate of 'staff exchange' between the various construction companies in Auckland. The corporate entity that the main contractor represented on this project is widely considered as being the talent 'incubator' for New Zealand. The company has a strong recruitment strategy of engaging with civil engineering departments in universities, recruiting many fresh graduates annually. These graduate trainees then get subsequently re-recruited by other companies as they gain

experience. Several NZ construction companies were actually set up by alumni of the graduate recruitment scheme of the main contractor. This is also true for the main consultants on this and other contracts. In the context of New Zealand this creates a generally non-confrontational contracting framework between companies. Therefore the ideas of partnering and alliancing are ones that naturally fit to the NZ context.

Although the personnel of the management team from the main contractor may vary, the subcontractors reported that the firm has consistency in management style. Two of these subcontractors considered that they have a strategic partnering relationship with the main contractor. The main contractor is their major customer, producing more than 80% of their turnover. Furthermore, some of the subcontractors have stable and trusting relationships with firms working in a sub-subcontracting capacity. At least one of the sub contracting companies represented by the respondents considered that they formed a strategic partnership with their suppliers and contractors. The relationship among these firms has been developed over several years – often in excess of five. Participants admitted that problems are inherent throughout the project lifecycle. That is the nature of construction on this type of project – bespoke design with high rates of client revision. However, the respondents reported that it is usually not difficult to resolve these issues, since effective communication has been formed during the years of cooperation.

The finding suggests that the general contractor's relationships with subcontractors are healthy in the studied project. All participants value highly of the relationships with the main contractor and their own subcontractors. It implies that the construction firms understand that the quality of a firm's relationships with other firms (i.e. subcontractors and material suppliers) is a strategic asset that can have critical implications on its operations and activities, which includes its economic performance.

5. Conclusions and implications

This paper is a preliminary attempt in understanding and conceptualise the current nature of SCM practice in the NZ construction sector. Although the case study is only focused on the ground works and structure stages of a commercial project, the findings provide a useful insight into current behaviours from a leading construction contractor and its assembled team.

This paper has shown that there is awareness of the importance of SCM in broad terms. However, the critical part of operational tools and techniques for effective SCM in construction is not well recognised or understood. The lack of theoretical understanding of the content of supply chain management is notable in this research and says much about are current training and education of the construction professions. The absence of formal education or training courses at a high level – i.e. engineers and project managers – is considered to be a key aspect of this lack of knowledge. This in turn implies that there is a pressing need in the New Zealand context to provide improved educational opportunities for teaching SCM principles and concepts to construction professionals. Arguably there is already so much technical content in embodied in the education of engineering graduates that to add additional management components in general would be challenging to achieve.

However in SCM discipline skills in particular it would be virtually impossible to deliver at present since the skills are largely not present in faculty staff. It could therefore be argued that in the NZ context there needs to be increased promotion of construction management related postgraduate offerings with special attention to SCM to address this skills gap.

At a lower level there is an apparent serious lack of skills coming out of school leavers who come in to the NZ construction industry. This is an issue much wider than the problems of NZ alone. This will take concerted efforts into the future to 'raise the game' of school leavers before they leave school. More broadly there are substantial issues related to the requirement of the construction industry to attract more capable school leavers. The 'sexiness' of the construction industry as a destination is a complex issue which goes beyond the purview of this paper (see Murray et al. 2001 for a wider discussion on this subject matter), but needs to be addressed if we are to achieve the potential benefits of SCM implementation in construction.

A very positive aspect of the findings from this study is that the industry in NZ has started moving towards the collaborative relationships and trust among the larger firms is an obvious evidence of this collaboration. As has been noted earlier in this paper, the reasons for this appeal are closely related to the small market size and the closely interrelated business that are extant in New Zealand. Some less charitable (Aussie!) commentators may conclude this is evidence of NZ inbreeding. However this is not the case. The behaviour observed is a normal and to be expected under small market conditions. Arguably the same type of behaviour will be seen in any large market (e.g. USA, France, Japan etc) that sees regional specialist firms coming into existence. In a large market, 'bad' contractors and suppliers can rely on the poor market knowledge of clients to gain more work and therefore survive for longer. A classic situation of poor industry practice capitalising on 'a sucker born every minute'. In small market situations, poor contractor and supplier behaviours will rapidly come to the attention of the majority of important clients in the industry. In a small market it is easy to get on to a blacklist and very hard to get off of it. Consequently poor behaviours will generally not be sustainable for the long term. Conversely, the housing market supports the "cowboys surviving for longer periods", because of the limited market knowledge of clients.

Probably the key finding coming from this study is related to logistics management. The evidence points towards the fact that the construction industry does not effectively address, or have the skills to solve, logistics problems. At present the lack of knowledge is masked by lack of immediacy in recognising that there is a problem at all. It is hard to solve a problem that the industry does not recognise that it has. At present, from the analysis of the deliveries arriving at the case study site, there is a lack of transparency in costs throughout the construction process. Decisions on choosing suppliers and quantities of materials are often made by evaluating the quoted "cost as delivered" per unit. Since the cost of transportation is embodied in the delivery cost, there is no way of identifying how much cost is attributed by suboptimal transport planning. Unless there is a differentiation between the elemental costs, it is difficult to identify who benefits from an effective logistics system. Those who may be required to do things differently do not necessary gain benefits from changing to an optimal transportation planning model. None of the respondents to the

survey were even slightly aware of the quantum of money that was embodied in the transportation of materials to site (>39% as noted previously).

The next step for the research team working on this project will be to broaden out the logistical study from the commercial construction site described into housing and infrastructure projects in order to map the patterns and logistical flows developing. The data generated is also anticipated to develop and refine the model outlined in Figure 1. Moving forward the research is intended to inform a much larger study supported and funded by BRANZ into the mapping of Auckland's construction lifelines, which superimposes the materials flows in Auckland over a wider GIS model of the development of the Auckland Super City.

Acknowledgement

The authors would like to thank BRANZ for financing the study.

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Ranking Construction Project Alternatives with the Analytic Network Process Method

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Abstract

In evaluating construction investments, public or private sector owners often have several project alternatives, e.g. different sites for development and different types of building. Assessing each of them so as to identify the best for implementation is owners' most important decision in the project planning stage. The traditional net present worth method has difficulty in including intangible benefits and risks, so the result of it may not represent the overall value of an alternative. The multi-attribute utility theory method can include all factors in producing a total utility score for an alternative, but it has difficulty in determining criteria weights and utility functions. The analytic hierarchy process method can derive criteria weights and priority scores of alternatives from paired comparisons, but it cannot incorporate feedback relations between criteria and alternatives as it is done hierarchically in a top-down manner. This paper proposes an improved model for assessing project alternatives using the analytic network process method as the generalized analytic hierarchy process method to include the feedback impacts absent from the analytic hierarchy process. To illustrate the model, three recent housing projects in Kaohsiung, Taiwan were used as hypothetical alternatives being considered by a medium developer. A study of related factors that influenced their economics as well as feedback relations between factors and alternatives were conducted to determine the criteria and the dependency links in the network model. Based on company and project conditions, values of inputs for the model were set and were processed to produce the criteria weights and the relative scores of the alternatives for establishing their priority ordering. The ANP model results in changes in the ranking of the sites from those produced by the AHP method due to the additional relations.

Keywords: construction, project site selection, decision analysis, analytic hierarchy process, analytic network process.

1. Introduction

In evaluating construction investments, public or private sector owners often have several project alternatives, e.g. different sites for development and different types of building. Assessing each of them so as to identify the best for implementation is owners' most important decision in the project planning stage. The traditional net present worth method has difficulty in including intangible benefits and risks, so the result of it may not represent the overall value of an alternative (Lifson and Shaifer, 1982). The multi-attribute utility theory

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method can include all factors in producing a total utility score for an alternative, but it has difficulty in determining criteria weights and utility functions (Skibniewski and Chao, 1992). The analytic hierarchy process (AHP) method can derive criteria weights and priority scores of alternatives from paired comparisons, but it cannot incorporate feedback relations between criteria and alternatives as it is done hierarchically in a top-down manner. This paper proposes an improved model for assessing project alternatives using the analytic network process (ANP) method of Saaty (1996) as the generalized AHP method to include the feedback impacts absent from the analytic hierarchy process. The ANP method has found increasing application, e.g. Meade and Sarkis (1998), Meade and Presley (2002), Cheng and Li (2004). For illustration of our proposed model, three recent housing projects in Kaohsiung, Taiwan were used as hypothetical alternatives being considered by a medium developer. In the following, we start with the AHP model and then extend it into the ANP model; the assessments made by the two are compared.

2. The AHP model

Compared to traditional multi-attribute decision analysis techniques such as utility theory, the analytical hierarchy process of Saaty (1980) is a relatively informal approach to decision-making problems and has been applied to a variety of problems, e.g. Cheung et al (2001). The AHP helps decision makers to identify and set priorities on the basis of their objectives and their knowledge and experience. The AHP framework organizes their feelings and intuitive judgments as well as logic so that they can map out complex situations as per their perception. The AHP solution process begins with structuring a complex problem by decomposing it into a hierarchy to include all attribute elements reflecting the goals and concerns of the decision maker. Next, elements are compared in a systematic manner using the same 1-9 scale to measure their relative importance and the overall priorities among the elements within the hierarchy are established, while the relative standing of each alternative with respect to each criterion element is determined using the same scale. The overall score of each alternative can then be aggregated, while the consistency of comparison can be measured using Saaty's (1980) consistency ratio.

2.1 The hierarchy and comparison matrices

The proposed model for ranking construction project alternatives is a hierarchy of evaluation elements as shown in Figure 1, which is used as an illustrative example for site selection for terraced houses. The three criteria at level 2 of the hierarchy are surroundings conditions, plot conditions, and demand & competition. Reflecting a developer's goals and concerns for the site selection problem, they are generally regarded as essential factors in project success for commercial housing in the local area. Surroundings conditions refer to a site's external physical environments including completeness of transport systems, access to public transports, availability of public facilities such as schools, markets, and services, nearness to unfavourable places such as cemetery and landfills. A site's plot conditions refer to suitability of plot shape and terrain as well as ground conditions for housing development. Demand & competition refer to potential of, and threat to, respectively, sales for new housing in the considered area. Table 1 gives the comparison matrix for surroundings conditions, plot conditions, and demand & competition in their influence on overall assessment for site

selection as perceived by the developer, with the eigenvector showing that surroundings conditions have the greatest weight (0.54), followed by demand & competition (0.297) and plot conditions (0.163).

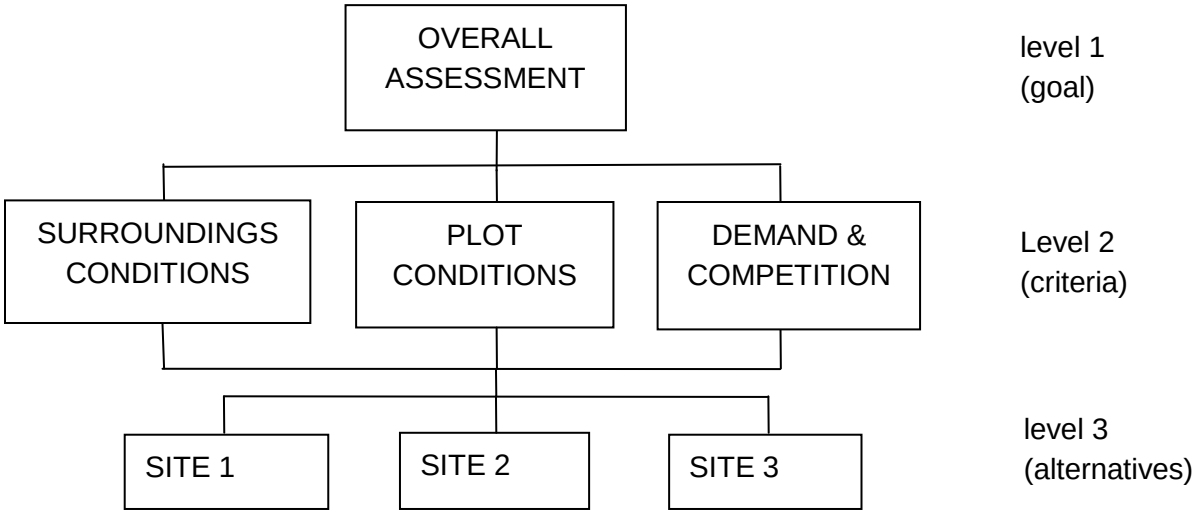

Figure 1. Decision attribute hierarchy for the example site selection problem

The three sites at level 3 of the hierarchy are the alternatives being considered for constructing terraced houses. Based on the data collected, site 1 is assessed as above-average in all three aspects: the surroundings, the plot itself, and the demand & competition in the nearby area. Situated in an area of intense construction activity, site 2 is assessed as excellent in surrounding conditions, but it is assessed as poor in plot conditions and in demand & competition, because of its shape making efficient land use difficult and the risk of over-supply in the area, respectively. Site 3 is located at a far-flung corner of the city with high potential for future housing developments and so it is assessed as poor in surrounding conditions, but good to excellent in plot conditions and in demand & competition. Tables 2, 3, and 4 gives the comparison matrices for the three sites in their performance on surroundings conditions, plot conditions, and demand & competition, respectively, as per the opinions of the developer; the obtained eigenvectors show their differences in scores as stated above.

Table 1: Comparison of surroundings conditions, plot conditions, and demand & competition in their influence on overall assessment

Attributes	Surroundings Conditions	Plot Conditions	Demand & Competition	Principal Eigenvector
Surroundings Conditions	1	3	2	0.540
Plot Conditions	1/3	1	1/2	0.163
Demand & Competition	1/2	2	1	0.297

Table 2: Comparison of alternative project sites in their performance on surroundings conditions

Alternatives	Site 1	Site 2	Site 3	Principal Eigenvector
Site 1	1	1/2	3	0.309
Site 2	2	1	5	0.581
Site 3	1/3	1/5	1	0.110

Table 3: Comparison of alternative project sites in their performance on plot conditions

Alternatives	Site 1	Site 2	Site 3	Principal Eigenvector
Site 1	1	3	1	0.429
Site 2	1/3	1	1/3	0.143
Site 3	1	3	1	0.429

Table 4: Comparison of alternative project sites in their performance on demand & competition

Alternatives	Site 1	Site 2	Site 3	Principal Eigenvector
Site 1	1	3	1/2	0.309
Site 2	1/3	1	1/5	0.110
Site 3	2	5	1	0.581

2.2 Aggregation of comparison results

The aggregation of comparison results, i.e. eigenvectors, can be accomplished by means of vector multiplication as below.

$$S_j = \sum_{i=1}^{3} w_i s_{ji} \qquad \text{……(1)}$$

where S_j=site *j*'s total score; w_i=criterion *I*'s weight; s*ji*=site *j*'s score on criterion *i*.

However, aggregation of AHP results can also be done by means of the limit matrix method used in analytic network process, as introduced next. First, create a 7 by 7 matrix in which each row (and column) corresponds to each of the seven attributes in the hierarchy in Figure 1, and then insert all the four eigenvectors obtained above into their corresponding columns and insert zeros where there is no dependency relation between the attributes, resulting in an initial super-matrix, *W*, as shown in Table 5. Notice that at the right-bottom area, there is an identity sub-matrix for the three sites, making sure that the matrix is so-called column stochastic, i.e. the sum of every column is one. Then, to obtain the sites' total scores, raise the power of the matrix until the product of multiplication converges, i.e. no change occurs. For more details, see Saaty (1996) and Saaty (2005). The limit matrix is represented as:

$$\lim_{k \to \infty} W^k \qquad \text{.....(2)}$$

Since there is no feedback relation in the hierarchy in Figure 1, convergence occurs at k=2. Table 6 (W^2) contains the three's total scores in the overall assessment column, showing that site 2 is rated the highest at 0.3697, because of its superior score in the most important criterion, surroundings conditions, which more than compensate for its shortcomings in plot conditions and demand & competition.

Table 5: Initial super-matrix for the AHP example, W

Attributes	Overall Assessment	Surroundings Conditions	Plot Conditions	Demand & Competition	Site 1	Site 2	Site 3
Overall Assessment	0	0	0	0	0	0	0
Surroundings Conditions	0.540	0	0	0	0	0	0
Plot Conditions	0.163	0	0	0	0	0	0
Demand & Competition	0.297	0	0	0	0	0	0
Site 1	0	0.309	0.429	0.309	1	0	0
Site 2	0	0.581	0.143	0.110	0	1	0
Site 3	0	0.110	0.429	0.581	0	0	1

Table 6: Limit super-matrix for the AHP example, W^2

Attributes	Overall Assessment	Surroundings Conditions	Plot Conditions	Demand & Competition	Site 1	Site 2	Site 3
Overall Assessment	0	0	0	0	0	0	0
Surroundings Conditions	0	0	0	0	0	0	0
Plot Conditions	0	0	0	0	0	0	0
Demand & Competition	0	0	0	0	0	0	0
Site 1	0.3286	0.309	0.429	0.309	1	0	0
Site 2	0.3697	0.581	0.143	0.11	0	1	0
Site 3	0.3019	0.11	0.429	0.581	0	0	1

3. The ANP model

The above analysis is lop-sided due to domination of one criterion, namely surroundings conditions, - in other words, the so called location effect. Not satisfied with the result, the developer re-considers the characteristics of the three sites and decides to incorporate feedback relations in the model thus making it an ANP model.

3.1 Additional comparison matrices

Besides comparison of surroundings conditions, plot conditions, and demand & competition in their influence on overall assessment in Table 1, three more comparison matrices are produced for evaluating the relative importance of the three criteria with respect to site 1 (Table 7), site 2 (Table 8), and site 3 (Table 9). Since the site alternatives occupy the bottom level of the hierarchy in Figure 1, these three more matrices define the feedback relations between the criteria and the alternatives in addition to the dependency relations between the criteria and the alternatives defined previously in Tables 2, 3, and 4. As shown in the obtained principal eigenvectors in Tables 7, 8, 9, varying weights for surroundings conditions, plot conditions, and demand & competition are generated, reflecting the developer's concerns for the weaknesses of each site. When the three eigenvectors are added to the model, they represent challenges to the superiority of each site and will influence the resulting scores.

Table 7: Comparison of surroundings conditions, plot conditions, and demand & competition in their importance with respect to site 1

Attributes	Surroundings Conditions	Plot Conditions	Demand & Competition	Principal Eigenvector
Surroundings Conditions	1	3	3	0.600
Plot Conditions	1/3	1	1	0.200
Demand & Competition	1/3	1	1	0.200

Table 8: Comparison of surroundings conditions, plot conditions, and demand & competition in their importance with respect to site 2

Attributes	Surroundings Conditions	Plot Conditions	Demand & Competition	Principal Eigenvector
Surroundings Conditions	1	1/2	1/2	0.200
Plot Conditions	2	1	1	0.400
Demand & Competition	2	1	1	0.400

Table 9: Comparison of surroundings conditions, plot conditions, and demand & competition in their importance with respect to site 3

Attributes	Surroundings Conditions	Plot Conditions	Demand & Competition	Principal Eigenvector
Surroundings Conditions	1	2	2	0.500
Plot Conditions	1/2	1	1	0.250
Demand & Competition	1/2	1	1	0.250

3.2 Super-matrices and final ranking

As shown in Table 10, the eigenvectors from Tables 7, 8, and 9 are inserted into their corresponding columns of the initial super-matrix, while the previous identity sub-matrix is deleted and everything else is retained. Then, the power of the matrix is raised until the product of multiplication converges at k=10. Now the ranking of the three sites has changed to site 1 (rated at 0.3431), site 3 (rated at 0.3328), and site 2 (rated at 0.3254), as shown in Table 11, as a result of the feedback relations added. The changes in the three sites' scores are due to changes in the criteria weights, as a result of the feedback relations added. Compared to the previous criteria weights of 0.540, 0.163, and 0.297, the final criteria weights of 0.437, 0.282, and 0.282 show moderated differences among them, also as a result of the feedback relations.

Table 10: Initial super-matrix for the ANP example, W

Attributes	Overall Assessment	Surroundings Conditions	Plot Conditions	Demand & Competition	Site 1	Site 2	Site 3
Overall Assessment	0	0	0	0	0	0	0
Surroundings Conditions	0.54	0	0	0	0.6	0.2	0.5
Plot Conditions	0.163	0	0	0	0.2	0.4	0.25
Demand & Competition	0.297	0	0	0	0.2	0.4	0.25
Site 1	0	0.309	0.429	0.309	0	0	0
Site 2	0	0.581	0.143	0.11	0	0	0
Site 3	0	0.11	0.429	0.581	0	0	0

Table 11: Limit super-matrix for the ANP example, W^{10}

Attributes	Overall Assessment	Surroundings Conditions	Plot Conditions	Demand & Competition	Site 1	Site 2	Site 3
Overall Assessment	0	0	0	0	0	0	0
Surroundings Conditions	0	0.4373	0.4377	0.4373	0	0	0
Plot Conditions	0	0.2819	0.2822	0.2819	0	0	0
Demand & Competition	0	0.2819	0.2822	0.2819	0	0	0
Site 1	0.3431	0	0	0	0.3432	0.3432	0.3432
Site 2	0.3254	0	0	0	0.3254	0.3254	0.3254
Site 3	0.3328	0	0	0	0.3328	0.3329	0.3328

4. Conclusions

Although the AHP method is used widely in decision analysis, it allows only bottom-up, one-way influences in the hierarchy since it cannot incorporate feedback and other dependency relations among the criteria and alternatives. On the other hand, as the generalized AHP method, the ANP method allows multi-direction relations among the elements and evaluates the impacts of all relations on the final assessment. In our study of project site selection, the hierarchical relations between adjacent levels as well as the feedback relations between the criteria and alternatives are included in the proposed model to determine the ranking of alternative sites for housing development. The ANP model results in changes in the ranking of the sites from those produced by the AHP method due to the additional relations. However, because of the increased complexity, use of ANP for the site selection problem is only justified by situations where it is important to include such extra links in the analysis. Further validation of the model by comparison of assessments from the model with those from other methods is required.

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Relationship Contracting: A Case Study of the Top Ryde Public Private Partnership (PPP)

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Abstract

The last two decades have seen the evolution of PPPs as an alternative procurement method to traditional methods of delivering public infrastructure. Competing demands for public sector investment for new infrastructure has prompted Australian governments to increasingly turn to the private sector to form partnerships in the construction, ownership and operation of infrastructure assets. This has become a major challenge for both public and private sector stakeholders but the emergence of PPPs provides an alternate means for developing infrastructure using private sector expertise. There is considerable growth potential for PPPs given that the New South Wales Government has developed policies to expand the application of PPPs to include social infrastructure, such as hospitals and schools. Subsequently Local government has been investigating the delivery of infrastructure and services PPPs. A key argument for Governments to procure projects using PPPs is that the process would deliver better overall value for all the stakeholders, including the broader community. The aim of this paper is to investigate current approaches to successful risk management of infrastructure using the Top Ryde PPP as a case study project. The method focuses on a case study approach involving an analysis of project documentation and a semi-structured interview process. The results of this research centres around an effective tri-partite contract agreement, innovative relationship management and a very successful risk management approach with a particular focus on legal, financial and community factors.

Keywords: Australia; Case Study; Local Government; PPP; Relationships; Risk.

1. Introduction

There is a strong body of opinion to support the concerns of the private sector that current social infrastructure projects in Australia are not true partnerships (Curnow, et al, 2005; Jefferies and McGeorge, 2009; Jefferies and Lau, 2010). The public sector needs to make PPPs more attractive to the private sector and clarify the risk identification in order to

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transfer more responsibility to the Private Sector. This issue is supported by recent industry criticism of PPPs concerning the 'narrowness' of the scope of work that is offered to the private sector (Jefferies and McGeorge, 2009). Stakeholders from the private sector are frustrated with the high transaction costs of PPPs, which offer only a marginal increase in scope of business opportunity. This is in stark contrast to opportunities that are available in the much lower cost-to-bid ratio of more traditional procurement models (Jefferies et al, 2010). This has led to the decision by a number of major construction contractors to withdraw from the PPP process.

Additionally Shepherd (1999) and Jefferies and McGeorge (2008) argue that there are fundamental reasons for the need to review the PPP process, these reasons include:

- Lack of flexibility in the evolution of the project where the host authority must juggle competing bidders and keep them on the same baseline;

- Current PPP arrangements lack flexibility in operation;

- High transaction/tender costs in taking at least two fully developed and underwritten bids to the finishing line (e.g. Melbourne City Link incurred external tender costs of $24Million at financial close); and

- PPPs need to allow the private sector to utilise its expertise and gain a broader scope of work and an increased transfer of risk and responsibility.

As illustrated by the above comments, measuring the success of PPPs and identifying the risk exposure by the various stakeholders has been, to date, largely problematic. The inability of the Private Sector to win enough projects to offset the significant tender costs for more complex PPPs appears to have had an adverse influence on the construction industry (e.g. reduction of company share-values, company mergers and take-overs). PPPs are normally linked to large-scale projects that, in many cases, have a high public profile. Therefore, the risks associated with PPPs are often perceived to be correspondingly higher than for more conventional forms of contractual relationships. However, irrespective of the form of contractual relationship there are two critical risk management issues that emerge during the bidding stage of any project. These have been identified from previous work by Tiong (1990); Walker & Smith (1995); and Jefferies & McGeorge (2008) as:

1. *Legal* - legislative framework, project agreement, tax, laws.

2. *Financial* - bid process, form of financing, evaluation, commercial investors, ownership, rates of return.

The genesis for this research project came from the both the main public and private sector partners involved in the Top Ryde PPP. Specifically, this paper will provide:

- *A review of relevant literature* including definitions of PPPs, the origins and emergence of Australian PPPs, and barriers and practical issues related to PPPs.

- *The latest thinking and insights* from select senior management personnel from both public and private sector stakeholders involved in the Top Ryde PPP.

- *Strategic recommendations* to resolve several of the key challenges currently faced by the Australian PPP industry.

2. Research Method

There is general acceptance that PPPs are part of the procurement landscape in Australia. Therefore, further and continued research into PPPs is vital to ensure the development of sustainable procurements methods that offer greater rewards for both public and private sector stakeholders and in particular, the community at large. The specific aim of this research is to map the current approaches to successful risk management of Public-Private Partnerships (PPPs) via a current case study project. Therefore, a Critique of the Top Ryde PPP project is performed and the findings are presented as a case study example of best practice.

A comprehensive review of related literature and critical industry reports was used to generate list of major challenges facing Australian construction PPP industry. Further analysis identified key issues and themes, in particularly focusing on successful risk management of PPP projects. An industry reference group, in the form of a PPP project Task Force, was then established. The Task Force consisted of the project's main industry partners, i.e. City of Ryde, Defined Developments and the RTA. Specifically, the Task Force consisted of committee members of the Top Ryde PPP Project Control Group. Each member self-volunteered and nominated other relevant experts from within their respective organisation who were experienced in the Top Ryde project and/or had broader PPP experience. Task Force members also provided access to relevant project documentation.

Semi-structured interviews were conducted with nominated experts and support staff. Interviews were conducted over series of stages to establish dialogue between researcher and participants and gain qualitative data. The interview process focused on key themes identified from literature review and participant's views were documented. Research findings were than compiled into a draft report and validated as an on-going process via Task Force meetings.

3. Public Private Partnerships (PPPs)

3.1 Defining PPPs

One of the problems with a PPP is with its very definition. Definitions tend to depend on a commentator's own particular perspective and, range from the very general to the quite particular. A general definition is provided by Akintoye et al (2003), where Public Private Partnerships (PPPs) are defined as a long-term contractual arrangement between a public

sector agency and a private sector concern whereby resources and risk are shared for the purpose of developing a public facility. PPPs are considered to be a form of Relationship Contracting, which according to Chueng et al (2005), is based on a recognition of and striving for mutual benefits and win-win scenarios through more cooperative relationships between the parties. Relationship contracting embraces and underpins various approaches, such as partnering, alliancing, joint venturing, PPPs, and other collaborative working arrangements and better risk sharing mechanisms. Relationship contracts are usually long-term, develop and change over time, and involve substantial relations between the parties.

Within the context of Local Government in New South Wales (NSW), the working definition of PPPs for this research project is:

"An arrangement between a council and a private person for the purposes of providing public infrastructure or facilities and/or delivering services in accordance with the arrangement" (NSW Department of Local Government, 2005).

3.2 Characteristics of PPP Projects

In discussion about the nature of social PPP projects, Jefferies and McGeorge (2009) state that comparisons were typically made against economic infrastructure projects. Key features and differentials are identified in Table 1.

Table 1: Key Features and Differentials Between Social Infrastructure Projects and Economic Infrastructure Projects

Key Features	**Social infrastructure projects, e.g. schools and hospitals**	**Economic infrastructure projects, e.g. motorways, tunnels and bridges**
Scale of project	Smaller	Larger
Examples	Schools and hospitals	Motorways, tunnels and bridges
Complexity	More complex – especially ongoing involvement with community	Less complex
Risks	Associated with performance of the facility, e.g., major failure in air-conditioning systems	High construction risk engineering projects (e.g. collapse of Lane Cove Tunnel during tunnelling phase). Financial risks can also be high.
Revenue generation	Rental streams via the Government. Value-adds are sought, e.g. rental space, service	Direct payments for example from tolls

	contracts and other additional means	

The public sector must make PPPs more attractive to the private sector and clarify the identification of risk in order to transfer more responsibility to the private sector. In relation to commercially viable value-adding, Government typically restrict the outsourcing of services to 'non-core' services such as administration, catering and cleaning. There appears to be some conflict in the division of 'core' and 'non-core', the example being given – the employment of nurses, many of whom are employed in hospitals via private enterprise agencies. A branch of a consortium could undertake such a function (Jefferies and McGeorge, 2009).

3.3 Barriers to Social Infrastructure PPPs

There are many barriers when considering the use of a PPP strategy. The following list has been developed using issues identified by the Australian Council for Infrastructure Development Limited (2003); Curnow et al (2005) and Jefferies and McGeorge (2009):

- *Tax reform* - Section 51AD of the Australian Tax Act is a serious barrier to many PPP projects. Rectification of this could pave the way for further use and implementation of PPP arrangements e.g. shadow tolling as a form of payment for infrastructure services is currently restricted, if not prohibited, under 51AD as it currently stands.

- *Whole of Government approach* - Strong central Government control has led to a lack of consistency in PPPs. To ensure PPPs succeed the consistency must be driven at the highest levels of Government.

- *Lack of suitable skills in Government agencies* - Agencies may not have the skills or experience to ensure a successful project. Greater training and experience will overcome these.

- *High participation costs* - High bidding costs viewed as the most prominent barrier to entry. It has been indicated that tender costs are up to six times higher than that of traditional procurement arrangements. Therefore it is unlikely smaller contractors will be able to participate due to high tender costs.

- *High project values* - The majority of PPP projects are larger than those for which many small contractors can realistically aspire to bid for.

- *High risk* - One of the fundamental requirements of a PPP is that the private sector must genuinely assume risk. Due to this high volume of risk many smaller companies would not be equipped to handle such large risk, which would prevent them from entering the PPP market.

- *Lack of credibility and contacts* - The PPP process invariably involves a contractor working in a consortium with partners from outside of the construction industry. This is an effective

barrier to smaller contractors as they are less likely to have external contacts to form a PPP consortium.

4. The Top Ryde PPP

The results of this research were developed from a qualitative data collection process. This involved semi-structured interviews with Senior Management participants representing various stakeholders involved in the project and an analysis of project documentation. Interviews were conducted over the period July to October 2010 and a documents analysis was carried out simultaneously. Over the course of the research the following themes emerged:

1.Project Background; 2.The Tripartite Agreement; 3.Contractual links; 4.Legal costs; 5.Relationship Management; and 6.Risk Management.

4.1 Project Background

The original Top Ryde Shopping Centre was built in 1957, being New South Wales' first regional shopping centre and one of Australia's earliest. The role of Top Ryde as an important retail and social centre declined over the 1980's and 1990's as its infrastructure became outdated with insufficient parking and a limited choice of food and retail outlets. The City of Ryde recognised that the redevelopment was required in order to reduce escape expenditure outside the suburb, increase employment and restore the Town Centre as a social and civic hub.

The Beville Group (i.e. the private sector contractual partner with CoR) purchased the Centre in 2000. The proposed expansion of the Town Centre was of such a significant size that an Integrated Traffic Solution (ITS) was required. Defined Developments (DD), a subsidiary of the Beville Group, was established as developer to deliver Top Ryde shopping centre and they signed a 49 by 50 year lease for a 'peppercorn' rent of $1. Under the terms of the lease, DD wouldn't pay any significant rent for the land providing they successfully linked CoR Civic Precinct land to the ITS in the form of bridges and underpasses. Under the *Local Government Amendment (Public Private Partnerships) Act 2004,* the NSW State Government subsequently deemed the project as a 'PPP' as the developer was providing free infrastructure to the City of Ryde in the form of rights of way through the underpasses and over the bridges linking CoR land from West to East and enhancing the access solution for CoR ultimately allowing for future redevelopment to be undertaken by CoR.

In March 2005, Bevillesta entered into a management services agreement with Bovis Lend Lease, requiring them to provide design master planning services that combined their in-house architectural expertise together with their cost planning programming and resources. In 2006, the LEP Number 143 was gazetted, which allowed for future growth of Top Ryde City and the surrounding suburbs. Bovis Lend Lease was appointed on a guaranteed maximum price contract to undertake the design and construction of the project. Construction on the Centre commenced in September 2007 with Stage 1 of the Centre officially opened towards the end of 2009.

Planning approval was based on the best traffic solution to minimise impact to the community but at the same time maximising customer efficiency. By working with the State and Local Authorities, DD were able to develop the best outcomes for all parties and execute long term agreements with the government departments that benefited the centre owner supplying the community with facilities and infrastructure for the future growth of CoR's land. In addition the RTA insisted on the removal of on-grade crossings across Devlin street to improve travel time on the network through improved signalised junctions and enhance public safety. It is also important to note that redevelopment of Top Ryde must be viewed in a broader context of establishing a momentum for revitalising the whole of the Town Centre over time.

4.2 Tripartite Agreement

Under the Tripartite Agreement, the City of Ryde is the roads authority and the owner of Devlin Street and Blaxland Roads. As owner, the City of Ryde agreed to lease a portion of these roads, comprising the site for Top Ryde, to the Developer under the Agreement. The Developer undertook the works on the site and agreed to own and operate the works (finance, design, construct and operate). Under section 138 of the Act, the consent of Council, as roads authority, with concurrence of the RTA, was required. A condition of the DA consent was that the three parties enter in a Tripartite Deed of Agreement. The Tripartite Deed served to clarify the roles and responsibilities of the three key players, i.e. City of Ryde, RTA and Bevillesta, at the beginning of the project. The tone of the Tripartite Deed was not adversarial. The roles and responsibilities of each party were discussed, agreed and formalised at the start of the project.

A three-layer communication model was established and embraced enthusiastically by all the parties to manage the PPP work. The three levels consisted of:

1. *PPP Communication Meeting* - Hosted weekly by the Main Contractor (Bovis Lend Lease) and attended by CoR, and often RTA, with stakeholders such as State Transit Authority and the Project Verifier as necessary. This meeting served to advise and discuss detailed works progress, certification issues, focus points for co-operation, feedback from the local community and communications required with local residents about future work.

   Weekly communication meetings were structured to review the works programme and the community's interest together to manage expectations and minimise inconvenience.

2. *PCG (Project Control Group) Meeting* - Initiated and hosted by CoR weekly as appropriate, this brings together the project managers operating on behalf of the CoR, the Developer, Main Contractor and RTA to overview general progress, identify and mitigate risks and issues, ensure information flow is timely, agree points of collaboration, resolve contentious issues, defuse potential problems and agree action points for all participants to ensure the project proceeds as smoothly as possible.

   Weekly PCG meetings have enhanced communication and collaboration between the three PPP stakeholders' representatives, the effectiveness of which has been reinforced by the

inclusion of the Main Contractor in this forum.

3. *High Level PCG Meeting* - This was held every two three months according to need and, as specified in the Tripartite Deed is chaired by an independent person. Given RTA's concurrence role in the PPP, the principal attendees have been the CoR and the Developer. These meetings have provided a platform of supervision, negotiation and control of the direction of the PPP works and design intent of the overall project. This forum is principally concerned with policy, direction and the progress of the project at a strategic level.

   Collaboration at quarterly High Level meetings between the Heads of the CoR and Bevillesta organisations provided a strategic control upon the relationship between PPP and DA. The nominated project managers for the CoR, RTA, Bevillesta and BLL operated as consistent principal contacts for their organisations facilitating resources as required and ensuring that communication is not weakened through dilution. The Tripartite parties and Bovis Lend Lease each have large organisations with many 'interested' members.

4.3 Contractual links

The Tripartite Agreement brought together the owner (CoR) and regulatory body (RTA) together with the private sector developer (in the form of Defined Developments). In removing key risks such as design and maintenance, CoR were able to supply infrastructure to the community at merely an 'administration cost'. The PPP model used for Top Ryde supplied a very low risk solution for local government (CoR) and also provided benefits to the RTA in the form of upgraded infrastructure, enhanced signal arrangements and reduced maintenance costs on a major section of the State road network.

4.4 Legal Costs

The legal aspects of a PPP include the contracts, the legal entity and the law and regulations that the PPP will be working under (Bult-Spierinh and Dewulf, 2006). Whilst all interview participants acknowledged that legal costs were an inevitable consequence of the construction industry's highly litigious environment, the dominant view was that PPP legal and administration costs were 'excessively high'. These costs can act as a deterrent to the private sector at tender stage and the public sector at development stage.

There were a number of legal and administration costs identified as part of the Top Ryde project, and indeed unique to PPPs. These include:

- Legal advice regarding the establishment of the PPP;
- The legalities of setting up the PPP and also arrangements with the contractor(s);
- Liaising with project stakeholders to work through the contract and assessing the risk in the contract;

- Costs incurred as part of the Independent Verifier process stipulated by the Department of Local Government (NSW State Government requirement of PPP projects);

- The lack of standardised contract documentation from projects of this nature; and

- Efficiency and effectiveness on the focus on the 'finer points', given the economics of long-term legal obligations contained in many PPPs, particularly in contracts of over 20 years, and in this case the 49 by 50 year lease arrangement.

4.5 Relationship management

The success of Top Ryde was driven by the need of delivering development to the City of Ryde and its broader community. All senior project stakeholders within CoR were involved in the negotiation and planning process and developed successful relationships with other senior project stakeholders from both the private and public sectors. *Relationships* within the project were driven by a 'win-win' mentality and the successful management of diverse stakeholder expectations. The cultural issue of relationship management (teamwork, trust, mutual goals etc) helped to drive the project away from typical adversarial contracting. This 'can do' attitude of senior project stakeholders, particularly at the negotiation stage, helped to foster a positive commitment throughout the project. Open levels of *communication* and the establishment of Project Control Group meetings further enhanced successful project collaboration. Further stakeholder management, in the form of the broader *community*, was managed with expert liaison techniques to ensure continued support from the Ryde community.

4.6 Risk Management

4.6.1 Compliance, Due Diligence and the Tripartite Agreement

The basis of the model used for the delivery of Top Ryde involved the establishment of: the risk profile; internal and consultant reports; deeds; marketing plans; statutory compliance; and Project Control Groups as the foundations for successful project structure. This process was authorised, with subsequent project approval to proceed by the State Department of Local Government. In order to mange this process, and particularly the process of engaging consultants, commissioning external reports and studies, especially where in-house expertise was lacking, the GM put together a cash surplus of $9m to support and fund these issues for the duration of the project.

At the pre-delivery stage $800,000 was spent with BLL under a consultancy agreement to mitigate risk in the ground (sub-soil). A detailed geotechnical and structural analysis was carried out by BLL under contract with DD. WT Partnership provided reviews of all BLL costs. These tests enabled a 'no latent conditions' clause under the contract and BLL did all necessary research to price and deliver the contract. This level of Geotechnical research enabled BLL to price work more accurately.

The Tripartite Agreement succeeded in bringing the owner (CoR) and regulatory body, RTA, together with the developer (DD). CoR and RTA mitigated some of their risk by having input into the design by ensuring compliance with design standards. CoR were allowed to enforce their rights under the design standards and DD, as developer, had to deliver this under the contract. CoR also mitigated some of their risk by putting bonds into place under Tripartite Agreement that were relevant to significant stages of project delivery. Further risk was mitigated by not issuing occupancy until the Integrated Traffic Solution (ITS) was complete and approved in accordance with the DA, i.e. in accordance with Local Government planning law and State Law (LEP) which meant that the centre could not expand until the ITS was developed. Maintenance risk was managed by using an ongoing clause in the centre's lease agreement that DD maintain and certify annually.

Major Design and Construction risk, which was enhanced by the complicated underpass system to allow traffic from RTA network into top Ryde site, was mitigated with the engagement of BLL as D&C contractor. The management framework was developed by Defined Developments and implemented via various levels of the PCG meetings. CoR via RTA had a requirement to engage the Verifier before the RTA would grant approval. Risk was mitigated by the Verifier approving the design. Defined Developments contributed towards the cost of the Verifier and therefore had risk mitigation as they had input into design.

4.6.2 Financial Risk

The Developer mitigated financial risk by establishing funding arrangements with a syndicate of 6 lending institutions. Finance could be effected if one or more of the banks pulled out of the deal but this in turn was mitigated by a 'no reason' clause, e.g. there had to be an significant event such as a dispute or extensions of time etc for them to do so and therefore allow financiers to enforce step-in rights.

The risk of ensuring centre occupancy (tenants) was managed by DD as the financiers would only fund the project if budgets were correct. This involved a significant projection and feasibility study of project finance costs, leasing plans and agreed revenue from centre. The financiers also undertook their own finance checks, assessed by an independent cost consultant, WT Partnership, who checked costs, values variations etc. The banks also engaged independent retail experts every month who sat on a agreed leasing panel to assess that DD were meeting budgets and adhering to the project's program. Checks were also carried out on demographic studies to ensure demand was there for a centre of this size and nature and DD had to sign up major tenants before finance was approved.

4.6.3 Community Risk

Community support for the development of Top Ryde was significantly high. This risk was initially managed at approval stage by going out to a full public review and debate. One frequent topic was the issue of pedestrian access to the Centre. Access was proposed to change via pedestrian bridges and the community raised the question as to why do we have to cross the bridge, why cant we cross the road like we used to? These issues change

overtime, as do community members, so referring them back to a public consultancy process years earlier doesn't always lead to a positive outcome for the public. These risks must be managed by and upfront agreement and continuously responding to public questions. A continued community interface, such as newsletters, meetings, consultation etc in order to provide a successful method for problem solving and keep the community in a positive frame of mind about the project. BLL have had very good people on the job but when they demonstrate how good they are they are often taken off the job and put on other projects sometimes without informing other partners such as CoR and DD. This was not a good example of open communication. BLL Engineers are good technical people but, in the main, not good at dealing with community.

The maintenance of the lifts that connected to the pedestrian bridges was a significant community and technical risk. There was community backlash to the first bridge when the lifts were not operational due to system failure. In hindsight, both bridges should have been operational at the same time in order to manage ongoing pedestrian access to the centre. Greater security measures were also introduced to prevent ongoing vandalism. This helped to enforce that the biggest risk was managing the change for people (community). Change can be perceived as simple to some, yet significant to other members of the community. The simple fact that they can no longer walk across the road and must now use a bridge, or that a bus stop is moving 50m down the road etc can lead to ferocious community backlash. Constant assessment on the impact on community is important to ongoing project success. The issue of the pedestrian bridges was a significant contractual issue as the RTA made it a condition that pedestrian crossing on Devlin Street, a main arterial route with over 90,000 daily traffic movements, be removed to improve traffic flow.

5. Conclusion

A PPP consortium is a temporary organisation with a complex network of players with competing goals and objectives, many of whom never get to see the complete picture. Inevitably the group operates under pressure, particularly the members of the SPV (Special Project Vehicle) who are the drivers of the process. Social, as opposed to economic, infrastructure PPPs are more complex. Much of the negativity and adversarial environment, which surrounds PPPs, is due to a lack of transparency not just in terms of the bidding process, but also with regards to the identification of risk and opportunity. PPPs act as an essential but relatively minor part of Governments' asset acquisition program. However, as they tend to be large, complex projects that can affect people's lives for a very long time, PPPs arouse a great deal of interest and passion.

The results of this research were developed from project documentation and semi-structured interviews with Senior Management participants representing the various project stakeholders from both the public and private sectors. Over the course of the interviews the following six themes emerged from the Top Ryde PPP: Project Background; The Tripartite Agreement/Legal structure; Contractual links; Legal costs; Relationship Management; and Risk Management. Three features appear crucial issues in the success of this project: *the delivery model; risk management; and communication.* Over-arching these three themes appears to be the adoption and integration of successful relationship management. All in all,

Top Ryde is an excellent example of how PPPs cab be successful, rewarding and provide value for money to all stakeholders including the broader community.

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The impact of construction organisations' learning capabilities on collaborative projects*

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Abstract

Dynamic capability theory asserts that the learning capabilities of construction organisations influence the degree to which value-for-money (VfM) is achieved on collaborative projects. However, there has been little study conducted to verify this relationship. The evidence is particularly limited within the empirical context of infrastructure delivery in Australia. Primarily drawing on the theoretical perspectives of the resource-based view of the firm (e.g. Barney 1991), dynamic capabilities (e.g. Helfat et al. 2007), absorptive capacity (e.g. Lane et al. 2006) and knowledge management (e.g. Nonaka 1994), this paper conceptualises learning capability as a knowledge-based dynamic capability. Learning capability builds on the micro-foundations of high-order learning routines, which are deliberately developed by construction organisations for managing collaborative projects. Based on this conceptualisation of learning capability, an exploratory case study was conducted. The study investigated the operational and higher-order learning routines adopted by a project alliance team to successfully achieve VfM. The case study demonstrated that the learning routines of the alliance project were developed and modified by the continual joint learning activities of participant organisations. Project-level learning routines were found to significantly influence the development of organisational-level learning routines. In turn, the learning outcomes generated from the alliance project appeared to significantly influence the development of project management routines and contractual arrangements applied by the participant organisations in subsequent collaborative projects. The case study findings imply that the higher-order learning routines that underpin the learning capability of construction organisations have the potential to influence the VfM achieved on both current and future collaborative projects.

Keywords: Learning capability, learning routines, collaborative projects, value for money, collaborative projects.

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* Supported by the Alliancing Association of Australasia and the Australian Research Council (Linkage Project 110200110)

1. Introduction

Collaborative contracting has been increasingly adopted by the Australian infrastructure industry in recent years as a procurement method for large and complex projects (Morwood et al. 2008). Project alliances, partnering, early contractor involvement, and early tender involvement are typical delivery approaches that apply collaborative contracting principles (Chan et al. 2010; Lahdenperä 2012; Mignot 2012). Collaborative contracting approaches are constantly evolving to suit market conditions. In particular, the recent turbulent economic environment of the infrastructure sector has generated increasing pressure to improve the efficiency and effectiveness of project performance during complex project delivery (Leiringer et al. 2009; Morwood et al. 2008; Ross 2008). These circumstances demand that organisations (both clients and service providers) demonstrate high level management and technological capabilities, so as to optimise project performance when applying collaborative contracting methods (Department of Infrastructure and Transport 2011; Hartmann et al. 2010; Hauck et al. 2004; Love et al. 2010; Manley 2002).

A recent Australian based study (Department of Treasury and Finance 2009) revealed significant performance heterogeneity between collaborative contracting projects. This implies that the extent to which value-for-money (VfM) is achieved is highly variable between projects. The causes of project performance heterogeneity within the collaborative contracting context have drawn intensive attention from academics, researchers and industry practitioners. Relevant published research studies and industry reports primarily focus on the influence of project governance mechanisms such as target cost arrangements, financial risk and reward sharing regimes, project leadership structure, and integrated team selection and formation (Chan et al. 2010; Eriksson 2008; Hauck et al. 2004; Lahdenperä 2012; Love et al. 2010; Rahman and Kumaraswamy 2008). Although recent years have seen an increase in studies regarding the resources of organisations engaged in construction projects (e.g. Hartmann et al. 2010; Jin 2010; Leiringer et al. 2009; Rose and Manley 2012), there is very little that emphasises the learning routines and capabilities that enable organisations to achieve VfM during collaborative project delivery.

The theory of evolutionary economics (Nelson and Winter 1982), and the resource-based view, (Barney 1991; Wernerfelt 1984) propose that rent differentials are caused by the resource configuration of organisations. Dynamic capability studies posit that such an advantageous resource configuration is achieved by dynamic capabilities, which are purposely developed through organisational learning in response to environmental changes (Eisenhart and Martin 2000; Helfat et al. 2007; Teece et al. 1997; Zollo and Winter 2002). Based on this theoretical background, the current study seeks to explain project performance heterogeneity from a ‘learning perspective’, and specifically focuses on the learning capability of construction organisations, and the performance implications of this capability.

This task is assisted by consulting the empirical propositions of the strategic alliance literature (e.g. Das and Teng 2000; Grant and Baden-Fuller 2004; Koza and Lewin 1998), as well as those arising from construction management research (Hartmann et al. 2010; Leiringer et al. 2009). Although strategic alliance literature focuses on on-going relationships,

rather than one-off project-based relationships, it is still relevant to this study because strategic alliancing and collaborative contracting share similar governance mechanisms (Das and Teng 2000). It has been empirically supported that alliance firms' learning routines are positively associated with alliance success rates (Kale and Singh 2007). Learning routines also help to develop a firms' overall ability for effecting superior alliance performance (Heimeriks and Duysters 2007; Schilke and Goerzen 2010). The evidence derived from recent construction management studies also suggests that the development of project participants' capabilities in managing collaborative projects is driven by deliberate learning and evolves in response to dynamic market changes (Hartmann et al. 2010; Leiringer et al. 2009).

This paper has two key sections. Firstly, the paper starts with the conceptualisation of 'learning capability' as a dynamic capability, by drawing from the literature streams of the resource-based view of the firm (Barney 1991; Wernerfelt 1984), the dynamic capabilities view (Eisenhart and Martin 2000; Zollo and Winter 2002), absorptive capacity (Cohen and Levinthal 1990; Lewin et al. 2011), and knowledge management (Grant 1996b; Nonaka 1994). Secondly, under the guidance of this conceptualisation, the subsequent section reports a case study that highlights the learning routines used by the participant organisations to achieve superior VfM for an award winning Australian alliance project. The case study also explores how learning routines applied at the project level affect the participant organisations' corporate strategies for delivery of subsequent collaborative projects.

2. Learning capability

The resource-based view of the firm emphasises that value maximisation of an organisation is achieved through the configuration and utilisation of valuable resources (Barney 1991; Wernerfelt 1984). The resource configuration perspective suggests that organisations that participate in collaborative contracting may be expected to identify two primary strategic objectives, which must be fulfilled in order to optimise project delivery performance. This assertion is supported by the strategic alliance literature. The first of these objectives is to obtain valuable resources, which are imperfectly mobile, imitable and substitutable (Barney 1991), and are unavailable through other transactional forms (e.g. traditional construction contracts). The second is to use the acquired valuable resources to reconfigure a unique resource base for the purpose of sustaining competitive advantage. According to the dynamic capabilities view (Helfat et al. 2007), which focuses on resource renewal and evolution, the extent to which an organisation fulfils these objectives depends on its ability to create, extend, or modify its resource base, augmented to include the resources of its project partners. In addition, the development of an organisation's overall capability to manage collaborative contracting projects is driven by the development and use of deliberate learning routines (Carrillo et al. 2006; Hartmann et al. 2010).

Routines are perceived as the building blocks of organisational capability (Winter 2003), and may be defined as "stable patterns of behaviour that characterise organisational reactions to variegated, internal or external stimuli" (Zollo and Winter 2002, p. 340). Different learning routines are applied at different levels of organisational capability to achieve specific

management outcomes that are unique to each capability level (Grant 1996a; Sanchez 2001). Operational or 'zero-level' capabilities are those that permit a firm to generate revenue and profit in the short term (Winter 2003; Zollo and Winter 2002). Collaborative project management is considered to be an operational capability, and is reflected by the project management and operating routines a participant organisation uses to run a project. Dynamic capabilities are 'higher-level' capabilities that operate to extend or create operating routines for the purpose of enhancing profit in the future (Winter 2003; Zollo and Winter 2002). The current study focuses on a particular type of dynamic capability – that of knowledge/learning – which helps sustain the long-term competitive advantage of firms.

The dynamic capabilities' view posits that more deliberate cognitive processes are required to enhance understanding of the causal linkages between the actions taken by an organisation, and the performance outcomes it obtains (Eisenhart and Martin 2000; Zollo and Winter, 2002). Learning that shapes and develops capabilities and operating routines needs to be "deliberate" and "go beyond semi-automatic stimulus-response processes and tacit accumulation of experience" (Zollo and Winter 2002, p. 341). In this vein, ideally, learning capability is purposely developed by organisations that frequently participate in collaborative projects, enabling them to systematically create and modify their project routines, and hence ultimately drive the evolution of their collaborative project management capabilities. Moreover, according to Helfat et al. (2007), the definition of learning capability applies to not-for-profit organisations, such as public sector clients, and for-profit organisations such as private sector clients and service providers. Both not-for-profit and for-profit organisations may face and/or initiate changes (Helfat et al. 2007).

Learning capability is structured, persistent, and represented by a stable pattern of higher-order learning routines (Lewin et al. 2011; Zahra and George 2002; Zollo and Winter 2002). The underlying routines of learning capability explore, retain and exploit knowledge both inside and outside firm boundaries, and are responsible for the creation and configuration of other organisational capabilities and operating routines (Lewin et al. 2011; Lichtenthaler and Lichtenthaler 2009). Due to the complexity of cognitive learning (Nooteboom 2009) and the tacit nature of knowledge (Nonaka and von Krogh 2009), learning capability is organisation specific and idiosyncratic. Thus, learning capability constitutes a valuable resource in its own right, and ultimately a source of organisational competitive advantage and project performance heterogeneity (Barney 1991; Nelson and Winter 1982). Although organisational knowledge, in particular tacit knowledge, is a valuable strategic asset that is not easily diffused across the boundary of the firm (Spender 1998), collaborative project management serves as an instrument for inter-organisational knowledge transfer and innovation (Carrillo et al. 2006; Love et al. 2002). Hence, organisations with better learning routines are more likely to both achieve and benefit from successful collaborative project delivery because they are better able to absorb and apply knowledge generated or held by other organisations (Hartmann et al. 2010; Love et al. 2002).

Recent developments in the areas of knowledge management (e.g. Nonaka 1994) and absorptive capacity (e.g. Cohen and Levinthal 1990) lead to an integrated perspective of knowledge-based dynamic capability (Lewin et al. 2011; Lichtenthaler and Lichtenthaler 2009). From this perspective, learning capability is underpinned by the micro-foundations of

internal and external learning routines (Lewin et al. 2011; Lichtenthaler and Lichtenthaler 2009). The external learning includes three types of routines: exploratory, transformative, and exploitative, as asserted by traditional absorptive capacity theory, particularly the consideration of knowledge leveraged from external sources (Lewin et al. 2011; Lichtenthaler and Lichtenthaler 2009). The internal learning routines facilitate variation and new idea generation, dissemination and combination of internally generated knowledge, and use of the knowledge to update old routines (Nonaka 1994; Zollo and Winter 2002). In addition, complementarities between internal and external learning routines are essential to make external routines useful (Lewin et al. 2011). Knowledge acquired through external learning routines needs to be selected, codified and internalised through internal learning routines in order to result in the desired modification of operational capabilities and routines (Lewin et al. 2011). Figure 1 illustrates the capability-based theoretical assertions that have been addressed above, as well as the relationships between them. The current study acknowledges the importance of operational capabilities; however, the focus here is on higher order level dynamic capabilities.

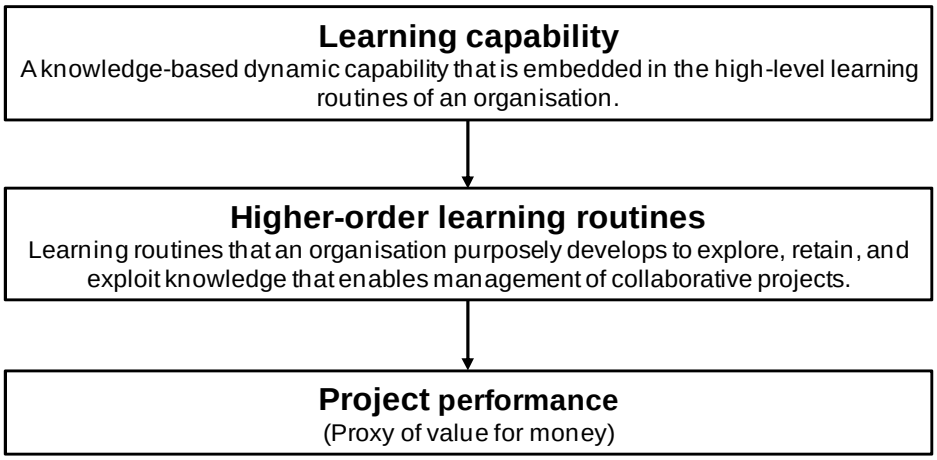

Figure 1: Learning Capability Model (Source: Authors of this paper)

3. Case study

3.1 Methods

An exploratory case study was carried out to investigate the value of the framework (Yin 2009). The objectives of the study were to demonstrate: 1) how learning routines at the project level can be applied by participant organisations to influence project VfM; 2) how project-level learning routines and knowledge affect the development of organisational (firm) level learning routines amongst participant organisations; and 3) how newly developed organisational level learning routines impact the VfM achieved on subsequent projects conducted by participant organisations.

An Australian rail infrastructure alliance was chosen as the case example. The Alliance was a project collaboration between five participant organisations, including two government

owners, and three non-owner participants, comprising a contractor and two design consultants. The Alliance was formed in 2007, with construction commencing during 2008 and project completion occurring in 2010 (Alliancing Association of Australasia 2012). The project was completed four months earlier than the target date, under budget, and in spite of numerous challenges including scope, political and procurement strategy changes (Alliancing Association of Australasia 2011; 2012).

Multiple sources of data were used to inform this case study. This enabled data triangulation so as to ensure the validity of the findings (Neuman 2003; Yin 2009). Sources of evidence comprised: (i) discussions with representatives from the Alliance during the Alliancing Association of Australasia Annual Convention in 2011; (ii) a presentation given by representatives from the Alliance team during the convention; and (iii) project information provided by the participant organisations in corporate brochures or web sites. At the AAA 2012 annual convention, further discussions were conducted with industry specialists in the field of collaborative contracting. These discussions assessed the existence of bias arising from the self-reports gathered the year before. No bias was revealed, and this was attributed to the gathering of data from both sides of the owner/non-owner divide.

The types of project-level learning routines that occurred in this project have been categorised as (i) joint learning, (ii) continual learning, (iii) learning governance and (iv) learning evaluation. This categorisation is the result of content analysis applied to the empirical data, viewed through the lens of the learning capability model. The final categories are the result of thematic grouping and coding undertaken independently by each of the three researchers involved, with refined common themes informing the final categories. This cross-referencing ensures the reliability and trustworthiness of the categories.

3.2 Case study findings

This section of the paper will outline the project-level learning routines developed and applied in the case study project, and how these routines impacted on the project VfM.

Joint Learning

The non-owner participant organisations of the case study Alliance team had worked together on a previous project. This enabled learning routines that had been developed jointly on the previous project to be applied from inception of the new project, whilst providing a strong platform for continuous improvement of those routines. The shared prior learning experiences also helped the team to bond rapidly and work together to design and price the Total Cost Estimate (TCE) (Alliancing Association of Australasia 2012). This was critical for managing the challenges of the complex scope. Learning routines such as detailed workshops consolidated the learning outcomes of the initial stage of the project, which were reflected in the resultant project proposal and the detailed TCE. Furthermore, a unique learning challenge faced by the Alliance team was to integrate the often conflicting product standards of the two owner organisations (Alliancing Association of Australasia 2012). All owner and non-owner participants worked together to develop a hybrid standard.

This involved learning routines such as discussion and negotiation, supported by the use of operational simulation technologies.

Continual Learning

The learning in this Alliance occurred continually throughout the project delivery period. The case study revealed that in line with the work of March (1991), the learning routines that were developed combined exploratory learning that allowed the Alliance team to experiment with new knowledge, and exploitative learning that helped the team to refine and extend existing routines and technologies. The complementarity between exploratory and exploitative learning was reflected in the process adopted by the Alliance team for the establishment and reinforcement of collaborative values within the team. Values represent essential knowledge that help to build organisational culture, leadership styles, and more formal governance mechanisms such as performance evaluation schemes (Foss and Michailova 2009; Nooteboom 2009). The Alliance team recognised the challenge of developing collaborative values to integrate the team, given that the team was formed by organisations representing intrinsic differences due to the nature of their work (e.g. designers vs. constructors) or the nature of their organisation (e.g. public vs. private sector).

The collaborative values of the Alliance team were developed by 20 core people when the alliance was formed (Alliancing Association of Australasia 2012). The knowledge associated with the new values was disseminated to over 100 people within a month to ensure that a distinctive collaborative culture was established (Alliancing Association of Australasia 2012). Through the project operations, the values were refined by the broader Alliance team. Exploratory learning routines were used to highlight the most common and important aspects of the values, and exploitative learning was carried out to disseminate and reinforce the values within the team. For example, weekly team briefings were usually carried out in morning tea settings to facilitate continuous knowledge externalisation and new idea generation. Team building activities were often integrated into the briefings for the purpose of forming a sustained integrated team spirit, and reinforcing alliance vision and values. According to Nooteboom (2009), these activities create cognitive focus within an alliance team, which enable the team to apply the project values and new knowledge in project operations more efficiently over time.

Learning Governance

The Alliance deployed governance mechanisms to facilitate and enable project-based learning. A typical example was the development of the Business Improvement Group (BIG), which was formed to coordinate the continual learning of the project (Alliancing Association of Australasia 2012). BIG committee members were professionals (e.g. project engineers) drawn from a range of functional areas including commercial and construction, design, quality, safety, community and environment. They were able to distribute the learning outcomes to their fellow workers at the operational level. For instance, learning outcomes were identified in early project operation activities, in particular those associated with repetitive works, such as earthworks, piling and concrete structures. Through the BIG mechanism, new experiences and best practices were actively shared to improve the

efficiency and quality of the works. BIG also disseminated learning through special learning workshops within an informal lunch setting, and distributed a regular newsletter to share problem-solving solutions.

Learning Evaluation

The construction management literature argues that learning outcomes are much more effectively disseminated if the review process and project performance evaluation embrace benchmarking and other continuous improvement approaches (Bresnen 2007; Love et al. 2002; Robinson et al. 2005). In line with these arguments, the case study found that the Alliance team integrated these types of learning routines within the reporting and evaluation process, which codified data on practices that resulted in both over and under performance. The team adopted an ongoing cost-planning process that facilitated a routine measure of productivity at a detailed level (Alliancing Association of Australasia 2012). In addition, monthly reviews were undertaken to assess the actual project progress versus the estimates. Every month the Key Result Areas (KRAs) (e.g. quality and traffic management) were evaluated against high standards to support the achievement of client goals. On a monthly basis, the evaluation results were recorded, reported and discussed with the alliance management team to generate continual improvement strategies for project operations. It was commented by a representative from the Alliance team that continual learning evaluation enabled the team to achieve an 'outstanding' overall performance. Completion of the project ahead of time fortuitously enabled the provision of essential services to the community following the floods in South-east Queensland in early 2011. The case study thus revealed that project learning indeed modified and improved the project management and operational routines which enabled the team to achieve superior VfM in delivery of the project.

4. Conclusion

Building upon the review of extant literature, this study conceptualises learning capability as a knowledge-based dynamic capability that a construction organisation purposely develops to improve the management and operation of its collaborative projects. Learning capability is built upon the organisation's high-order learning routines. Based on this conceptualisation, an exploratory case study was carried out within the context of an award winning infrastructure project alliance team in Australia. The findings of the study suggest that project-level learning routines might constitute the most essential and dynamic micro foundations for the learning capabilities of construction organisations which are involved in collaborative project delivery. Their project-level learning routines have the potential to provide an essential contribution to the development of corporate knowledge and corporate learning routines which ultimately configure their corporate strategies for managing collaborative projects.

In addition, the learning routines that have assisted one project to achieve VfM are highly likely to be applied in other projects based on either collaborative or conventional contracts. The case study findings show that the learning within a collaborative project is undertaken together by both owner and non-owner participants. Joint learning is a continual process,

which is: influenced by the prior collaborative learning experiences of participant organisations; carried out continually to deal with the challenges of the current project; and impacts on the learning practices of future collaboration in project delivery. Moreover, it is to be expected that collaborative project learning outcomes impact on the collaborative practice of other construction organisations through external learning mechanisms such as industry forums and conventions.

The generalisability of the case study findings is limited because the data sources were all official in nature, suggesting that personal views were overlooked. Nevertheless, this exploratory case study has prepared a good foundation for further empirical investigations with larger scope. Such research is planned by the authors for 2013. The concept of learning capability will be expanded by identifying highly disaggregated learning routines, based on the literature. A large-scale survey will be carried out to examine the extent to which these learning routines influence project outcomes in the construction context. The authors expect that the future empirical investigations will identify the fine-grained learning routines that maximise VfM on collaborative construction projects.

While the conceptual discussion in the current paper extends the theoretical basis for understanding organisational learning in the construction project context, the case study results provide interim guidance for project managers seeking to improve Vfm on collaborative contracts. As discussed, both these contributions fill important gaps in construction management literature.

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CIB 2013 World Congress

BIM-supported planning process for sustainable buildings – Process Simulation and Evaluation through Exploratory Research

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Abstract

One of the consequences of increasing complexity of planning and construction process is a large number of disciplines participating in planning process, all of whom use wide spectrum of specialised visualisation, simulation or calculation tools. With the maturing of BIM tools and their increasing presence on the market, the hope for possibility of maximisation of process-integration through joining all of the different building-representation models in one single joint model came up. The planning practice reality however demonstrated a number of upcoming problems with BIM implementation on technical- (heterogonous data, interfaces, large data volumes) but even more so on process-level (question of responsibilities and work-load distribution, lacking standards or conventions on building-representation). The optimal data management, transfer and synchronisation within very inhomogeneous software context, such as employed within construction projects, require enormous organization, coordination and communication effort in the earliest design-phases. The BIM implementation implies therefore on necessity of fundamental rethinking of the traditional design process; for which the knowledge is still largely lacking.

In this paper we will present the first results of the exploratory research carried out at the Vienna University of Technology. We simulated a BIM-supported multi-disciplinary planning process with students of architecture, structural engineering and building physics, using several BIM-software tools. First insights on process-quality, such as team-, process- and technology satisfaction, as well as conflict- and stress levels will be presented. We were able to identify numerous technical problems related to the data transfer and inconsistencies in translation, which resulted in participant dissatisfaction and significant increasing of work-loads.

The first results imply on the importance of traditional process-design techniques such as face-to face communication, coordination and work-load allocation between the team-members in order to conduct efficient BIM-supported process; as well as on urgent need for advancement of the tools in terms of data transfer- and exchange. In the next step, using mandatory protocols and timesheets, a detailed statistical analysis of the people-process-technology issues will be conducted, as well as comparison of „Open-Platform-BIM“ to „One-Platform-BIM” model.

Keywords: BIM, Collaboration, Integrated Planning, Exploratory Research, Experiment

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1. Current issues in BIM-adoption and utilization

With upcoming requirements for sustainable building, the need for more integrated planning practice, which would enable simultaneous collaboration of various disciplines in order to share and create new common knowledge, arises. BIM (Building Information Modelling) has often been recognised by research and practice as suitable tool for support of collaborative planning, facilitating communication and information exchange between diverse planning process participants; and eventually to leading to maximization of efficiency- and quality and reducing time effort (Sebastian and van Berlo, 2011). Especially promising seems BIM in terms of life-cycle oriented planning and optimisation. BIM is largely understood as object-oriented digital representation of a building or built environment that enables interoperability and data-exchange in digital form (Kiviniemi et al 2008). In this context BIM addresses primarily the process of model-building and information exchange (Succar, 2007). BIM is believed to bear large potential towards integrated design (Prins and Owen, 2010) inducing a shift from AFC fragmented practice that still largely dominates the AFC industry (Fellows and Liu 2010). Rekkola et al (2010) argue that “integrated design” is still handled rather loosely in the practice – often is the creation of BIM model sufficient for the project to be referred to as “integrated project”, regardless of actual interdisciplinary data sharing and model use. BIM, in our understanding is much more about how (design of design process), that about what (building model and its properties). Since the AEC industry is project-oriented, the small markets are characterised by high fluctuation of the employees and of the related know-how loss. Owen et al (2010) point out the need for enhancement of skills of project members, which are often highly specialised in own fields of expertise, but seldom trained to work in integrated project environment. The organizations also seldom support this kind of professional development. The introduction of the new BIM-tools therefore mostly means more than simple CAD-tools shift, since the adoption is mostly related to the reorganization of the processes and management strategy of the project-based organization. In the practical BIM operation and use a number of problems on different levels can be met. On the technological level the questions of the interfaces in the data transfer of the interdisciplinary models arises, as well as of the heterogeneous data-structure of the different software the art of model building and management of ever larger data-volumes. On the semantical level, it can be noticed that each discipline needs individual information; the professional languages differ strongly as well as the means and methods to represent a building (Bazjanac and Kiviniemi, 2007). The spectrum reaches from diverse lists for project management and quantity surveys, over reduced slab model for structural engineering for earthquake simulation, to complete spatial representation of architectural model in the full geometric complexity. The optimal management, filtering and reliable synchronisation of these very differentiated information in the context of in the building industry still dominant heterogeneous software-structure requires high effort in organisation, administration interdisciplinary communication and know-how. A standard solution offering the complete software package for this large spectrum does not yet exist, and it is a question if such solution is viable for every building and consequently every design process is of prototypic nature.

The high fragmentation of the design and construction process disables the management of complexity the linear planning process of highly specialised disciplines proves as not

suitable for the achievement of sustainable buildings. The necessity for change in the way the buildings are designed, constructed and operated is being continually reported by the practice. The emerging of highly developed BIM tools together with maturing of promise a paradigm change from the linear, fragmented process towards more integrated practice that would not only bring benefits for the planning and construction but even more so for the optimisation of operation. A life-cycle oriented approach brings whole-life value enabling knowledge management and -transfer form life-cycle phase to phase and integrating building services and automation systems (Owen et al, 2010). The BIM-based Software-packages that would fully support and enhance the integrated, interdisciplinary planning practice and holistic life-cycle oriented data integration are still rather seldom. One-stop architecture and structural engineering, MEP (mechanical and electrical engineering), energy optimization, cost- and life cycle cost calculation are not available for the needs of Central European planning practice and building policy. Caused by the different project-constellations and mostly changing project-stakeholders with each new project, new combinations of software tools are to be met with each new project. For a successful implementation life-cycle oriented planning and management strategies, enabling smooth data exchange without information losses, standing in close relation with further development of open formats for data-exchange is a pre-requisite.

The BIM research was mainly focused on the problem-solving of the software-interoperability and efficient data exchange, only recently has the academic community realised that the successful BIM-adoption towards more integrated design and delivery is not only related to the handling of technical, but even more over so of the issues related to the need for the re-organisation of the design process itself (Succar, 2010, Pentilää 2008). This relates to the inter-organisational organization and standardization of the work-flows, role descriptions and related responsibilities of the stakeholders, as well as to the general commitment towards collaborative planning attitude. Rekkola et al (2010) argue the lack of knowledge beyond technological issues, in domain of workflow and business practices, where actual benefit of BIM is. In their case study of university building project, they identified problems and benefits of BIM-supported integrated process by creating categories: people (competence or knowledge problem), process (work-flows, timing, contracts, roles) and technology (software). They argue that a) for enhanced integrative practice a participative process is necessary and b) that the slow BIM-adoption in the practice is caused by the difficulty of interrelation (triangulation) of the people-process-technology problems.

2. Towards a research model

The over-all understanding for of BIM- related benefits for planning networks and for built environment is still not well understood, due to the complexity of the tools, but more over to the related transformation of planning process and inter-organisational procedures. Therefore, we argue that closer research of examining interrelations within the triangle: technology (operability) - people - process is necessary. In order to evaluate BIM performance regarding technology-people-process framework within an integrated planning process we conducted an experiment with students, simulating a multi-disciplinary planning process for sustainable building, using different BIM-software settings. Several experiments on BIM-performance either in real-time projects or simulating planning process with students

have been conducted, however always primarily focusing either on technology performance (interoperability, building model semantics) or on people-process issues.

Plume and Mitchell (2007) conducted in 2004 an experiment with 23 in a design studio setting students testing the IFC-model performance in multi-disciplinary collaboration (architecture, landscape architecture, MEP, statutory planning, sustainability and construction management.) They focused primarily on operational issues, such as building model (representation of a building model in different tools) and IFC –server data sharing issues. They conclude that the original architectural model needs significant adoption for the use of other disciplines or their tools. Further issue that needs attention is modell management – tracing of the changes and updates carried out on the common model

Sacks, Kaner and Eastman (2010) carried out the "Rosewood experiment", comparing the BIM-supported versus the traditional 2D CAD the planning and fabrication process of the pre-cast façade. BIM proved to be more efficient by 57%, however IFC proved not mature enough causing data inconsistency in transfer between architectural and engineering system. Losses in translation are to be assigned to object-semantic, a similar problem addressed by the Plume and Mitchell.

Sturts Dossick and Neff (2011) observed the collaboration of several teams on three real projects using a BIM-technology supported design process, focusing on people and process issues. They concluded that technology can even hinder the innovation of the design process through a too rigid corset of work-flow and knowledge exchange, hindering the exchange of tacit, informal knowledge. Their concept of "messy talk" – the informal, unstructured information exchange as often practiced in architecture and construction engineering is tested within student experiment, where geographically distributed teams work using BIM on a project in a virtual environment. They conclude that "…messy talk requires both the flexible, active, and informal setting described in the 2011 study as well as mutual discovery, critical engagement, knowledge exchange, and synthesis." (Dossick et al 2012).

3. Empirical Research through Experiment

Through exploratory research – an experiment within an interdisciplinary design class involving 40 students, the collaborative, multi-disciplinary BIM-supported planning for an energy-efficient office building is simulated. The experiment is a part of an on-going research project "BIM-Sustain: Process Optimisation for BIM-supported Sustainable Design" involving three institutes of Vienna University of Technology and seven BIM-software vendors. The close collaboration of academy and industry in this setting enables development of the customised strategic concepts for the BIM-tools within multi-disciplinary planning process and immediate impulses for improvement of software-tools. The multi-disciplinary teams taking part in the experiment consisting of: architect, structural engineer, building physicist (BS) were formed by the means of a pre-questionnaire, which questioned skill-level, experience and preference of the software. Upon the results of questionnaire a matrix of software-combinations used by each team was compiled (Figure 1).

	Architect	Structural Engineer		Building Science (Simulation in TAS)	
	CAD	CAD	FEM	CAD	Calculation
1	Allplan	Allplan	Scia Engineer	Allplan	Allplan
2	Autodesk Revit Architecture	Autodesk Revit Structure	SOFiSTiK	Autodesk Revit MEP	PLANCAL
3	ARCHICAD 16	TEKLA	Dlubal	PLANCAL	PLANCAL
4	ARCHICAD 16	Allplan	Dlubal	PLANCAL	PLANCAL
5	Autodesk Revit Architecture	Allplan	Scia Engineer	PLANCAL	PLANCAL
6	ARCHICAD 16	Allplan	Dlubal	Autodesk Revit MEP	PLANCAL
7	Allplan	TEKLA	SOFiSTiK	Autodesk Revit MEP	PLANCAL
8	Autodesk Revit Architecture	TEKLA	Scia Engineer	Allplan	Allplan
9	ARCHICAD 16	Autodesk Revit Structure	Dlubal	PLANCAL	PLANCAL
12	ARCHICAD 16	Allplan TEKLA	Dlubal	Autodesk Revit MEP	PLANCAL
13	ARCHICAD 16	TEKLA	SOFiSTiK	Autodesk Revit MEP	PLANCAL

Figure 1: Software-combinations used by the teams

In the course of the experiment (design class) basically two work-flow models can be identified: One-Platform BIM (proprietary) and Open-Platform BIM.
The Open-Platform BIM (Fig. 1, Groups 3-11) uses different, for each discipline relevant (typical, custom) software and works with central architectural building model, exchanging the data using the IFC. The One-Platform BIM (Fig. 1, Groups 1 und 2) work with one software family Nemetschek Allplan (2012) or Autodesk Revit (2012) using proprietary standard.

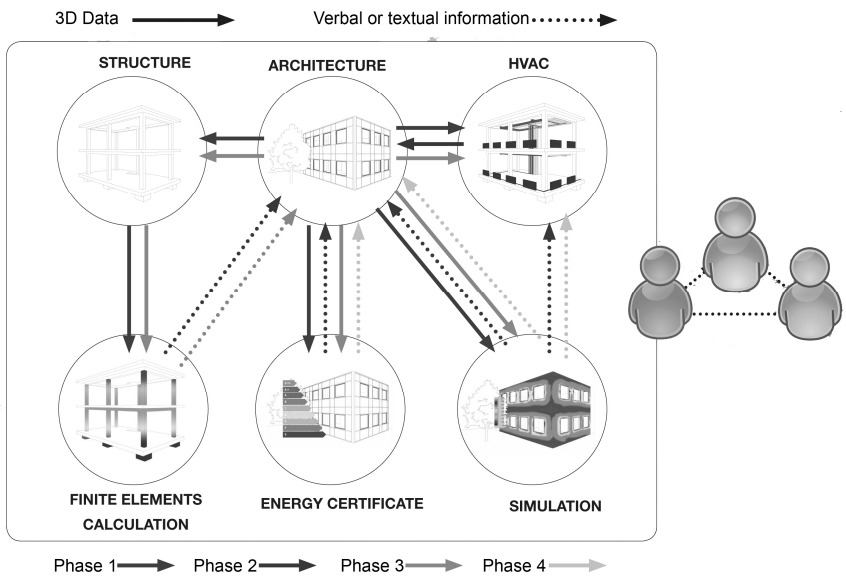

Figure 2: Multi-disciplinary teams, related building models and data transfer

The teams are producing the architectural-, structural, thermal and ventilation (as representative of MEP) models, as well as thermal simulation and energy certificate in collaborative manner (Figure 2). The groups were given an assignment consisting of a functional programme, site-plan with orientation and set origin, layer-structure and colour scheme for latter room-stamps. The time-schedule of the design-class is strictly organized; the experiment is taking place for one semester. We have organised three presentations, where in the first one the architectural model is presented, in the second presentation the structural and thermal and in the final presentation the optimised, full model containing all

the information. Between the presentations the crits as well as tutorials provided by software vendors are taking place. The experiment is examining the efficiency of the two BIM-models, communication effort, and work-allocation (work-flows) as well as satisfaction and conflict levels. Through the mandatory protocols and time-sheets the problems related to the technology (data transfer inconsistencies or losses, semantics) but also to the process-people related problems (conflicts, communicational difficulties, lack of work-flow definitions or responsibilities etc.) can be tracked. Additionally an e-learning platform has been set up, with a forum for tutor feedback as well as for student-communication, scheduling and posting of tasks is taking place.

4. First findings

The first data on satisfaction was gathered at the point close to the second presentation of structural and thermal models – basically one data exchange step has taken place – export from architectural model towards RFM and thermal simulation software. In the student workshop through rough questionnaire answered by 19 students (three architects, two engineers, 14 BS), a) satisfaction with BIM-technology, b) satisfaction with teamwork, c) satisfaction with process (work-flows), d) conflict-level and e) stress-levels were questioned on the scale ranging from 0 (low) to 6 (high).

Table 1: Results of the first questionnaire

Question	Mean Value	Meadian Value
Satisfaction with BIM	1,89	2
Satisfaction with teamwork	3,84	4
Satisfaction with process	2,37	2
Stress level	4,16	5
Conflict Level	1,37	1

The general BIM-technology dissatisfaction resulted through data transfer problems, reported especially by the BS students, using TAS simulation software, where data exchange uses gbXML standard. Mostly all of the architectural models had to be newly drawn in TAS due to the data loss or wrong interpretation by TAS. It was reported by the students that the time effort for the adaption of the imported model was equal to the time effort for creation of new model (two days).

When passing architectural geometry into structural analysis software two types of IFC-Files are used: Coordination View and Structural Analysis View (BuildingSmart 2012). Software for Finite Element Method (FEM) Simulation requires the Structural Analysis View of an IFC-File. But only a few CAD-Programs support the export of this type (Tab. 3), as well as not every FEM-Program supports the import of the physical model (Coordination View –Tab. 2). As a consequence, an intermediate step is needed to transfer the model from architecture to structural model: an import into a program which can import and export both types of files, a step which goes along with a loss of information (Figure 3). Due to this incompatibility it was

i.e. not possible to import an Allplan-Model as an IFC-File into the FEM-Software Sofistik (2012), because both programs support the type which cannot be read by the other one.

Table 2: Compatibility with IFC – Coordination View

CAD		FEM	
Archicad	⇄	Dlubal RFM	←
Allplan	⇄	Scia Engineering	⇄
Revit	⇄	Sofistik	
Tekla	⇄		

Table 3: Compatibility with IFC – Structural Analysis View

CAD		FEM	
Archicad		Dlubal RFM	⇄
Allplan		Scia Engineering	⇄
Revit	⇄	Sofistik	⇄
Tekla	⇄		

The IFC 2x3 (structural analysis view standard) still leads to variety of problems: especially more complex geometry such as sloped or rounded walls, roof elements and openings are very likely to cause problems or even disappear when being imported.

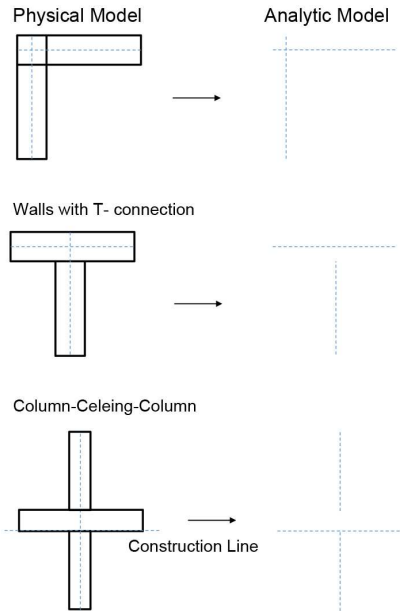

Figure 3: Results from export from architectural model, import in RFM simulation

For example, problems were the identified with Tekla Structures (2012): stairs become boxes, openings disappear, and round elements become rectangles. Findings from data transfer from Allplan to Scia (2012): when round walls are used, the model takes long period of time to get imported in Scia (hours). To illustrate further problems, we assembled a scene containing several pertinent elements, exported an IFC file and imported this into different structural analysis programs. Figure 4 illustrates the architectural model; Figures 5 and 6 the interpretations by different FEM software - a completely different result when importing the exact same IFC file.

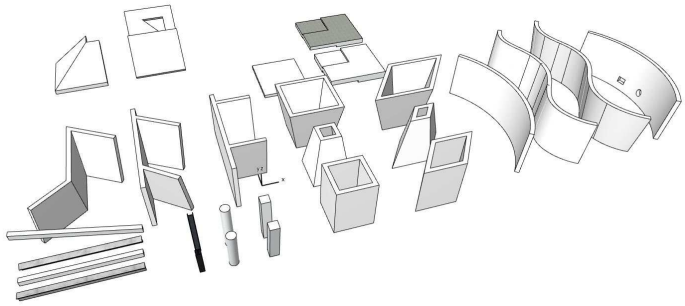

Figure 4: Architectural model from ArchiCAD16a

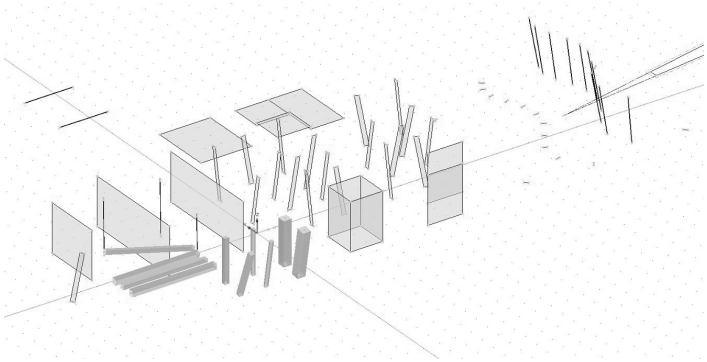

Figure 5: Import in Dlubal REFM

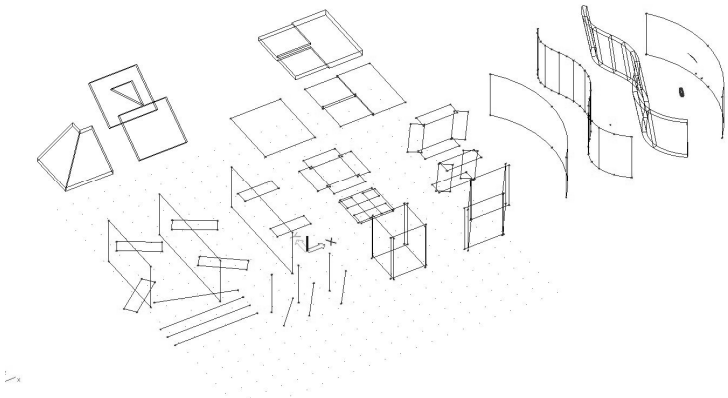

Figure 6: Import in Scia

5. Conclusion

This paper presented the first results of an experiment: simulation of BIM-supported multi-disciplinary design of energy-efficient office building, using various kinds of BIM-tools for architectural, structural, ventilation and thermal simulation modelling. For both structural engineering and thermal simulation, the data transition becomes difficult as soon as there is complex geometry involved, such as round walls, which have caused problems in all software-combinations. A problem of semantics of building models is a constant issue – architects use different room-stamps than BS, the pillars are drawn from slab to slab whereas structural engineers work with one continuous pillar from top to bottom slab. Further difficulties originate from incompatible software-combinations such as Allplan → Sofistik, or Archicad → Sofistik (see Tables 2 and 3). Such constellations can lead to significant problems in the current BIM-supported planning practice, if e.g. an architectural office using Archicad has to work with the structural engineers using Sofistik, since the data transfer will not be possible and purchase of additional software or of additional "BIM-services" will lead to increase of the planning costs.

In terms of comparison of One-Platform BIM versus Open-Platform BIM, it can be concluded that One-Platform BIM constellation, as closed system, does not exist on the market yet. The One-Platform BIM Software (Nemetschek Allplan and Autodesk Revit) both leave the original platform in order to conduct structural calculation and simulation; however offer proprietary interface to these software or even plug-ins (Revit to Sofistik). Even with proprietary interfaces the complex geometry causes problems in transfer through very long transfer-time (Allplan to Scia). The Open-Platform BIM, using IFC interface has proved as time-efficient and exact in transfer, if there is a standardised setting used for IFC transfer from architectural in structural model, and under condition that simple geometry is involved.

Our findings when compared to the student experiment executed in 2004/05 by Plume and Mitchel show that Archicad has made significant progress (at that time it was not able of producing a functioning IFC); however the question of the building-model semantics for different disciplines and the difference in the grade of required detailing for each model has not been solved yet. Our findings basically confirm the findings of the Rosewood experiment – we experience similar data losses and wrong interpretations at export-import of IFC; Rosewood experiment works with the same version of IFC. Further development of IFC is urgently necessary.

The **satisfaction with the BIM-technology** at current intermediate stage is has been reported as low, due to the very difficult data-transfer, inconsistency and data losses, especially so for the thermal simulation, where models had to be redrawn. **Processes-satisfaction** has been found as weak: work-flows are poorly organised among team-members, there are many problems in allocation of responsibilities. In many teams it is expected from the architect to undertake all of the major adaptions of the architectural model in order to make it fit for the transfer (the consultants are not ready to adopt the imported models). Teams often report that some team members are often not available.

On the level of **people-related problems**, despite the reported low conflict level, team-satisfaction is only average. We were able to observe a lack of team affiliation with most of the teams, often a bonding between the two disciplines can be observed and the third one is not playing along. This phenomenon might be referred to the lack of an organised kick off meeting. Some of the problems originate in the lack of professional knowledge (e.g. design of an office building or energy efficient facade) and in generally to lack of experience and knowledge of collaborative planning. In some cases the lacking of the team-building/bonding, and following the aim to „just finish the project“ led even to an increase of fragmentation of the design process (architect defines everything, the consultants only optimise in following steps), which is exactly the opposite of the expected BIM-effect. We can confirm the argument by Sturts, Dossick and Neff (2011) – BIM-technology is advantageous for exchange and presentation of explicit knowledge, but does not support the tacit knowledge of how the buildings are designed. Our first findings also imply that BIM-technology does not support integrated practice by itself, for the support of the collaboration other means are necessary such as well organised formal (kick-off meeting) and opportunities for informal communication (von Both and Zentner 2004).

Finally, BIM as presently used, hardly changes the work-flow between architects and structural engineers, not only due to technical interface limitations but even more so due to a logical contradiction. FEM models require a far lower level of detail than the architectural model delivers, so any automatically converted model necessarily needs to be post-processed manually by the engineer in order to simplify the model for reasonable meshing and resulting calculation times. When importing a coordination view IFC into calculation software, the discretization of architectural models into FEM-suitable meshes is carried out within the import and is hence forced to accept the model geometry “as it is”. For example, a small rounded wall opening, let’s say for a drainage pipe, will produce a complex mesh in the FEM model when being imported. For the structural system however, this opening is irrelevant, but still causes enormous effort in calculation and will hence be deleted by the engineer. Once simplified, such a wall element cannot be re-exported into the central model, because otherwise the opening would be missing. Vice versa, once the architectural model changes and is re-imported, the opening is back. The possible solution is either the radical improvement of FEM-software performance concerning calculation time for meshing; or enabling of the FEM software to directly manage the referential architectural model. The problem of bi-directional model-management remains one of the greatest challenges, not only because of the technical issues but mostly because of the process issues: definition of rights (who may change what and when?) related to change management. As first future step, detailed statistical analysis of the mandatory protocols and time-sheets will be carried out in order to gain more knowledge on performance of One-Platform BIM versus Open-Platform BIM, as well as of communication effort, work-allocation, satisfaction and conflict levels. In 2013 we will conduct the second experiment, where we will be able to use the first findings and propose framework for data-exchange procedures as well as careful design of communication. Finally we will compare the results of the two experiments, evaluate the benefits and verify the framework.

Acknowledgements

This paper is a result of an on-going research project “BIM-Sustain” funded by FFG (Austrian Research Funding Agency) and following BIM-software vendors: A-Null, Artaker, b.i.m.m. Gasteiger, Dlubal REFM, Sofistik, Construsoft Tekla and Nemetschek Allplan. We gratefully acknowledge the work of the academic partners: Institute for interdisciplinary Construction Process Management, Prof. C. Achammer, Institute for Management Sciences, Prof. S. Kösegy, Dr. M. Filzmoser and Institute for Building Physics and Ecology, Prof. A Mahdavi, L. Skoruppa and K. Kiesel, and to all the students taking part in this project of Vienna University of Technology.

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The effect of resource availability on completion time in volume home building

Adnan Fadjar[1], Nick Blismas[2], Ron Wakefield[3], Ehsan Gharaie[4]

Abstract

Volume home builders in Australia generally employ specialised subcontractors in their house construction projects which introduces immense coordination and production challenges. One of the challenges is increasing construction completion times due to resource shortage. The volume home building industry is often considered as the part of the construction industry that is very similar to the manufacturing industry. This paper investigates to what extent resource availability affects the completion time of individual houses when the volume home building production system is viewed as a manufacturing production system. To achieve this objective a typical single storey house construction process, which is based on actual data from a large volume home builder in Victoria, is simulated with a number of different resource availability scenarios using discrete event simulation methods. The simulation results demonstrate that the completion times stay relatively stable up to a certain level of resource availability. However, further reduction in resource availability leads to vast increases in completion times. This research shows how simulation methods can be used effectively to predict the effect of resource shortage on the completion time of individual houses.

Keywords: **Volume home building, house completion time, simulation, resource availability.**

1. Introduction

The Australian home building industry is an important contributor to the Australian economy. The home building industry provides jobs for 370,000 people and builds approximately 140,000 brand new homes, worth about $19 billion, every year and contributes 3.5 per cent of Australia's GDP (Housing Industry Association, 2012).

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The Australian volume home building industry is characterised by massive fragmentation. It consists of many small, medium, and large companies ranging from material suppliers, to home builders, and specialised subcontractors or trade contractors. This array of companies, often linked by poor communication, introduces immense coordination and production challenges; such as increasing construction completion time due to resources scarcity when housing demand is high.

During the period of 2000 to 2008 there was an increase in the average house completion time across Australia, as depicted in Figure 1.

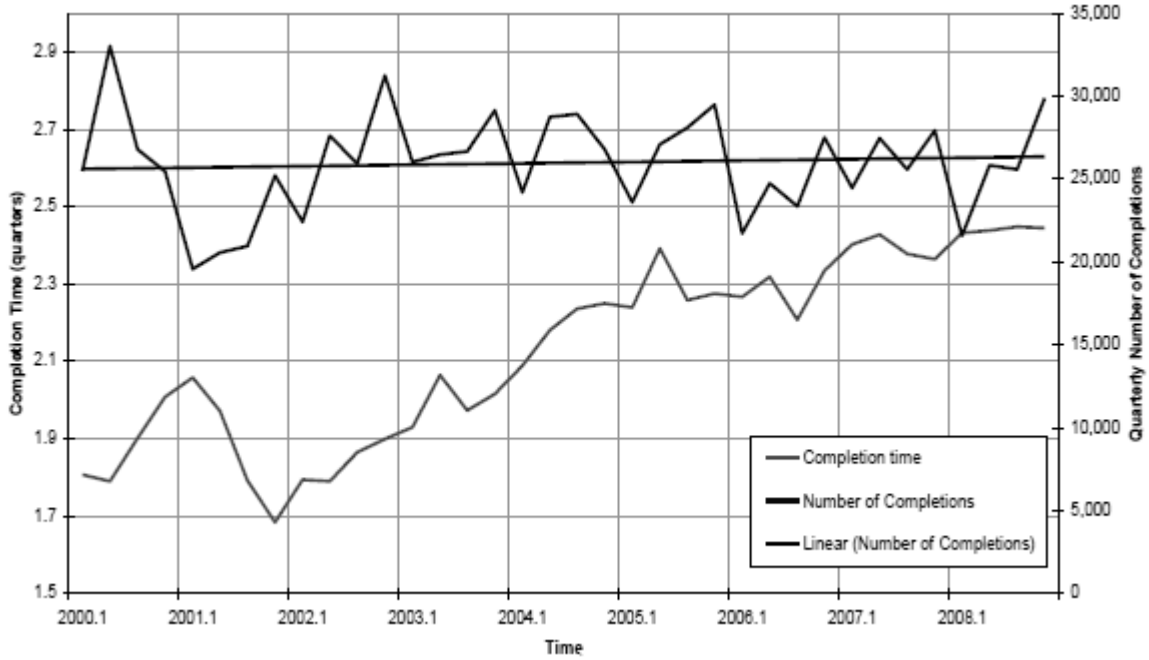

Figure 1: Australia quarterly average house completion times and number (Gharaie et al., 2010b)

Gharaie et al. (2010b) and Gharaie (2011) examined whether house size, in terms of house floor area was responsible for the increasing completion time and reached a conclusion that house size had limited impact on completion time. Dalton et al. (2011) suggest that a possible explanation for the lengthening in completion times could be resource availability which is related to the contract system used in the Australian volume home building industry.

This paper investigates to what extent the completion time of individual houses in the volume home building production system are affected by the availability of resources when viewed as a manufacturing production system. To achieve this, the construction process of a typical detached single storey house, which is based on actual data from a large volume builder in Victoria, has been modelled and simulated with variations in crew availability for one trade (concreter)

2. Context

The Australian volume home builders' contract system consists of three forms of contracts (Dalton et al., 2011), as follows.

- *A Supplier contract* is a contract between the home builder and a building material supplier for the supply of building material only. The home builder will have other contracts with specialised subcontractors to use these materials in the construction of the house.

- *A Supply and install contract* is a contract between the home builder and another company for the supply and the installation of materials on the house construction site.

- *A Subcontract* is a contract between the home builder and a subcontractor, who is usually a tradesperson employed directly to complete a specific job using materials and building components supplied by the home builder. These building components and materials are usually delivered to the house construction site by using a supplier contract.

In a typical house construction there are 108 contracts formed (Dalton et al., 2011) which consist of supplier contract (31%), supply and install contract (53%), and subcontract (16%). This number of contracts in new house construction is quite large and requires sound coordination and scheduling between contractors. Bashford et al. (2003) state that one of the critical factors that determines the successful completion of a residential project is the management of the numerous handovers between predecessor and successor trade contractors.

Dalton et al. (2011) state that each detached house project is delivered by a temporary organisation. Cherns and Bryant (1984) describe the temporary organisation as follows:

> … it is, in fact, a multiorganization since its membership is drawn from representatives of many different organizations; these representatives will eventually disperse, going back to their own organizations or on to some new project, when the building is complete, so it is only a temporary multiorganization. (p. 181)

In the Australian residential housing industry, many of these organisations become part of a multi-organisation comprising of partners or sole traders (Dalton et al., 2011). In the construction industry as a whole, approximately 60% of enterprises were sole traders and about 30% employed between 1 and 4 people (Australian Industry Group and The Australian Constructors Association, 2008). Furthermore, each of these organisations may be involved in other building projects being carried out by other multi-organisations or in other words by other volume builders. For instance, a carpet company is probably supplying and installing carpet material and fixing them in new homes being built by many volume builders. This situation could lead to resource shortages which in turn would increase completion times as jobs are delayed because subcontractors are not available when the volume home builder needs the job accomplished (Master Builders Australia, 2010).

Volume home builder production systems are more comparable to manufacturing production systems where more or less similar houses are being built repeatedly in a limited space. Such views of residential construction as manufacturing production systems have been

discussed by numerous authors (see for example; Ballard and Howell, 1998, Barlow and Ozaki, 2005, Blismas and Wakefield, 2009, Blismas et al., 2009, Gann, 1996, Koskela, 1992, Koskela, 1999, Koskela and Vrijhoef, 2001, Wakefield et al., 2001, Wakefield and O'Brien, 2004, Winch, 2006)

This study attempts to model the effect of resource availability on the completion time of individual houses in volume home building by using simulation methods. This study uses a discrete event simulation approach which has been recognised as a useful technique for quantitative analysis of construction operations (Bashford et al., 2003, Damrianant and Wakefield, 2000, Gharaie et al., 2010a, Gharaie et al., 2010c, Lu et al., 2008, Lucko et al., 2009, Martinez, 2010, Sawhney et al., 2005, Sawhney et al., 2001, Velarde et al., 2009, Wakefield, 1998, Wakefield and A.Sears, 1997, Wakefield and O'Brien, 2004).

3. Definitions and Assumptions

In order to have a clear understanding of the study results, the following definitions and assumptions are used in this paper.

3.1 Definitions

In this paper *project duration* refers to the duration of the construction of 100 houses; *completion time* (CT) refers to the duration of the construction of one house; *inter-arrival time* refers to the time between the construction start of two consecutive houses; *work in process* (WIP) refers to the number of houses under construction; *resources* refers to human resources only; *throughput* (TH) refers to the number of house completed per day; *job* refers to an activity performed by a specific crew.

3.2 Assumptions

All the houses are identical in design and size; inter-arrival time remains constant during the project; there is only one crew available for each job; job durations are deterministic.

4. Simulation of Volume House Production

A simulation model of a single story detached house construction process is developed based on a construction schedule employed by a large volume home builder in Victoria. This model comprises construction activities such as, slab construction, wall framing, roof tiling, etc. Logical relationships between activities is then included in the model to represent activities dependent on preceding activities.

The house construction process model is then simulated using Simul8 software with different scenarios to investigate to what extent the variations in resource availability that occur in day to day operations of volume home builders affect the completion times of individual house in the production system.

4.1 Dynamics of the volume house production

The duration of the jobs vary between 1 and 7 days. There are 100 houses to be constructed and each house construction process consists of 173 jobs performed by subcontractors and suppliers. Figure 2 shows a small section of the Simul8 representation of the construction process. All 173 activities are not included in this paper due to space limitation.

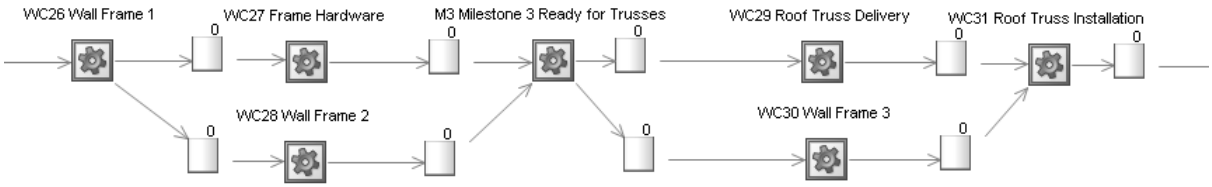

Figure 2: Simul8 representation of the house construction process

4.1.1 Inter-arrival time sensitivity analysis

With the assumption that all resources are always available when needed the simulation is conducted with different inter-arrival times ranging from 15 days to 1 day. These inter-arrival times are arbitrarily chosen in order to find out which inter-arrival time best represents the current situation of supervisors of detached housing, as they are usually responsible for the construction of up to 15 houses at any one time (Dalton et al., 2011). The simulation results as shown in Table 1 are then used to calculate *throughput* and *work in process* as follows.

4.1.2 Throughput and work in process calculation

Throughput of the simulation model is calculated by dividing the *number of houses completed* by the *project duration*. Once *throughput* has been determined the *work in process* can then be calculated using the equation known as Little's law which is a production modelling equation relating WIP to TH and CT (Hopp and Spearman, 2008). Little's law is presented in the following equation:

$$WIP = CT \times TH \quad (1)$$

Where WIP = work in process; CT = completion time; and TH = throughput.

Table 1 shows the result of the simulation runs and the results of *throughput* and *work in process* calculation.

Table 1: Simulation results of different inter-arrival times

Inter-arrival time (day)	Average Completion Time (day)	Project Duration (day)	Number of House Completed (house)	Average Throughput (house/day)	Average Work in Process (house)
15	160	1660	100	0.060	9.64
14	160	1560	100	0.064	10.26
13	160	1460	100	0.068	10.96
12	160	1360	100	0.074	11.76
11	160	1260	100	0.079	12.70
10	160	1160	100	0.086	13.79
9	160	1060	100	0.094	15.09
8	160	960	100	0.104	16.67
7	160	860	100	0.116	18.60
6	209.5	859	100	0.116	24.39
5	259	858	100	0.117	30.19
4	308.5	857	100	0.117	36.00
3	358	856	100	0.117	41.82
2	407.5	855	100	0.117	47.66
1	457	854	100	0.117	53.51

Based on the simulation results in Table 1 it is then determined that a 9 day inter-arrival or about 3 houses start every month which yields work in process of 15 houses is the best inter-arrival time to represent the current situation of the supervisors, as determined by Dalton et al. (2011).

4.2 Various resource availability simulation scenarios

The scenarios shown in Table 2 look at how the production system may behave by altering the availability of the concreter crew while assuming other resources are always available when needed and keeping inter-arrival time at 9 days for each scenario. In scenario number 3, for example, the concreter crew is only available 70% of the time that is 30% of the time the crew is working on other sites for other builders and other supervisors.

Table 2: Overview of the simulation scenarios

Scenario	Select resource availability	Other resources availability	Inter-arrival time (day)
1	Concreter crew 90%	Always available when needed	9
2	Concreter crew 80%		
3	Concreter crew 70%		
4	Concreter crew 60%		
5	Concreter crew 50%		

5. Results

The simulation results in Figure 3 show that up to 80% concreter crew availability yields relatively stable completion times. However, when only 50% of the concreter crew is available the completion times start to increase right after the third house enters the system and the difference in completion time between the earlier and the later houses in the system becomes larger. Take for example the completion times of house number 29 and house number 94 which are 300 and 600 days in length respectively; that is a 300 day difference when the resource is only 50% available. Whereas at 70% resource availability, the completion times of the same houses are 191 and 297 days respectively yielding a 106 day difference.

The simulation results show that the completion times stay relatively stable up to a certain level of resource availability. However, further reduction in the resource availability leads to vast increases in completion times.

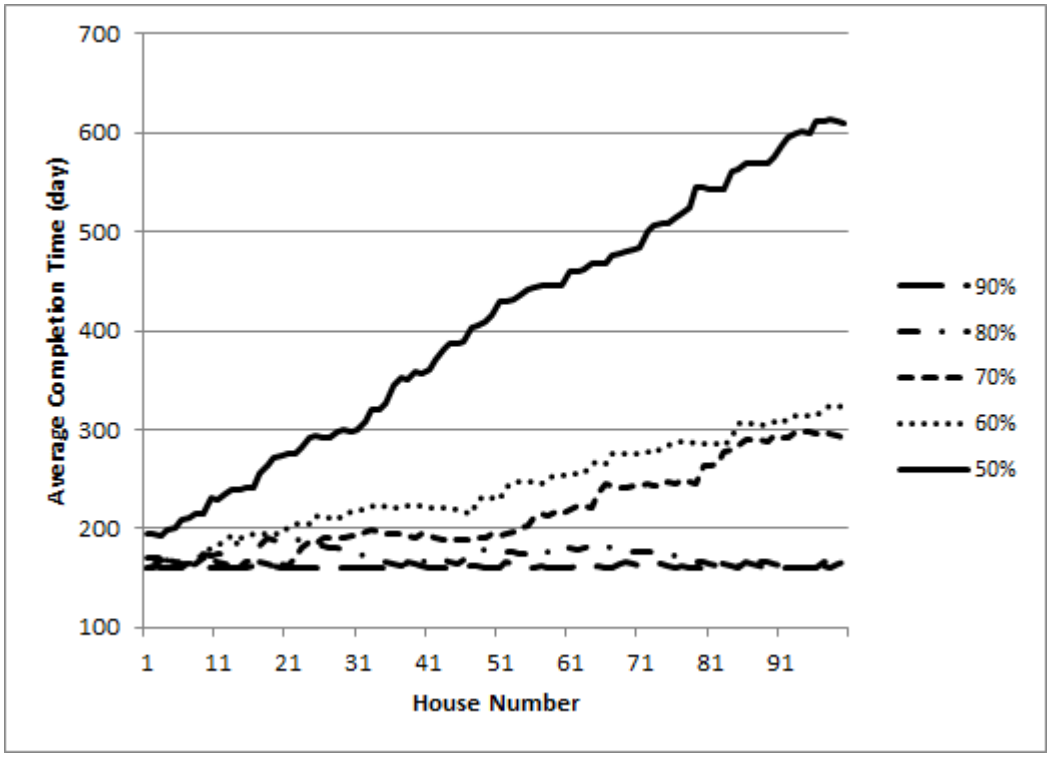

Figure 3: Completion time of individual house at different concreter crew availability

6. Conclusions

The nature of the Australian volume home building industry where subcontractors may work for more than one volume home builder could lead to resource shortages when housing demand is high. This study shows how simulation methods can be effectively used to demonstrate the effect of a key resource shortage on individual house completion times when volume home building production systems are viewed as manufacturing production systems. However, further research in this area is needed to investigate the effect on

completion time when more than one resource shortage exists and when resources entering and leaving the market are taken into account.

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Evidence-based Performance Enhancement for the Built Environment

Peter Barrett[1], Lucinda Barrett[2]

Abstract

The key role of understanding the societal impacts of the built environment, as highlighted in the CIB's Revaluing Construction initiative is highlighted and, in particular, the importance of the experience of the users. This is then contextualised in the struggles of the research community to evidence the holistic impact of spaces on human performance. Proposals are made to handle the conceptual and analytical complexity inherent in this issue. Building from these ideas a successful test of the approach is reported. This provides evidence that the built environment aspects of a sample of thirty-four UK primary schools explain around 25% of the variation in pupils' learning rates over a year.

The paper comes full circle to conclude on the systemic nature of built environment impacts, and the opportunity, if they can be better understood, to improve peoples' lives and make optimal use of the huge investments being made in the built environment. This could have radical impacts on how construction is seen – not dirty, dangerous and disruptive; but life-giving, economy-driving, a source of happiness and effectiveness. As well as raising the perception of the societal value of construction this perspective also has radical business implications for those in industry or design. By designing and building with the impact on users' health, well-being and effectiveness centrally in mind, greater value can be delivered for clients and thus the sustainability of the businesses will be enhanced.

Keywords: Industry effectiveness, user, impacts, evidence.

1. Introduction

The CIB proactive theme Revaluing Construction highlighted seven key aspects that demand comprehensive attention if sustained industry improvement is to be achieved (Barrett P S 2007; Barrett P S 2008). These are shown in Figure 1.

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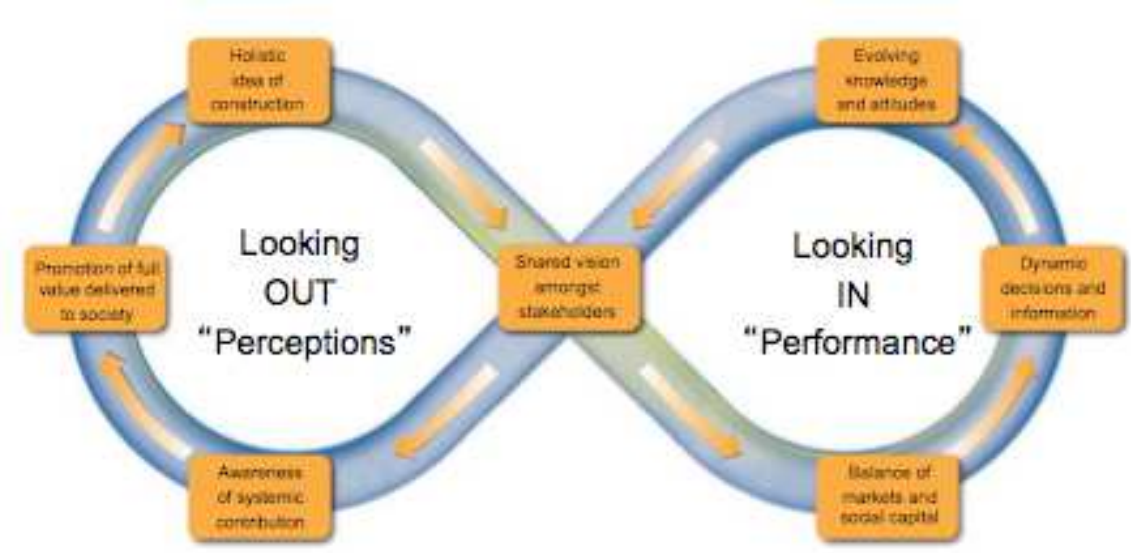

Figure 1: Revaluing Construction: Seven Linked Areas for Industry Improvement

In the UK at least significant activity around the items can be seen. For example:

(a) The multi-disciplinary / stakeholder UK Strategy Panel for Construction has adopted an *holistic idea of construction* that extends to include the whole building life cycle by taking a "built environment" perspective. Thus in their strategy document for the industry it is stated that: "the built environment industry represents some 20% of the UK's GDP … and is therefore a major national economic driver" and it is argued that beyond this it "… influence[s] all aspects of our quality of life and enable[s] the economy and society to function" (National Platform for the Built Environment 2008). This *shared vision* represents a significant shift in thinking from the group's traditional stance, which was to think about what would be good for construction in itself as 7% of GDP. This scaling of the built environment sector within the economy was based on the CIB's activity scoping of a conceptual framework for a meso-level economic analysis (Carassus J 2004). This addressed the illogicalities of the way in which the SIC economic categories work for construction as highlighted by Winch (2003), such as architects and other consultants not being counted in as part of the industry, but the meso-level analysis also factored in the use phase in terms of operating costs and property activity.

(b) The above shift in perspective has chimed with a range of practical actions to move away from lowest bid selection and towards longer term, value-orientated relationships through initiatives, such as partnering and PPP arrangements. These have not been without problems, but do represent efforts to factor in *social capital*, rather than a focus solely on market forces. However, it would seem that these initiatives are coming under pressure in the current recession as clients strive to minimise short term costs. This may look sensible, but the theory at least is that partnering arrangements should deliver better value longer term (at the end of the project and beyond) and so it will be interesting to see what the consequences are in thee medium term.

(c) The area of *dynamic decisions and information* has been building up for many years as technologies became available. The impetus for implementing Building Information Models (BIM) was given a significant boost by the NIST Report that highlighted the huge losses incurred through a lack of interoperability between the phases of design, construction and use (Gallaher M P, O'Connor A C, Dettbarn J L et al. 2004). In the UK, the Government's decision to stipulate that public sector projects "will require fully collaborative 3D BIM (with all project and asset information, documentation and data being electronic) as a minimum by 2016" (Cabinet Office 2011). This has led to a flurry of activity amongst technology providers and users in industry. There is a danger that this will be treated as a compliance issue by industry focused on getting and using the technology. There is a wider strategy at large (HM Government 2012) and this aspires for BIM to impact very broadly on the whole supply chain, but also, hopefully, supporting the whole life cycle approach by enhancing the operation and functionality of assets. This is important as the NIST report suggested that most benefit is to be had to the client within the use phase, although most potential to act was asymmetrically located at the earlier phases of the process. The Government lead as a major client overcomes this motivational disjuncture by force, but to be entirely successful the scope and impacts of BIM need to kept broad.

(d) There has been an immediate response within educational institutions to train and educate students and practitioners around current / emergent issues and BIM has been no exception and it is to be hoped that this will impact favourably on the *evolving knowledge and attitudes* of those making up the human capital of the sector. There is no doubt that research has proactively delivered large aspects of the possibility of BIM and encouraged progress by linking those engaged in international good practice. For example academics were actively moving things from 3 to 4 to "n" dimensional CAD many years (Issa R, Flood I and O'Brien W 2003) before the industry was stung into action by public sector client demand. Even more specific is the growth of the national implementation effort in the US around the energy and expertise of a Stanford University postgraduate from their CIFE programme.

(e) Of the seven action areas two have been lagging. The *promotion of the full value delivered* by construction is a challenge, but is important if clients are to be inclined to invest and workers motivated to choose to work in this sector. The UK strategy above is an example of a strongly positive view being promoted and parallel activity has been evident elsewhere. For example an ambitious and strategic programme of activities is being instituted in Malaysia, which shows many resonances with the Revaluing Construction approach (Barrett P and Hamid Z 2011) and carries high economic and societal ambitions for that country. Within Europe the European Construction Technology Platform (ECTP) has grasped a representative role for the sector towards the EC and has produced an impressive and ambitious strategic research agenda (ECTP 2005). This led to a higher profile for the sector and it is interesting to note that, when the financial crisis first hit, construction representatives were involved from the start in high-level discussions around investments to progressively work the European economies out of the recession.

(f) This leaves the last area, which is gaining an improved *awareness of the systemic contribution* of the sector. This is implicit to the 20% GDP argument, but this just shows the built environment sector is big and important in itself, it does not show that massive benefits flow from its activities. Of course we all intuitively know, for example, that we need shelter from the elements and that certain places provide important cultural foci with deep historical connections. There is also a wealth of evidence about physiological and psychological impacts of various environmental dimensions. For example, poor air quality as indicated by high CO_2 levels are common in schools and pupils can be measured to show that this results in reduced attention and cognitive performance (Bakó-Biró, Clements-Croome, Kochhar et al. 2012). However, there is surprisingly little evidence of the holistic, combined impact of the features of spaces on general human performance / well-being. This aspect is picked up below, with a particular emphasis on the characteristics of schools and connections to pupils' learning rates.

2. The systemic contribution of the Built Environment

Gaining an understanding of this aspect is a key element of how industry is perceived, but also how it performs. It is a crucial aspect for the European Construction Technology Platform's (2005) aspiration to maximise the *positive* contribution that the built environment can make by addressing value, rather than just cost considerations. Value is derived from the built environment in many forms. For example, Macmillan (2006) has suggested (and illustrated) six: exchange value, use value, image value, social value, environmental value and cultural value. It would seem logical to think that "use value" is an important concept amongst these, as if it is taken beyond the work context suggested, then impacts on users will feed many other sorts of value. For example, if a building, say a retail outlet, is effective in supporting the sales, then its exchange value will increase. Or if image value is negative, it is because it has a negative impact on those affected by the building.

Thus, it is argued that fundamentally the value delivered by the built environment is fundamentally founded on impacts on users. This leads to the question as to how these impacts occur between the built environment and individual users. The basic currency would seem to be impacts the built environment has on our senses, which are then noted and interpreted as a holistic experience by our brains. This is a simple thought experiment, but leads to some interesting possibilities.

Rolls (2005) tracks the routes from our senses to our brains and starts to dissect how they are judged and balanced through processes of primary (hard wired) and secondary (learnt) reinforcers. This is all within a context that is so information-rich that a simple calculated response is impossible and so responses to spaces are really quite implicit, or emotional in nature. So, first, as our emotional systems have evolved over the millennia in response to our natural environment, it does not seem unreasonable to suggest that our comfort is likely to be rooted in key dimensions of 'naturalness', stressing positive aspects of naturalness, such as clean air. Second, the personal way in which individuals build connections between primary reinforcers and complex representations of secondary reinforcers, situated within memories leads to the importance of 'individualization' as an additional, key, underlying design principle. Third, there is also a recurrent theme around the general level of

stimulation that is appropriate for given situations. Nasar (1999) reinforces the central importance of the level of stimulation and suggests that combinations of pleasantness (or unpleasantness) and different levels of arousal yield either excitement (or boredom) or relaxation (or distress). More detailed arguments are provided for these three underpinning design principles in Barrett and Barrett (2010) and can be summarised as shown in Figure 2 – the individual at the intersection of the natural, task and personal environments.

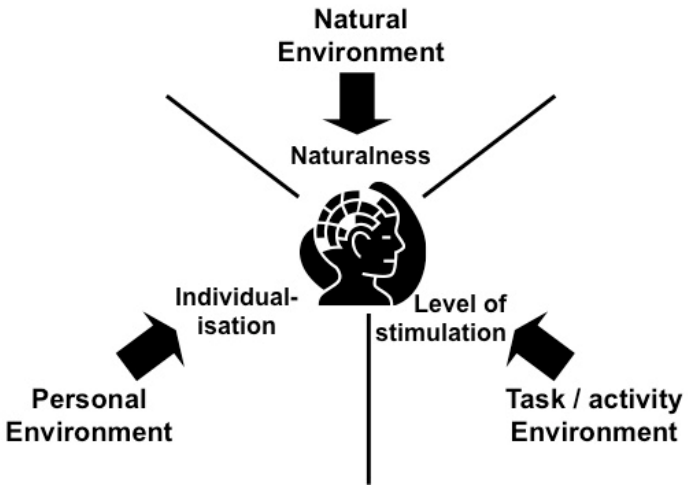

Figure 2: Neuroscience-informed analytical structure

3. Evidencing holistic impacts

Taking school design as an example, there has been a lot of research over the years. When summarised (Barrett PS and Zhang Y 2009) the overriding impression is of lots of views about good schools, some evidence of linkages between specific aspects (say layout) on pupils' learning, some evidence of impacts on users' preferences, but very little evidence of an understanding of the holistic impact of school spaces on validated learning rates. There are exceptions and Tanner (2000) is one, but this study suffers from performing a regression analysis on a multitude of factors that in many cases overlap with each other, causing problems in interpretation.

Looking more broadly, it is apparent from the internal environment quality (IEQ) literature that the analysis of the interactions of multiple sensory factors and linking these to human responses (let alone variations in performance) is a current and unresolved issue, (Bluyssen P M, Janssen S, van den Brink L H et al. 2011). IEQ research has primarily focused on the readily measurable aspects of: heat, light, sound and air quality, and although impressive individual sense impacts have been identified, it has been a struggle to explain variations in overall human performance with these variables. Indeed Kim and de Dear (2012) argue strongly that there is currently no consensus as to the relative importance of IEQ factors for overall satisfaction.

So it is interesting to note that since Ulrich's (Ulrich R 1984) ground-breaking work on views of nature and healing (one dimension of the environment) and Heschong Mahone's (1999; 2003) studies on daylighting in schools there seems to have been very little development in linking the impact of the holistic, multiple aspects of the environment on human performance. There appears to exist an important research challenge around the issue of better understanding, and evidencing, the holistic impacts of spaces on users. To address this challenge it is argued that, first the *conceptual* complexity of the real world factors to be considered needed to be prioritised and structured. Secondly, the *practical* complexity of the analysis needs to be addressed.

The struggle that the IEQ researchers are having to address the interactive impacts of combinations pairs of factors argues for the need for a complementary effort, working from the other end of the telescope, by adopting a top-down selection and structuring of the factors to be considered. This is where the neuroscience-informed model described above may have utility. This over-arching conceptual perspective could be a route to synthesise the alternative design factors into a form that generates hypotheses for optimal design that can provide a basis for understanding the combined effects of sensory inputs on users of buildings at a level of resolution where "emergent properties" (Checkland 1993) may be evident. Until recently the only exemplar study using this sort of thinking was focused on Alzheimer's care facilities (Zeisel J, Silverstein N, Hyde J et al. 2003), which successfully demonstrated how characteristics of the built environment can have medically convincing impacts on symptoms such as aggression and depression. The implication is that the structuring of the brain's functioning could be used to drive the selection and organisation of the environmental factors to be considered, not just their inherent measurability. Thus, the three neuroscience-derived design principles could be used to choose and order the factors to be included, covering the usual four IEQ factors (heat, light, sound and air quality) but also others, such as aspects linked to "appropriate level of stimulation", for example, colour and visual complexity.

The second aspect concerned the analysis of the data. As the focus is on people in spaces it will tend to be inherently nested (e.g. pupil in class in school), thus to avoid misleading results due to the overestimation of significance, a multi-level analysis approach can be adopted (Goldstein H 1995; Peugh J 2010). This provides a rigorous way of dealing with unmeasured effects by allowing the residuals to be partitioned at each level. Multilevel modelling is well tested in educational research, a specialist support centre exists at Bristol University (Rasbash J, Steele F, Browne WJ et al. 2009; MLwiN 2012) and this approach was used with success in Zeisel's study.

4. Testing the proposition in the context of schools

Using these two approaches together to address the issue of holistic built environment effects on humans in spaces is novel and a project on primary schools has been carried out with funding from industry and the UK's Engineering and Physical Sciences Research Council. The HEAD (Holistic Evidence and Design) project research model, built on the above ideas, is given in Figure 3.

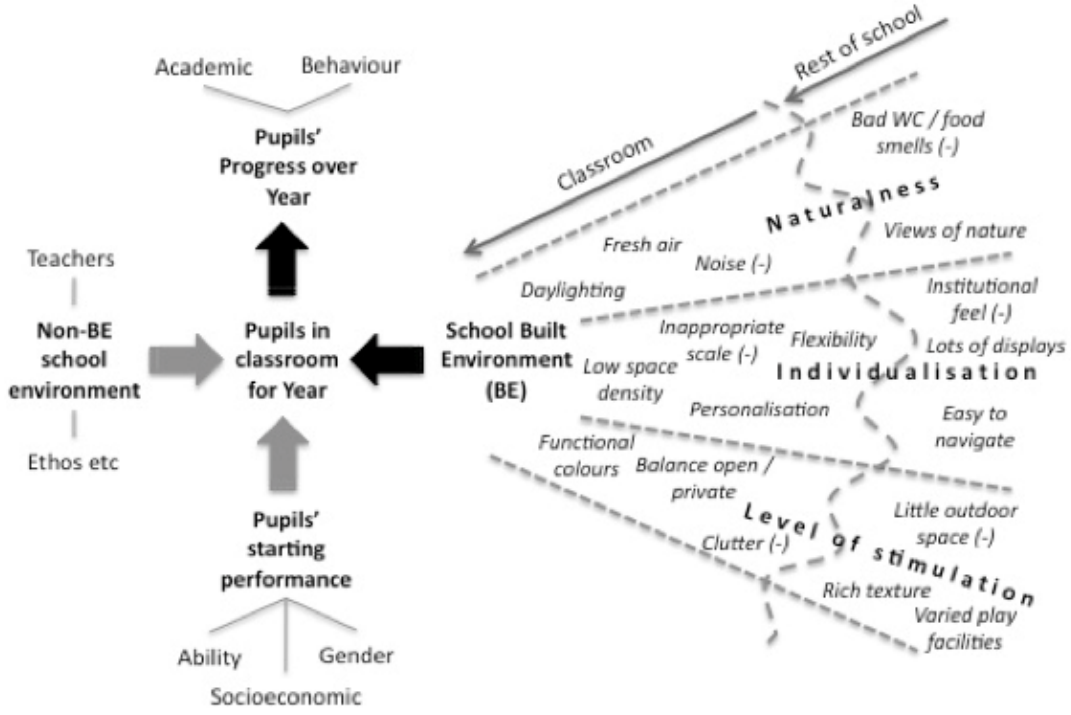

Figure 3: Research Model for Schools study

Blackpool Council supplied access to seven primary schools. All of the schools studied had their own unique features in terms of school site and buildings. They displayed a good level of variety across the sample, which facilitated meaningful analysis. Similarly SATs results for the pupils in the chosen classrooms were obtained so the improvement in "learning" over the preceding year could be assessed. Primary schools provided an ideal test environment for the ideas in play here, as young pupils of this age spend almost all their time in the same room, so any influence of the characteristics of that room should be at a maximum. The study design and results have been described fully in Barrett et al (2013).

The results of this study of schools have provided strong *proof of concept* for the efficacy of this approach to both the conceptual and practical complexity inherent in "natural" data of the sort studied. At the "class" level, 73% of the variation in learning rates of 751 pupils, based on exam their results, was explained by six built environment design parameters, which together contribute at an estimated 25% of the overall influences on learning rates. Thus, it is apparent that the holistic impacts of spaces on people can be identified and are potentially

very large. The six environmental aspects that were found to be significant are summarised in Table 1.

Table 1: Summary Results from Schools' Project

Design Principle	Design parameter		Good classroom features
Naturalness	Light	◆	Classroom receives natural light from more than one orientation. And (or) natural light can penetrate into the south windows.
		◆	Classroom has high quality and quantity of the electrical lightings.
		■	The space adjacent to the window is clear without obstruction.
Individualisation	Choice	◆	Classroom has a high-quality and purpose-designed FF&E
		◆	Interesting (shape and colour) and ergonomic tables and chairs are welcomed.
	Flexibility	◆■	More zones can allow varied learning activities at the same time.
		◆■	The teacher can easily change the space configuration.
	Connection	◆	Wide corridor can ease the movement.
		■☛	The pathway has clear way-finding characteristics.
Stimulation,	Complexity	◆	Big building area can provide diverse opportunities for alternative learning activities.
appropriate level of		■	With regard to the display and decoration, classroom needs to be designed with a quiet visual environment, balanced with a certain level of complexity.
	Colour	■	Warm colour is welcomed in senior grade's classrooms while cool colour in junior grades, as long as it is bright.
		■◆	Colour of the wall, carpet, furniture and display can all contribute to the colour scheme of a classroom. However, it's the room colour (wall and floor) that plays the most important role.

◆ design-related classroom features
■ usage-related classroom features
☛ future study is needed to pursue its positive characteristics.

5. Conclusions

This paper started with the Revaluing Construction perspective on industry improvement. This led to the identification of the importance of making progress on the "awareness of the systemic contribution" of the built environment within society. The focus was then targeted down on the impact of spaces on users via their senses and mediated by their brains. The problem with studying the complexity of human performance in "natural" settings was illustrated and strategies proposed for dealing with this conceptually and analytically. The results were reported of a study that successfully took this approach.

This brings us full circle. If the holistic effects of the built environment can be more fully understood for all users of spaces there is tremendous potential to improve peoples' lives and make optimal use of the huge investments being made in the built environment. In addition it will provide a meta-structure with potential to sweep in a lot of very rigorous laboratory studies of single dimensions, such as the light work by the Lighting Lab at the Rensselaer Polytechnic Institute. Finally, it will provide a way forward for the development of functional, holistic, standards for *spaces*.

The approach and initial test described above have taken several years, but offers real hope that the issue of the value of the built environment within society can be understood and evidenced. This should have radical impacts on how construction is seen – not dirty, dangerous and disruptive; but life-giving, economy-driving, a source of happiness and effectiveness. For the industry the challenge will be to work with clients to accommodate new knowledge about user impacts within an already congested briefing space.

This is only a small start, but hopefully it will help researchers and practitioners crab-wise sneak up on the issue of how to create better spaces in real situations to the benefit of users and so society.

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Does an urban design laboratory process contribute to construction of assets that responds to social needs?

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Abstract

The last decade brought about significant changes to the social and political relationships in many developing countries. In Sub-Saharan Africa, there was a movement for multi-party democracy while in North African and Middle-Eastern countries, an "Arab" spring toppled governments. Parallels can be drawn between the emerging community social needs for a say in decision-making and the social movements that occurred in the western world in late 1960s.

This paper argues that the research and academic community should be at the forefront of place making process in response to newly emerging social needs of empowerment. It looks at the urban design laboratory process at Carnegie Mellon University in the USA and proposes that the methods and strategies could fit the newly found democratic spaces in Africa and the Middle East.

Keywords: Urban Design Laboratory, participatory process, empowerment, place-making, developing countries, social needs

1.1 Introduction

The social and political relationships within a community are constantly shifting, yet creates opportunities for redefining and developing new ones. This is more evident in countries in Sub-Saharan Africa and the North Africa and the Middle East where a wave of change swept through, as those in margins of society demanded a say in the decision-making processes over things that affected their lives. The field of architecture and urban design where policies enacted or ignored could have consequences on the everyday lives of the residents offer opportunities for the professionals to engage local communities as they address the social needs of shelter and the public realm among others.

This paper starts by reviewing literature on the social context that led to the uprising and links it to the issue of community assets. It then makes comments on the role of social policy in the construction of sustainable community and how the academic community could contribute to the process of building social capital. It then takes an example from the work of

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Urban Laboratory at Carnegie Mellon University to highlight the benefits of the participatory methods used there. The paper concludes with a discussion suggesting what the role of the methods used at the UL has on construction the social needs of a society.

The revolutions that occurred in the Middle East and parts of sub-Saharan Africa has been linked to a host of issues, Clark suggests they include the:

> "…lack of personal liberty due to the dictatorial regimes, rampart corruptions within those governments, economic disparities between the citizens, high youth unemployment, uncontrolled rise in the cost of essential commodities and lack of opportunities to participate in civil and political rights…" (2012, p.72).

These societal needs have an impact on the individual needs as can be seen from the reaction that erupted in Tunisia and eventually Egypt from a single event when Mohammed Bouzizi set himself on fire because of what he perceived as deprivation from the means of livelihood or economic survival (Martin, 2012).

His actions were an indicator of problems that had existed within the institutional structures of Tunisia and similar in other countries in the developing world, placed barriers to political decision making processes, the economic quest for independence and ability to provide for self and family. Martin (2012) argues that people in those countries could almost be forgiven for the fatalistic attitudes that existed for a long time preceding the events because only the needs of those close to the centers of power were met. The context is very similar to one that existed in the USA in 1950s and 1960s when decision on urban developments were made through an Urban Regime Coalition of influential business leaders based on their value judgment in disregard to the rest of the society. [Detailed discussions on Urban Regime Coalition can be found in Hunter, F. (1953). *Community power structure: A study of decision makers*, and Crowley, G., J. (2005) *The Politics of Place: Contentious Urban Redevelopment in Pittsburgh*.]

However, looking at the events of the Arab Spring, three distinct ingredients seem common; firstly, the existence of good communication channels used by the young savvy technophiles in social media such as Facebook and twitter to express opinions and as a platform for peer feedback. Secondly, there was societal network that had grown over time allowing for the building of trust. Castells argues that the new media created an emerging social need of freedom for the community, it was the "…social space where power lay and it empowered those on the fringe of the political locus to intervene more decisively on matters of social needs…" (2007, p.238). The use of social network enabled the mobilization of the masses to occur because the messages calling for the manifestation could be sent quickly and securely outside the authoritarian regime's control. There were several attempts by the governments to shut the Internet networks down, or jam wireless communications to no avail, [For detailed discussions on participation see Sanoff (2000) *Community Participation Methods in Design and Planning,* Alinsky, S. (1971) *Rules for Radicals: A Practical Primer for Realistic Radicals*].

Thirdly; the uprising was led bottom up at the grass roots level with no particular leadership structure, an essential component of its success allowing all to feel accountable for the all the communal decisions. Fourthly; the high percentage of unemployed urban youth [15-24 year olds] who were fairly well educated and were adept at using technology were able to "…spread the message of non-violent change…" as pointed out by Elman (2012, p.1). These tactics parallel those used during the Civil Rights Movement of the 1950s and 1960s in the USA. Elman subtly points out that the success of the uprising very much depended on the benevolence of non-partisan armed forces and where there was failure, the partisan forces were used for brutal reprisals, for example in Bahrain, and initially in Tunisia, Egypt and Yemen.

1.2 Community and Society Assets

The paper will now look at definitions of society and what are the assets used to meet those social needs. The ideal state of any society is utopian, where all human needs are met allowing for "…people to work and live together closely and cooperatively using a self-created and self-chosen social order…" (Kanter, p.1). It suggests the promotion of a way of life or vision of community where things are shared in a way that there is equitable benefits accrued by all.

Before interrogating the meaning of community engagement, it is important to frame how the term is understood within the paper. The definition of community is nebulous, and equally raises questions on who can and should participate in the process of constructing or transforming the environment. This is not new because there has always been a struggle between two views espoused by those who support individual rights versus those who support the collective rights. According to McMillan and Chavis (1986) there are five factors that influenced the sense of community scale:

> "…informal interaction (with neighbours), safety (having a good place to live), pro-urbanism (privacy, anonymity), neighboring preferences (preference for frequent neighbour interaction), and localism (opinions and a desire to participate in neighbourhood affairs)…." (1986, p.6).

The above factors were found to influence the desire to participate in affairs of the place, the willingness to assert the right to the city and the use of a new consciousness to question how things run. Ahlbrant and Cunningham (1979) carried out a study, which found out that people who are most satisfied with their locality were likely to contribute to its social structure. Therefore, a shared vision of a place, sense of place resulted in communities with active social structures, one willing to construct their assets so as to meet their social needs.

A community can therefore be defined using the geographical and territorial aspects, and the quality of human relationships irrespective of the location Gusfield (1975). McMillan and Chavis (1986) building on the above saw the community to have explicit and identifiable characteristics, that included the sense of belonging, influence in the sense of having a voice

to make a difference, integration, which relates to the first and finally shared emotional connection.

Heller (1989) saw the community as place, as relationships and as collective political power whose members strove to improve the quality of life within through voluntary participation. Fundamental to the ability to participate is the level of empowerment that the members have access to, giving them the sense of community, sense of place which in return contributes to the developments that would meet the society's social needs. Chavis and Wandersman (1990) reviewed how the sense of community was a catalyst for participation and concluded that there was a relationship between the individual's belief and their actions and outcomes from them. Other scholars pointed to the fact that the community members are able to take control of over their lives and are involved in democratic participation (Zimmerman and Rappaport, 1988). Therefore, the term community is used in this paper to mean a group of people that identify with the territory or geographical location and have claimed the rights to make perceptible influence to its management and are emotionally tied to the location through the various activities and relations.

1.3 Social Needs

The term social needs will now be defined and distinguished from human wants. The use of term human needs is fraught with ambiguities; it is subjective and has ethical value judgment connoted; in addition it is context dependent in that it is determined by norms or standards as pointed out by Doyal and Gough (1984). They further argued that the individual's and societal needs are closely tied, for instance the need for survival has through history led to the quest for human liberation, freedom from oppression, desire to be heard. While at the societal level, the individual need for survival is manifested through production, reproduction, political authority and communications that occur and which in turn form the framework through which human liberation occurs. Their work postulated that the success of human liberation requires an empowered citizenry, who are educated to be able to participate in the debates that would curtail the vested interests to allow for growth of the collective well being or sense of belonging.

Literature review reveals that the social needs of a society have been examined through the theory of social production functions, (Lindenberg, 1996, 2001; Ormel, 2002; Ormel, Lindenberg, Steverink, & Verbrugge, 1999) and is concern with the needs, goals and resources. The needs can be satisfied in various ways through the setting of goals and distribution or allocation of resources to them as argued by Steverink and Lindenberg (2006).

All communities have inherent assets that are the resources for meeting the social needs and include the people (local residents), emerging leaders, local institutions, informal community and neighborhood organizations, and existing community leaders who are committed to building a more vibrant community as pointed out by Beaulieu (2002). Therefore mapping of assets is important because evidence has shown that significant community development occurs when "…when the local residents are committed to investing themselves and their resources to the efforts…" McKnight and Kretzmann (1996, p.2). It is

therefore essential for capacity building to take place to bring all this assets into use, which raises a question of what is capacity building and how can this be achieved?

1.4 Methodology

The work presented here is from literature review on the uprising in North African and Middle-Eastern countries and has been correlated to content analysis of UL process of one project, Charm Bracelet carried out by the students at the School of Architecture at Carnegie Mellon University. Content analysis methodology involves the systematic reading of texts, images, and symbolic matters to give an intuitive, interpretive and systematic examination of the data (Rosengren, 1981). It allows for data even minute ones to be looked at closely using explicit rules that are applied equally to all units.

1.5 Urban Laboratory

The urban laboratory, (UL) is an institution that uses an alternative approach to the education and practice of architecture and urban design and rooted in larger social values that demands a proactive practitioner and is based on social architecture, (Onyango, 2011). It is typically housed in an activist university, one that is proactive in engaging the community and uses the city as the field of study thereby building the assets targeted at social needs. The UL, acknowledges that growth in knowledge comes from interested parties sharing various perspectives while also changing the internal representations as they respond to feedback from others.

1.5.1 Urban Laboratory at Carnegie Mellon University

David Lewis founded the Urban Laboratory at Carnegie Mellon University in 1963 and was the first urban design or architecture programmes that engaged communities in the design process. Lewis (2007) pointed out that the founding corresponded with the activities of Civil Rights Movement, one that empowered communities. Fundamental to the founding of the Urban Laboratory was; firstly, of a process that acknowledged that the *power of decision-making lies with the citizens* and is therefore a participative methodology is required. Secondly, it accepts that *not all citizens have the knowledge and skills that would give them the full capability to make that decision* and as such the methods must be underpinned by ethical values. Therefore, it calls for designers to take a moral stand by building the capacities of the community enabling them to fully participate in the design decisions that affected them. The next section will take one example of the studio project to examine how the UL process contributed to the construction of community assets and how it met social needs.

1.5.2 Charm Bracelet Project

It was located on the Northside of Pittsburgh and was a collaborative project in partnership with Pittsburgh Northside Community, Pittsburgh Children's Museum and the Urban Laboratory at CMU (Figure 1). The National Endowment for the Arts funded the project and in addition they received a Heinz Endowment grant for an International Idea Design

competition. The Charm Bracelet project was a catalyst aimed at “creating linkages among the varied cultural, educational and entertainment destinations spread across the Northside...” (Hutzell and Rico-Gutierrez; 2007, p.6).

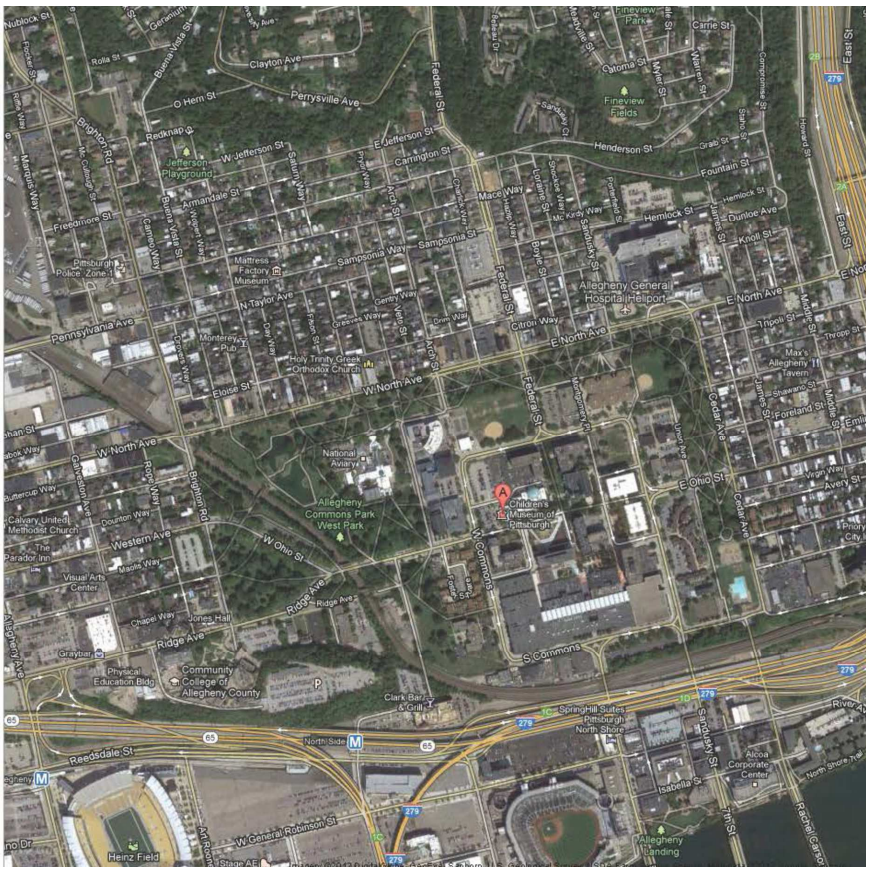


Figure 1: Location of Pittsburgh Children’s Museum and Northside Community (Google, 2012)

The content analysis of the urban laboratory report revealed that emphasis was placed on addressing the pressing social needs of economic conditions (high poverty levels), social rights and political opportunities in participating in policy decisions that affected them. This perhaps relates to the booming economic conditions that existed in the mid 2000s and the economic disparities that were apparent between the residents of the Northside communities and even the destinations or charms (Children’s Museum).

The baseline survey work was carried out by the students and was shared with the international design teams that had been invited to participate in a competition that they also participated in. The local community were engaged earlier in the process to identify and define the problem that the community faced, and to assess their existing assets. Hence, their participation brought the buy in factor into play, it gave the community the power to decide on what they considered as important assets (or charms) and how these were to be reorganized to address their pressing social needs of social integration, economic opportunities, safety at the park and others.

The four teams that participated were: Suisman Urban Design (collaboration between office from Santa Monica, California and Pittsburgh; Colab Architecture (collaboration between teams from New York and Pittsburgh); Muf Architecture/ art and Objectif (teams from London and San Francisco) and Pentagram from New York.

The first community meeting was used to "check and confirm" whether the designers got it right! David Lewis concurred when he pointed out that:

> "…conflicts over community design issues between the advocacy groups and the bureaucratic officials and technical specialists are caused by their different viewpoints…" (1979, p.28)

The perspective from which the scenario is viewed determined it's understanding as such one could argue that the citizens perhaps have a better view and understanding of their social needs, have greater clarity of the issues than the experts from outside and should ideally be party to any process that attempts to construct the community assets. This has necessitated a need for a different approach to designing communities, cities, and neighbourhoods, based on the local societal contexts, by collaborating with, and allowing the participation of, the local community.

The project was carried out using the collaborative model not only between the stakeholders and the students, but also with the students co-designing alongside the multi-disciplinary professional teams from both the US and abroad. This simulated real life project scenarios and enriched the learning experience of all the participants (community, students and the design professionals). The laboratory used a mixture of methods to address the issues, beginning with a top-down approach where community leaders and professionals led in identifying the key issues. This was followed by a bottoms-up approach involving the community in not only framing the questions and clarifying them but also in the use of the *charrete* process to work out the possible solutions.

There was great emphasis on community participation either directly or at some stage through the delegated power of the community leaders during the various forums. The engagement, that began at the outset of the process and continued through to the last community meeting where the final framework and detailed proposals were presented and celebrated. The tactics/ strategies used in the process of constructing community assets is therefore important.

The students used x-rays techniques to show the community before and after the intervention proposals, the 3D models and drawings; all showed understanding of the contextual issues, respect for typology and innovation through the use of light as the theme to connect the charms. The use of lighting as a feature has surely proven to be an innovative solution drawing communities out in the evening to use the new assets of public places created and has spurred other activities that met social needs of economic activities (food stalls, vendors, public realm etc.) along the routes. It has been catalytic indeed judging by the continued investments in the area and its growth with the Children's Museum continues

to invite the community to participate in annual projects to improve its vision and outlook based on adverts in 2011:

> **Urban Garden Art + Design Project**
> The Children's Museum of Pittsburgh and Team Laminates Co. (TLC) invite architects, artists, gardeners and designers to propose artistic / design solutions for a new community garden at the corner of Vinial Street and Spring Garden Avenue on the Northside. (2011, Children's Museum of Pittsburgh)

The consequence of the project is a shared community vision that has developed legs and grown into the community events lasting years since the Children's Museum got a new building as a part of the process. The reviews in Post-Gazette, Pittsburgh Courier, MetropolisMags has been positive. For instance:

> "Most design competitions pit one group against another to generate the best design for eventual construction. Here, however, Children's Museum Assistant Director Chris Siefert worked with architect Paul Rosenblatt, of Springboard Design, to select and work with teams whose variety of skills and perspectives would enrich the project in a more collective fashion." (Pittsburgh City Paper; February 22, 2007).
>
> "Siefert cites light installations, projects for an underpass, and museum/school partnerships as noteworthy proposals. "There are things that stand out--a strong idea for a public art program which would look at specific sites and curate events and installations over time," says Siefert. "One exciting idea is an annual treasure hunt across the whole district."
>
> (PopCity Media)

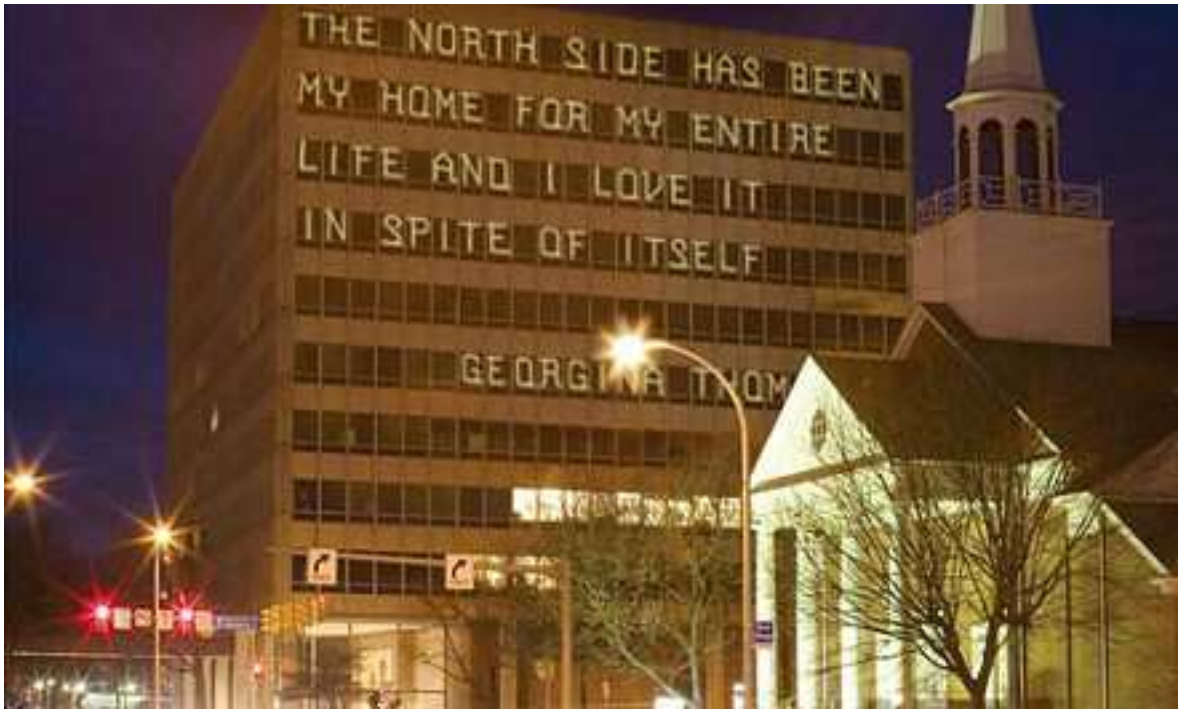


Figure 2: Charm Bracelet Project-2007 Urban Laboratory (Hutzell and Rico-Gutierrez, 2007)

2. Conclusion

The proposals in this UL were very innovative perhaps as a result of the higher degree of community involvement and also from the fact that the problems were jointly framed and therefore represented their vision (**figure 2**). This is perhaps due to the fact that for the first time there was a real project on board, and four professional teams were invited and the students had opportunity to not only provide the baseline data but to participate alongside them. The project has not only connected the community charms, but by strategic placing of the active functions and activities there has been increased surveillance, new places created, enhanced cohesion and businesses started along the paths connecting them

This would have been difficult to achieve without an empowered community efforts in collaboration with the Children's Museum, donor agencies (Heinz Foundation and the National Foundation for the Arts), and the university. It enabled firstly, the identification of community assets and needs, secondly defining what the pressing problems are, thirdly, deciding on what assets were to be funded. The process no doubt requires a lot of work and effort, creative solutions and the academic institutions have a lot to offer in the form of a large body of enthusiastic students and faculty eager and willing to take risks as the look for innovative solutions. This is an assets that is freely available to the community especially if one considers that in most cases the student body do not normally come from the local community where most pressing social needs are.



- ***Figure 3: Notes from above ground: Brett Yasko proposes displaying text messages in North Side window grids. Image courtesy of Brett Yasko.***

The choice of using a participatory methodology created a forum where the annual projects continually empower the community in identifying those tacit assets that exist and that can be used to address the pressing social needs over a period of time. It helped the community to see what could be possible, their future vision, the ability to engage not only design professionals working for clients in the area but also to stand up to the decision / policy makers if none of the local issues were targeted and addressed objectively.

The UL as a design program created opportunities for the school of architecture to collaborate with other allied schools within the university such as public health, public policy, business, law, real estate, finance among others to address societal needs. The emphasis in the process are multi-disciplinary, trans-disciplinary, collaborative, participation, capacity building, all arranged in a way that the community was at the center. It is only through such a process that the constructions of assets that address the societal needs are met. The countries in Sub-Saharan Africa, North Africa and Middle East will continue to grow rapidly in many areas and perhaps there is an emerging opportunities for partnerships between universities there and those in the western world.

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Sustainable Buildings – best and worst performers in terms of Comfort, Health and Productivity

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Abstract

The author has undertaken user surveys of thirty commercial or institutional buildings, all with strong sustainability credentials. The main aim was to find out what features enhanced the comfort, health and productivity of the building users and what features would cause them to diminish.

The buildings were spread throughout 11 countries, and in virtually every case the client or the design teams (frequently both) were strongly committed to sustainability and energy efficiency. In addition to seeking basic demographic data the survey questionnaire asked respondents to score, on a 7-point scale, up to 45 variables grouped into Operational, Environmental (temperature, air quality, lighting, and noise), Control, and Satisfaction categories. The author spent time in all the buildings and interviewed members of the design teams for each.

Analysis of the responses yielded a mean value for each variable and enabled calculation of a Summary Index which took account of 11 key variables. While these analyses indicated a clear correlation between Comfort, Health and Productivity, perhaps unsurprisingly they also indicate that it is very difficult to achieve perfection in every respect. Even the 'best' building, in terms of its Summary Index, was perceived as performing relatively poorly in terms of Noise, for example. The corollary to that was also evident in that some buildings with low Summary Indices were perceived as performing relatively well in terms of particular factors, such as Lighting or Temperature in Winter. Nevertheless, the overall trends were clear and the paper will discuss the particular design features associated with these results.

Keywords: sustainable buildings, comfort, health, productivity.

1. Introduction

The overall mission of the author and his collaborators has been to provide independent and unbiased evaluations of how the users perceive some of our commercial and institutional sustainable building developments. It is still surprising that building designers (with rare exceptions) do not systematically evaluate their projects, if only for the benefit of their own practices.

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The overarching aim of the research described in this paper is to advance the practice of environmentally sustainable building design. A world-wide set of commercial and institutional buildings, all of which had well-recognised sustainability credentials or features, were sought out and evaluated. The intention was to find out the context for these projects, how they were designed, and most importantly, the users' perceptions of the performance of these buildings.
This paper focusses on the features of the 'best' and the 'worst' buildings as indicated by the scores for particular factors or categories of factor, in terms of the comfort, health and productivity of the users, and overall as indicated by a Summary Index. It must be emphasised that in this context 'best' and 'worst' simply means that the buildings were at opposite ends of the Summary Index scale for a set of buildings which it is believed would be at the 'best' end of a sample of buildings of this type. 'Worst' should not be taken to imply these buildings were particularly poor performers overall – quite the contrary.

1.1 The Buildings and their Users

The thirty buildings selected were all commercial or institutional in nature. Fourteen accommodated office activities predominantly, ten were tertiary-level academic teaching buildings, four housed laboratories or research organisations, and two contained a combination of light industrial and administrative functions. *V*irtually all were recipients of national awards for sustainable or low energy design, were highly rated in terms of their respective country's building sustainability rating tool, or in some way pioneered sustainable architecture.
Fifteen had Advanced Natural Ventilation systems, broadly defined as natural ventilation where some of the ventilation openings are automated or some specially designed natural ventilation elements have been incorporated into the design. Most of the remainder utilised a Mixed-Mode system of ventilation – these were predominately Changeover systems where the mechanical systems were designed to operate during cold or hot outside conditions, and the natural ventilation systems during mild conditions, though two buildings had Zoned systems where large parts of the building were either air conditioned or naturally ventilated. Only three of the buildings were fully air conditioned with predominantly sealed facades. Fuller details of the systems of environmental control in each building are described elsewhere (Baird, 2010). Most had been built or refurbished in the course of the last fifteen years, and all had been occupied for a year or more before the survey work was carried out, giving most occupants time to experience their surroundings over at least a full annual cycle.

1.2 Survey Methodology and Analytical Procedures

Generally speaking, these investigations involved undertaking several visits to each of the buildings to personally distribute and collect a questionnaire survey seeking the users' perceptions of a range of factors. The questionnaire used was the Building Use Studies (2011) standard two–page office version. During these visits a structured, recorded interview was conducted with a key architect and environmental engineer from the design team, and a

detailed tour undertaken of each building and its facilities, photographing key features, and collecting relevant documentation.
The sixty or so questions of the standard two-page questionnaire used cover a range of issues. Fifteen of these elicit demographic information with the rest asking the respondent to score a number of aspects of the building on a seven-point scale and categorised as Operational, Environmental (temperature, air quality, lighting, and noise), Control, and Satisfaction.
Analysis of the responses yielded a mean value on a 7-point scale for each variable and enabled the computation of a number of indices to provide indicators of particular aspects of the performance of the building or of its 'overall' performance. These include a Comfort Index which was dependent on a set of seven 'environmental' factors; a Satisfaction Index, which was dependent on the scores for Design, Needs, Productivity, and Health; and a Summary Index which is the average of these two indices (see Appendix). These are intended to 'provide snapshots of how a building works for its occupants' (Leaman and Bordass, 2001, 130).
In what follows the features of the buildings with the highest and the lowest Summary Indices will be described in more detail in an attempt to discern those particular features that may have led to such values. The Summary Indices and average scores for Comfort, Health and Productivity for all the buildings are listed in Table 1, together with their rankings.

2. Design features of buildings with High Summary Indices

In this section the reasons for high and low perception scores amongst those buildings with high Summary Indices will be explored, in an attempt to reveal the factors that influenced them, and the design features that could be involved. Five projects will be described in more detail – all had Summary Indices greater than +2 on a -3 to +3 scale:

2.1 NRG Systems Facility, Vermont, USA

Located at latitude 44.5^{O}N in a cold-temperate climate (winter/summer design temperatures -21°C/+29 ^{O}C) this 4320m^2 floor area building houses a manufacturing facility with offices, workshops and a warehouse. With a Summary Index of +2.93, the highest of all the buildings in this set, average Comfort and Health scores of 6.56 and 5.47 respectively (on a 1 to 7 scale) and a Productivity increase of 19.51%, what design features might have influenced these perception scores?
The building was oriented to the sun, with its long axis E-W and its North side bermed into a hillside. It was well insulated and airtight, with carefully designed daylighting via high-level strip windows and skylights integrated with dimmable artificial lights. Pipes embedded in the exposed floor slab enabled under-floor heating and cooling of the entire building. The offices and workshops had CO_2-controlled mixed-mode ventilation via air handling units and opening windows, with red and green indicators letting the occupants know when opening or closing the windows was preferable (but not mandatory). The warehouse area was designed for natural ventilation mainly but had extract fans at either end. Clearly, these systems were combining to provide an environment that was perceived to be near-perfect by the building users. The project team for the NRG Systems Facility had conceived and executed a

building in which all of the basic 'rules' of good passive design have been applied, coupled with transparent control systems and well documented procedures (NRG Systems, 2008).

2.2 Torrent Research Centre, Ahmedabad, India

Located at latitude 23°N, Ahmedabad has three distinct climatic seasons - hot and dry with outside temperatures of +41.0^{O}C, warm and humid during the monsoon, and cool and dry with temperatures around +13°C. Housing a pharmaceutical research organisation, the facility was comprised of five three-storey laboratory buildings radiating from a central core building, and linked to separate administration and utilities blocks. Two of the laboratory buildings were air conditioned (AC) while the administration block and the other three laboratories were equipped with a passive downdraft evaporating cooling (PDEC) system. Their total floor area was some 12,000m^2. Separate surveys were carried out of the AC and PDEC buildings (Thomas and Baird, 2006) and as can be seen from Table 1, their Summary Indices (2.83 and 1.95 respectively) placed these buildings 2nd and 6th.
The design team committed to a building that could function during daylight hours with the minimum use of electricity. The concept for all of the laboratory buildings was for a central corridor flanked by working spaces. Centrally-located towers provide fresh air via the corridor; having passed through the working spaces it is exhausted via a set of towers on the perimeter. In the case of the PDEC laboratories and administration building a fine mist of water is released at the top of these central towers during the critical hot season. This cools the air which then circulates through the building by natural convection. In the case of the two AC laboratories, the towers serve as routes for the distribution of conventional air conditioning ductwork. The overall structure is thermally massive and the external walls and roof are white. Both high and mid-level exterior windows are utilised – these are shaded from direct sun penetration by fixed horizontal overhangs and the perimeter towers.
The AC buildings appeared to outperform the PDEC buildings in terms of Comfort (5.72 vs 5.16), Health (5.53 vs 4.74) and Productivity (+20.88% vs 13.66%). Nevertheless, the PDEC buildings scored well over the mid-point of their respective scales and significantly better than the relevant benchmarks. It is their performance that is arguably the more notable. To be ranked 6th overall out of this set of buildings, given the severity and variability of the climate, is remarkable. The effort to minimise solar heat gain through shading, exterior colour, insulation and mass, together with careful attention to the disposition of the fenestration have paid dividends. Of course these same efforts have benefitted the AC buildings too in terms of their overall performance.

2.3 Natural Resources Defence Council (NRDC), California, USA

Located in Santa Monica in the relatively benign climate of Southern California - latitude 34°N with design temperatures around 31°C and 6°C – this 1,400m^2 three-storey building houses the offices of the NRDC. As befits its high Summary Index of +2.82, Comfort and Health score 6.50 and 5.85 respectively while the perceived Productivity increase is +23.00%. The rectangular plan building is sandwiched between adjacent buildings on a 37m by 14m site. Three lightwells punctuate the plan and these, together with a 2m gap between the long facades and the adjacent buildings enable daylight penetration to the building. The

perimeter windows are all openable to allow natural ventilation, and the upper glazed section of two of the lightwells is fitted with a louvred opening and an extract fan (NRDC, 2004).
Six small fresh air supply units deliver heated or cooled air at peak times. Thermostats in each office enable personal control of these systems, and care has been taken to ensure the staff are aware of conditions in the building and can respond appropriately. Not only are inside temperature and humidity readings on display at strategic points throughout the building, but CO_2 readings are also displayed, together with a warning light set to come on at around 750ppm as a way of reminding the occupants to open the windows.
The fenestration is fairly conventional and has no external shading. Minor noise issues (from colleagues mainly) appear to be a concomitant of natural ventilation strategies which tend to necessitate the use of large open passages across and even between floors, together with facade openings. The potential for airborne sound transmission within the building, and the entry of external noise is evident.

2.4 Military Families Resource Centre (MFRC), Toronto, Canada

Located at latitude 44°N in a cold-temperate climate (winter/summer design temperatures of -17°C/+29 ^{O}C) this 1840m^2 floor area building caters for the needs of the spouses and children of military personnel in terms of child care, counselling services and educational programmes. MFRC had the 4th highest Summary Index (2.45) of all the buildings and a matching profile of high scores: 5.92 for Comfort, 5.17 for Health and +20.00% for Productivity.
The outcome from what was reported as an intensely integrated design process was a compact two-storey circular plan, with sloping timber roof structures, with mainly offices and child-care facilities on the ground floor and a large multi-function space on the upper level (GBI, 2005). Roof, walls and floor slab were well insulated and clear double-glazing used throughout. The perimeter and roof-level glazing enables daylight penetration to the majority of the spaces that are in frequent use, such as the child care areas and the offices. Windows at both high and low level have openable sections to enable natural ventilation to take place when climatic conditions allow – typically spring through autumn. An under-floor system is the primary heating source for the building, while a small air handling unit distributes fresh air, heated or cooled as appropriate, to the occupied spaces, though there was a hint of the users finding it to be too hot in winter and too cold in summer.

6.5 The Erskine Building, Canterbury University, New Zealand

Located at latitude 44°S in a medium-temperate climate (winter/summer design temperatures of -1^{O}C/+26 ^{O}C) this 11,551m^2 building is split approximately equally between a seven-storey academic block, containing staff and postgraduate student offices, and a four-storey undergraduate teaching block. The two blocks are linked by a glass roofed atrium space and a basement area containing mainly teaching and service spaces (Architectus, 1998). Lying 5th in the Summary Index rankings with a score of +2.39, Comfort and Health scored 5.86 and 4.52 respectively and Productivity +9.80%, all significantly better than their respective benchmarks.
The offices and the majority of the adjacent seminar rooms in the academic block are naturally ventilated and heated by a conventional radiator system. With their deliberately

northerly orientation and fixed overhangs, exposed thermally-massive interior walls and ceilings, fixed and adjustable exterior and adjustable interior solar shading devices, and large number of window/natural ventilation opening options, the office modules are equipped with a full range of passive thermal environmental control systems. The undergraduate teaching block and basement computing laboratories have separate air handling units.
By the use, inter alia, of a well-insulated external envelope, internally exposed thermally massive construction, predominantly manually operated window openings and shading devices, and deliberate orientation of staff studies to the sun, this building has been able to satisfy the varying needs of a diverse staff and student population. However questions regarding control of sun and sky glare remain.

3. Design features of buildings with Low Summary Indices

In this section the reasons for high and low perception scores amongst those buildings with low Summary Indices will be explored, in an attempt to reveal the factors that influenced them, and the design features that could be involved. Five projects will be described in more detail – all had Summary Indices less than zero on the -3 to +3 scale, but none under -1.0.

3.1 Institute of Technical Education, Bishan, Singapore

Located close to the Equator (1.5^{O}N) in the hot-humid climate of Singapore (1% temperature range 23 to 32°C) this 20,300m^{2} building caters for 100 staff and 1,600 students. Twin parallel teaching blocks (one four storeys, the other three) place the building squarely in the path of the prevailing winds. The designers' aim was to respond to the challenges of a tropical climate with the least use of energy (Powell and Akitek Tenggara, 1997). Thus the majority of classrooms were designed for cross-ventilation, with fixed and adjustable openings on opposite sides, extensive solar shading, and wall mounted fans. Some specialist classrooms, a large lecture theatre and administration offices were air conditioned. Unfortunately, the condensers from some of these were located close to the opening windows of the naturally ventilated classrooms.
The Summary Index for the staff was around -0.80, the lowest figure for this particular set of buildings. Comfort and Health scores were 3.29 and 3.00 respectively, while perceived productivity was decreased by 10.61% on average. Designing for natural ventilation in the climate and culture of Singapore was always going to be a challenge, and the designers are to be congratulated in resolving it as well as they did. The difficulty lies in the constant transfer of staff and students from air conditioned to naturally ventilate spaces, with the inevitable 'thermal shock' that involves and having to acclimatise after every move, making the achievement of a satisfactory thermal balance or comfort problematical. But locating the condensers from the air conditioned spaces under overhangs just outside the opening windows of the naturally ventilated spaces is almost guaranteed to sabotage thermal comfort in the latter and, just to add insult to injury, lead to additional noise issues.

3.2 Liu Institute, University of British Columbia, Vancouver, Canada

This Institute, comprising office accommodation and a conference space, is located in a cold-temperate climate at latitude 49°N and with 1% design temperatures of -4.7^{O}C and

23.2^{O}C. Sustainability targets were set and an integrated design process adopted, resulting in a three-storey main office building in which natural ventilation, external shading and daylighting strategies have been applied. With offices on either side of a central corridor and fresh air supply via perimeter windows, transom openings allowed air transfer to the corridor and then to vertical ducts for exhausting to outside at roof level. The building envelope was well insulated and the thermally massive internal surfaces exposed. Low temperature hot water is supplied to under-sill heating terminal units (Macaulay & McLennan, 2006).

Despite the great effort put into its design, the Summary Index for this building is a disappointing -0.71. At 3.55, the average Comfort score is below the mid-point of the 7-point scale and worse than the benchmark; while that for Health, at 3.70 is similar to the benchmark. However, in terms of Productivity, the users perceive that to have been decreased by 13% on average.

A degree of trade-off had been agreed between acoustic privacy and the free flow of air, but noise appeared to be a key issue in this building, not helped by the preponderance of hard surfaces. Remedial measures, designed to reduce sound transmission but without impeding air movement were being investigated. This is not a unique problem, but is important for knowledge workers for whom acoustic privacy can be essential.

3.3 General Purpose Building, University of Newcastle, NSW, Australia

Newcastle is located in the warm-temperate climate of New South Wales at latitude 33°S, with winter lows of 4°C and summer highs reaching up to 40°C. Completed in 1995, the General Purpose building was one of the first on this campus to explore the limits of purpose designed natural ventilation, at a time when such a move was not typical. The building is four storeys high and consists of three floors above a public ground level. It has offices to the north on three levels, larger classrooms or staffrooms to the south, and a central north facing atrium acting as the building circulation/airflow spine. Exposed masonry walls provide thermal mass running internally through the atrium of the upper two levels. In summer the walls provide an internal heat sink and utilise night ventilation for cooling. The same walls are warmed in winter by sunlight entering north facing clerestory windows (Dixon, 2006) .

Considering the pioneering nature of the design and the characteristics of the climate, the Summary Index has worked out at a creditable -0.39. While the Comfort score of 3.48 was less than the mid-point and worse than the benchmark, that for Health (at 3.55) was similar to its benchmark. Disappointingly, perceived Productivity was down by 11.9%.

Users commented how summer and winter temperature discomfort and the uncontrollable infiltration of noise were impacting on overall comfort and productivity. The building is well oriented to the north, utilises natural light, opens up to natural airflows and makes best use of thermal mass. In simple terms it covers all the requirements for good passive design. Unfortunately the provision of personal 1kW heaters has not successfully dealt with the winter cold in office spaces and the fans provided in all spaces have failed to combat the effects of summer humidity and high temperatures. Reported noise from visitors in corridors, and both outdoor and indoor sources generally indicates a building fabric that is susceptible to noise transfer, possibly due to the open nature of the natural ventilation system.

3.4 The Red Centre Building, University of New South Wales, Sydney

This 150m long, six/eight storey, 17,500m^2 gross floor area building was first occupied in 1996. University policy was for air conditioning not to be installed in other than specialist areas with high internal heat gains - a definite challenge to the designers, given the latitude and climate of Sydney - 34°S and with 1% design temperatures of 6.8 and 29.5^{O}C.
The main accommodation comprises offices, classrooms, studios, lecture theatres and computer rooms, only the last of which is air conditioned (Cantrill, 1997). Air shafts are integrated into the vertical cross section of the building so that air can move readily between selected floors, and thermal chimneys provide the method for exhausting air from the majority of the classrooms in the lower two-thirds of the building. Substantial sections of the glazing on the facades and some of the internal partitions are fitted with ventilation louvres and large sliding doors to allow fresh air entry and air transfer across the building. Manual control of the window openings, the ventilation louvres, the ceiling fans, the gas heaters, and the blackout roller blinds, is left in the hands of the staff.
The Summary Index worked out at -0.37 for this building, while Comfort and Health scores were 3.75 and 3.72 respectively, just under the mid-point of the scale and similar to the benchmark. For the staff, perceived Productivity was decreased by 5% on average, and the building was too cold in winter, too hot in summer, and suffered from what appear to be the inevitable noise problems of naturally ventilated spaces.

3.5 Scottsdale Forest Ecocentre, Tasmania, Australia

Completed in 2002, this three-storey building has a floor area of around 1,100m^2. It is located at latitude 41°S. The building consists of an inner 15m square three-storey office structure inside a truncated cone which houses an exhibition space and café (Spence, 2002). Thermal environmental control is through a combination of high and low level automated louvred openings on the external envelope, manually adjustable sliding windows on the inner envelope, transfer grilles on the office doors, and cones in the vent running up the centre of the offices with a reversible fan at the top, enabling air to be transferred as appropriate to the prevailing climatic conditions.
The volunteer staff of the ground floor Visitor Centre, scored 6.00, 4.11, and +5.00% on average for Comfort, Health, and Productivity and achieved a Summary Index of +1.29. The office staff were less enamoured with conditions. Overheating in the top floor offices and glare issues, led to the installation of a small air-conditioning system. With a Summary Index of -0.28, the office staff scored the building 4.04 and 4.10 for Comfort and Health, and perceived Productivity to be decreased by 4.29%, all of which were similar to the corresponding benchmarks. While winter conditions were fine, summer conditions were found to be too hot, and noise was a key issue, not so much from colleagues, but from the adjacent Visitor Centre. Air transfer paths had become routes for noise transmission and the dangers of combining two quite different functions under the same roof had become evident.

4. Conclusions

This final section will summarise the features of these buildings that had an influence on their users' perceptions. While the focus of this paper has been on the users' perceptions of Comfort, Health and Productivity and on identifying key design features associated with the 'best' and 'worst' performing buildings, it is by no means the whole story. Informed readers will be well aware that the priorities of the client, the experience of the design team, their commitment to integrated design, and the time available for the whole process can all have a profound influence on the building and its eventual performance.

Without exception, it was found that the clients for these buildings were highly committed to the principles and practice of sustainability. This commitment to sustainability was also evident in the client's choice of architect. All of them were established practitioners familiar with the culture and climate of the locality and employed integrated design methods. All had strong track records and in several cases a philosophical commitment to the application of environmentally sustainable design principles.

One of the main drivers of all of these projects was to maximise daylighting while minimising the adverse effects of unwanted solar heat gains and glare via the windows. This was particularly evident in the window arrangement at NRG Systems and at the Torrent Research Centre. Even buildings on restricted sites were set back in a variety of ways to enable daylight penetration.

An equally important driver, was to enable good natural ventilation. This too influenced the building planning and layout in fundamental ways to enable cross-ventilation and stack-ventilation to take place. Where deep plans were necessary, atria or other types of vertical openings between floors were utilised and in some cases special devices employed to enhance the air flow. Some of the change-over mixed-mode ventilation buildings featured a simple visual system which informed the occupants when it would be appropriate to open the windows, and in one naturally ventilated case even let the occupants know when the CO_2 level had exceeded 750ppm. Provision for night ventilation had been made in several instances.

Where the sites allowed, the high latitude buildings were oriented appropriately to make best use of winter solar heat gains, while in those closer to the equator strenuous effort had been made to minimise the year-round solar heat gains to which they were inevitably subjected. In the former case measures taken ranged from simply arranging the long axis of the building to be on an east-west axis to 'turning' the plan to face the sun. Shading systems of one kind or another were used to good effect in many of the buildings. These ranged from deep reveals and fixed external shading to automated internal louvres and blinds.

It should go without saying that all of the buildings were well insulated and designed to be as air-tight as possible, and virtually all had double glazing. The hot-humid climate zone buildings had white or light coloured walls and roofs to help reduce the effects of year-round solar heat gain. Judicious use of exposed thermal mass was evident in a number of the buildings – from the floor slabs at NRG Systems, to the internal walls at Erskine – all with insulation located appropriately.

Despite these efforts to provide a thermally comfortable environment, summer overheating was noted in several of the naturally ventilated or mixed-mode temperate zone buildings. Of particular interest was the finding that many of the buildings in warm-temperate climates were felt to be on the cold side in winter – an indication that more attention should be given

to this aspect of design. Nevertheless, there were hints of a growing acceptance of a wider temperature band and tolerance for internal thermal conditions to change gradually in accordance with the seasons.

Other design issues that were revealed by this investigation included noise and glare – issues that could usefully be given more attention in future projects. In the case of noise, juxtaposing offices with other activities such as auditoria, meeting rooms, showrooms, visitor areas, even corridors with hard surfaces and wooden floors is best avoided. Noise and disturbance within the open plan offices themselves could probably be alleviated by the establishment of appropriate etiquette and some education of the staff on the implications of moving from cellular to open-plan offices, as well as appropriate layout and acoustical design. Direct glare from the sun was noted in buildings in every climatic zone and is somewhat surprising, given the predictability of sun angles and the effort put into shading systems – perhaps more care needs to be taken with internal layouts and the positioning of workstations in relation to the windows.

Acknowledgements

My particular thanks must go to all the building users who responded to the questionnaire, the building owners who facilitated the surveys and the designers and building managers who gave so freely of their time. Thanks too to all my collaborators and research assistants and to Adrian Leaman of Building Use Studies.

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Table 1: List of buildings in descending order of Summary Index, together with scores for Comfort and Health (on a 1 to 7 scale where 7 is best) and the percentage by which the users' Productivity was perceived to be increased or decreased.

Note: superscripts indicate the relative ranking of each factor out of all 30 buildings.

Building	Summary Index (-3 to +3)	Comfort Scores (1 to 7)	Health Scores (1 to 7)	Productivity % (up or down)
NRG Systems Facility, Vermont	2.93[1]	6.56[1]	5.47[3]	19.51[4]
Torrent Research Centre (with AC)	2.83[2]	5.72[5]	5.53[2]	20.88[2]
Natural Resources Defense Council	2.82[3]	6.50[2]	5.85[1]	23.00[1]
Military Families Resource Centre	2.45[4]	5.92[3]	5.17[5]	20.00[3]
Erskine Building, Christchurch	2.39[5]	5.86[4]	4.52[11]	9.80[10]
Torrent Research Centre (with PDEC)	1.95[6]	5.16[12]	4.74[7]	13.66[6]
St Mary's Credit Union, Navan	1.73[7]	5.67[6]	4.67[10]	10.83[8]
40 Albert Road, Melbourne	1.42[8]	5.65[7]	4.73[8]	10.00[9]
Min Energy Water & Communication	1.33[9]	5.20[10=]	4.77[6]	16.00[5]
60 Leicester Street, Melbourne	1.23[10]	5.62[8]	5.24[4]	11.39[7]
AUT Akoranga, Auckland	1.18[11]	5.20[10=]	4.18[13]	3.64[15]
Arup Campus , Solihull	0.96[12]	4.93[14=]	4.16[14]	4.47[14]
Nikken Sekkei Building, Tokyo	0.88[13]	4.98[13]	3.94[18]	8.51[11]
Computer Science & Engineering	0.81[14]	4.91[16]	3.86[20]	2.54[17]
Gifford Studios, Southampton	0.73[15]	4.73[19]	3.91[19]	2.80[16]
Renewable Energy Systems	0.58[16]	5.41[9]	4.72[9]	5.77[12]
Tokyo Gas, Yokohama	0.48[17]	4.75[18]	4.44[12]	5.62[13]
City Hall, London	0.48[18]	4.76[17]	3.75[22]	-1.64[20]
Student Services Centre, Newcastle	0.34[19]	4.52[23]	3.44[28]	-2.04[21]
National Engineering Yards	0.33[20]	4.53[22]	3.81[21]	0.19[18]
Science Park, Gelsenkirchen	0.13[21]	4.93[14=]	3.57[26]	-2.27[23]
Institute of Languages, Sydney	0.12[22]	4.65[20]	4.04[16]	0.48[19]
Landcare Research, Auckland	0.09[23]	3.97[26]	3.66[25]	-2.18[22]
ZICER Building, Norwich	0.07[24]	4.41[24]	3.31[29]	-7.81[27]
Foundation Building, Eden Project	0.05[25]	4.63[21]	4.03[17]	-7.00[26]
Scottsdale Ecocentre	-0.28[26]	4.04[25]	4.1[15]	-4.29[24]
Red Centre Building, Sydney	-0.37[27]	3.75[27]	3.72[23]	-5.00[25]
General Purpose Building, Newcastle	-0.39[28]	3.48[29]	3.55[27]	-11.9[29]
Liu Institute, Vancouver	-0.71[29]	3.55[28]	3.70[24]	-13.00[30]
Institute of Technical Education	-0.80[30]	3.29[30]	3.00[30]	-10.61[28]

Appendix - Calculation of the Summary Index

First, it should be made clear that each of the factors has been assigned a benchmark (copyright BUS) on its 7-point scale. At any given time, these benchmarks are simply the mean of the scores for each individual factor, averaged over the last 50 buildings entered into the BUS database. As such, each benchmark score may be expected to change over time as newly surveyed buildings are added and older ones withdrawn. Nevertheless none of them was observed to have changed significantly during the five years or so over which these buildings were surveyed.

The Summary Index is simply the arithmetical average of the Comfort and Satisfaction Indices.

The Comfort Index involves temperature, air quality, lighting and noise factors. It encapsulates, in a single figure, an overview of users' perceptions of that aspect of the building's performance. This index is formulated from the Z-scores for Comfort Overall, together with the main environmental factors of Lighting Overall, Noise Overall, Temperature Overall in both winter and summer and Air Overall in both winter and summer. The Z-scores are derived from (actual score – benchmark) / (benchmark standard deviation). They are standardized scores with mean = 0 and standard deviation = 1, and are used here to give equal weights to the seven constituent values of the index.

The formula for calculating this index is simply the average of the Z-scores for these seven factors, i.e.

$$CI = (Z_{comfort} + Z_{light} + Z_{noise} + Z_{tempwinter} + Z_{tempsummer} + Z_{airwinter} + Z_{airsummer}) / 7$$

The Comfort Index is based on a scale of '-3' to '+3', where '+3' is considered 'best' (the mid-point lies on zero).

The Satisfaction index Involves design, needs, health, and productivity factors. In a similar way to the Comfort Index, the Satisfaction Index encapsulates, in a single figure, the users' overall satisfaction with the building. It is formulated from the Z-scores of the overall ratings for Design, Needs, Health and Productivity. The formula for calculating this index is simply the average of the Z-scores for these factors, i.e.

$$SI = (Z_{design} + Z_{needs} + Z_{health} + Z_{productivity}) / 4$$

As before, the Satisfaction Index is based on a scale of '-3' to '+3' where '+3' is considered 'best' (the mid-point lies on zero).

Capacity Building in International Construction Joint Venture Projects – the case of South Africa

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Abstract

Although International Construction Joint Venture (ICJV) projects are believed to be beneficial with regard to aiding capacity building in the local construction industry, it is still debatable whether such skills and technology transfer effectively occurs in the hosting companies. South African construction companies are therefore not immune from these undesirable trends. This paper reports on a research project which was carried out in South Africa to identify salient challenges in ICJV environments, and proposes a conceptual structure of international construction joint venture at projects delivery stage that can appropriately assist to accelerate the transfer of expertise from the international JV partners to the host companies in South Africa.

Keywords: International construction joint venture, projects, capacity building, South Africa.

1. Introduction

The performance and capability of the industry is pivotal to transport and communication, import and export, industry development, and to all the logistics of a growing economy that increasingly supports an integrated and economically active population [Construction Industry Development Board (CIDB) (2004)]. Furthermore, the SACI is considered as one of the few African advanced construction industries and thus its role extends beyond the borders of South Africa to other countries across the continent, and the current African infrastructure backlog strongly suggest that the SACI's role is more prominent across the continent to-day than ever before.

According to Infrastructure Consortium for Africa (ICA) (2010), inefficient and insufficient infrastructure holds back Africa's economic growth per capita by 2% each year, and reduces firms' productivity by as much as 40%. Thus, Africa will need to invest approximately 40 Billion US Dollars of annual investment in infrastructure over the coming decade and a further 40 Billion US Dollars, worth of upkeep on existing networks (Emerging 2008).

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In order to meet the South African and African infrastructure demands, the SACI needs to possess sufficient competent skills, technology and resources capacity. However, Merrifield (2006) indicates that the industry is currently operating at close to capacity limits and there are concerns that the current capacity is already showing strains of not coping. The SACI is lacking experienced skills and technology to meet the demand for successful delivery of these projects both within South Africa and across the continent. Unless serious efforts are made to address capacity constraints, cost escalations and poor quality are likely to stifle growth going forward (Merrifield 2006 and Rwelamila 2007). Hence, the need to overcome the shortage of domestic skills, technology through joint ventures with overseas partners (Sewapaul 2007).

Although ICJVs are believed to be beneficial with regard to aiding capacity building in the hosting construction industry, it is still debatable whether such skills and technology transfer effectively occurs in the hosting South African (SA) companies. Lowitt (2007) argues for research on technology and skills transfer from developed country construction companies to their less developed counterparts.

The research project reported in this paper involved a case study of an international joint venture between Group Five (Pty) Ltd (a SA company) and Spiecapag (a French company) within the New Multiproduct Pipeline Project (NMPP). The NMPP comprised the construction of approximately 700 km of welded steel pipeline with new pump stations and storage terminals throughout the KwaZulu-Natal, Free State, Mpumalanga and Gauteng provinces in South Africa. The client of the NMPP project is Transnet Pipelines, a division of Transnet Ltd, which currently operates over 3,000 km of pipelines in South Africa. At the time of commencing this study, the NMPP project was valued at approximately 5 Billion Rands (approximately 650 Million US Dollars). The construction of the NMPP project was undertaken by an integrated international construction joint venture partnership known as Spiecapag/G5 JV and it was established so that the partnering companies could assist one another in their fields of expertise in order to deliver the NMPP project, which was considered challenging. Spiecapag provided its technical expertise in pipeline installation while Group Five (Pty) Ltd provided its South African local knowledge, and the administration and financial support necessary in facilitating a project of this scale. The implementation of the project commenced in August 2008 and at the inception of the research study, progress was at 60% with final completion in May 2011. As Group Five (Pty) Ltd., seeks to build its standalone capabilities in pipeline construction, especially in petrochemical pipelines, the establishment of a joint venture with Spiecapag in the NMPP project was viewed as an opportunity to acquire knowledge and technology.

This paper is organised as follows: literature review of theory and practice of knowledge and technology acquisition in ICJV; research methodology; research results and their synthesis and analysis; and finally, a conceptual structure that is suitable for speedy knowledge and technology acquisition in ICJV is proposed.

2. Theory and practice of capacity building in ICJV projects

An International Construction Joint Venture (ICJV) involves one or more local construction companies teaming up with one or more foreign construction companies to undertake a construction project (Vaughan 2010). However, in other cases, an ICJV may involve two or more foreign companies undertaking a construction project in abroad territories without partnering with a local company. Vaughan (2010) stresses that regardless of the scope of the undertaking, the nature of the ICJV or the respective degrees of equity or management involvement, a joint venture must possess the following features: (a) It must be a separately identifiable entity; (b) It must have an ownership interest in such entity by joint venture partners (JVPs); and (c) It must have an active management involvement or deliberate rejection of the right to such involvement by each joint venture partner.

2.1The drivers and benefits of ICJV

Several factors have been acting as catalysts for ICJV throughout the world including Africa. The construction industry in most developed countries, e.g. European countries, is operating in maturity stage as the new construction demand has slowed and de-industrialization has occurred (Lowitt, 2007). The subsequent fierce competition has compelled construction companies in these countries to seek markets in other geographical areas (Africa being the emerging market due to its high infrastructure demand) to strengthen their strategic positioning, competitiveness and performance. Dlungwana and Rwelamila (2004) indicate that Africa, particularly Southern Africa, is increasingly experiencing globalization in construction works. While African construction companies seek external expertise and technology to execute large complex infrastructure projects, foreign companies perceive teaming up with local companies via joint ventures as an ideal option to overcome government-mandated barriers to entry in Africa (Boateng & Glaister, 2003). Among those African countries seeking external expertise and technology to execute large complex infrastructure projects is South Africa (Sewpaul 2007). Rowan (2005) identified the following as the motives to formation of ICJV:

(a) A foreign contractor takes a project that is larger than it normally would undertake outside its country and therefore teams up with a competent local contractor with a view toward spreading the risk.

(b) A foreign contractor teams up with a competent local contractor to generate bonding capacity that each contractor would not have individually.

(c) Two or more contractors with special expertise e.g. a civil and mechanical contractor, team up to undertake a project that requires diverse expertise e.g., a power plant.

(d) A contractor that has an established organization in a country teams up with a contractor with little or no experience in the country but with specialized engineering knowledge or technology.

(e) A foreign contractor teams up with a local contractor that may have political or other valuable relationships in the country where the project is executed.

Therefore, the foreign companies benefit the feasibility of entering new geographical markets in pursuit of strengthening their strategic positioning, competitiveness and performance while the local companies gain from the expertise and technology brought in by the foreign companies which can vitally contribute to the performance improvement of local companies

2.2 Types of ICJV and agreements

According to Rowan (2005), International Construction Joint Ventures can take any of these three forms:

Integrated joint venture: This type of joint venture's primary characteristic is that it can represent a true partnership in that the parties share profits and losses.

- **Non-Integrated joint venture:** In this type, there is no sharing of profit and losses between the parties.

- **Combination joint ventures:** These joint ventures present a combination of an Integrated and Non-Integrated joint venture partnership. Each member takes on a specified scope of work and is responsible for that scope of work.

While the joint venture is not a partnership (usually the JV agreement will expressly stipulate that it is not), its structure and form closely resemble a partnership (Rowan, 2005). Vaughan (2010) alerts that structuring international construction joint venture agreements may pose challenges due to the fact that, parties are from different jurisdictions and various cultural backgrounds. After parties have decided on fundamental issues such as the commercial nature, scope and mutual objectives of the joint venture, the JVP must determine what legal structure the joint venture will take (Vaughan, 2010). Usually and particularly where the JV involves a local partner, the legal structure of the ICJV follows the laws of the host nation. Vaughan (2010) and Rowan (2005) suggest that, the joint venture contractual agreement should at least define and address the following:

- **Specific Limited Purpose and Duration:** Joint ventures are formed for a specific business objective and can have a limited life span or long-term.

- **Sharing of Profits and Losses:** Whether the joint venture is an integrated or non-integrated joint venture.

- **The Project Leader:** When there is a non-integrated joint venture in which each party is undertaking its own separate scope of work, it is critical that all joint venture agreements contain provisions that either specify that the party is the Leader of the ICJV or identify who is the project manager or provide a mechanism to appoint the project manager.

- **Working Capital:** Regardless of whether the joint venture is an integrated or non-integrated joint venture, provisions must be included that address the responsibility of the parties for working capital contributions.

- **Default:** As in any main contract or subcontract, the joint venture agreement must address default by one of its members. Default must be defined as clearly as possible and the remedies for default must be included.

2.3 Structure and management of ICJV projects

An international construction joint venture project structure refers to formal and informal framework of policies and rules, within which an ICJV arranges its lines of authority and communications, and allocates rights and duties. Graham and Englund (2004) argue that structure influences behavior of the project team members. Thus the objective in designing a project structure should be to provide a formal environment that the project manager can use to influence team members to do their best in completing their assignment and duties (pm4dev, 2007). Vaughan (2010) further highlights that some JVs are dominant partner enterprises in which projects are managed by one parent like wholly owned subsidiaries. Management normally will be in two tiers, i.e., project level and board level (Rowan 2005).

- **Management Board:** This forms the top layer of ICJV management. The management board usually comprises senior management personnel from head offices of the respective members and not project staff.

- **Project Level Management:** The project-level management often is left to a project manager, with or without the support of a project board. Generally, unanimity is not required of the Project Committee and frequently the project manager will be given the right to break tie votes.

2.4 Knowledge and technology acquisition in ICJV

IJVs are viewed as a practical vehicle for knowledge and technology transfer, and such knowledge transfer can contribute to the performance improvement of local companies (International, 2010). Such transfer of knowledge and technology from the foreign company to the local partner is not guaranteed. Hence the need to firstly understand the terms, technology and knowledge in order to have a better view on the dynamics of their acquisition in ICJVs. These terms from various sources are articulated in Table 1.

Table 1: Understanding technology and knowledge aquisition

Researcher(s)	**Arguments, definitions and assertions**
Cohen and Levinthal (1990)	Aspects that make absorptive capacity distinctly organizational include structure of communication between external environment, and the organization and the character and distribution of expertise within the organization itself.
Grant (1996)	Knowledge classified based on transferability as tacit (knowledge which is only known by an individual and that is difficult to communicate to rest of the

	organization) and explicit (knowledge which can be codified, articulated and easily communicated).Knowledge transfer involves both transmission and receipt. An organizational structure that promotes interaction between individuals is highly pivotal to knowledge and technology acquisition among other factors.
Toukas (1996)	Knowledge acquisition or transfer, results from participation and interactions with task, technology, resources and people within a particular context. Individuals acquire knowledge but an organization creates a context for acquiring that knowledge.
Meschi (1997)	An ICJV structure that can facilitate mutual interaction between employees can enhance the foreign employees' successful adjustment to the cultural differences.
Davenport and Prusak (1998)	Knowledge is a fluid mix of experience, values, contextual information and expert insight that provides a framework for evaluating and incorporating new experience and information.
Lane, Salk and Lyles (2001)	Ability to learn directly reflects the ability to assimilate new knowledge and cultural distance serves as the context that facilitates or inhibit this ability.
Anh *et al.* (2006)	Investment in training is critical in determining the level of knowledge acquisition.

2.5 Previous research on knowledge and technology acquisition ICJV

Learning from foreign partners is considered to be a determinant of success of the IJVs especially IJVs in transitional economies, hence the importance of learning from foreign partners in international joint ventures (Lane, Salk & Lyles, 2001). Some factors that affect successful technology and knowledge acquisition by local partners from the foreign partners in IJVs, include, internal environment of the firm, external environment of the firm and the process of consultation (Wallender III 1979), and absorptive capacity (Cohen & Levinthal 1990). Of all these factors, absorptive capacity has attracted the most attention. Based upon Cohen & Levinthal (1990), Lane *et al.* (2001) and Minbaevas *et al.* (2003) studies which point out that both human and organizational mechanisms are important aspects of organizational absorptive capacity, Anh *et al.* (2006) reaffirm the important role of absorptive capacity in inter-organizational learning context and further argue that different absorptive capacity components contribute to knowledge acquisition from foreign partners in different ways.

2.6 Synthesis of theory and practice – identifying the gap

The synthesis of literature above indicates that there is no research or any significant documented work that has been conducted in South Africa and across Africa and other

developing countries generally on knowledge and technology acquisition by local partnering firms, specifically in international construction joint venture projects.

3 Expertise acquisition in ICJVs in practice – the case study

The research project was carried out in order to partly fill the gap described above, by carrying out a case study of the NMPP project in South Africa as briefly described in Section 1, above.

For lack of space and brevity, only case study salient information is provided and extensive case study details are found elsewhere (Rwelamila and Mkandawire 2010).

- **The main hypothesis:**

H_{main}: *The ICJV structure that promotes joint participation of local personnel with expertriates in shared activities of the international construction joint venture project is positively correlated with the local company's level of skills and technology acquisition from the foreign partner.*

- **Sub-hypotheses:**

Two sub-hypotheses were formulated from the main hypothesis and tested:

On the relationship between interaction at work place and collaboration in job tasks (Question 26)

H_0: There is no significant relationship between collaboration in job tasks and the foreign employees' willingness to share their knowledge and technology with local employees.

H_1: There is a significant relationship between collaboration in job tasks and the foreign employees' willingness to share their knowledge and technology with local employees.

On the relationship between collaboration in job tasks and sharing and sharing of knowledge and technology (Question 27)

H_0: There is no significant relationship between interaction at work place and collaboration in job tasks.

H_1: There is a significant relationship between interaction at work place and collaboration in job tasks.

3.1 Design of research method

The case study incorporated both *qualitative* and *quantitative* research methods via a two-phase design, in which *quantitative* study was followed by *qualitative* study. The *quantitative* research method was aimed at assessing the extent to which knowledge and technology acquisition occurs in the ICJV project. The *quantitative* research approach was purposed to profoundly describe and analyse the common drivers of knowledge and technology acquisition or lack thereof in the ICJV project in relation to its structure. This led to identification of the critical success factors for speedy acquisition of knowledge and technology. This is supported by Eisenhardt (1989), Tellis (1997) and Lee (1999) as a leverage to the weaknesses inherent in each.

3.4 Design of research instruments and profile of respondents

3.4.1 ***Research instrument***

A 44 questions structured questionnaire was administered to the project participants and the philosophy and details of the instrument (including its administration) are described elsewhere (Rwelamila and Mkandawire 2010).

Follow-up interviews were conducted to simple sampled focus groups of not more than 20 people, in which open-ended questions were asked.

3.2.2 Profile of respondents

A total of 125 randomly selected employees in the Spiecapag/G5 JV within NMPP project were involved in the case study. As expected from a typical construction project in South Africa, the majority of respondents were male (82%) and the rest were female (18%).

On the job level, the sample was stratified into non-management, middle management and senior management levels. The non-management strata, was made-up of 58% of respondents, while middle and senior management represented 33% and 9% respectively. For a typical organisation or project, the sample was deemed to be fairly distributed across job levels.

3.5 Summary of research results

For lack of space and brevity, summary of questionnaire and interview results are presented here and detailed results are reported elsewhere (Rwelamila and Mkandawire 2010).

The following key findings from the research project are fundamental to ensuring that these critical success factors materialize, and that the local partner acquires enough knowledge and technology from the foreign partner:

- **The structure should enhance project success:** project success which is determined by factors such as cost, time, quality, utility, stakeholder management, health and safety,

etc., should not be hampered at the expense of knowledge and technology acquisition. JV partners were concerned with this.

- **The structure should help minimize the cultural shock period:** the study discovered that regardless of whether the employees are foreign or local, they all go through a cultural shock period when mobilized together in a project.

- **The structure should emphasize sharing of same project objectives:** it was found from the study that knowledge and technology sharing may become feasible when employees share the same project objectives. When employees share the same project objectives they bear the responsibility of achieving those objectives, as a result they find it compelling to collaborate in tasks and share information, knowledge and technology.

3.6 Conclusions and recommendations

3.6.1 Conclusions

- ***The importance of the JV structure:*** even though the primary rationale for adoption of the section-based structure is to facilitate knowledge and technology acquisition in an international constriction joint venture project, the structure is also perceived to be pivotal to enhancing project success.

- ***The need for integration***: with the integration of local and foreign employees in one project section, the foreign and local employees will feel compelled to collaborate in jobs tasks and share knowledge and technology.

- ***The importance of risk mitigation:*** in any international JV, the foreign partner is more likely to be risk averse than the local partner and hence will incline more toward adopting a structure that is more capable of mitigating project risks.

- ***The importance of local partner commitment to knowledge and technology acquisition:*** the local partnering company should also show commitment to knowledge and technology acquisition to its employees.

3.6.2 Recommendations

Overall, it is recommended that where international construction joint venture projects are involved and that knowledge and technology acquisition from the foreign partnering company becomes one of the objectives of a local company, a section-based structure should be adopted as indicated in Figure 1.

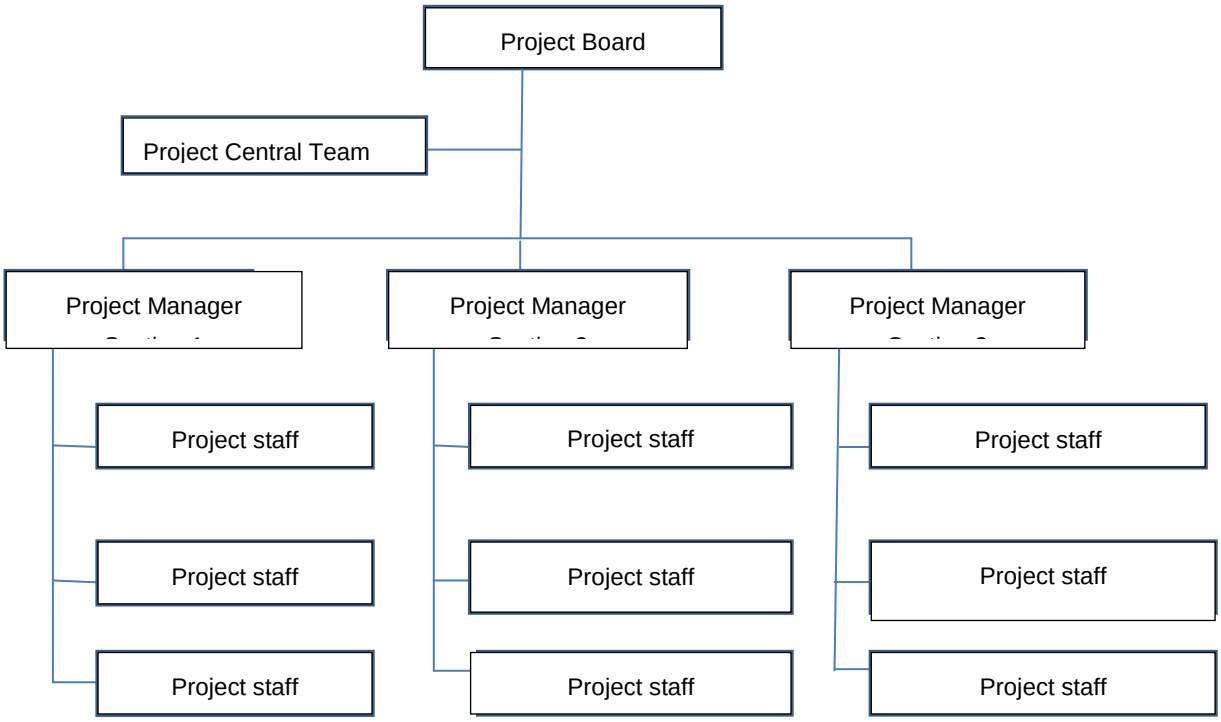

Figure 1: Section-based joint venture project structure

A section-based structure should be supported by a conceptual framework (Figure 2).

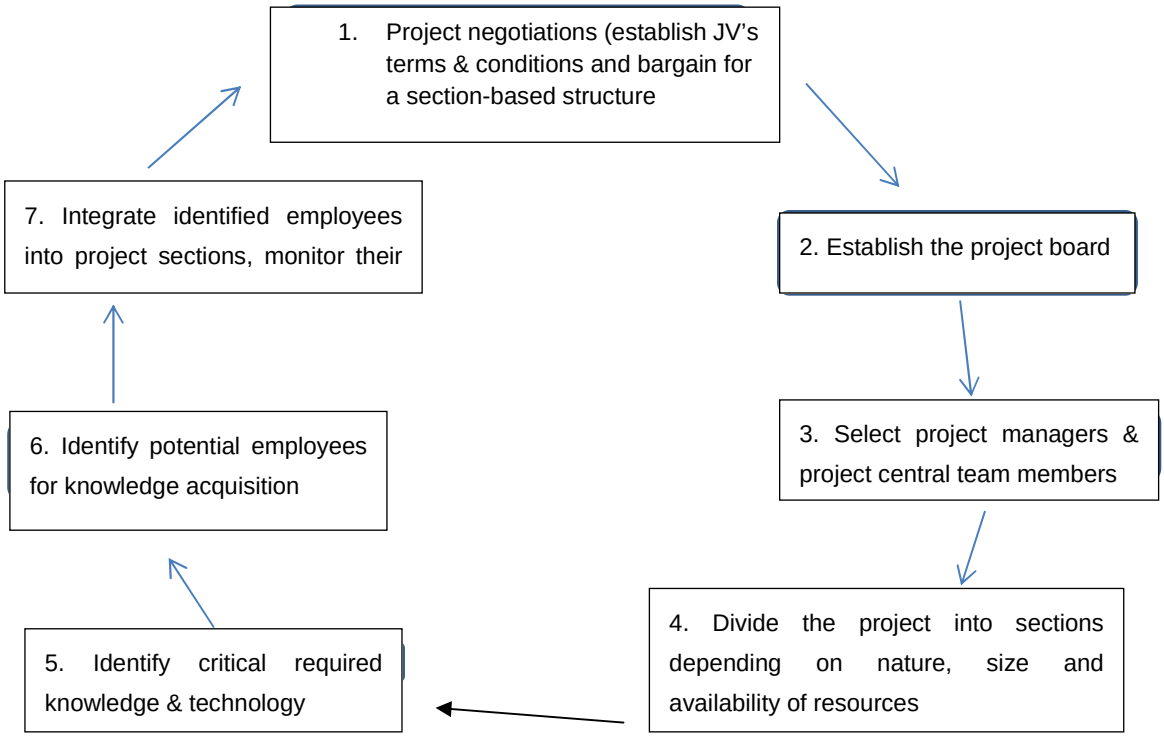

Figure 2: A conceptual framework for effective adoption of section-based structure

Other recommendations include:

- ***Induction of project team on project objectives****:* induction should involve orienting employees to the project partners, the reasons for the international joint venture, the different cultures, and what they should expect from the partnering companies and their employees.

- ***Identification of required knowledge and technology:*** unless the local company identifies the knowledge and technology it needs to acquire from the foreign partnering company, it may not acquire sufficient knowledge and technology in the ICJV even if a section-based structure is adopted.

- ***Training and monitoring of employees:*** it is not enough to induct employees on ICJV project objectives, identify required knowledge and technology, and single-out potential employees. It is important that the above is coupled with training of employees and continuous monitoring of their progress.

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The mandatory and voluntary approaches to sustainability: BASIX vs BEAM Plus

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Abstract Title

Many assessment systems have been introduced to measure the environmental sustainability of buildings that aim to reduce energy consumption and carbon emissions over the last decade. Examples are the BRE Environmental Assessment Method (BREEAM) in the UK, Leadership in Energy and Environmental Design (LEED) in the US and Canada, the Green Star and Building Sustainability Index (BASIX) in Australia, and the Building Environmental Assessment Method (BEAM) Plus in Hong Kong. Some of the systems, such as BASIX, apply a mandatory approach for implementation; others, such as BEAM Plus, are voluntary with incentives. This paper aims to compare the difference between BASIX and BEAM Plus and discuss their different approaches to building sustainability. The comparison is important because it would then be possible to evaluate the implications of the environmental assessment policy tools in which two different approaches are used. The paper will first study and compare both the BASIX and BEAM Plus assessment systems. Second, the advantages and pitfalls of the mandatory and voluntary approaches will be identified and discussed. The paper is based on desk research. The impacts of the environmental policy tools, determined through case studies that will be conducted, should reveal if a voluntary-with-incentives approach is the stronger motivation for the building industry to improve its environmental performance.

Keywords: Environmental assessment tools, Mandatory and voluntary approaches, BASIX, BEAM Plus

1. Introduction

The international debate over sustainable development has emphasized development that "meets the needs of the present generation without compromising the ability of future generations to meet their own needs" (WCED, 1987). This brings up the issue of the importance of environmental sustainability, which prompts the development of environmental assessment systems. The Environmental Impact Assessment (EIA) and Life Cycle Assessment (LCA) are two well-known environmental assessment systems and two basic methodological frameworks. The EIA is an official assessment of the possible outcome of

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the proposed policy, program, and project on the environment to ensure environmentally sound and sustainable development (Gilpin, 1995; UNEP, 1996); while the LCA is a tool for measuring the use of resources and the impact on the environment integrated with a product and process (Park and Seo, 2006). Yet, the building and its activity falls somewhere in between the EIA and the LCA (Crawley and Aho, 1999).

The activities associated with the buildings have a negative impact on the environment (e.g. high energy consumption due to HVAC and lighting, pollution due to building construction; excessive consumption of natural resources due to the manufacture of building products; construction waste, etc.). Building environmental assessment systems are inevitably required for the Earth's sustainable development. Some building environmental assessment tools have been launched since early 1990s. The currently available tools vary greatly, as they are designed for different needs and purposes. Some were developed to gauge different building types; while others focus on different stages of a building's life cycle (Haapio and Viitaniemi, 2008). Examples are the BRE Environmental Assessment Method (BREEAM) in the UK, Leadership in Energy and Environmental Design (LEED) in the US and Canada, the Green Star and Building Sustainability Index (BASIX) in Australia, and the Building Environmental Assessment Method (BEAM) Plus in Hong Kong. A number of studies have discussed and compared these assessment systems (e.g. Cole, 1999; Crawley and Aho, 1999; Forsberg and von Malmborg, 2004; Ho et al., 2005; Seo et al., 2005; Ding, 2008; Haapiio and Viitaniemi, 2008; Reed et al., 2009, 2011; Kajikawa et al. 2011). Yet, little concern has been given to the significance of the mandatory and voluntary approaches of building environmental assessment systems. BASIX in New South Wales (NSW), Australia implementing a mandatory approach and BEAM Plus in Hong Kong adopting a voluntary approach with incentives could be cases worth studying. The main objectives of this paper are to compare the differences between BASIX and BEAM Plus and discuss their different approaches to building sustainability. These two assessment systems are selected due to their popularity as green building initiatives in Australia and Hong Kong. This paper will also identify and discuss the advantages and pitfalls of mandatory and voluntary approaches for building environmental assessment tools. The paper is based on desk research.

2. The need for building environmental assessment tools

Global warming and climate change have been a main concern of nations around the world. Excessive energy use has led to an increase in the Earth's temperatures to critical levels. Energy consumption in the Asia-Pacific Economic Cooperation (APEC) region, which also includes the U.S., Canada, Russia and some countries in South America, continues to escalate. Per capita electricity consumption in countries like China and South Korea has been exceptionally high, rising from 764 kWh in 1999 to 2,287 kWh in 2009 and from 4,594 kWh in 1999 to 8,325 kWh in 2009, respectively (EMSD, 2012). Meanwhile, per capita electricity consumption in Hong Kong and Australia has grown modestly by 13% and 10%, respectively, over the last decade. In contrast, countries like the U.S. and Canada experienced a decrease in electricity consumption – by 2% and 7%, respectively – over the same period.

About 40% of a nation's primary energy consumption comes from buildings (Kua and Lee, 2002). Energy is required for heating, ventilating, cooling, and lighting a building. Most modern buildings rely heavily on artificial heating and air conditioning, which result in high electricity consumption and carbon dioxide generation from the production of electricity. This can jeopardize human health and the Earth's ecosystems. Much effort has been put into reducing energy consumption and carbon emissions and improving the environmental performance and quality of buildings. A growing interest in building environmental assessments has resulted in more qualitative and quantitative assessment tools (Forsberg and von Malmborg, 2004). Before 1990, most benchmarks for buildings were concerned with a single criterion to gauge a particular aspect of building performance, e.g. energy use, indoor comfort, or air quality (Ding, 2008). BREEAM, the first commercially available building environmental assessment tool introduced in the UK in 1990, made the first real attempt to measure a comprehensive range of environmental considerations in buildings (Crawley and Aho, 1999; Grace, 2000). In partnership with private developers in the UK, BREEAM was launched as a credit award system for new office buildings and later extended to all building types, including residential, educational, medical, and industrial units (Ding, 2008). BREEAM has been a reference model for the schemes established in Canada, Hong Kong, New Zealand, Norway, and Singapore (Lee and Burnett, 2008). Thereafter, numerous environmental assessment tools for buildings were developed around the world (Haapio and Viitaniemi, 2008). LEED in the U.S. and Canada is among the most popular building environmental rating schemes. Like BREEAM, LEED is a voluntary program that deals with the entire phases of a building's life cycle and covers individual buildings all the way up to entire communities. In addition, LEED offers tax rebates and zoning allowances.

Other building environmental assessment tools include Green Star and BASIX in Australia, BEPAC in Canada, Eco-Quantum in the Netherlands, GOBAS in China, BEAM Plus in Hong Kong, Greenmark in Singapore, and CASBEE in Japan. These systems provide a wide-ranging assessment of environmental impacts due to the activities associated with buildings by aiming to measure the sustainability of the built environment (Reed et al., 2009). Some of the literature on this field have discussed these building environmental assessment tools (e.g. Cole, 1999; Crawley and Aho, 1999; Ding, 2008; Kajikawa et al., 2011). Some studies even compared these rating tools (e.g. Forsberg and von Malmborg, 2004; Seo et al., 2005; Haapiio and Viitaniemi, 2008; Reed et al., 2009; Kajikawa et al. 2011). Lee and Burnett (2008), for example, compared HK-BEAM (the former version of BEAM Plus), BREEAM, and LEED; while Kajikawa et al. (2011) explained the building environmental assessment tools in detail in their coverage of BREEAM, LEED, GBTool, and CASBEE. In Hong Kong, Ho et al. (2005) compared HK-BEAM, Intelligent Building Index (IBI), Building Quality Index (BQI) and Comprehensive Environmental Performance Assessment Scheme for buildings (CEPAS). Despite these distinctive systems, a comprehensive assessment of a building's environmental characteristics is required for designers and building owners to achieve higher environmental standards so as to be able to protect the environment and achieve sustainability for the built environment (Cole, 1999; Ding, 2008). The assessment tools can raise stakeholders' awareness of environmental issues and provide a verifiable framework for professionals to design, construct, and manage property more sustainably (Reed et al., 2011).

3. Australian context

In Australia, the three most commonly-known systems are Green Star, established by the Green Building Council of Australia (GBCA); the National Australian Built Environment Rating System (NABERS); and the Building Sustainability Index (BASIX). Green Star is the most commonly-used tool there and is equivalent to BREEAM and LEED (Reed et al., 2009). It rates a building in regards to the health and wellbeing of its occupants and their accessibility to public transport; its management, water use, and energy consumption; and the embodied energy of its materials, land use, and pollution (GBCA, 2012). It uses "Stars" to rate these performances, with four, five, and six stars indicating 'Best Practice', 'Australian Excellence', and 'World Leadership', respectively. All dwellings in Australia, except for those in NSW, must achieve 4-5-star thermal performance standards, as regulated by the Building Code of Australia (BCA).

NABERS is another indicator that assesses an existing building's environmental performance during its operational stage. It rates a building by the impacts from its building operations, namely in the energy, water, waste, and indoor environment categories (NABERS, 2012). NABERS was developed for commercial buildings and houses by the Department of Environment and Heritage in 2001 and operated by the government (Ding, 2008). It is a voluntary self-assessment tool with an accredited rating score of 10 being the best (Ding, 2008).

In NSW, BASIX overrules the BCA requirements and sets the required levels of environmental performance in a number of areas, namely energy, water, and thermal performance. Like NABERS, BASIX is operated by the government. It was introduced in July 2004 by the NSW Government to assess the potential performance of residential buildings against a range of pre-determined criteria (Ding and Ge, 2009). It is the first scheme to be introduced to Australia with mandatory requirements, which is implemented under the 1979 NSW Environmental Planning and Assessment Act. BASIX is an online assessment tool accessible to everyone and is easy to use. It applies to all new residential developments with a total estimated cost of A$50,000 or above and all residential alterations and additions (A&A) works with total cost of A$100,000 or above in NSW. Sustainability features must be incorporated into the building's design to meet the water and energy targets. A BASIX Certificate has to be obtained and attached to a development application. The applicant (the building owner, designer or developer) must input the data of the building's design (e.g. building materials, location, size, etc.) into a BASIX tool, in which the data will be automatically analysed and the score for the water and energy targets generated. A BASIX Certificate contains the description of the proposed development, a list of its commitments (covering water, thermal comfort, and energy) from the applicant to promote the sustainability of the proposed development, and a statement to fulfil the sustainability requirements. The certificate can be printed online if the design passes the water and energy targets, which vary by building type and location. Council staff will verify the development application against the certificate and the certifying authority will inspect the agreed-upon commitments at various phases of the construction. An occupation certificate will only be issued upon the satisfactory compliance with the particular commitments stated

in the BASIX Certificate. A BASIX completion report will be issued upon the completion of the development (BASIX, 2012).

4. The Hong Kong Context

In Hong Kong, two assessment schemes have been introduced, namely the Comprehensive Environmental Performance Assessment Scheme (CEPAS) and the Building Environmental Assessment Method (BEAM) Plus. CEPAS, commissioned by the government and announced in 2007, is a voluntary scheme that intends to promote green buildings. It applies to new and existing commercial and residential buildings and provides a common benchmark to gauge a building's environmental performance. It employs an adaptive/weighting approach and has eight performance categories: 1) resource use, 2) loadings, 3) site impacts, 4) neighbourhood impacts, 5) indoor environmental quality, 6) building amenities, 7) site amenities, and 8) neighbourhood amenities (Cole, 2005; Ho et al., 2005). The original plan of promoting CEPAS was to offered exemptions from the calculation of gross floor area (GFA) and site coverage in exchange for building construction with environmentally friendly features. However, the idea was dropped due to objections to spending public funds to subsidize developers (Lee and Chen, 2008).

The former version of BEAM Plus, the Hong Kong Building Environmental Assessment Method (HK-BEAM), was introduced in December 1996 with two assessment methods, namely new and existing office buildings. It was originally initiated by the Real Estate Developers Association of Hong Kong together with the Planning Environment and Lands Bureau, Swire Properties, Hong Kong Land, Hong Kong Polytechnic University, and the Business Environment Council in 1995 (BEAM, 2012). It follows the structure of BREEAM's global, local, and indoor scales by embracing a wide range of environmental issues on buildings. In 2003, the standards were revised to cover all types of buildings during all stages of each building's life cycle. HK-BEAM aims for more environmentally sustainable building designs and operations (HK-BEAM Society, 2004a, 2004b). By the end of October 2009, approximately 199 landmark developments totaling more than nine million square metres of commercial space and 50,000 residential units had been assessed. HK-BEAM clients include the public and private sectors.

The BEAM Society merged with three other industry associations (the Construction Industry Council, the Business Environment Council, and the Professional Green Building Council) to form the Hong Kong Green Building Council (HKGBC) in 2009. The BEAM Society, however, remains the owner and operator of the BEAM assessment system. The revised green building rating systems, BEAM Plus New Building and BEAM Plus Existing Building, were officially launched in April 2010 and endorsed by the HKGBC. The BEAM Plus Version 1.2 for New Buildings and Existing Buildings, introduced in 2012, are improvements over the earlier versions by introducing a holistic element for Passive Design (BEAM Society, 2012).

Similar to CEPAS, the certification of BEAM Plus is voluntary. Its certification enjoys an incentive of 10% GFA concessions upon the submission of a development application to the relevant authorities. Since the incentive means an additional bonus to developers, a BEAM

Plus certification will become a standard requirement for new developments. Currently, there are over 240 projects registered for BEAM Plus assessment. Buildings are assessed by trained assessors called BEAM Professionals (BEAM Pro). The training program was introduced in 2010 and as of now, there are approximately 1,800 BEAM Pro-accredited assessors (HKGBC, 2012b).

The buildings will only be assessed upon their completion to certify their actual performance. However, Ding (2008) criticized that such a system assesses a building 'as it is built' rather than 'as it was designed' and the assessment process is not transparent. An assessment should be undertaken at the early stage of the design to incorporate environmental issues. Nevertheless, BEAM Plus covers the relevant regulatory or basic design requirements, including health and safety issues. It is an instrument for benchmarking building sustainability and improving building performance, thereby ensuring safe, healthy, efficient, and environmentally friendly working and living environments (BEAM Society, 2012). Credits will be awarded if a building's performance meets the defined criteria. Similar to BEAM earlier versions, BEAM Plus employs checklists to facilitate the consistent assessments (HK-BEAM Society, 2004a, 2004b). As a leading building environmental assessment tools in Hong Kong, BEAM Plus and its voluntary approach is worth studying and being compared against the mandatory approach of BASIX.

5. Comparison between BASIX and BEAM Plus

Both BASIX and BEAM Plus are building environmental assessment systems. BASIX is an assessment tool for residential buildings (new and Alteration & Addition works); while BEAM Plus covers all types of buildings (new and existing), including residential properties. Despite their fundamental similarities, BASIX and BEAM Plus are quite different in nature. BASIX is mandatory and was introduced to ensure that dwellings are built to be more energy and water-efficient (BASIX, 2012), while BEAM Plus is a voluntary scheme with diverse objectives. BEAM Plus aims to make building developments more sustainable and ease the long-term impact of buildings on the environment by improving safety, hygiene, and indoor environmental quality (IEQ); minimising pollution; promoting energy efficiency; trimming the consumption of non-renewable resources; and encouraging the recycling and reuse of materials (BEAM Society, 2012). The scope of BASIX's assessment includes the commitments of water use, energy use, and thermal comfort performance, while BEAM Plus covers site aspects, material aspects, energy use, water use, and IEQ. The scope of BASIX looks much simpler than that of BEAM Plus, as some sub-items of BEAM Plus's site and material aspects were actually incorporated into BASIX. No incentive is offered for BASIX; while the certification of BEAM Plus enjoys an incentive of 10% GFA concessions. A comparison of BASIX and BEAM Plus is shown in Table 1.

Table 1: Comparison of BASIX and BEAM Plus

Aspect compared	BASIX	BEAM Plus
Nature	Mandatory	Voluntary with incentives
Launch date	2004	1996
Incentive	N/A	10% GFA concessions
Governance	Department of Planning & Infrastructure, NSW Government	HKGBC
Award classification	N/A	Bronze/Silver/Gold/Platinum
Scoring system	Target for each commitment: • Water: Range between 0% and 40% across NSW • Thermal Performance: Pass or Fail • Energy: Average of 36% across NSW	Percentage of applicable credit gained: • Bronze : 40% • Silver : 55% • Gold : 65% • Platinum : 75%
Type of buildings	Residential (New and A&A works)	All type of buildings (New and Existing)
Assessment stage	Early design stage	All stages; recommended at the planning stage
Assessment method	Feature-specific criteria	Performance-based
Assessment category	• Water Use • Energy Use • Thermal Performance	• Site Aspects • Material Aspects • Energy Use • Water Use • Indoor Environmental Quality
Assessors	• Verification of development applications against BASIX criteria by Council staff; • Inspection of the BASIX commitments during construction by Professional Building Certifiers	By independent BEAM assessors (BEAM Pro) on behalf of BEAM Society Limited
Certification Authority	Director-General of the Department of Planning	HKGBC
Issue of certificate	During design stage	Upon building completion
Certification Fee*	Certificate Issuing Fee: A$50-$120	Registration Fee: HK$20,000–$110,000
		Assessment Fee: HK$90,000–$400,000
Completion Report Fee	Free of charge	N/A
Online registration	Yes	Yes
Online certification	Yes	No
Number of residential units certified**	46,000 individual homes	50,000 residential units***
Availability of assessment tools	Free of charge	Free of charge
Revision of documentation	N/A	Annual

Source: BASIX, 2012; BEAM Society, 2012; HKGBC, 2012a

Note: * Fee for new development, A$1 = HK$8 approximately;
** as of 2009;
*** HK-BEAM (former version of BEAM Plus).

On the subject of governance, BASIX is administered by the state government, while BEAM Plus is managed by the HKGBC, a non-governmental organization (NGO). The certifying authority for BEAM Plus is therefore the HKGBC; while that for BASIX is Director-General of the Department of Planning. The entire certification process (from registration to certification) of BASIX can occur online, while BEAM Plus only provides online registration. A BASIX applicant can input the design data into an online assessment tool that can generate a target score and print out a BASIX Certificate, which will later be verified against the development applications by the council staff; while BEAM Pro on behalf of the BEAM Society undertakes a BEAM Plus assessment. Time required for BASIX certification is shorter, but the applicant will later be involved more in the assessment process than under a BEAM Plus assessment. More time (no fewer than 90 calendar days from the submission of materials for assessment to the issue of a certificate) is required for a BEAM Plus assessment. As of 2009, number of residential units being certified was 46,000 for BASIX and 50,000 for HK-BEAM (former version of BEAM Plus). BASIX was launched in 2004; while BEAM assessment in 1996. BASIX is comparatively much "green" in terms of establishment year. Nevertheless, the number of residential units certified for both assessments are relatively similar. This implies that BASIX certification process is more efficient. In the long term, BEAM Plus should consider shortening the certification process to attain more high quality built environments.

Every applicant for a BASIX certification must submit an application for a new development to the Council attached with a BASIX Certificate. A dwelling is assessed during its design stage and the energy and water reduction targets must be met before printing the BASIX Certificate. In comparison, a BEAM Plus certification is not required before application for a new development. Assessment starts through a developer's initiative to obtain the certification, such as being motivated by the incentives offered. An applicant can register online with the HKGBC during the planning or design stage. Once the HKGBC has received the application, it will disseminate it to the BEAM Society for assessment. The assessment for a new building will only occur upon the building's completion to certify its actual performance (BEAM Society, 2012). The above mentioned indicates that the assessment of BASIX is feature-specific criteria and BEAM Plus is performance-based. In fact, an assessment is recommended before the building's design is conceptualised so that environmental issues can be incorporated into it (Ding, 2008). Such an assessment may be insufficient if it happens when the design is about to completed (Crawley and Aho, 1999; Soebarto and Williamson, 2001; Ding, 2008).

The award classification of Bronze, Silver, Gold, or Platinum is shown in a BEAM Plus Certificate. These ratings are derived from the overall assessment grade determined by the percentage of available credits obtained under each performance category and its weighting factor (BEAM Society, 2012). Each category has its own weighting factor, which is assigned to indicate its significance and global trends. BASIX does not have an awards classification. The BASIX Certificate merely reveals the score of each target. An applicant will not obtain the certificate if the targets of water, thermal comfort, and energy cannot be achieved.

Basically, a BASIX assessment is free of charge. The government only charges a fee to issue the BASIX Certificate. The charge for the certificate is comparatively low, costing from A$50 for a single detached dwelling to A$120 for each of the first three apartments in a building and A$20 for each additional apartment (BASIX, 2012). Another type of charge for BASIX is optional, which is on top of the charge by the government issuing a BASIX Certificate. The applicant may pay for a private BASIX consultant to prepare a set of BASIX documents for submission. The charge to prepare a set of BASIX documents for submission is usually about A$300 for each detached house. The BEAM Plus assessment and certification fee is more expensive than that of BASIX. Its registration fee ranges from HK$20,000 (A$1 = HK$8 approx.) for small projects (with a construction floor area of less than 2,499 square metres) to HK$110,000 for mega projects (with a construction floor area of 200,000 to 400,000 square metres). The assessment fee ranges from HK$90,000 for small projects to HK$400,000 for mega projects. Despite the GFA incentive, the expensive registration and assessment fees often discourage small homeowners from trying to obtain BEAM Plus certification. Nevertheless, small homes only account for a very small portion of Hong Kong's housing stock.

6. Discussions: mandatory and voluntary approaches

The voluntary approach has been gradually accepted around the world since the Earth Summit in Rio de Janeiro in 1992 (Lyon, 2003). A number of manufacturing companies have made voluntary pledges to enact environmentally friendly programs. Additional research studies have emerged to examine how well these voluntary approaches have performed (Gunningham and Sinclair, 2002; Annandale et al., 2004; Arimura et al., 2008). In the mining and forestry sectors, the voluntary approach for improving environmental performance can play a role from the view of foreign direct investment (Gunningham and Sinclair, 2002). Compared to the emergence of the voluntary approach two decades ago, the evolution of the mandatory approach started much earlier. Mandatory codes to control energy use in buildings emerged during the mid-1970s (Lee and Chen, 2008). Both approaches have advantages and pitfalls.

The mandatory versus voluntary schemes of control have been discussed in other disciplines, such as in the disclosure of financial and real externalities (Dye, 1990); food safety (Segerson, 1999); the disclosure of product risks (Polinsky and Shavell, 2006), etc. Within public policies for environmental protection, Lyon and Maxwell (2003, 2007) compared the voluntary approach to a subsidy payable to a plant that adopts environmental technology and the mandatory approach to the adoption of an environmental tax. Lyon and Maxwell (2007) found that a mandatory scheme can yield greater environmental enhancement than the voluntary scheme with incentives, as long as there is no significant political obstruction. But when there is intense political obstruction, the voluntary scheme is more desirable. This confirms the outcomes of Lyon (2003), who investigated the outcomes of voluntary versus mandatory approaches and highlighted that voluntary schemes were unable to reach similar levels of environmental protection than when they were mandatory. Lyon (2003) further argued that a voluntary scheme is a weak mechanism when political resistance thwarts the implementation of a more robust mandatory scheme.

In the area of building environmental assessment systems, only a few places have implemented mandatory systems (e.g. BASIX). The majority of assessment systems adopt the voluntary approach, with some systems offering incentives, such as LEED providing tax rebates and zoning allowances and BEAM Plus offering 10% GFA concessions. The mandatory approach of BASIX sets one environmental standard and well-defined sustainable housing targets to ensure that new built dwellings are more energy and water-efficient (BASIX, 2012). However, the drawback of BASIX is that it applies only to new developments and A&A works. Ninety-eight percent of existing homes consume non-renewable resources and pollute the environment (Ding and Ge, 2009), which means that BASIX does not do much for environmental sustainability. Besides, relying on the design of a project to realize the goal of sustainable development is insufficient to solve current environmental problems (Ding, 2008).

On the other hand, the voluntary-with-incentives approach of BEAM Plus can encourage designs to incorporate more environmentally friendly features. The incentive of 10% GFA concessions is attractive enough to a number of developers in Hong Kong, while the call for environmentally sustainable building designs can be transmitted fully throughout the economy. This extra GFA will mean additional income to developers. It is not surprising that BEAM Plus certification will become a standard requirement for new developments in Hong Kong. However, Haapio and Viitaniemi (2008) argued that it was possible for “low quality buildings” to opt out of the assessment if it is not mandatory. They also pointed out that the assessment will only focus on “high quality buildings” due to their high success rate to obtain higher grades. They suggested that assessments should become mandatory. A standardized framework needs to be developed for the ease of studying and comparing new designs and buildings. Yet, a mandatory approach can only work when there is an absence of political obstruction. When political pressure exists, the voluntary-with-incentives approach governed by NGO will be an effective alternative to achieving environmental sustainability. The effective incentives may include density bonuses, tax rebates and faster building permits (Miller et al., 2008). Furthermore, the certification fee is another aspect to consider. Despite the incentives, the expensive certification fee of BEAM Plus may discourage the small developers to obtain the green building certification. Studies need to be undertaken to promote environmental sustainability to this group of developers. The final question is whether the government will use taxpayers’ money to subsidise building owners to undertake their building certifications. To this end, the voluntary-with-incentives approach remains a more desirable tool for the building industry to improve its environmental performance.

7. Conclusion

The comparison of BASIX and BEAM Plus was reviewed in this study. Despite fundamental similarities between the two, both BASIX and BEAM Plus are different in nature and approach. BASIX is mandatory, while BEAM Plus is voluntary with incentives. Each has a distinctive assessment method, scoring system, and certification fee scale. Applicants for BASIX certification are required to include in their dwellings sustainable housing features that meet energy and water reduction targets. A certificate cannot be issued if the targets are not met. This mandatory approach is more likely to be seen as a

form of punishment than as an encouragement to building owners. It can be more effective and deliver greater environmental enhancement than the voluntary-with-incentives approach if there is no political hindrance. On the other hand, the voluntary scheme of BEAM Plus can motivate building owners to incorporate environmentally friendly designs into their structures in order to obtain GFA concessions. This incentive can spread throughout the economy and motivate building owners to improve their buildings' environmental performances. However, due to its voluntary nature and third party (BEAM Pro) certification approach, the registration and assessment fees for BEAM Plus Certification are high. Such costs will discourage many building owners, particularly small developers, from seeking certification. The time-consuming of BEAM Plus certification process will also be a hindrance to achieve building environmental sustainability. Further studies are required to address the issue of high certification fees and length of certification process. Case studies should also be conducted to confirm if the voluntary-with-incentives approach is adequate to motivate building owners to improve the environmental performances of their properties.

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BIM at small architectural firms

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Abstract

In the architecture, engineering, and construction industry, the interest in Building Information Modelling (BIM) is growing. The frontrunners in the application of BIM are mostly larger firms and the question arises whether the use of BIM by smaller firms can be successful and profitable. Architects are not always convinced about the value and necessity using BIM; a commonly heard note is that BIM is to be used by large parties and it has too little benefits for smaller firms. This paper provides insight in the uptake of BIM use among small architectural firms in the Netherlands, and answers the question if and to what extend contemporary BIM technology is adopted by this group. Additional, recommendations are given for implementation strategies. In cooperation with The Royal Institute of Dutch Architects (BNA), research was done amongst all 1300 BNA-associated small (≤10 FTE) architectural firms, using an internet survey (response 22%). At 8 small architectural firms with BIM experience, employees were interviewed to enrich the data coming from the survey. The outcomes of the research seem promising for future application of BIM, also for smaller architects offices.

Keywords: BIM, **BIM adaptation**, **AEC sector**, **Small architectural practices**

1. Introduction

Building Information Modelling (BIM) is often assumed to force a real paradigm shift within the AEC world (Eastman, 2008; Prins & Owen, 2010). This as utilising full BIM potential supports –and requires- better and early collaboration between the partners in a building project, for instance like in so called IPD processes (Thomsen, 2009), and thus will result in more integrated and so likewise assumed better projects. The rise of the use of BIM within the AEC industry is expected to a rather quick adaptation. For instance Deutsch (2011) expected that already in 2012 the use of BIM within the AEC sector, would be at almost the same level as CAD after it's introduction in the late eighties of the previous century was approximately after 10 years in 1997. The Government Building Agencies (GBA) of Several Countries (Wong et.al, 2010) already requires the use of BIM by some or all parties for their projects. Recently, Bernstein (McGraw-Hill Construction Report, 2012) reports a 71% level of BIM adaptation in North America with the larger firms (contractors) on top with 91%.

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Remarkably amongst the non-users a growing resistance is reported, this especially amongst architects. In general BIM is assumed to led to more integration by better coordination, information exchange, process management and consequently cost and time reduction.

2. Literature survey

BIM technology often is assumed to result in a real paradigm shift within the AEC sector (Eastman, 2008; Prins & Owen, 2010) in terms of its potential for new ways of better collaboration and integration. However a lot of parties at the moment are struggling with the technology, or even still have to start using BIM. It might seem reasonable smaller firms, not having as much financial means as their bigger brothers, might face the largest problems here. Sources like Jernigan (2008), Succar (2010) and Lu & Li (2011) define as a precursor of the collaborative 'Big BIM, the so-called 'little BIM', which is limited to the use of BIM in internal processes. However, it needs to be mentioned that the transition between both terms is rather smooth and cannot be seen binary. The use of 'Open BIM' further supports participation in integrated projects, regardless of the specific software tools used by the involved parties. 'Open BIM', an initiative of buildingSMART International, is a platform unbound approach to the collaborative design, realization and operation of buildings based on open standards (e.g. IFC) and workflows (e.g. VISI) (buildingSMART, 2012).

Research to the experienced advantages and barriers of BIM within several national contexts' has been done before in Australia, the UK, the USA, Germany and France (Bernstein and Pittman 2004, Yan and Damian 2008, Gu et al. 2009, Gerrard et al. 2010, Deutsch, 2011), as well as it is widely covered within more general research literature (Hartmann et al., 2008; Succar, 2009; Thomsen, 2009; Harris, 2010; Nederveen et al., 2010; Owen et.al., 2010). The most mentioned advantages for the use of BIM by architects are improvement in coordination, process and product integration, less rework, reduction of avoidable costs, increased production and fewer requests for information and change orders, catalyst for innovation, supply chain integration and sustainability. The presumed disadvantages and barriers that restrain architects from implementing BIM are examined as well by different authors. According to Howell and Batcheler (2005) the reduction of costs and time is not sufficiently proven yet. Software vendors often list the use of the traditional 'Design-Bid-Build' organizational model as a barrier for implementation of BIM. Thomsen (2009) supports this point of view. In his publication on Integrated Product Design (IPD), it is shown that an integrated way of working, like IPD, can avoid problems with self-interest of parties (Prins, 2004; 2009) and legal issues. Another view, mainly focussed on a lower level of implementation, is that some benefits can also be reached without an integrated approach (Deutsch 2011). The effort that has to be put into the design in case of BIM usage shifts from later design stages to earlier design stages resulting in an expected overall gain of time. This might not seem a problem at first sight, but most clients refuse to adapt their fee structure to this new situation what could be a serious problem, especially for smaller firms. This, even more, seems to be the case, when also the division of hours spent between the parties involved is changing. Deutsch (2009) and Schultz (2011) report on 'five fallacies' concerning the use of BIM amongst architects: productivity loss, costs for learning how to use the new technologies, hindrances with the regular processes, profitability is more at the client side

than at the designers', failure risks. Chao-Duivis (2009) and Deutsch (2011) mention in addition some juridical aspects as intellectual ownership and liabilities, which are often experienced as unsolved at the moment.

Research to the impact of BIM on small firms within the AEC industry, especially architectural firms, has not been done in this way. Above listed researchers haven't focussed on small firms especially, however different sources address the need for special attention for small firms (AIA; Haliburton, 2010). To measure whether or not one is using BIM isn't really sharply delimitated. In some publications BIM use already starts when one uses 3D-object modelling. Actually in the early nineties' of previous century applications like Architrion and ArchiCad already were 3D object based. Even for the early AutoCad, and –originally Unix-Like – MicroStation packages, special domain bound 3D object based applications were built, running additional on top of these –vector based- software. Measuring BIM application is also problematic due to the different so-called BIM maturity levels, which can be distinguished (Succar, 2010, Berlo & Sebastian, 2010). In line with Eastman (2008) and according to a lot of following authors, BIM use starts when the actual BIM model contains object-based information of least two different disciplines and the BIM model is shared by at least two or more disciplines whether or not concurrently working together with the same model. In this research we included the stage before in which practices use 3D object based modelling to advance their processes and internal collaboration within the office. Typically for architects' offices in a lot of countries within and outside Europe is the relative amount of small offices. According to a report of the Architects' Council of Europe (ACE, 2008), of the in total 130.000 private architectural practices, more than half (54%) of these practices are one-person firms. A further 35% have between 2 and 5 architectural staff. Eight per cent of practices have between 6 and 10 architectural staff and 3% have 11 to 30. Only 1% of architectural practices have more than 30 staff. Within the Netherlands 87% (1300 out of 1500; numbers are only valid for BNA registered offices, which are around 70% of all Dutch architectural practices) of the architects' offices is smaller than 10 persons. Of this population around 58% are one to two persons' firms. For these Small -and Medium- sized Enterprises (SME's) it is reasonable that the investment in BIM software, hardware and training might be a substantial barrier to start implementing it within their daily practice. In addition momentarily the credit crunch put the whole AEC sector under pressure. In addition to this, it can be assumed that the new paradigms connected to the implementation of BIM technologies are forcing practitioners to redefine their business models (Smith and Tardif, 2009; Hardin, 2009; Prins & Owen, 2010; Haliburton, 2012). As far as in the literature survey these adaptations are made explicit, no sources could be found presenting evidence based guidelines focusing in special on architectural SME's. Smith and Tardif (op. cit.) even more note the general lack of knowledge on the needed change of business models while utilizing full BIM potential, which given the literature survey done within this research project, is a still valid observation nowadays. It is widely accepted that the existence of small architectural firms, in particular due to the nature of their small size, is a typical necessity for the creativity and innovation potential of the architectural domain. Especially young designers who have strong visions and high innovation potential often choose to establish a design office of their own. So as the wider construction industry seems rapidly adapting BIM, smaller practices have to follow but it seems reasonable these smaller offices due to their rather unique social

structure (Mintzberg, 2001; Kalay, 2006; Haliburton, 2012) will adopt and adapt to BIM technologies in a different manner than larger practices.

3. Methodology

The aim of this research was to investigate first the actual BIM use amongst small architects' offices. Secondly, to investigate the experiences of these –assumed early- architect SME adaptors concerning the use of BIM in terms of challenges and pitfalls. Thirdly to determine, whether or not, specific guidelines for architectural SME's could be retrieved out of the experiences of the early adaptors. The research was done in three parts: a short explorative literature study (described in paragraph 2), an internet based survey, and expert interviews to reflect on the survey findings. The survey was developed, in collaboration with the Royal Institute of Dutch Architects (BNA), and was send out to all (BNA-registered) 1300 architect SME's (≤10 FTE) within the Netherlands. Of this population 58% has up to 2 fte, 27% has 2 till 5 fte and 15% has 5 till 10 fte.

Almost 300 offices responded to the questionnaire. Based on the literature research, the survey and the interviews afterwards, the state of BIM use among small architectural firms is reported and suggestions for implementation strategies are given, both on the level of small architectural firms as well as on the level of professional representative bodies like the BNA. The goal of the survey was to get insight in the current state of BIM use and to explore the pros and cons that small architect firms experience or expect. The questions within the survey consisted of series of subjects, partly based on the BIM Maturity Index (Succar 2010), and the Dutch based BIM QuickScan (Sebastian and van Berlo 2010). Questions about experiences, performance, incentives and barriers are added based on the literature study. To increase the willingness to complete the questionnaire, routing is used depended on the BIM maturity level. Specific questions are asked to respondents who are experienced in the field of BIM and to respondents with less experience. This division also leads to closer insights into the percentage of uptake of BIM, as will be explained in the 'results' section of this paper. The subjects of the questionnaire were devised in: Leadership, Hardware & Infrastructure, Collaboration, Human Resources, and Products & Services. Points were awarded to answers on questions within these subjects to compute a maturity level from 0 to 4 mainly according to Succar's (op. cit.) maturity levels. The scope of the levels reaches from 'very little BIM use' to 'optimised BIM integration'. Level 0 is the pre-BIM stage; level 1 represents just using BIM software for 3D modelling, at level 2 one starts collaborating – foremost internally- with the use of BIM technologies; at level 3 real network based integration is taking place, level 4 are all those uses outreaching level 3 in terms of real innovations. Compared to the terminology of Jernigan (2008), who separates 'Big BIM' from 'Little BIM', level 2 is quite similar to 'Little BIM'.

The results from the questionnaire were discussed with architects with BIM experience at eight architectural firms. This list was made up in consultation with the region managers of the BNA and based on an equal distribution over the size categories.

4. Results

4.1 Results from the survey

The questionnaire was spread among 1300 small BNA-offices. A response rate was reached of 22% (n=283). The segmentation of the offices, categorized by size class, is consistent with the overall segmentation of the researched population as given in figure 2. The routing of the questionnaire devides the respondents in two categories:
A) Respondents that call their firm 'frontrunner' and have at least 2 BIM-projects delivered or/and respondents with more than four BIM-projects delivered.
B) Firms with less BIM-projects delivered or no BIM experience at all.
Apart from the general questions, specific questions were asked to the groups on their BIM use. See figure 1 for routing procedure and numbers.

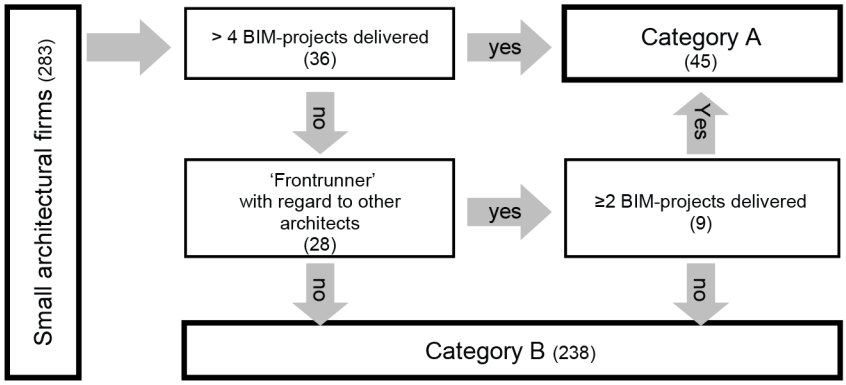

Figure 1: Categorization of respondents

Sixteen per cent of the respondents met the requirements for category A and were labelled 'experienced'. Table 1 provides the details on the amount of projects executed per category, using BIM technology. The level on which BIM is applied in those small architectural firms is relatively low. Only the experienced group (category A) reaches an average level 2. Among the less experienced firms, the first steps of BIM implementation were made by starting to use BIM software. Table 2 and 3 and figure 2 show that the use of BIM-compatible software as well as the use of BIM modelling methods is present in the less experienced group although at relative low rates (only 15% of the B category uses full 3 D object modelling within their projects). More in special table 3 provides insight in the own judgement of the responders on their maturity level. Thirty-five firms that already delivered BIM-projects, didn't meet the requirements for category A. In terms of the use of BIM software by smaller practices in the Netherlands, ArchiCad is the most widely used package followed by Revit (Autodesk). A recent report on the use of BIM in the construction industry in the Netherlands (Berlo & Dijkmans, 2012) revealed (surprisingly given all data-exchange problems in the recent past) that Vectorworks is one of the most often used BIM software packages industry-wide.

Table 1: Number of BIM-projects per firm

	No projects	1 project	2 projects	3 projects	4 projects	5 projects	6 projects	7 projects	8 projects	9 projects	10 projects	> 10 projects	> 20 projects	> 30 projects	**Total**
Category A	0	0	0	3	6	9	1	2	1	1	10	5	2	5	**45**
Category B	201	16	13	3	5	0	0	0	0	0	0	0	0	0	**238**
Total	**201**	**16**	**13**	**6**	**11**	**9**	**1**	**2**	**1**	**1**	**10**	**5**	**2**	**5**	**283**

Category A: Experienced firms (see Figure 3)

Category B: Firms with no experience or little experience (see Figure 3)

Collaboration by using BIM technologies amongst small architectural firms is underdeveloped, it only occurs incidentally and in most occasions parties aim at data exchange within the same software family and within their own office. Most interviewees point out concerning their future expectation that BIM methodology is about collaboration, but almost none has reached this level yet. Some interviewees don't even describe their current approach as 'BIM', they call it, and most probably right, just 3D-modelling and plan to upgrade their level to 'real' BIM in the near future.

Table 2: Position of respondents

Position of respondents' firms with regard to other architectural firms?				
	Awaiting	Follower	Frontrunner	**Total**
< 2 FTE	118	93	19	**230**
2 - 4 FTE	0	8	9	**17**
> 4	1	6	29	**36**
Total	**119**	**107**	**57**	**283**

Table 3: Crosstab way of modelling by category

		Category		
		A	B	**Total**
Most used way of drawing/modelling within the firm?	Full 2D	0	48	**48**
	CAD with visualizations in 3D	2	93	**95**
	Both 2D CAD and object based 3D	14	62	**76**
	Full object based 3D	29	35	**64**
	Total	**45**	**238**	**283**

The results that small architecture firms achieve by using BIM are experienced positive and – even in case of low maturity and integration levels – the use of BIM is reported to be profitable for all interviewed firms. The most often mentioned barriers and motives to hesitate implementing BIM are time and costs expected to be involved with it. The investment in both acts as a barrier for the inexperienced firms, while contrary experienced firms took cost and time reductions as a motive to start the implementation. Some of the interviewed architects confirm these findings stating although also in first instance facing time and cost as to be barriers, after having made the steps for implementing BIM and having had the first experiences, clearly these were worth the investments made. To investigate this in more detail, all category B firms were asked about their main reasons hesitating to implement and further develop BIM within their practices. Fifty per cent of the responders mention a lack of interest from their clients. This might be reasonable assuming these smaller firms often will

serve most non-professional clients with relative small not too complex projects. Direct and indirect costs involved are on the second and third place (42 and 36%). Figure 2 provides a detailed overview. It's remarkable that further analysing the data only 30% of the respondents expecting too high direct cost for implementing BIM only can define this proposition on a guess without having tested it based on experiences of colleagues or market research. The same figures appeared to be true as results of our questionnaire concerning indirect cost estimates.

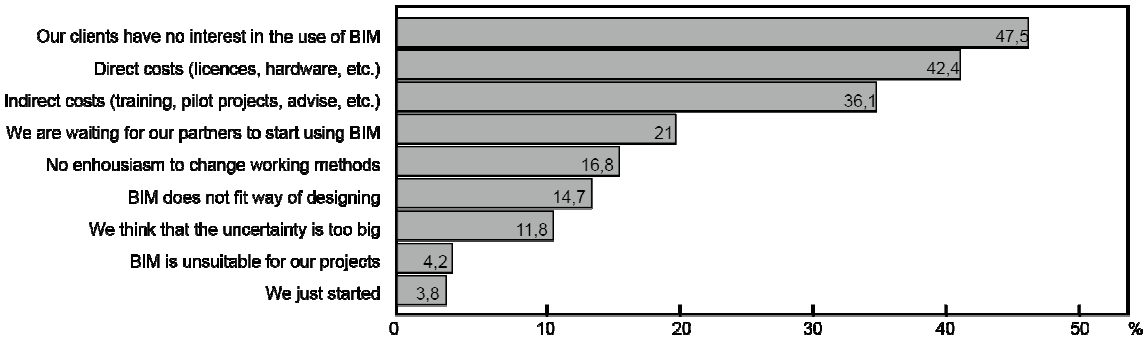

Figure 2: Reasons for not applying BIM (yet)

Within the A category of respondents the questionnaire asked for prime motivators for using BIM. Remarkable here, given the contrary expectations as expressed in other answers, are the expected cost savings (50%) although with 70% on top is future market position of the firm (figure 3). Further analysis of the data shows that only 3% of the responders frequently is confronted with clients asking BIM, 17% now and then, 19% seldom and 62% never. In terms of acquisitions, procurement routes and design contests, BIM requirements follow almost exactly the same numbers. The common made estimation in the literature that BIM leads to more integration is refused by 7 % of the respondents while 25% took a neutral position.

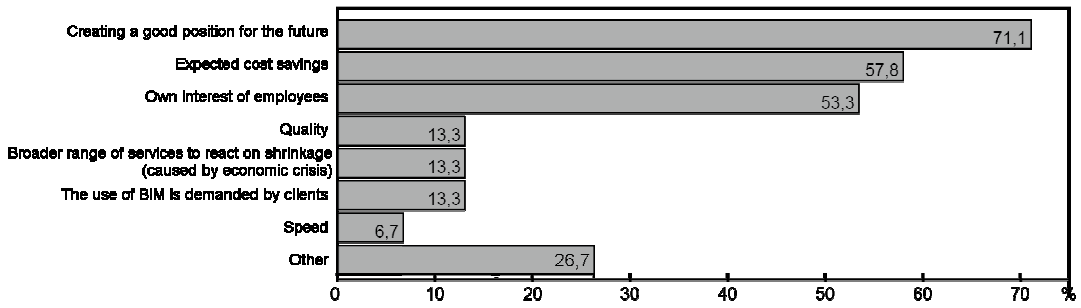

Figure 3: Motivators for applying BIM

Only 13% fully agreed with this proposition. The proposition that the hours spend by practices at the moment cannot be properly declaimed in time with the client seems to be true within the survey population. Only 30% is satisfied here, 30% is dissatisfied and 40% is neutral. This is equally spread within the A and B categories. Seventy-eight per cent of the respondents have stable partners for collaboration, like engineering consultants, cost engineers and constructors. It might seem a reasonable assumption that having such

partners stimulate the use of BIM (sharing experiences for future benefits). Applying the so-called Chi-square test however shows within our data there is not a significant correlation. Within the survey results also no significant correlation could be found between the amount of employees and category A and B practices. In line with this there was also no significant correlation between BIM maturity level and the amount of employees.

4.2 Expert-interviews

The survey results were discussed in 8 expert interviews. In addition to the comments already made within the previous paragraph this revealed the following insights:

Clients of small architecture firms differ much in size and typology. Private clients with smaller projects have a large share in numbers, but small architectural firms also work for professional clients. These professional clients develop bigger projects as well. Architectural firms within our population that do not use BIM see a lack of interest among their clients as the main barrier. Experienced firms endorse the lack of familiarity with BIM under clients; however they do not experience this as a barrier. In their experience, after having been confronted with the use of BIM, most clients are positive and willing to aim at BIM use in following projects. So not only the industry but also clients have to be informed about the benefits of BIM. To convince clients in general on the advantages the use of BIM technology might have for their projects, seems a challenge here. Clients also have to be convinced that for getting these benefits, the fee structure between consultants and phases needs to be adapted to the new way of working with BIM. Setbacks that occurred when implementing BIM were concentrated around costs and software. The large investment costs are experienced as drawback, but interviewees immediately compensated these drawbacks with the experienced benefits. The interviewed architects describe the problems with software as part of the development stage in which BIM-software is at this moment. Big investments in software applications, object libraries and hardware have to be under serious consideration. With that the gains of increasing productivity have to be taken into account. Organizations like BuildingSMART International develop international object libraries and local organizations like CUR B&I and industry organisations like the BNA cooperate with firms from the AEC industry to develop national implementations of these standards. The interviewed architects seemed well informed on these developments.

The most important step in the implementation of BIM is the convinced choice to start using BIM. The organizational structure of the office is important to mention since the strategy for a flat, operational adhocracy like organization (Mintzberg, 2001) characteristic for most SME's within the researched population, is different from the stratified hierarchical structures often seen in larger firms. Encouraging employees in an early stage and involving them thoroughly in the process shows good results. Cooperation with other parties with experience in the field of BIM happened mostly by coincidence but acted in all cases relevant as real catalyst for the implementation. Also –the very few- clients willing to start working with BIM are supporting the implementation process.

The choice which software and hardware to apply is part of the implementation process and should be well considered. The researched firms had different reasons for their choice:

experience with a certain software developer, compatibility with the systems already used, the aim for open standards and sometimes refusal to work with the bigger and more expensive software vendors. Another important part of BIM implementation is training. The researched firms report good experiences with a basic course, followed by training in real projects. Following Deutsch (2011), this gives much better results than training on unrealized pilot projects. A side effect of this approach is that these real projects bring in financial revenues and therefore keep down the lid on costs. Exchange of knowledge between experienced engineers and younger employees with less practice experience but more – academic based- modelling skills, is advocated.

Legal issues concerning contracts, intellectual property and the responsibility for the coordination of the model are well known (Chao-Duivis, 2009). These issues are also part of the experiences of the small architecture firms.

5. Conclusions and reflection

The main finding of this research is that the application of BIM is profitable for small architecture firms, even when practiced with a relatively low maturity level. At the moment, the use of BIM by small architectural firms is mainly limited to internal processes because of a lack of experience of the architectural firms themselves, their clients, as well as the other parties in the AEC industry they work with. However, the majority of those who undertook the effort to implement BIM within their organizations consider these 'little BIM' implementations already profitable.

The amount of BIM use amongst small architectural practices isn't at real high numbers. At this moment in our survey only 22% of the smaller practices are at a level of full 3D object modelling. This at least was far lower than expected by the researchers. Not surprisingly and consequently only 13 % of the respondents experiences advantages of BIM in terms of integration. It seems, the wider belief in the research community and industry that BIM technology will introduce a real paradigm shift in terms of integrated working methods and consequently also will support integrated working procedures and/or procurement, isn't really shared yet by the population researched. The same seems valid for supply chain integration, as we found no correlation in our respondent group concerning the use of BIM, related to the level practices are used to work with the same partners for their projects.

The large majority of firms in this research didn't experience possible profits of effects integrating disciplines and processes between parties outside the own firm. This might be due to their own, rather low, maturity level as measured, the implementation level of the firms they cooperate with, or the level in general of BIM usage outside the architects' domain. At least it can be concluded here is route to go, and more research to be done.

The opportunities, advantages, disadvantages and barriers that emerge from this study are largely consistent with the results of Yan and Damian (2008) and Gerrard et al. (2010) in a wider field of larger architectural firms and other parties within the AEC industry. Therefore the assumption is made that results from research in this wider field have a strong relationship with the situation for small architectural practices as well.

Remarkably barriers, which are more specific for the category of practices studied, are the not knowledgeable clients they are confronted with. Educating the client audience might be put high on the agenda to support the use of BIM technology by smaller practices. Although it has to be remarked based on our interviews that clients, confronted with architectural practices using BIM, don't see this as a threat for their project. Another point connected to this is the fee structure, which at the moment is not adapted to the amount of hours spend while the division of hours is different from the traditional processes. It might be assumed for smaller practices this will lead to bigger problems in terms of their financial stability as for larger firms.

Those not utilising BIM at the moment see the amount of direct as well as indirect cost as one of the main barriers. However those practices already using BIM have contrary experiences to these cost assumptions. Most of them, independent the amount of employees are convinced also on short terms that the use of BIM is profitable.

None of our findings within the group of architectural practices smaller than 10 FTE, correlates significantly with further segmentations on the amount of employees. Size doesn't matter, seems a valid statement here. The same can be remarked concerning BIM maturity levels.

The potential of BIM technology goes beyond the responsibilities of de different parties and reaches the whole lifecycle of the building. Roles will become different, as well as the division of hours spend throughout the phases of the process. New tasks have to be defined to fully reap the benefits of BIM application during the whole lifecycle. For legal transparency and full integration within the project team, services rendered must be rewarded and the new roles should be introduced and laid down in the professional regulations. Especially for the smaller practices, which might face more difficulties as the larger ones, here is an import role for the professional bodies. Also especially for our target group, knowledge dissemination and education might considered to be essential.

Architects had an overall coordination mandate in the past and some still aspire to do so. BIM technology provides the change for architects as 'prime model makers' (Prins & Owen, 2010), to uptake their traditional tasks again, and doing so widen their portfolio of services to the market. Whether an architectural firm is able to do so depends on the typology of the firm and other parties could be able as well, but for those firms able to, here are challenges to develop their businesses. For utilising this growth potential the architects sector and thus the professional bodies have to develop and disseminate the appropriate knowledge and process models and regulations connected. An open approach to collaboration in building projects is needed to gain all the benefits BIM technology can provide. Classically parties in building processes have a certain resistance for unconstrained information sharing (Prins, 2004; 2009). The risk to lose control or to be held responsible for other's mistakes is one of the reasons for this. Rules and regulations should be developed to cope with these issues. As the AEC sector all over the world is rather active in this respect, dissemination of these developments ought to be a point of attention, given the remarkable small percentage found in this research of practices using, or even believing BIM can be of help collaborating with others aiming for integrated processes and products.

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Prevision of Delay in Brazilian Residential Unit Construction Contracts

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Abstract

Delays in the delivery of residential units create numerous problems, not only for the homeowners, but also for society. This is due to the legal actions necessary to adjudicate disputes between the parties. The aim of this paper is twofold: firstly, to verify the existence of a clause in Contracts of promise of property sale which defines the consequences of delay in the delivery of property; and secondly, to discover whether owners demanded any compensation for delays occurred. The total number of buildings delivered after the scheduled deadline in the cities of Balneário Camboriú and Itajai in the period between December 2009 and January 2011 was found (n = 542), and a sample of 82 residential units was taken. In order to obtain the data, a semi-structured questionnaire was given to the homeowners. It was observed that only 35% (n = 29) of the Contracts of promise of property sale included a penalty clause for delay in delivery. However, in 19 of the 29 contracts the clause regarding delay came with other clauses that allowed the company to delay the delivery of the building for up to six months. This clause is considered null in Brazilian legislation. As for compensation, only one (1.82%) owner demanded that the company provide a rental property during the period of delay. The others (n = 98.18%) did not demand any compensation. It could be concluded that contractors are not observing Brazilian legislation regarding the delay in the delivery of residential units. They prepare contracts according to private interests. In addition, a certain conformism is perceived in the attitude of the homeowners as to the delay in delivery of the property. They don't insist on the compensation that they are entitled to, in accordance with current legislation.

Keywords: Delay, contracts, buildings

1. Introduction

In the past, the delay in completion of the buildings was deemed acceptable by consumers. But nowadays, tight budgets mean that delays are more significant and costly. As a result of construction delays, many customers have been demanding compensation from construction companies (Kaliba, Mumba, Muya, 2009).

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Delays in completion of construction can cause a lot of damage to civil construction companies, such as higher costs, cash flow problems (Assaf, Alhejji 2006), unavailability of staff, loss of credibility in the consumer market, loss of customers, plot returns and indemnities (Kaliba, Mumba, Muya, 2009).

Delays can also cause loss of revenue when production facilities or rental units are not completed on time. As well, higher overhead costs may be incurred due to the longer work period and the inflation in the price of materials (Alaghbari, Kadir, Ernawati, 2007).

1.1 Contracts

In the construction industry, construction companies generally work in an environment of risk and uncertainty caused by economic factors such as fluctuations in the costs of materials, labour, and equipment. Contractors and suppliers working in today's volatile materials market find that estimating, bidding on, and financing construction projects are challenges (Maram, Rajendran, Kalidindi, 2011).

A well-prepared contract reduces business risk. In countries under European jurisdiction, construction contracts are considered to be independent contracts regulated by the laws to which they are bound. Construction contracts also differ from other types in having great and long-term financial responsibilities. Contract conditions define the rights and responsibilities of the parties (Mitkus, Trinkūnienė, 2006; Lordi, 2004).

Fong and Choi (2000) have analysed methods of contractors' selection and observed that some methods are not comprehensive and are generally tendentious. In accordance with this, it is sometimes difficult for owners to consider at once all variables such as price, time, quality and security.

The obligation of the contract is based on the concern that goes beyond private interests to serve the interests that are collective. Whoever, for free expression of will, promises to give or do creates an expectation in the social environment that the law should guarantee. Thus, the contract should not be viewed from the individual angle, but from the social angle, since these consequences could affect the balance of society (Rodrigues, 2007).

One type of contract according to Brazilian law is the Contract of promise of property sale. The Civil Code (Brasil, 2002) cites in article 481 that: "According to the Contracts of promise of property sale, a contractor undertakes to transfer to the domain a certain thing and the other, to pay a certain price in money."

1.2 Brazilian law about contracts during or before the construction phase

In a Contract of promise of property sale, the seller undertakes to transfer the domain, and this effectively moves with the transcription of the title in the registry of property. The three basic elements that constitute a purchase and sale agreement are the price, the date of delivery and the object (e.g. homes, apartments).

The Civil Code, Article 439, states that whoever promises to deliver a product to a consumer must offer compensation when said product is not delivered according to the agreement between the two parties (Brasil, 2002).

If construction companies do not fulfil their obligations, or fail to comply by the way and in due time, homeowners can sue the builders for damages (Civil Code article 1056). These damages may include rental costs (or an equivalent value) incurred by homeowners during the delay and a reasonable value for the lost profit that the building could have generated for its owner (Civil Code article 1059) (Brasil, 2002).

The purchase of an object is also regulated by the Consumer Protection Code (CDC). According to this law, contractors can delay for a maximum period of 180 days. However, in article 18, paragraph 2, the CDC states that both the owner and the contractors may agree to reduce or increase the period specified in the preceding paragraph, though not less than seven or more than one hundred and eighty days (Brasil, 1990).

The contractor, however, must pay a price for this delay. The only exceptions permitted are: a) the existence of a fortuitous event or force majeure or b) the proof that the delay is the exclusive fault of the consumer. Proving these exceptions is the joint responsibility of the contractor and consumer, who respond objectively according to article 14 of the CDC.

The aim of this paper was to verify if there is a clause that defines the consequences of delay in the delivery of Contracts of promise of property sale and assess whether the owners demanded any compensation for the delay occurred.

2. Methodology

To obtain the data for the building units delivered in the period between December 2009 and January 2011, a survey was conducted among the construction companies registered in the Construction Union in the municipalities of Balneário Camboriú and Itajai (Brazil). The participants owned buildings that were over 10 floors or had more than 20 apartments.

During this period 30 buildings were delivered. Of this total, 16 were delivered late. In relation to the number of buildings, 973 residential units were delivered, with 542 being late.

The number of observations required is defined by Equation 01 (Gil, 1999). With these values, the numbers needed for sampling were 82 residential units. For a better distribution of the number of interviews per building, these were listed according to the number of properties of each one (Table1).

$$n = \frac{N \cdot \hat{p} \cdot \hat{q} \cdot \left(Z_{\alpha/2}\right)^2}{\hat{p} \cdot \hat{q} \cdot \left(Z_{\alpha/2}\right)^2 + (N-1) \cdot E^2} \qquad \text{Eq. 01}$$

Where:

n – Number of residential units delivered with delay in the sample (82)

N – Total of residential units delivered with delay (542)

p – Population proportion of individuals who belong to category (50%)

q – Population proportion of individuals who do not belong to category (1-p)

$Za/_2$ – Critical value that corresponds to the desired degree of confidence (95%)

E – Margin of error or maximum error of estimate. An error of 10% was adopted in this research.

TABLE 1 – Sample of properties per building delivered with delay.

Building delivered with delay	Quantity of residential units	% of the total residential units delivered with delay	Sample by building
1	17	3,14	3
2	20	3,69	3
3	18	3,32	3
4	28	5,16	4
5	18	3,32	3
11	45	8,30	7
15	30	5,54	5
16	48	8,86	7
17	80	14,76	12
18	22	4,06	3
20	42	7,75	6
25	29	5,35	4
26	28	5,17	4
27	54	9,96	8
29	45	8,30	7
30	18	3,32	3
TOTAL	542	100	82

Three municipal construction companies were consulted to verify the instrument used in the delivery of the residential units to homeowner when the building was finished. From this instrument, the questionnaire was elaborated which contained the questions regarding:

- The performance of the contract;

- The form of communicating the delay to the homeowner;

- The satisfaction of the homeowner with the residential unit and the company.

The interviews took place in person or by telephone.

3. Results and Analysis

Only 35% (n=29) of the contracts had clauses that defined possible damages because of the delay in delivery. However, in buildings 17, 18 and 26 (totalling 19 contracts) clauses were added to the delay clauses that allowed the company to deliver the residential units within six months, for reasons of force majeure.

Contracts of promise of property sale should provide conditions for the completion and delivery of the residential unit. They should specify the circumstances in which the construction company might be exempt from meeting the agreed period of delivery of the unit and thus extend the contract term. However, none of the companies gave details explaining the force majeure responsible for the delay. Thus, the clause concerning the extension of the delivery period is null and considered unfair in accordance with the Consumer Protection Code (Brasil, 1990) and the Civil Code (Brasil, 2002).

Only 28% of homeowners (n=23) were informed about the new date of delivery of their residential units. For the 72% (n=59) of homeowners who were not informed of the new date of delivery, the discovery occurred as follows: 56% (n=33), through visits to construction sites, and 44% (n=26) through telephone contact with the construction company. It is possible to observe that most construction companies violate Brazilian Federal Law No.4.591/64, complemented by Law 8.078/90. These laws regulate the activity of real estate development and cite that homeowners must be informed at least every six months of the progress of the building.

Neglecting the client can create many problems for the construction company, such as customer dissatisfaction which may result in law suits and retaliation.

The residential units were delivered completely finished for 91% (n=75) of the homeowners. For the other 9% (n =7) there were still some outstanding issues in the building. In buildings 4, 11 and 29 the common area was not completed at the time of the delivery of the residential units (19%). In building 16, two homeowners said the common area was not completed.

This difference between the percentage of common area and residential units delivered complete can be explained because some companies deliver the residential units before having completed the whole building, due to pressure exerted by homeowners.

According to Pereira et al (2011), in a research conducted with construction companies, the main causes for delay occurrences are: changes ordered by the client, lack of compatibility in design, lack of skilled labour, and unskilled labour.

It can be noted that almost all the above mentioned causes are not valid excuses to delay according to Brazilian laws. Only the change ordered by the client can be an excusable

delay. But, in this scenario, it is very difficult to determine which delays were caused by the owner sand which were caused by the construction companies.

3.1 Compensation demanded by consumers or offered by construction companies due to the delay.

Only one (1.82%) homeowner demanded that the company provide them with a rental unit during the period of delay. The others (n = 98.18%) did not demand any compensation. None of the respondents received monetary compensation from the company because of the delay occurred.

For 30% (n=25) of homeowners, delay affected the construction companies' image. However, if consider only those buildings that were delivered with more than six months delay (buildings 1, 4, 11, 16, 17, 20, 26, 29, n=50), the delay would have affected the image of the construction company by 46% (n =23).Thus, we can deduce that the greater the delay in delivery of residential units, the worse the image of the construction company held by homeowners.

Concerning the issue of whether homeowners would recommend the company to others, 80% (n=66) said yes and 77% (n=63) would buy another property from the same company. In buildings that were more than six months late in delivery, 29% (n=14) did not recommend the construction company to others. An increase of 9% of homeowners who do not recommend the company to others can be noted in buildings with six or more months delay. Only one company (building 1) was rejected by 100%the homeowners.

Through the analysis of answers collected, it appears that the delay in delivery of the residential units is not the only factor responsible for client satisfaction. Other factors, such as perceived quality and documentation, can interfere with the positive assessment of the construction company by homeowners. But for Silva, Brasileiro and Duarte (2011), delays may generate higher recoveries of homeowners regarding the quality of the building units because the homeowners become more demanding.

In a research conducted by Medvedovski et al. (2005) regarding a building located in Pelotas (Brazil), 13.13% of the homeowners were dissatisfied with the units received. The biggest complaints were about the numerous entries to the building and the size of the corridors. According to Cardoso (2003), in a survey conducted with homeowners of a building in Belém do Pará (Brazil), the main items that generated dissatisfaction were the design and construction of the building's facade, the security relating to the building's entrances, the dimension of the garages, and the condominium costs. The reasons for customer dissatisfaction were numerous.

It can be concluded that delay is only one of several factors affecting customer satisfaction; however, companies should be concerned about unhappy customers since they can produce negative publicity for the construction company, reducing the reliability of the brand.

77% (n=63) of the homeowners considered themselves demanding clients.

3.2 Considerations made by homeowners

In interviews with homeowners, it was possible to observe other factors that could account for the satisfaction of consumers whose residential units were delivered late. One of the owners said that he had been considering the possibility of litigation against the company because of the delay (seven months). However, when he received the completed unit, it exceeded his expectations which resulted in a change of heart. Another homeowner whose unit was delivered after a four-month delay was considering legal action against the construction company because it was below his expectations. He claimed that the tiles used were of poor quality, causing a depreciation of the property.

From these interviews, it can be inferred that delay is not the only factor responsible for the satisfaction of the homeowner. According to Chauvel (2000), satisfaction is a psychological state resulting from the comparison of internal references to the reality of ones circumstances.

Another topic mentioned by the home owners was the cultural acceptance of delay. A homeowner whose residential unit delivery was delayed for four months, said: "This is common and happens to all construction companies." Another homeowner, who is a lawyer, pointed out that despite being aware of his rights, he would not take any action against the construction company, because "they are nice people."

This attitude on the part of homeowners demonstrates conformity. The subject conformed not only accepts what is presented, but also puts into practice actions that demonstrate conservative actions by the homeowners (Chauvel, 2000).

There are also some inconsistencies on the part of construction companies. Sometimes they feel abused because of the tax burden imposed by the government, but in other circumstances, they abuse their clients by failing to respect the law of the country.

4. Conclusion

In Contracts of promise of property sale that had clauses defining the delay, it was perceived that this was unfair according to Brazilian law, because it permitted the construction companies to delay the delivery of residential units without having to compensate owners for damages. Only one homeowner demanded compensation from the construction company, demonstrating that delay is culturally accepted in the study area. However, it was observed that the longer the delay, the more chance of dissatisfaction with the residential unit received.

Moreover, some properties were delivered without being fully completed. This may generate additional costs and subsequent disputes, since the occurrence of defects can be difficult to attribute the responsibility to the client and /or the construction company.

Regarding informing customers of the new delivery date, companies may have had difficulty in determining it because there may have been simultaneous delays during the building construction phase.

It is also important to state that Brazilian law should clarify the meaning of events of force majeure, in order to avoid disputes between homeowners and construction companies.

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Sustainable and affordable housing: a myth or reality?

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Abstract

The Australian government has released a draft National Building Framework that will likely tighten the building standard for new houses to meet higher sustainability requirements. There are uncertainties about the impact this could have on the cost of housing and the supply of affordable housing. This paper aims to provide evidence-based conclusions on the possibility of delivering sustainable and affordable housing for low income people. The case studies are gathered from Brisbane and Gold Coast. Case studies are analysed by unpacking the features that were included to meet sustainability and affordability goals for housing. This paper outlines the key factors for their success and also challenges for replication of the projects. The study shows that the key success drivers for delivering sustainable and affordable housing are providing planning incentives, subsidies for increased energy efficiency, supportive regulatory frameworks and appropriate allocation of infrastructure charges. It shows that government can prioritise their resources to support affordable and sustainable housing for low income people.

Keywords: Sustainable housing, affordable housing, energy efficiency, Australia

1. Introduction

Housing is defined as 'affordable' if the cost of housing (rent or mortgage payment) is not more than 30 per cent of household income for households in the lowest 40 per cent of the income distribution range (Susilawati, 2009; National Housing Strategy, 1991; Miles, Weiss and Berens, 2000:293). This affordable housing definition is known as the 30/40 rule.

Lack of accessibility to affordable housing has been a major problem for low income people. The annual international Housing Affordability Survey conducted by Demographia uses the 'median multiple', which compares the median house price to median household income, in order to measure housing affordability. The affordable score is under '3'. The latest survey (for 3rd quarter 2011) suggested that all Australian major cities (population > 1,000,000) are above the severe unaffordability threshold of 5.1 and that the Australian national median of 5.6 fell into the severely unaffordable category (Bruegmann, 2012). The survey has not discussed whether the unaffordability level is caused mainly by increases in house prices or by decreases in household income or a combination of both. Whatever the reason, the very

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high median house prices can present affordability difficulties for low income families in both the home ownership and rental markets.

In the third quarter of 2011, the median housing price in Sydney was $637,600 which is the highest in the country, followed by Melbourne ($567,000) and Canberra ($513,000). The highest median household income is in Canberra ($105,100), followed by Darwin ($82,500), Alice Springs ($79,600) and Perth ($78,900) (Bruegmann, 2012). Sydney and Melbourne, with the highest median housing prices, have the tenth and eleventh highest median incomes (i.e. the disparity between median house price and median income is very high). This paper will focus on case studies in Brisbane and Gold Coast. Bruegmann (2012) ranks the Gold Coast and Brisbane as the 4th and 12th most unaffordable Australian cities for housing affordability (based on the median multiple methodology).

Table 1 illustrates the latest census data for the Greater Brisbane area. The average household size is 2.7 persons and the median weekly income is $1,388. The table shows that whilst the median weekly rental equates to only 23% of median income, the median mortgage repayments represent 35% of median household income. These statistics would seem to indicate that affordability is more of an issue for low income home buyers (mortgage repayments greater than 30% of income) than for renters in this region.

Table 1: Census (2011) information for Brisbane (ABS, 2012)

	Greater Brisbane
Population	2,065,996
Average people per household	2.7
Median weekly household income	$1,388
Median monthly mortgage repayments	$1,950
Median weekly rent	$325

It could be argued that the ideal housing solution for low income families would have a low initial cost (to meet the affordable housing criteria) and low operation and maintenance costs. Lower operating costs were potentially a benefit of sustainability requirements in building regulations. The first environmental sustainability requirement introduced into national housing regulations in Australia related to the energy efficiency of the building envelope. Despite the core aim being the reduction of greenhouse gas emissions from space heating and cooling, this regulation would also conceivably reduce the operational costs of the home by reducing the need for occupants to 'purchase' thermal comfort. This is an example, in theory at least, that affordable housing with sustainability features would be an ideal solution for the housing affordability problem. However, in real world application, there are many reports of industry, government and public perceptions that 'sustainable' housing costs more than 'standard' housing (Kenny, 2003; Salama and Alshuwaikhat, 2003, Senick, 2006) or perceptions that affordability and environmental quality are mutually exclusive (Salama and Adams, 2004) or require some 'tradeoff' (Crabtree and Hes, 2009). On the other hand there is strong evidence supporting the view that cost barriers are perceptual rather than real (van Hal, 2007) and that the benefits of sustainability outweigh the costs (Power, 2008).

This study uses case studies to evaluate and reflect the opportunities and challenges for mutual inclusion of sustainability and affordability for future low income housing. Many sustainable and affordable housing initiatives are designed exclusively to either sustainability or affordability, not generally both. Thus, this study will use case studies which have a combination of both features. The selection criteria for the case studies were sustainable housing projects and affordable housing projects that included sustainable features.

The case studies represent exemplar projects, including an affordable housing project in Brisbane's city fringe which provides some sustainability features; a sustainable housing project that has flexible features to make it potentially more affordable; a sustainable house with a building system that reduces the time and cost of construction; and a sustainable housing estate that embraces a very broad and prescriptive definition of sustainable housing. The next two sections review aspects of affordable housing and sustainable housing. This will provide a theoretical framework for the review of the case studies that contain elements of both affordability and sustainability.

2. Affordable Housing

2.1 Affordable housing features

The Queensland government's broad definition of affordable housing includes not just the initial housing cost criteria, but also other criteria such as meeting household needs (e.g. size and functionality) and being well located in relation to services, employment and transport (Queensland Department of Housing, 2001). In order to provide a long term affordable housing solution, low income housing should also have low long-term operation costs. This includes energy efficient homes which will be discussed in the next section under sustainable housing.

2.2 Supply of affordable housing

An indication of affordable housing needs for low income people can be illustrated by the number of people on the waiting list. The Queensland government consolidated all waiting lists under one social housing system and one housing register from 2005. The waiting list illustrates the distribution of both short term needs and long term affordable housing solutions by locality (suburb). The Queensland government facilitates the increase of affordable housing in the very high need areas, for example by providing incentives for affordable housing projects located in these high need areas. Table 2 shows the localities in Brisbane that collectively incorporated 30% of the total waiting list in Brisbane.

3. Sustainable Housing

3.1 Sustainable housing features and regulation

Sustainability is defined in the National Strategy for Ecologically Sustainable Development (1992) as "development that improves the total quality of life, both now and in the future, in a way that maintains the ecological processes on which life depends" (Queensland

Government Department of Public Works, 2008:2). The Queensland Government breaks down the elements of sustainable housing into social sustainability (safety, security and universal design), environmental sustainability (water, waste and energy efficiency) and economic sustainability (cost-efficiency, peace of mind and resale value) (Queensland Government Department of Housing and Public Works, 2012).

Table 2: Housing register (wait list) for long term social housing Queensland (Department of Housing and Public Works, 2012)

Wait list area	Very high need	High need	Moderate need	Lower need	Total
Brisbane	1357	2780	2571	167	6875
Annerley	156	274	251	25	706
Chermside	95	194	135	8	432
Bowen Hills	71	75	59	3	208
Acacia Ridge	55	191	219	19	484
Corinda	31	102	94	4	231
	30%	30%	29%	35%	30%

Views and practices on how and to what extent sustainability is or should be incorporated into housing are varied and sometimes conflicting, but despite this, the definition of 'sustainable housing' appears to be widening, encompassing issues such as energy and water efficiency, indoor air quality, accessibility, affordability, reduced carbon emissions, life cycle considerations etc. (Gething and Bordass, 2006; Williams and Dair, 2006). The National Building Energy Standard-setting, Assessment and Rating Framework was drafted, after public consultation, to establish a pathway for possible future increases in minimum building standards to 2020 in order to significantly improve housing standards. The draft Framework proposes increases in the energy efficiency requirements of the building envelope and the potential inclusion of broader sustainability issues such as greenhouse gas emissions, on-site electricity generation, energy and water efficient fixed appliances, indoor air quality, embodied energy etc (DCCEE, 2012).

3.2 Sustainable housing supply

Sustainability in housing tends to be addressed in a segmented manner with multiple criteria being examined in isolation and with a strong focus on the construction industry segment (Holloway and Bunker, 2006). The incorporation of sustainability into housing can occur at difference phases: concept, design, materials selection, construction processes and building operations (Birkeland, 2002; Crabtree and Hes, 2009; Gray, 2002). It has been argued that the failure to apply a 'systems approach' leads to an underestimation of savings (from energy efficiency measures), an overestimation of costs and less stringent policies relating to energy use and greenhouse gas emissions (Harvey, 2008; Larsson, 2004). The traditional linear design-construct process, together with entrenched building practices and a conservative culture, constrain the implementation and optimization of sustainability requirements and frequently lead to high cost of implementation (Miller and Buys, 2012; Osmani and Reilly, 2009; Ryghaug and Sorensen, 2009).

Assigning costs to the delivery of sustainability outcomes in housing is also complex. A typical method applied in Australia is to consider the costs of a 'standard' house, then calculate the 'additional' costs of implementing features that are considered to be sustainable. This method is frequently deployed by the housing industry in fighting against any proposed changes in building regulations, and was the method deployed by Luxmoore (2005) in his evaluation of the 'additional costs' of integrating sustainability features into small lot developments west of Brisbane. He reported that sustainability features (passive design, energy efficiency, rainwater tanks etc) added about 9% to 'standard' construction costs. This 'cost analysis' process however is flawed. Lack of clarity about what defines a 'standard' house and the diversity of factors that impact on housing costs make it difficult to conduct robust comparisons of 'affordable' versus 'sustainable' versus 'standard' homes. These factors include the wide range of housing types, locations, sizes and construction volumes; the variety and depth of sustainability features that could be included compared with what is 'standard' in traditional housing; the time span of the cost calculations (infrastructure and development costs; project management costs; construction costs; operational costs; lifecycle costs; finance costs); the design/construction phase at which sustainability is incorporated; and the 'avoided' costs or benefits associated with environmental protection, improved human health and enhanced community well-being (van Hal, 2007; Miller, 2012b).

4. Case studies

As mentioned in the introduction section of this paper, four case studies that are classified as affordable and/or sustainable are reviewed. **Case study 1** is a *sustainable affordable housing development* located near a major activity centre. The development, on 900 m^2 of land, consists of two detached town houses each with 2 bedrooms and 2 bathrooms, and three attached town houses each with 3 bedrooms and 2 bathrooms. The dwellings were designed to meet a 4½ star building envelope efficiency rating (in a 10 star rating scheme), using building orientation, landscaping and natural ventilation to reduce the need (and cost) for space heating and cooling. The dwellings also incorporate natural lighting and water sensitive design (rain water harvesting). The development is well located within walking distance of shops and public transportation. Such in-fill development is supported by local and state government because it is widely believed that increasing urban density helps lower the cost of providing housing whilst still meeting the profit requirements of housing providers. The small size of this development, and other similar in-fill projects, is also thought to benefit from a shorter development approval process which can reduce holding costs.

Case study 2 is an *affordable rental housing development* provided by a not-for-profit organisation (social developer). The medium rise housing complex (32 studio and 1-2 bedroom units) has used passive design principles to optimise natural ventilation, cross ventilation and natural light into individual dwellings. A water tank (for rain water harvesting) is located in the core of the building. The design incorporates wide balconies and extensive moveable sun screens to maximise privacy, sun protection and natural ventilation. Strategies for maximising the value of the capital outlay (short term and long term) included applying a uniform floor plan, selecting materials with low maintenance costs and consideration of life cycle costs. Government subsidies and incentives were utilised to the fullest extent

possible, such as state government rebates for rainwater collection and local government planning incentives allowing increased density and relaxation of car park requirements for affordable housing projects. In addition to the above incentives, not-for-profit organisations have additional tax concession such as income tax and GST exemption. This would indicate that the social developer may be in a better position to offer affordable housing because maximising shareholder profits is not a core consideration for development decisions.

Case study 3 is a *single family detached sustainable house in a greenfield in-fill development* within 3km of shopping, school and train services. It was constructed in 2011 utilising a new 'manufactured housing' system. This 8 ½ star house has been designed to provide a very high level of occupant thermal comfort through excellent insulation and natural ventilation, as well as very low operating costs through incorporation of rainwater collection, energy and water efficient appliances and solar power. The construction system allows for homes to be constructed in much shorter time frames, impacting on the cash flow and finance of both the builder and the client. It also appears to be cheaper (materials cost) than common alternatives.

Case study 4 is a *144 lot sustainable housing development* on the Gold Coast, 90 kilometers south of Brisbane. The estate, 65% complete, consists of detached housing of 1, 2 or 3+ bedrooms, for either single family housing or co-housing. Extensive and quite prescriptive covenants are applied over and above existing state and national building regulations. These covenants attempt to embrace a very broad range of sustainability considerations that could be loosely characterised as environment protection (of land, soil, hydrology and landscape), resource management (of energy, water, waste, materials) and social cohesion (reducing transport needs, accessibility, and balancing security, safety, privacy and social interactions). House construction costs, based on study of eight houses 2008-2011, ranged from slightly less than a 'standard' house on the Gold Coast built to minimum regulation standards to costs similar to a medium level finish of an architecturally design executive home (2010 prices). Performance evaluation of the eight homes revealed no correlation between house construction costs and environmental performance outcomes.

5. Discussion

Table 3 provides a comparative overview of the affordability and sustainability features of these case studies. The four case studies illustrate that a range of affordability strategies and a range of sustainability strategies can be incorporated to achieve housing that has a measure of both affordability and sustainability. From a sustainability perspective, all four case studies addressed, to different levels, the thermal efficiency of the building envelope. Passive solar design and natural ventilation were no / low cost strategies to minimize the need for mechanical cooling. All case studies provided ceiling fans to enhance occupant comfort when natural ventilation is insufficient. Maximising natural lighting was another common energy efficiency strategy incorporated, as was rainwater harvesting.

In the affordable housing case studies (1 and 2), sustainable features have been included when it required no or minimal additional cost, such as passive solar design and rainwater tanks (with government rebates). Reduction in time and cost are also driven from

government initiatives such as tax exemptions, deferred payment of infrastructure charges and planning gains (e.g. increased density and car park relaxation). Government incentives have a significant impact on implementation of sustainable features in affordable housing projects. In the sustainable housing case studies (3 and 4), sustainability features were integral to the design, and costs were managed through a variety of measures such as changing construction processes, special purchase arrangements with suppliers, government rebates, use of recycled or second hand goods, and end-user time investment.

Table 3: Case study comparison of affordability and sustainability features

	Case study #1	Case study #2	Case study #3	Case study #4
Year of completion	2007	2007	2011	2006 - ongoing
Affordable housing features				
Increase density	Yes	Yes	No	No
Car park relaxation	No	Yes	No	*Alternate approach
Tax exemption	No	Yes	No	No
Not for profit	No	Yes	No	No
Discounted rent	No	Yes	No	No
Discounted sales	No	No	No	Yes, for 1-2 bedrooms lots
Location close to employment	No	Yes	No	*Alternate approach
Public transport	Yes	Yes	No	*Alternate approach
Government incentives and support	Yes, rebates	Yes, grants and rebates	Yes, rebates	Yes, rebates
Time reduction	Yes, planning approval	No	Yes,construction time	No
Sustainable housing features				
House and lot layout optimise solar orientation	Yes	No	Yes	Yes
Natural lighting	Yes	Yes	Yes	Yes
Natural ventilation	Yes	Yes	Yes	Yes
Shading	Yes	No	Yes	Yes
Space cooling appliances	Ceiling fans	Ceiling fans	Ceiling fans	Ceiling fans; no air conditioners permitted
Energy and water efficient appliances	Buyers' choice	Tenants' choice	Provided	Buyers' choice within limits
Energy efficient hot water system	Yes, gas	Yes, gas	Yes, gas and heat pump	Yes, gas-boosted solar
Solar (PV) power	No	no	Yes	Yes
Rainwater harvesting	Yes, for toilets and gardens	Yes, for toilets and gardens	Yes, outside use only	Yes, potable water supply is rainwater
Recycle water supply	No	No	No	Estate level waste water treatment plant and reticulated recycled water
Food production area	No	No	No	Yes
Materials life cycle considerations	No	No	No	Yes

Another common feature of case studies 1, 2 and 4 was the controlling of overall costs (or the maximization of project investment) by limiting the size of the dwellings. These three developments all offered a range of dwelling types suitable for different household types, in contrast to standard market offerings. The high proportion of small units in their dwelling portfolio prompted the social developer (case study 2) to petition the state government

(unsuccessfully) for a review of water infrastructure charge methodologies. This is discussed in more detail in the next section.

Case studies 3 and 4 had different means of achieving cost effective sustainability. The key benefit of case study 3 is in the combination of good design for the climate (to reduce operational costs for heating and cooling) with a construction system that reduces building error that can compromise indoor climate performance and reduces construction time (and hence finance costs). Case study 4 reduced development infrastructure costs through water sensitive urban design (no connection to centralized storm water system), an estate level waste water treatment plant (no connection to centralized waste water system), and energy efficiency covenants (reduced capacity electricity network). These reduced infrastructure costs impact on land purchase prices and ongoing household rates and operational costs. This case study also implemented a number of 'alternate solutions' that included maximizing non-car options for mobility (e.g. cycle and walking facilities) and reducing the need for mobility for work and recreation (home offices, fibre-to-the-home communications network, neighbourhood enterprises and recreational facilities).

Because of the diversity of options and sustainability inclusions presented by the case studies, it is not possible to conduct a benefit:cost comparison between the developments. It would be reasonable to assume that the total 'house cost' of case studies 3 and 4 are not likely meet the cost target of the developers of case studies 1 and 2, however significant learnings can be transferred between the affordable and sustainable housing sectors.

6. Future sustainable and affordable housing

Housing is a critical national asset more than just shelter that underpins Australians' and Australia's economic, social and environmental well-being. The role of housing could be argued as '*sustaining occupants' safety, health and physiological comfort*' (Kim, 1998) or as *'expressing personal and social identity and enabling and supporting inhabitants in living sustainably'* (Miller, 2012c). Clearly defining, as a society, the essential elements of housing will help to determine levels of affordability and sustainability and identify the processes required to achieve these levels. Two key questions frame the context:

Can we, as a society, afford to provide housing that is NOT sustainable?
Can we, as a society, afford NOT to provide housing to low income families?

The challenge of providing housing that (i) sustains its inhabitants socially, economically and environmentally, (ii) is inherently sustainable for the planet as a whole, and (iii) is accessible to families in the lowest 40% of income distribution, may best be achieved by focusing on the *process* of achieving sustainability and affordability rather than looking at the multiple issues in isolation (Salama and Alshuwaikhat, 2003). There are convincing arguments supporting the belief that addressing how houses are produced is bound to have limited effects unless the focus expands to the broader housing sector to simultaneously address issues of urban design, occupants, infrastructure, finance and housing markets (Miller, 2012c).

What are some of the strategies revealed in the case studies that could be successful in the joint implementation of affordability and sustainability? The *planning incentives* to develop

affordable housing in Queensland had been based on the case by case negotiation between the local government and the developer. The new Sustainable Planning Act 2009 has supported both sustainable housing and affordable housing projects. Some of the case studies were developed prior to the new Act and required great involvement by the owners or occupants. The incorporation of both affordable and sustainable housing in the new planning scheme will increase certainty and fast track the planning approval process. The certainty of the planning process will help to reduce project holding costs and increase the certainty of the project, reducing risk. This has the potential to enhance affordability provided the housing developer passes on the savings.

Government subsidies play an important role in enhancing the immediate affordability of some sustainability features. From Table 3 it is clearly evident that rebates for specific appliances / technologies (e.g. solar water heaters and rainwater tanks) are important in the early stages of product diffusion into an established market, and become less important over time as the technology matures and the market adjusts to the new products.

Government regulatory frameworks have an important role to play in setting expectations and minimum requirements. Experience from the previous building regulation changes (2003-4) showed that additional regulatory requirements increased the housing price and put pressure on affordable housing delivery. Investors chose to switch the housing supply towards the higher-end market which provides a better return for their investment (Susilawati, Armitage, Skitmore, 2005). However this risk should be minimized by the nature of the Framework that clearly articulates the future pathways, providing industry with ample time to prepare for change in advance. The draft National Building Framework includes the whole building approach from planning and design through to construction, and includes built-in appliances such as hot water, lighting and heating, cooling and ventilation systems (DCCEE, 2012). Other sustainability requirements such as indoor air quality, water efficiency, onsite electricity generation and embodied energy of building materials may be considered for later inclusion. Building processes (e.g. design, simulation and rating tools), market processes (e.g. Mandatory Disclosure - requiring certain features of dwellings to be revealed to potential buyers and renters) and education and training initiatives, form part of the Framework. Some of these inclusions will conceivably enhance occupant comfort and health, and may reduce household operational costs, however the pressure on meeting the higher sustainable ratings has the potential, unless current industry practices change, to place upward pressure on housing prices. A key risk that still needs addressing, however, is lack of compliance: if the regulations are not enforced and housing is not inspected to ensure that the sustainability features are appropriately installed and operating, then the expected savings in operational costs may not be realized.

The *allocation and implementation of infrastructure charges*, in particular the synergies between dwelling energy and water efficiency, dwelling size and dwelling impact on infrastructure requires more scrutiny. Infrastructure charges (e.g. for potable water, waste water, storm water and/or electricity supply networks) could be restructured to reflect some of the significant reductions in consumption that occur with the implementation of high levels of energy and water efficiency, and by the lower consumption rates attributable to smaller units in affordable housing developments. The reduced impact on infrastructure has been verified in post occupancy evaluation of case studies 2, 3 and 4. The inequitable allocation of

infrastructure charges in water and energy (between high and low consumption households) stymie the further implementation of both sustainable and affordable housing. Other changes to infrastructure charges could include discretionary subsidies for affordable housing developments and delayed payment of infrastructure charges (using secondary mortgages as security).

Perhaps the biggest challenge lies in *identifying and determining the system boundaries*: what is meant by affordable sustainable housing? What sustainability features should be considered 'standard' for all housing, and what level of environmental performance is required? Over what time period? How are costs and value defined and calculated? From whose view point are costs and value determined? What conditions or assumptions contribute to affordability, cost and value calculations? What processes or development forms are more likely to be able to provide holistic systems solutions?

These are difficult questions to answer because an understanding of the exact nature and extent of current and future challenges that face housing occupants (e.g. higher incidence of heat waves, resource depletion, indoor air quality, human health, fuel poverty, resilience) is still evolving, and the economic and regulatory context of housing changes frequently. It is within this context of uncertainty of the end goal that the concept of 'sustainable affordable housing' needs to be developed and be implemented.

7. Conclusion

This paper presented Australia's dilemma of very high median house prices and the impact this has on housing affordability and the supply of affordable housing. It outlined sustainable housing features and key issues that affect the supply, and cost, of sustainable housing. Four case study residential developments were presented, providing a degree of comparison of strategies deployed to incorporate affordability and sustainability features. It showed that planning incentives, subsidies, regulatory frameworks and allocation of infrastructure charges all play a critical role in the feasibility of providing affordable sustainable housing in Australia.

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Rural Water Supply Projects and Sustainable Development

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Abstract

The study reviews the sustainability issues that are associated with rural community water provision and some of the challenges experienced in the in Niger Delta region of Nigeria within the context of project benefits sustenance. Several rural communities in Nigeria derive water supply through hand pump operated water supply wells. The sustainability of this approach to water provision was assessed using a qualitative research methodology and undertaking a comparative review of Micro-Projects Programme (MPP3) in Nigeria with that of Volta Region Community Water Supply Programme (VRCWSP), in Ghana. The findings reveal the absence of sustainability in the current approach and the paper recommends that if community based hand pump operated rural water supply projects are to be sustainable; the sustainability factors must be given full consideration in its design and implementation. A post-project management approach is suggested which should be effectively monitored, assessed, linked and integrated into the implementation and post-operational management of hand pumps water supply systems. The use of a community based and community driven project-management options in the management of community rural water supply is proposed as this remains a credible alternative over control by external or government agencies.

Keywords: Sustainability, water-supply, hand-pumps, project management, project benefit.

1. Introduction

This study reviews the sustainability issues using a project management approach in order to provide a more sustainable strategy for managing hand pump operated water supply projects. It assesses whether there is the need to adopt a dynamic process that will promote sustainable management of a project's benefits. The rationale centres on the assertion that community rural water supply consisting of hand pump operated shallow wells is considered to be a suitable technology for water supply in low-income (rural) communities of Niger delta. There are however several cases where they have fallen out of service within a limited

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period after creation (Harvey and Reed, 2004). Most of these projects have been planned and created without a strategy for long-term operations (Franks, 2006). Africa recorded a 45% rural water coverage in 2000 compared with 40% in 1990, leaving 237 million people without water (WHO/UNICEF, 2000). Urban water coverage in Africa recorded at 85% in 2000, with 37 million urban dwellers not supplied with water. In Nigeria, the percentage of rural water coverage in 2000 was 40% and urban 60% as compared to 37% rural and 83% urban in 1999 (ADI, 2004). In this context, it is clear that rural communities are lagging significantly behind urban areas in water provision. According to Lockwood, (2004), Harvey and Reed, (2004) and Wood (1994), the hand pump is an appropriate technology because: they are low cost; easy to operate and maintain; the financial implication to the community and the donor is low; the recurrent costs are low; the financial responsibility for the on-going O&M of water supply systems falls within the users' community; .the technical skills, tools, and spare parts required for the O&M is available; also, the availability of shallow groundwater resources beneath the earth surfaces in the developing countries makes it a most viable option for community rural water supply. However, other technology options exist such as protected springs; hand pump equipped boreholes on wells; rain water harvesting; hand-dug wells; gravity fed system and semi-scale pumped systems for rural water supply.

According to Lockwood (2004), and Wood (1994) the set of assumptions in the choice of hand pumps, is that it is the best low-cost measure for community water provision. It is affordable; easy to maintain; an appropriate technology; readily available to the communities; easy to construct and install; efficient and easy user friendly. The simpler the technology, the less the Operation and Maintenance (O&M) requirements and the more sustainable it is likely to be. However, as good as these assumptions are many hand pump projects have failed to achieve the desired benefits. For example, in Sub-Saharan Africa, countries like Ghana and Nigeria, hand pump water supply projects have rarely fulfilled the intended purposes (Parry-Jones *et al*, 2001). Developing countries are littered with remains of projects that died when donor funding ended' The question is why do these projects fail or get abandoned, and even become 'white elephants' within the very poor communities that desperately need them? Cusworth and Franks (1993) contend that the ''missing link'' is seeing beyond the project implementation phases and to appreciate that the end result is not the project but the assets created by the project when put into operation. Multi-year financial planning is not usually provided for. Other authors contend that it is the wider institutional issues that are not put in place or properly implemented and poor or lack of regular preventive maintenance practices (Harvey and Reed, 2004, Parry-Jones *et al,* 2001). In Nigeria, non-functional hand pump operated water supply projects are abundant. .There are several reasons:

- Who is responsible for the maintenance for the benefit of future generations after project implementation and How will they be maintained;
- What factors can obstruct or aid the sustenance of the alternative in order to curb the threats of water-borne diseases in the community that are often associated with unsafe drinking water resulting from the use of contaminated stream and rainwater sources.

Communities perceive it as the responsibility of the donor to make provision for sustaining the benefits of these water projects. It is felt that in communities where they are unable to,

make such provision, they should liaise with the local government or the community leaders to develop strategies for its sustenance. This view has in the past generated communal crises, political dichotomy, crime, corruption even in a case where the project requires minimal maintenance. Therefore, the need to focus attention on sustaining these projects and its benefits is just as crucial as the project itself. Sustaining the benefits of a project involves the management of the scheme that are put in place by the project, which centres on long-term investment and accumulation with the prime objective of providing opportunities for the project beneficiaries and the owners of the assets created by the project (Franks, 2006, Cusworth and Franks, 1993)..

2. Sustainability Factors in Community based Hand Pump Operated Water Supply Projects.

2.1 Sustainability and Sustainable Development Conceptualised

The World Commission on Environment and Development (WCED 1987, 8) defines sustainable development as development which '*meets the needs of the present without compromising the ability of future generations to meet their own needs'*. The concept of sustainability at first relied on environmental phenomenon, but currently, it has gone beyond the boundaries of environmental issues to include social, economic, political, and development issues (Edum-Fotwe and Price, 2009). Understanding what constitutes sustainable and unsustainable development is crucial in any project management and post-construction management system. Hence, it would be sustainable development if it reduces the disparities between the poor and the rich. In addition, Porritt (2000) in Lutzkendorf and Lorenz (2005, 213) argue that for the achievement of sustainability, it is necessary to measure it against a set of four 'system conditions' such as:

- Finite material (including fossil fuels) should not be extracted at faster rate than they can be redeposit in the earth's crust;
- Artificial materials (including plastics) should not be produced at a faster rate than they can be broken down by natural processes;
- Biodiversity of the ecosystem should be maintained; whilst renewable resources should only be consumed at a slower rate than they can be naturally replenished;
- Human needs must be met in an equitable and efficient manner.

Cooper and Jones (2008) argue that development will be sustainable when attention is given more to greater community engagement; deliberative forums to help people live more sustainable lifestyles; investigating ways in which stakeholders can influence decision-making; new commitment to support education and training in sustainable development; and response to key environmental issues. Therefore, while the concept of sustainable development from literature is well known and widely used, there appears to be no common understanding of it.

2.2 Policy support and Organisational Arrangements Factors

Policy development and implementation is essential to project sustainability and has led to a high interest of voluntary organisations (NGO'S), private sector and community based organisations (CBOs) providing active services delivery in Africa (ADB, 2005, IIED, 2000).

Where there are no policies developed, every sector and actor will see the issues differently and use different execution strategies that will cause disintegration. The level of politics is a core issue to sustainability and the democratic system of a country must be one having the total commitment to providing conducive atmosphere for the water supply project otherwise the possibility of project failure is high (Parry-Jones *et al,* 2001). Policy formulation is multi-dimensional and dynamic in nature, which the actors supporting the low cost technologies must be ready to adapt for the successful implementations of the projects. ADB (2005), Harvey and Reed (2004), assert that institutions and personnel to drive policy implementation; stakeholders that adhere to policy and strategy guidelines; a consistent regulatory and legislative framework; and an adequate financial resources are necessary to ensure sustainability. Again, the institutional and organisational set-up particularly the maintenance strategies put in place which would guarantee the financial returns over the expected project life span is equally vital. Management at the lowest appropriate level requires the role of the local and national government, the private sector and non-governmental organisation. Community Level Operation Maintenance has been overwhelmed by the community management preference, which requires proactive approaches (Colin, 1999). Although, this management strategy seems good, it appears that there is need to accept decentralisation of maintenance approaches for effectiveness and efficiency as highly centralised decision-making does not promote sustainability (Boydell 1999). As such, Anand (2007) suggest that the federal government should have the main role of setting the policy and institutional framework which other sectors follow through participatory democracy, but, sustenance of water supply through good governance is a priority.

2.3 Technological Factors

The United Nations Development Programme (UNDP) and the World Bank initiatives in the 1970s on global/ interregional project laboratory testing and technological development of hand pumps for rural community water supply indicate that technology might no longer be a limiting issue to hand pump operated water supply project sustenance in the rural community (Parry *et al,* 2001), and suggests that better sustenance of such projects and the related local benefits can still be gained when the pumps are purchased offshore and delivered through local participation. On the matter of availability of spare parts relating to hand pump water project sustenance, it is a problem in most Africa countries because the quality, availability, procurement and supply of these hand pump parts are challenging and at most times, the project developers fail to consider the future consequences of these factors to the project sustenance. Baumann (1994) argues that the purchase of hand pump parts should be made to be economically feasible and viable. Locally manufactured spare parts should have a strong linkage to the community market for better contact with the beneficiaries of a project as in the case in Ghana, Nigeria and Tanzania (Woodhouse, 1999;).

2.4 Environmental Factors

Parry-Jones et al (2001) maintain that, the Sustainability of community based water supply projects in the context of the environment is related to groundwater resources. Arlosoroff (1987) estimated that an India mark II hand pump characteristically yields 12 litres of water

per minute which measures less than 6 cubic metres per day for eight hours of continuous operation. Well siting and development, screen obstacle and chemical composition of the water are fundamental environmental factors in community hand pump water supply project and the successful sustenance of its benefits. In the context of sustainability and water composition, the more saline the water, the more the metallic component of the hand pump is subjected to corrosion syndromes. Anand's (2007) suggests that coastal communities are more vulnerable to salinity ingression. However, there is advancement towards using plastic rising mains that help to prolong the life span of hand pump in aggressive water environments. The odour and colour of the water are also important considerations.

2.5 Community Social Perceptions:

Community needs and priorities have become common factors why community water supply projects fail because of their belief in the use of their natural water sources as a ready alternative. This is a common cause of water supply project failures in Africa and particularly Niger Delta in Nigeria where most of the area is covered by fresh and salt water. Furthermore, gender diversity, which is on the global agenda, affects water provisions and project request requires the involvement of all community groups irrespective of the gender in the decision-making and management of the system. According to Hoffman (1992) there is still gender discrimination for example, where men and women were trained on how to maintain the hand pumps, the female input or efforts were not rewarded while the male were rewarded for the same service rendered. Cleaver's (1991) confirmed that while women were members of a hand pump water project committee, all the tasks were performed only by men. The study suggests that the committee set-up is not the case rather the changing community leaders and at most times the traditional rulers influence the decision-making in the community. UNICEF report in Nigeria (WELL, 2001) confirms that the most active group in hand pump maintenance were the CDC that was democratically elected by the community themselves. Parry-Jones et al., (2001) and Cleaver (1991) emphasize that one of the main substances of community participation in project decision-making and implementation is to stimulate a sense of ownership, which could increase the level of maintenance to hand pump projects.

2.6 Economic/Financial Factor:

The economic/financial factors stem from capital costs and community contributions, water tariff and real costs of maintenance. Harvey and Reed (2004), Parry-Jones et al. (2001), Woodhouse (1999) suggest that, since the capital costs of hand pump operated water supply projects are huge and the community or individual cannot afford it, the responsibility should be left for the government, donors or NGOs. However, Parry-Jones et al (2001) suggest that even though such concern should be carried by the project financier, the community must prove commitment either in-cash or in-kind as it is through this commitment that a community provide an organisational capacity to sustain it. An evaluation of a UNCDF project in Guinea Bissau indicates that the failure of hand pump operated projects and other projects was the failure to develop an appropriate strategy for operation and maintenance (O&M) cost recovery at the community level which then undermines the sustenance of the projects benefits. A WSP (2001) study reveals that the costs of operation and maintenance

of rope hand pump in Nicaragua is only US$10 per year as in contrast with the India Mark II of US$59-107 per year. Water tariff is a means of recurrent costs recovery from the hand pump which can be used for the annual operation and maintenance as in the case of Ghana (Harvey *et al*, 2002). An understanding of the real costs of operation and maintenance of hand pump water project is important but usually neglected.

3. General Perspectives in Sustaining Project Benefits.

''Projects are regarded as a temporary undertaking to create a unique product or service'' (PMI, 2000). However, the British Standard states that projects are ''unique set of coordinated activities, with a definite starting and finishing point, undertaken by an individual or organisation to meet specific objectives within defined schedule, cost and performance parameters'' (BS 6079, 2000).Whatever be the understanding from these definitions, Cusworth and Franks (1993), describe it as the venture of capital in a time-bound interference to create fruitful assets. There is need to see beyond the project to the creation of assets of continuing benefit and value to the clients and beneficiaries''. The post-project phase of commissioning, operations and maintenance for project sustainability is considered. Project Commissioning is that phase connecting the project implementation to the project operation and marks the 'handing over' time when the assets created by the project is put into use. Cusworth and Franks (1993) maintain that the thought that the facilities once created could immediately be put into operation and that no running in period was required is contradictory, misleading and is discarded. Sometimes an important activity such as commissioning, which is a key step to project successful operation is overlooked in project planning and management. Operational objectives entail putting the created assets into use, looking at the most efficient, effective and profitable strategy of operating them, and training the operators or users in an economically effective and efficient manner, with the familiarisation of the clients with the products or services that may be availed to them. Safety objectives entail passing tests and safety checks, training and testing operators in emergency procedures and the search for hazards to which the facilities might give rise to contractual objectives entail providing predictions of performance, passing of acceptance tests and provision of triggers for payment stages. Once the commissioning phase is completed, the operational phase of the project starts which covers the period when the project starts normal activities to yield the expected benefits. Cusworth and Franks (1993) maintain that commissioning is an important phase in the project cycle but too often insufficient attention is given to it during the project preparation phase, even many contractual project cycles do not include it as part of the project development. Nevertheless, three main features exist in managing operations which are

- Operational procedures: Ensure the effective operations, safety, records and maintenance of the created assets/facilities. It entails aspects such as 'what', 'who' and 'how' things must be done.
- Resource Control is concerned with the management of capital, fund, materials and machines for the effective operation of the project.
- Environmental project Relationship: Entails the management through monitoring and control of the internal and external environmental system in relation to the project output and possible impacts to the project operations.

According to Field and Keller (1998), effective and efficient project maintenance is a key element to sustaining project benefits and health or safety. It takes the form of planned maintenance programmes, which ensures that the assets created, continue to operate continuously without further injection of external resources from the government or donor agency for rehabilitation. Cusworth and Franks (1993) assert that project maintenance goes beyond keeping the facilities in operation, to a maintenance programme based on the principles of moving ‘‘from the crises of unplanned maintenance to the inevitability of planned, preventive maintenance’’ There are a few project Management constraints associated with hand pump operated water supply projects. The constraints are lack of technical know-how and local management staff as a result of insufficient capacity building; lack of education, information, awareness, participation, involvement, decentralisation and communication; much interest on the implementation stage; and lack of monitoring and appraisal/evaluation strategy..

4. Micro-Projects Programme (MPP3) and VRCWSP Projects.

4.1 Methodology

A qualitative approach with two explanatory case studies was used. The study reviewed reports on the Volta Region Community Water Supply Programme in Ghana and the Micro-Project Programme (MPP3) in the Niger Delta region of Nigeria. For the MPP3, the report is a midterm evaluation aimed to assess the relevance and the performance of the programme, its impact on poverty alleviation among the rural communities and its contribution to the reduction of the social tensions in the area; review the organisational and management structure of the Micro-Projects Management Unit (MMU) and advice on appropriate enhancement. It is also to advise the Technical Programme Committee (TPC) and MMU in policy formulation for further implementation of the MPP3 and investigate factors that ensure the project sustainability. This was geared toward ensuring that the objective of the MPP3, which is to help improve the living standard in poor settlements of the Niger Delta (Rivers, Bayelsa and Delta States) in Nigeria, contributing to the reduction of the poverty, social tensions and crisis. The purpose of the project was to implement basic infrastructure and support income-generating activities. The MPP3 is an evolution from the Lomé convention and the multi-annual micro-projects programmes, one of the instruments the EU/ACP uses to build a development co-operation with nations. It was on this basis that the Federal Republic of Nigeria and the Commission of the European Communities commissioned the Micro-Projects Programme (MPP3) for a total amount of €21 million in the three core Niger delta states.

The Volta Region Community Water and Sanitation Programme started in the Keta Municipal, Ghana but other areas were also covered through a non-governmental organisation such as Danish International Development Assistance (DANIDA) in pursuit of adopting, implementing and achieving the Millennium Development Goal (MDG) objectives in Ghana. The programme overall aimed to provide 49% of the rural communities in the region with potable and accessible drinking water. The overall objective of the programme was **t**o bring water supply and sanitation services in rural communities and small towns up to basic acceptable levels; to ensure sustainability of the services; and to promote the best use of the services so as to realize their potential benefits. The programme used the approaches of community participation; demand driven approach to the utilization of funds under the

programme; community management concept; private sector participation in implementing the programme; municipal assembly's involvement; and community water and sanitation agency as facilitators.

The choice of these cases was hinged on the premise that it offered an in-depth understanding and explanation of the issues affecting rural water supply sustainability, convenience, time and cost reduction. The study also reviewed national statistics on water supply sources in Nigeria. Both cases are within the West African sub-region and share similar geographical, socio-cultural, political and environmental norms and values. A content analysis method was used to compare and contrast various dimensions from the selected cases. Participant observation and also played a key role in the methodology. The discussions are based on the sustainable factors and the post-project management approach to community hand pump operated water supply projects and the sustenance of its benefits such as: policy support; institutions and project operations management structures; maintenance management; project commissioning; environment/ technology; community perception/involvement; economic/financial contributions; and monitoring, evaluation, and reporting strategy (Harvey *et al*, 2004, Parry-Jones *et al*, 2001, Cusworth and Franks, 1993).

4.2 Findings/Discussions

The study reveals that community hand pump operated water supply project benefits, are sustainable where all the institutional factors and the post-project management approaches are properly incorporated, interconnected and tackled rather than focusing on wider institutional issues alone. Also, that some intervention is in reality run as a project instead of programme as claimed in their objectives. This is indicated in the case of the MPP3 in Niger Delta region of Nigeria. From the critical analysis of the MPP3 and the VRCWSP, the paper suggests that wider external project environmental issues and internal project environmental approaches is very important and fundamental, except monitoring, evaluation, and reporting which remains the mortar to all other factors.

4.2.1 Technological Factors

Most hand pump operated water supply project failures are associated with lack of standardised spare parts, hardware problems, technological transfer and unplanned maintenance design. In the case of hardware problems, the most frequent issue is the breakage of pump rods (Parry et al., 2001), as it is noticeable in Nigeria, Ghana and other African countries, but the level of this problem regarding sustainability is a function of the technological advancement of that country in the area of water supply. However, local manufacturing of hand pump particularly in Nigeria is predominant which is in line with the Afridev and India mark III technology but the quality and durability of these pump are often poorly manufactured to the extent that its use becomes risky to water provision (Parry et al., 2001). Nevertheless, quality specification can be put in place and monitored for compliance on the hand pump production for hand pump sustainability in Niger delta. Irrespective of this strategy, most of the locally manufactured hand pumps are more costly in certain Niger delta states than those imported.

4.2.2 Policy Support:

Policy is aimed to provide a supportive and conducive environment for community water supply. With clarity and proper enforcement/implementation of the developed policy, the better the project benefits sustenance. Hence, successful community water supply management requires policy and strategic support from all levels of the government. The VRCWSP has a national policy strategy for community rural water supply to grassroots communities through the Community Water and Sanitation Agency (CWSA), whilst the MPP3 has a policy statement at the national level without proactive strategy to encourage the policy to the rural community. Also, the VRCWSP policies supported and encouraged community rural water management, contributions, involvement, ownership and standardisation of hand pump water supply system and the hand pump project benefits is sustained (Harvey et al, 2002) whilst the MPP3 lacks this merits (MPP3 report, 2006). According to Harvey et al (2004), there is no guarantee that the development of appropriate policy for community hand pump operated water supply project benefits sustenance will result in sustaining water supply but a dynamic process is encouraged to regularly repeat, review and revise policy as to address the problems

4.2.3 Project Commissioning:

This is a fundamental issue in project sustenance usually overlooked in project management cycle. It is the period of handing over the created asset to be put to productive use. In the case of the VRCWSP in Ghana, commissioning is seen by the government, donor and the beneficiary communities as an ‘‘event driven’’ activity signifying their empowerment to totally participate and commit to the management and operations of the project. The project commissioning is done between the government, the donor and the recipient communities. Whilst in that of the MPP3in Nigeria is between the government and donor (EU) and at times even done on radio or television announcement, based on the authors’ experience. The hallmark of transferring the created asset from a project to a system guarantees that operational, safety and contractual aspects are more certain with the VRCWSP, therefore making the project benefits more sustainable and assured in the Ghana VRCWSP than the MPP3 in Nigeria.

4.2.4 Institutions and Project Operations Management Structures:

Sustaining the project benefits is a function of the institutions/operations management structures put in place to manage the on-going project system when the created assets are put into operations. The VRCWSP has strong and proactive management structures starting from the CWSA, the District Assemblies to the village technical teams with two-ways feedback reporting system. This indicates that the projects are managed, maintained, financed through community contributions, controlled, used and monitored by the community and the CBOs focuses on the Project Operations Management (POM) of procedures, resources control, and procurement. In contrast, the MPP3 has only an implementation team and no OPM structures in place either within the community or from the national level to manage the post-project operations, which implies that at the completion of the project, the team ceases to function and then, water supply sustenance is doubtful.

4.2.5 Community Social Perceptions:

According to Anand (2007), UNDP (2006), Parry–Jones *et al* (2001), Harvey and Reed (2004), Cleaver, (1991), WELL, (2001), Woodhouse, (1999), etc, community social aspects in terms of their needs and priorities, technology choice acceptance, gender diversity, village level power structures and project ownership, capacity buildings, involvements, participations and communication are vital and fundamental.. In the VRCWSP case, the recipient communities have their rights to choice of technology option, take ownership, participate and involve right from the on-set project initiation phases. Communities make financial commitments, which give the community the opportunity to be aware of the product that is to be delivered in their communities. Also community capacity building is done to the CWSA, the District Assemblies and to the Village Machines Teams (VMT) on regular basis to take new challenges. Because of these, the community make their highest total commitment and financial contributions to projects maintenance and sustenance. On the other hand, the MPP3 in Nigeria considered all these issues as typically revealed in the implementation strategy adopted. Also, capacity building and inclusion of the women in the community implementation committee is considered. But the choice of their needs and priorities, appropriate technology that will be cheap to maintain and ownership of the project is to debate as most of the implemented project are imported into the community on the grounds that, it is the decision of the government and failure to accept the technology deprives the community the opportunity.

4.2.6 Programme/Hand pumps Project Maintenance Management:

The sustenance of the water supply projects depends on the maintenance approach implanted for the continuous operations. The preferred approach is the planned ‘‘preventive’’ method, either routine regular or periodic shutdown maintenance, as unplanned maintenance leads to maintenance crises thereby affecting the benefits sustenance. On the VRCWSP, the community maintenance teams CWSA, DA and the APM including caretaker committee’s set-up by the community do the maintenance operations. These bodies through the VRCWSP charge and collect water tariff at the hand pump points which is used for the repair, purchases of spare parts and other necessary routine services. Through the VLOM approach to rural water supply, the VRCWSP emphasised the choice of ‘when’ and ‘who’ to involve in the hand pump mechanics and to make payments of all repairs. The community selects people who are trained in hand pump habitual repairs and fault identifications. The strong supported community operated maintenance system via planned preventive through routine regular maintenance strategy provided more than 85% of steady potable water supplies in the recipient communities. On the other hand, the MPP3 has no advantage of this sort, as their main focus is to complete the project without evaluating the internal and external project environment for the hand pump water project benefits sustenance in the communities.

4.2.7 Financial/Economic Issues:

According to MacDonald and Pape (2002), cost recovery system is a better choice for the community operation and maintenance of community rural water supply through hand

pumps. This entails the act of charging the recipients of the service the full or near full costs of rendering the services including the costs of constructions, installations, operations and maintenances. In the VRCWSP the communities are charged money in form of water tariff to cover hand pump repairs, spare parts purchases and replacement. The communities are mainly supported to ensure all costs related to the operations and maintenance while monitoring and reporting plus other administrative costs are the institutional responsibilities. In the case of MPP3, the emphasis is made on community contribution to the project implementation costs without thought to the post-project success and benefit sustenance to the beneficiaries. There are also no strategies in place to encourage the community to provide recurrent cost of the project after completion since the operational costs are not made feasible to the communities. Franks (2006) and Harvey and Reed (2004) argue that for the project benefits sustenance, all the financial /economic issues to the direct cost of the O&M must be known to the communities and should be willing to contribute to cover such amount.

4.2.8 Environment and Technology Issues:

Technology choice depends on the environmental condition as well. The community's right to choose from a range of technology options that is most appropriate, low-cost, easy to maintain, repair and affordable is significant rather than sophisticated one that is difficult to understand and manage by the community. Considering the cases, the MPP3 water supply failure is related to the hydrological nature, water quality, the groundwater level, pump type and the well siting and lack of drainage around the hand pump (MPP3 report, 2006). Also, the inability of the project provider to allow the community to choose from hand pump alternatives that will suit the community is lacking. According to Harvey *et al* (2002), the VRCWSP considered the benefits, limitations, costs, maintenance and management needs of the present environment, technology preference and then allowed the users to make decisions on which option that will better address the priority need of the community. Therefore, the environmental and technological sustenance of water supply project benefits demand full assessment and assurance of the water availability as the more porous the basement rock and moderate the depth, the better the aquifer and the more the water quality and availability with less difficulties of operations to the people.

4.2.9 Monitoring, Evaluation, and Reporting:

Monitoring, evaluation and reporting is the mortar that holds the other factors of sustainability and the post-project management phases together. Monitoring is an on-going process that ensures the determination of whether or not a particular approach is achieving set landmarks. The VRCWSP opted and adopted a strong monitoring, evaluation and reporting process that made the recruitment of environmental health officers in the hand pump water projects management team at all community levels. It is now established at the village level for community to play central role in project supervision, feeding the CWSA with adequate information need for the compilation of periodic reports (Harvey *et al*, 2002). On the MPP3, monitoring ends once the project is implemented. Above all, the critical analysis shows that sustainable water supply projects, benefits, is achievable through regular monitoring, evaluation and reporting of the various sustainable factors and the post-project management

approach of project commissioning, POM, and PMM. However, the procedures adopted are no guarantee to the sustenance of community rural water supply project benefits rather it is to be implemented and managed as a ‘‘process’’ than as a ‘‘blue-print’’ project.

5. Conclusion

Community rural water project and the benefits are sustained when the various concepts and management of the post-project issues are understood, correlated, applied and followed. As well as having strong policy support from the national level to the community with regular monitoring and reporting, helping to identify areas of concern for immediate mitigation measures. It is only on this proviso that community rural water supply through this alternative would have 85-90% functionality and sustainability. Also, community involvement, contributions, ownership and participation in making technology preference, needs to be proactive. Although, huge success with the advent of good ‘‘paper’’ strategies for the implementation of the projects exits, the sustenance of the benefits of these projects is doubtful when it fails to encourage community water management, ownership, technology choice, and environmental assessment. Above all, the post-project management approach in addition to monitoring, evaluation and reporting which are the pivot to the other factors that usually ends once the project is implemented, is pertinent. The community should be involved and allowed participation in the project decision- making stages leading to no imposition or deprivation of projects to the communities. This paper advocates careful follow-up of the post-project management approach and suggests that the institutional factors are vital where the benefits of community water supply projects is to be achieved.

This paper recommends that community rural water supply using whatever technology alternative should be managed as process rather than as a blue print -project. This will allow future challenges associated with a particular alternative to be properly managed through regular reconsideration, amendment, and possibly modification as the case may be. Also further research should be contextualised and where possible no hand pump project should be implemented in any particular environment without a strategic approach for the maintenance. Communities should be encouraged to set-up their own management committee and structure to look after the on-going operations and maintenance of their respective hand-pump water projects.

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Towards a Low-Carbon Urban Housing Sector in Colombia

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Abstract

Low-carbon concepts in the construction industry have been one of the most widely discussed topics among researchers interested in studying sustainability issues within the built environment. Over the last years, many investigations have been focused on examining greenhouse gas (GHG) emissions produced by the housing sector. This paper presents the preliminary findings of an on-going study, which is directed towards generating an abatement cost curve of GHG emissions for urban residential buildings in Colombia and formulating alternative scenarios for public policies, up to 2040. Three major Colombian cities (i.e. Bogotá, Medellín, and Barranquilla) were studied through the characterization of their housing stock and a multivariable forecast of the CO2-eq emissions generated during the building life cycle of their typical residential projects. Characterization was based on a literature review and statistical data analysis. Emissions were estimated by taking into account the different life cycle phases for representative residential projects in each of the urban areas under analysis, current building technologies and energy consumption patterns. This was carried out by conducting interviews with main actors of the Colombian construction industry, using information from real projects, and employing energy-efficiency simulation software along with the national energy balance data of the National Planning Unit of Mining and Energy (UPME in Spanish). Preliminary results show that many Colombian households live under low comfort and health standards. Therefore, conclusions seek to highlight not only the importance of reducing GHG emissions; but also, the relevance of improving the living conditions of the Colombian households. The study was financed by the British Embassy in Colombia and developed under the supervision of the Colombian Green Building Council (CCCS in Spanish); results are part of the National Low-Carbon Development Strategy (ECDBC in Spanish), in process of formulation by the Colombian Ministry of Environmental and Sustainable Development.

Keywords: Sustainable building, Greenhouse Gases Emissions (GHG).

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1. Methodology

Building Life Cycle Analysis (LCA) was the base methodology of the study and was applied through the process of calculating GHG emissions, evaluating the mitigation potential and estimating the associated costs. According to this, every life cycle phase: materials extraction and the transformation and transportation to the construction site, design phase, actual construction of the building, use and operation phase, and finally the decommissioning, demolition and final waste disposal, should be analyzed in order to identify GHG reduction opportunities.

Three Colombian cities, Bogotá, Medellín and Barranquilla, were selected to carry out the analysis due to their representativeness in terms of climate and socio-economic conditions around the entire country. According to the building categories defined by the Colombian Department of National Statistics (DANE in Spanish) (2011), there are two (2) residential segments, low income residential units (VIS in Spanish), and other than low income residential Buildings (No VIS in Spanish), two (2) typologies, houses and apartments, and three (3) construction methodologies, that represent the major portion of the buildings around the country including: confined masonry, structural masonry and reinforced concrete high rise buildings, all combined conform a group of 12 categories. "Real" case projects were studied, for every category which were significant and whose information was available and appropriate for purposes of this investigation. Therefore 12 building prototypes were defined per city, for a total of 36 prototypes at a national level. These 12 categories represented the entire building stock of Colombia. Using information provided by DANE, the total residential units were distributed within the defined categories.

During the first stage of the investigation, the research group developed a characterization report of the building sector in Colombia including a historical brief about the housing industry in Colombia, growing rates, and how the building activity has coped with the increasing urban housing deficit of the country, calculated in 2.2 million units until 2011. In order to describe the complete residential building stock, important milestones, the most influential policies and regulation were mentioned as well. It also included a description of representative construction techniques and a quality analysis of houses and apartments.

The information required for every project included: architectonic and technical designs, list and specifications of building materials, cost estimates of the building, and energy consumption during construction. The emissions at the first year, for the operation phase specifically, were calculated for the entire stock per city by defining the consumption behavior. In order to characterize households' energy consumptions, the study also took into consideration information from different studies performed by the UPME and from the Unified System of Public Utilities Information (SUI in Spanish). GHG counting for materials were calculated using the methodology of the Intergovernmental Panel on climate change (IPCC) and local studies to consider specific local characteristics of the sector in Colombia.

The methodology is also aligned with the Energy Assessment Protocol of the US Environmental Protection Agency (EPA) and the Common Carbon Metric document developed by UNEP Sustainable buildings & Climate Initiative. A National GHG emission

inventory developed by the National Institute of Hydrology, Meteorology and Environmental studies (IDEAM in Spanish) was also used as a reference.

The GHG emissions baseline at a national level was intended to be determined for every project life cycle phases, and at least two scenarios were considered: an inertial scenario or Business as Usual (BAU), and a reference scenario that incorporated new technological, political or socio-economic conditions.

At the construction stage, GHG emissions baseline was calculated for two different aspects. First, the GHG emissions of producing and transporting the amount of cement, clay bricks, steel and glass result of buildings quantity's take-off. No other materials were considered because they do not have enough information for calculation a local GHG emission factor. Second, the energy consumed at the construction site (heavy machinery, other construction and administration equipment). GHG emissions due to construction waste were not considered because the information available was very limited.

LEAP (Long Range Energy Alternatives Planning System) software allowed the evaluation of energy policy and climate change mitigation actions during the activities of energy production, transformation and consumption. The GHG emissions allocation considered two residential segments low-income and other than low-income residential units, and the three cities under evaluation. That way, two average households were defined per city for a total of six consumption prototypes. There was no difference in terms of materials or construction technique, from the consumption point of view.

The growth rate of the residential units at every city and the Inertial (BAU) were calculated. The reference scenario was calculated; incorporating the mitigation goals included in the Rational Energy Use Program (PROURE in Spanish), and considered that the income per capita is increasing the energy intensity of residential units. GHG emissions baselines for the decommissioning and demolition phase were not calculated due to incomplete information.

Regarding mitigation actions, three building life cycle phases were considered including: design, materials production, construction and operation phase. Relevant mitigation actions were reviewed in a literature review (i.e. International Code Council, 2010), and were classified into applicable and non-applicable, according to the national context of the building industry. The list of applicable measures was validated in one of the focus group meetings carried out as part of the ECDBC.

In order to evaluate actions applicable at the design phase, a bioclimatic simulation was performed in each of the 36 prototypes using the software HEED (Home Energy Efficient Design). This software supported analysis of all different design alternatives such as architecture, ventilation, lighting, materials, etc. The simulation aimed for improving comfort conditions and reducing energy consumption. Other aspects that are also considered in the simulation included electronic and gas equipments that registered the highest consumption in every residential segment, reported by the Unified System of Information, SUI (2012). The mitigation actions evaluated included measures applicable for new and existing residential

units, where “Retrofitting” processes were considered. The final results of the simulation provided a reduced amount of GHG emissions and the annual costs for energy consumption.

At the construction phase, mitigation actions during the production phase of the most important materials were evaluated. A determined pace of adaptation, to new and better technologies, was taken into consideration.

Regarding mitigation actions at the operation stage, the alternatives considered included actions towards lighting and refrigeration efficiency, fuel substitution and implementation of new fuel sources and technologies. The applicability of these actions was evaluated based on their positive effect in terms of energy efficiency and the possibility of using existing mechanisms for its implementation. Variations of energy consumption patterns and implementation of non-existing standards or regulation were not taken into consideration. A new reference scenario was defined to address the issue that most of the houses in Colombia are below minimum comfort standards, in terms of temperature, and that per capita income could increase significantly, therefore many households will start making use of more HVAC (Heating, ventilation and air conditioning) equipment in order to achieve a higher level of comfort.

Finally, based on the estimation of the GHG mitigation potential of the actions defined for every buildings life cycle phase, and their associated costs, the abatement cost curves were calculated.

2. Scope Adjustment

According to the characteristics of the information available, the investigation had many limitations. The scope of the project at every life cycle had to be redefined, as it follows:

2.1 Materials Production Phase

A complete estimation of GHG emissions due to materials should considered the entire processes, beginning at the extraction of raw materials, transport to the plant, the transformation process, the disposal of waste material and finally transport to the construction site. Due to the lack of information about the mining (raw materials extraction), and transportation activities in Colombia, the scope at this stage was limited to GHG emissions for fuel consumption and direct emissions at materials production plants.

Regarding mitigation actions during the production of materials, it was possible to analyze actions, at an acceptable level of detail, applicable just to the cement industry. Other materials industries did not provide appropriate information.

2.2 Construction Phase

The construction phase was defined as the sequence of processes at the construction site. The GHG emissions baseline was calculated including energy consumption at the construction site and transportation of cement from the plant to the construction site.

GHG emissions calculation at the construction phase can be only used as a reference, because only three projects out of the 36 analyzed had precise information about their fuel, electricity and other energy form consumption. Therefore, GHG emissions mitigation actions were not evaluated.

2.3 Use and Operation Phase

At the operation phase, different energy uses were considered. As mentioned before, the information included studies from UPME, DANE, SUI, that information allowed the characterization of household energy consumption including: consumption behavior, equipments; for different geographic regions and socio-economic conditions. That information allowed the calculation of a GHG emissions baseline. Energy consumption figures for the residential sector are updated permanently. Information is adjusted very frequently, affecting the mitigation potential of the actions considered and their associated costs.

The reference scenarios, considered at the operation phase, included replacement for more efficient equipments at a certain scale, consumption pattern modifications, higher levels of comfort, and fuel / energy substitution. The software used to estimate the impact of the mitigation actions was LEAP.

2.4 Design Phase

In order to evaluate the impact of mitigation actions related to technical and architectonic design, the study used the results of bio climatic simulation in HEED. It was assumed that every prototype has HVAC equipment, so every action was evaluated based on its capability of producing a positive impact in comfort and energy efficiency. For baseline calculation purposes, it was considered that residential units will have an acceptable level of comfort that means higher energy consumption (according to the criteria defined by IDEAM).

Mitigation actions included: building orientation, residential unit lay-out, interior and exterior walls isolation, solar protection elements, inner temperature, lighting and humidity control, interior finishes, natural ventilation, etc. Actions were categorized into three packages: Package 1 - passive actions in new designs, Package 2 - active actions in new designs, Package 3 - retrofitting that applies to new designs and existing buildings, some of these actions were taken from S.E. Chidiac, E.J.C. Catania, et al (2010). These packages of actions were implemented in four scenarios as seen in Table 1.

Table 1: Scenarios for mitigation actions implemented at the design phase

Scenarios	Description	Period of application	Other assumptions	Residential units implementing the measure
Short term - applies only for new projects.	A new green building code is implemented and will require Package 1 actions	2013-2018	Implemented at all new projects.	512,881
Midterm - applies only for new projects.	The construction industry embraces Package 2 actions.	2019-2024	Implemented at all new projects.	736,927
Long term - applies only for new projects.	The construction industry apply Package 3 actions.	2025-2040	Implemented only in the other than low income projects.	328,042
Midterm – applies for existing projects	Properties apply Package 3 actions.	2019-2040	Implemented for 20% of the low-income segment units and 50% of the others	10,956,865

2.5 Demolition and Decommissioning Phase

Information regarding required energy resources at demolition activities, transport and disposal of demolition waste, and recycling opportunities was unavailable or incomplete, so this phase was completely excluded from the study.

2.6 GHG Emissions forecast

In terms of building sector growing forecasts, two scenarios were defined: an inertial (BAU), where housing deficit was calculated based on the families conformation and the historic rates of residential units production, and a reference scenario that took into consideration the governmental goals of reducing housing deficit, established in the document Vision 2019, by promoting residential large scale projects. These scenarios are presented in Figure 1 for the use and operation phase.

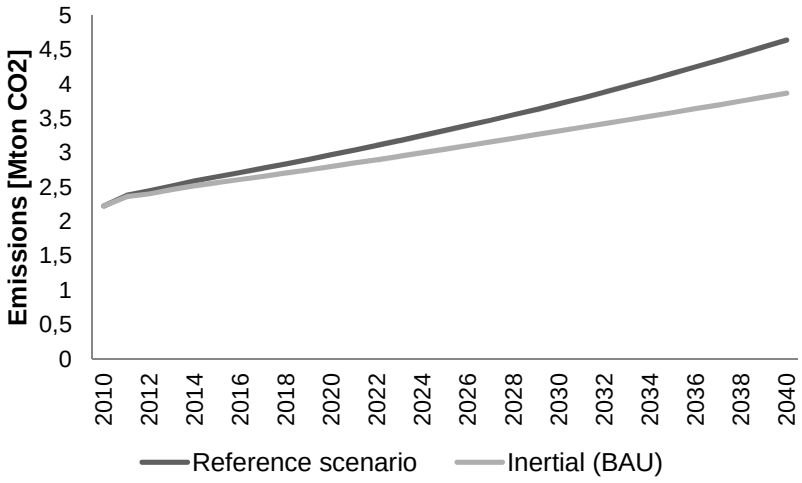

Figure 1: Inertial and reference scenarios in the use and operation phase.

Due to the limited information about the building sector explained in detail later on the article, the initial scope had many modifications, as seen in Table 2.

Table 2: Project Compliance

Activity (as defined in the initial scope)	Description	Materials Production phase	Construction phase	Use and Operation phase	Design phase	Demolition phase
1	Available data collection	Included	Included	Included	Included	Included
2	Building sector characterization	Included	Included	Included	Included	Not Included
3	Building sector Forecast	Included	Included	Included	Included	Not Included
4	Identification of available actions	Included	Included	Included	Included	Not Included
5	Abatement cost curve	Included	Not Included	Included	Included	Not Included
6	Cost / benefit analysis	Included	Not Included	Included	Included	Not Included
7	Co-benefit analysis	Included	Included	Included	Included	Not Included

3. Unavailable data and assumptions

3.1 Building Stock Composition

In Colombia, a very critical housing phenomenon is what it is called “informality” which consists on an accelerated growth of the residential stock most of the time driven by the “self-construction” sector. These residential units, generally at the low- income segment, are built with no licenses or permits, sometimes with low-quality materials and at high geological risks areas. There are very few studies about “informality” in Colombia. They indicate that the dimension of this sector ranges from 40% to 50% of the entire building stock and provided description of the technical conditions of the houses. The predominant construction technique for this segment is masonry at a maximum of three storey buildings. That information was useful to include this important category in the estimation of the stock. However, it is important to mention that the results presented at this study can be highly affected by any new consideration about this issue.

3.2 Forecast

There is not official Information about population growth through 2040, for every region included in the study. It was assumed that the population increase rate estimated for 2008-2020 will be the same for the period between 2020 and 2040. However, it is not expected that the three cities analyzed follow the same dynamic throughout the period under study.

Similarly, there is not official information about the households’ size by 2040, so it was assumed it will remain constant during the period under study. It has been observed that

families are reducing their size, so the residential units demand could be underestimated at the long run. Finally, governmental goals in terms of reducing deficit are not very clear in any of the cities analyzed.

3.3 Materials Production Phase

There is no detailed published information regarding GHG emissions of construction materials produced in Colombia, specifically, information about current production techniques and technologies, the type and amount of energy consumed in the processes, the specifications of mining equipment to extract raw materials, fuel consumption for all different transport, vehicle types, number of trips and distances, is very limited. In general, materials producers don't have current documents about the impact of GHG emission mitigation actions.

3.4 Construction Phase

Only three projects out of the 36 analyzed documented information of their energy consumption during construction. No specific activities were identified for the energy used reported. That limited the identification of GHG emission mitigation actions. It would be necessary to have a complete characterization of the heavy machinery available in Colombia in terms of technologies and energy used.

One of the construction techniques, identified by DANE as the most representative in Colombia, is the "industrialized systems". Its definition, for the building census purposes, was very imprecise; therefore, in this category were classified a very important number of buildings. For some cities industrialized means "manufactured houses", but in other regions the category was used for high rise buildings with reinforced concrete structure.

There are no records of previous large-scale studies evaluating GHG mitigation actions at construction sites. Another important difficulty was finding official information on energy consumptions due to the residential building activity. UPME reports consumption for the construction activity in general, making no difference between buildings and infrastructure.

3.5 Use and Operation Phase

At the national energetic records, there is no differentiation between household consumption per city, or region and use, so the variations of consumption patterns, due to climatic and cultural conditions, are difficult to determine. Similarly, the type of electronic equipment at the different segments of residential houses has not been fully characterized.

It would be very helpful having official current sales statistics on electric and gas equipment at every region. That would provide an indication of the increasing acquisition of equipments to improve comfort inside the residential units due to an observed increasing per capita income. Regarding the evaluation of the GHG emissions actions at the operation phase, it was very difficult to estimate the maintenance local costs associated with the implementation of the different actions, and provide a complete cost / benefit analysis.

By the end of this study, there is no an officially published study regarding energy consumption of the urban and rural residential sector, so it was not possible to use it for purposes of this study. The information that will be provided at this study will address many of the difficulties mentioned before.

3.6 Design Phase

There were compatibility issues between the climate information available and the bioclimatic simulation software. Also, It would be very useful if we had a unified local materials data base compatible with the simulation tools. The information provided by developers of some of the prototypes was incomplete in terms of their technical specifications.

The local definition of comfort or better quality conditions could be evaluated. It is necessary to propose local criteria that incorporate cultural, physiological, social and other contextualized relevant aspects that can be included in the local regulation.

3.7 Demolition and Decommissioning Phase

For this particular phase, we observed lack of information of most of the relevant issues including:

1. Buildings life span
2. Characterization of demolition or retrofit waste
3. Rates of demolition activities in the cities
4. Recycling potential and required resources
5. Amount and quality of construction waste arriving at disposal sites.

4. Conclusions

This study was the first evaluation of GHG emissions of the residential sector at a national level. According to international defined protocols, an inventory of GHG should be divided by those sectors that produce the emissions. However, emissions from the residential sector, as seen in this study, considered all building life cycle phases. The residential sector has emissions that can be allocated to industry (materials), energy transformation and distribution, waste management and transportation sector; therefore it is a transversal or crossover sector. Consequently, the results may contribute to other sectors´ figures. Seen as an end user sector, it would only contribute with the emissions associated to activities at construction sites. Through this study, we identify the importance of having studies to determine all interactions between sectors and its implications in policy and mitigation actions that can be implemented by users.

This study incorporated the preliminary results of other sectors participating in the ECDBC. This collaboration provided better insight in terms of collateral benefits and external issues of the mitigation actions identified. Through the study it was observed that there is an important necessity of evaluating different models of city and regions, and their impacts on GHG emissions together with other relevant indicators. Territory planning and configuration should incorporate GHG considerations that could have collateral environmental, economic and social benefits or requirements.

Through bioclimatic simulations, it was concluded that most of the population lives in uncomfortable conditions even at new residential developments. Temperatures early in the morning in cities such as Bogota are much lower than the comfort threshold defined by IDEAM. In cities such as Barranquilla, that have very warm weather, the comfort rate was only 10%. It was observed that the population presents a low-consumption attitude. However, it is uncertain what would happen if the country keeps on a sustained economic growing pace. It was confirmed, through this study, that Colombia has a very low emission level, 0,37% of the world's total GHG emissions. However, it was observed that doing nothing would lead us to an emission level much higher than we expect. It can be said that better social and economic conditions will necessarily represent higher household's energy consumption, so the actions proposed in this study may have a critical impact.

Having said that we have a low emission level, it is also important to mention that the emission index in terms of the Colombian GDP is very high, 0.7 Kg Co2-eq / PIB per capita in PPP (Purchasing Power Parity). Therefore, mitigation actions towards to materials production sectors and construction sites could have a positive impact in their productivity and profitability margins of those sectors. In general, actions that address energy efficiency could lead organizations to document, improve and control many processes, having a positive impact on health and safety procedures.

Mitigation actions considered at the operation stage are basically related to energy efficiency. Traditional measures such as solar water heating were included. The application of these actions may depend significantly on developers, who can have a better insight of the financial implications through the results provided in this study.

In Colombia emissions due to materials are more significant, compared to cases registered in international literature. It was concluded that the contribution of emissions at the operation stage is low. A low comfort level is one of the causes.

It was concluded that emissions increase at a low rate, because our energy is mostly produced at hydroelectric projects. However, and as said before, emissions may increase unexpectedly due to higher GDP per capita. The mitigation actions proposed could balance higher consumption. However, from 2030 it is observed that we will need to implement alternative technologies and more ambitious GHG goals to maintain our emissions at an inertial level, which can be a good scenario for international trade and negotiations.

The evaluation of mitigation actions related to technical and architectonic design show that implementing basic bioclimatic design principles have a positive impact in comfort and GHG emissions, at a very low cost. These kinds of actions, that have more improved technical

requirements, have collateral benefits in terms of economic development and competitiveness of the building sector.

There is a package of design actions that have important benefits in terms of comfort and GHG Emissions at a high implementation cost. Those actors administrating buildings and other residential assets will perceive the financial benefits of these measures. This suggests that residential development schemes such as DBO (design, build and operate) have better financial performance through the implementation of GHG mitigation actions. These mechanisms would not only contribute to the quality of residential products and energy efficiency features, but also may have a positive impact on the housing deficit.

The lack of information related to the residential sector, and identified through this study, will facilitate the formulation of future studies and research projects. For example, comprehensive characterization of the informality phenomenon in Colombia would allow the government to address many issues associated with this enormous problem, including critical social aspects.

One of the most important conclusions of this study is to confirm that the relative importance of the new houses over the entire stock is very low. So, the priority may be intervening houses at the operation phase. This confirms the importance of promoting renovation and improvements to houses.

5. Recommendations

1. It is recommended to carry out studies with wider environmental criteria. Air quality, comfort, health, and impact on water bodies are very critical issues in Colombia.

2. Incorporating urban planning topics to the discussion of GHG and other environmental issues may provide more integral solutions.

3. The informality phenomenon should not be addressed with an "elimination" approach, and it must be found a systematic and strategic mechanism of transformation and improvement of the significant portion of the building stock under this category.

4. It is necessary to establish housing observatories that provide information on the dynamics of the building stock.

Acknowledgements

The authors of this paper would like to recognize the financial support from the British Embassy in Colombia, the advices of the CCCS and the Colombian Ministry of Environmental and Sustainable Development. Moreover, the conclusions of this study were achieved due to the important labor of members from the Engineering Faculty of the Universidad de los Andes: the guidance and review provided by the Associate professor Angela Cadena and the assistance received from the Research Assistants: Katherine Ovalle, Mónica Espinosa, Camila Rodríguez and Andrea Prada.

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Analysis of the design-construction supply chain in the thermal performance of sub-tropical and tropical housing

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Abstract

Background: In sub-tropical and tropical Queensland, a legacy of poor housing design, minimal building regulations with few compliance measures, an absence of post-construction performance evaluation and various social and market factors has led to a high and growing penetration of, and reliance on, air conditioners to provide thermal comfort for occupants. The pervasive reliance on air conditioners has arguably impacted on building forms, changed cultural expectations of comfort and social practices for achieving comfort, and may have resulted in a loss of skills in designing and constructing high performance building envelopes.

Aim: The aim of this paper is to report on initial outcomes of a project that sought to determine how the predicted building thermal performance of twenty-five houses in subtropical and tropical Queensland compared with objective performance measures and comfort performance as perceived by occupants. The purpose of the project was to shed light on the role of various supply chain agents in the realisation of thermal performance outcomes.

Methodology: The case study methodology embraced a socio-technical approach incorporating building science and sociology. Building simulation was used to model thermal performance under controlled comfort assumptions and adaptive comfort conditions. Actual indoor climate conditions were measured by temperature and relative humidity sensors placed throughout each house, whilst occupants' expectations of thermal comfort and their self-reported behaviours were gathered through semi-structured interviews and periodic comfort surveys. Thermal imaging and air infiltration tests, along with building design documents, were analysed to evaluate the influence of various supply chain agents on the actual performance outcomes.

Results: The results clearly show that in the housing supply chain – from designer to constructor to occupant – there is limited understanding from each agent of their role in contributing to, or inhibiting, occupants' comfort.

Keywords: building simulation, housing, post-occupancy evaluation (POE), subtropical and tropical climates, thermal comfort

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1. Background

The minimum energy performance standards set by the Australian Nationwide House Energy Rating Scheme (NatHERS) and incorporated into the National Construction Code (NCC) aim at reducing the heating and cooling energy demand of the residential sector (NatHERS, 2011). The intent of the regulations is to enhance the thermal efficiency of the building envelope in order to minimise the necessity for using appliances to add or extract heat from the internal environment to meet particular comfort needs of occupants. Building simulation software provides a means of taking a lot of the guess work out of predicting the likely space heating and cooling requirements of any particular design in any climate zone. The software protocols adopted by NatHERS allow for a comparative evaluation of different designs in the same climate, or the same design in different climates.

The pervasive reliance on air conditioners for comfort has changed cultural expectations of comfort and social practices for achieving comfort and impacted on building forms (Healy, 2008). A major challenge facing Queensland housing is that a legacy of poor housing design, minimal building regulations with few compliance measures, an absence of post-construction performance evaluation and various social and market factors has lead to a high and growing penetration of, and reliance on, air conditioners to provide thermal comfort for inhabitants. This has placed extreme pressure on the electricity distribution system and contributed to significant rises in the price of electricity (Energex, 2011). These issues were recently explored in a specific subtropical Queensland context showing disparity between inhabitant expectations of the internal thermal environment, design intent and actual building performance (Miller, 2012a), the importance of regulation, design and ethical professional practice in achieving high performance outcomes (Miller, 2012b), the synergies between building performance outcomes and urban design (Miller, 2012c) and the value of holistic systems thinking in performance optimisation (Miller, 2012d).

A second challenge for Queensland housing is the changing climate which is expected to significantly increase the number of extreme heat days. Heat events have killed more people than any other natural hazards experienced in Australia over the past 200 years, and Brisbane (the state's capital) as already experienced significant deaths in heat events. Modelling of the mid range climate change scenario suggests significantly increased rates of mortality and morbidity than currently experienced, by the middle of the century (Price Waterhouse Coopers, 2011; Huang, Barnett, Want & Tong, 2012). Making housing, and occupants, more resilient to extreme and/or frequent heat events is an important policy issue.

The purpose of this research project is to investigate the post-occupancy thermal performance of subtropical and tropical houses in Queensland and occupants' self-reported comfort. The aim was to evaluate the role of various supply chain agents in the realisation of housing thermal performance outcomes particularly in hot summer periods.

2. Methodology

This paper's field evaluation of Queensland homes uses quantitative and qualitative methods to collate and examine multiple data sets within a clearly defined climatic and social context, a typical real-world approach of building evaluation (Leaman, Stevenson and Bordass, 2010). The methodology is based on a concept of holism that addresses both the sense of dwelling within a home and the home's environmental performance (Hyde, 2008), and the adaptive model of thermal comfort (de Dear and Brager, 2001).

2.1 Case study climates

Two climate zones were selected for the study: sub-tropical south east Queensland (SEQ) (latitude 26-28° south) and tropical Townsville (19.25^{o} south). The targeted geographic area for recruitment in south-east Queensland were Ipswich suburbs and Brisbane western suburbs, as these inland suburbs have a more extreme climate (hotter in summer and colder in winter) than eastern suburbs that benefit from the moderating effect of the Pacific Ocean. Their climate is arguably best represented, in simulation software used in NatHERS, by climate zone 9 (Amberley). The targeted areas for recruitment in Townsville (climate zone 5) were new housing developments to the north and north-west of the city centre. The typical meteorological year (TMY) climate of zones 5 and 9 are shown in Table 1, whilst the maximum annual space heating and cooling allowance for each zone is shown in Table 2.

Table 1: annual outdoor hours within temperature bands (based on TMY)

Climate Zone	% of annual hours within band				
Temperature band	<15°C	15-17.9 ^{o}C	18-19.9 ^{o}C	20-28 ^{o}C	>28 ^{o}C
Climate 9 (inland sub-tropical)	23.5%	12.9%	11.1%	45.2%	7.3%
Climate 5 (tropical)	8.2%	4.9%	6.7%	74.3%	11.6%

Table 2: star ratings and maximum space heating and cooling allowance

Climate zone	Location	Star Rating / Maximum total annual MJ/m2 for space heating and cooling								
		Star rating	1	3.5	5	6	7	8	9	10
9	Western suburbs and inland SEQ	MJ/m^2	334	132	85	67	52	38	24	12
5	Townsville	MJ/m^2	309	200	153	127	103	81	61	44
Year performance requirement incorporated into National Construction Code Regulation			Nil: typical 1990's	2003	2006	2010	Australia 2012 – 2020?			

2.1 Adaptive comfort band

Taking into account research relating to adaptive comfort, acclimatization and the bioclimatic chart (de Dear and Brager, 2001; Auliciems and Szokolay, 2007), summer and winter comfort bands were calculated for the two locations according to the following equations:

Eq. 1 $T_n = 17.8 + 0.31 \times T_{om}$(January) +/- 2.5°C (90% acceptability)

Eq. 2 $T_n = 17.8 = 0.31 \times T_{om}$(July) +/- 3.5°C (80% acceptability)

Where T_n = thermal neutrality and T_{om} = mean outdoor monthly temperature (Auliciems and Szokolay, 2007)

These adaptive comfort bands are shown in Table 3 together with the assumed room occupancy hours and heating and cooling thermostat set points applied by NatHERS. The rating scheme's summer neutral cooling temperatures are based on *effective temperature*. NatHERS also assumes a three staged approach to the achievement of comfort in summer: natural means (e.g. operating windows); mechanical ventilation (ceiling fans) and lastly the extraction or provision of heat (artificial heating / cooling). The annual adaptive comfort band is therefore taken to be 18-28°C for south east Queensland, the same range used by Tuohy et al (2001) as one approach for thermal modelling based on adaptive comfort criteria. The comfort band for Townsville is slightly higher (20 - 29°C).

Table 3: Comfort bands and NatHERS heating / cooling schedules and set points

	Summer Comfort		Winter Comfort	
Location	Adaptive comfort band	Cooling thermostat setting and time schedule	Adaptive comfort band	Heating thermostat setting and time schedule
South-east Queensland inland / western suburbs	22.0 – 27.9 °C	26.0°C **Living spaces** 2400-0700 - no cooling 0700-2400 - cooling **Sleeping spaces** 1600-0900 – cooling 090001600 – no cooling	18.2 – 23.2 °C	**Living spaces** 2400-0700 -no heating 0700-2400 - 20 °C **Sleeping spaces** 2400 – 0700: 15 °C 0700-0900: 18 °C 0900-1600: no heating
Townsville	23.6 – 28.6 °C	26.5 °C (Schedule above)	20.1 – 27.1 °C	16:00-2400: 18 °C

2.2 Case study homes

Twenty-six households were recruited in Queensland – 20 in south east Queensland and 6 in tropical Townsville. Selection criteria consisted of dwellings constructed since 2006 and dwellings smaller than the median house size (253m^2) for new Queensland homes in 2008/9. Participants were recruited through direct mail campaigns and neighbourhood newsletters in targeted suburbs, email distribution lists and word of mouth. Participation was requested for 12 months. In addition to the case study homes, some display homes in the

vicinity of the participating homes were also measured and/or simulated to gauge a comparison of existing homes with new homes.

The participating households represent a broad spectrum of household types found in Queensland: 2 adults (31%); 2 adults + 2 children (31%) and 3 adults (18%); single adult (4%); 2 adults 1 child (4%); 1 adult 2 children (4%); 1 adult 1 child (4%) and 2 adults 2 children (4%). The mean household size was 3. A quarter of participating households had children under school age. Fifty percent of the households were single income households. No households had an annual gross income of less than $50,000 and half of the households had an annual gross income greater than $110,000.

The recruited homes represent the diversity of housing that make up the Queensland housing market, as shown in Table 3.

Table 3: housing types participating in study

Feature	Year (number of houses)
Construction year	2006 (5); 2007 (2); 2008 (5); 2009 (6); 2010 (3); 2011 (5)
Building foundation	1/3 of the homes are elevated construction whilst the remainder are slab-on-ground.
Construction type	1/3 of the homes are light weight construction, with the remainder heavy weight construction (brick veneer or cement block)
House form and ceiling height	Most homes a single storey. 2.4 m ceilings for homes constructed prior to 2010. Minimum ceiling height of 2.7m for homes approved and constructed post 2010.
Air conditioner penetration	25% of SEQ had no air conditioning (consistent with regional statistics). All Townsville homes had at least one air conditioner.
Air conditioner type	Split systems were the predominant air conditioner type (46% of houses). Other types: window/wall box units (17%); ducted systems (12%)
Air conditioner placement	Four households (20% of air conditioned houses) had an air conditioner in the living room only. Of those houses with more than one air-conditioner, the majority had a split system in each of the bedrooms
Other cooling appliances	The majority of houses had ceiling fans in living areas and bedrooms.

2.3 Monitoring equipment

Temperature sensors (*Maxim ibuttons*), programmed to record every 15 minutes, were installed in the main living room (temperature and humidity); the air conditioner outlet in the main living room (temperature); the main bedroom (temperature); a second bedroom or office (temperature) and a covered outdoor living area (temperature). Recorded data was downloaded approximately every 80 – 90 days and the sensors reprogrammed for the next monitoring period.

2.4 House simulation

Where building plans were available, house designs were simulated using BERS PRO 4.2, NatHERS accredited software commonly used in Queensland for housing regulatory

purposes (i.e. a simulated energy performance certificate is one way to meet requirements for building approval).

2.5 Thermography

Eleven of the homes in SEQ and two of the Townsville homes (plus 2 display homes in Townsville) were subject to thermal imaging and air infiltration tests. The testing was carried out by a certified Building Science Thermographer and Air Leakage Technician, and member of the Australian Professional Thermography Association (AUSPTA). Thermal imaging utilised a *FLIR E50bx* camera. Air leakage testing was conducted using a *Retrotec 2000* fan, and in accordance with the following standards:

- ATTMA TS1 Issue 2 – Measuring Air Permeability of Building Envelopes
- BS EN13829:2001 Thermal Performance of Buildings
- BINDT – Quality Procedures and Explanatory Notes for Air Tightness Testing

2.6 Household surveys and periodic comfort surveys

Households participated in a general questionnaire at the beginning of the study, gathering general demographic information as well as more detailed information about their behaviour to manage their comfort during hot weather: thermostat set points, frequency and time of use of air conditioner and other comfort strategies they used (e.g. opening or closing doors and windows / window dressings; changing clothing; using fans; having a shower/bath; using a swimming pool; relaxing outside etc). Throughout the study, and particularly during periods of hot weather, participants were asked to complete a short comfort survey (via SmartPhone, online or paper) indicating their current location (e.g. which room of the house), comfort level, comfort preference and clothing level. At the end of a minimum of a full year of monitoring for all houses (March 2013) these comfort surveys will be correlated with measured temperature data from each of the houses.

3. Results

3.1 Building documentation

In general, the study revealed very poor levels of housing documentation. 50% of occupants did not have copies of their house plans (building documents) despite all homes being relatively new (generally less than 6 years old) and mostly owner-occupied. Only three households could provide a copy of the energy certificate for the house or provide information on the expected thermal performance of the house (e.g. the star rating). Sales staff at display homes were also not able to show building documentation and energy certificates in response to requests for information about the energy efficiency of the houses. The lack of building documentation raises the need for further research to understand and quantify potential risks and liabilities for both sellers and buyers.

3.2 Building Simulation

House construction plans were obtained, from owners or estate developers, for 18 of the 26 homes. Of the twenty SEQ homes, only five were designed above minimum performance standards set by regulation. All five of these homes were non-airconditioned. (Future analysis will include a comparison of all simulation files, and an analysis of simulated versus actual performance for each house). In Townsville, the 'as designed' plans of nine display homes were simulated by an independent rating assessor, and compared with the building documentation supplied by the display homes. Five of the nine homes showed a discrepancy in building rating of 2 stars or more (i.e. the display homes over-claimed the actual rating performance). Six of the display homes had under-represented the actual housing floor area in the simulation software by more than 10%, affecting the calculation of the space cooling requirement. Four of the nine homes had underestimated the cooling requirement by more than 10%. Additionally, each of the nine homes, plus an additional 10 display homes, was re-rated after incorporating 3-5 minor design improvements suggested by the independent assessor. Design improvements, and estimated costs (2012), are shown in table 4. Applying these design improvements resulted in a star rating improvement of 0.5 to 2 stars, or, in energy terms, a space cooling reduction of 16-45MJ/m^2.

Table 4: housing design improvements and associated costs (no rebates applied)

Improvement	Light colour (roof and walls)	Additional ceiling insulation	Sarking to roof sheeting	Ventilate roof space	Low-e glass
Cost	$0	$300	$1,200	$950	$1300

3.3 Temperature measurements

Preliminary analysis was conducted for several SEQ homes for the summer period February 28 – March 2, 2012. These dates presented four consecutive days where the maximum temperature was over 30°C, as recorded by the Bureau of Meteorology (BOM) at weather station 040004 (Amberley), approximately 22 km north-west of the location of these six homes at Springfield Lakes (Table 5). The table shows that whilst the diurnal temperature range of Amberley and Springfield Lakes was similar (average 14.3 and 13.6^{o}C respectively), Springfield Lakes' temperature extremes were higher than the BOM weather station. This is not unusual as housing estates are likely to suffer from the urban heat island effect due to higher radiant heat and restricted ventilation due to urban forms (building and road materials and urban layout). The data recorded in this study shows higher minimum temperatures (about 4°C) and higher maximum temperatures (about 3°C), resulting in a mean temperature (for these 4 days) 2.4^{o}C hotter than Amberley. This is significant because housing regulations are based on simulated performance according to BOM TMY data and do not incorporate the heating effects of urban forms nor the changing climate.

Table 5 Amberley BOM (and Springfield Lakes) weather observations for study period

	28 Feb 2012	**29 Feb 2012**	**1 Mar 2012**	**2 Mar 2012**

Minimum temperature (°C)	17.9 (22.16)	16.2 (21.66)	17.3(21.16)	16.9(20.66)
Maximum temperature (°C)	30.4 (35.16)	32 (34.66)	31.9(34.16)	33.2(36.16)
Mean temperature (^{o}C)	24.15(26.5)	24.1(26.86)	24.6(26.99)	25.06(27.19)
9am Temperature (°C)	26.1(25.6)	23.8 (27.17)	25.6(27.17)	25.8(27.17)
9am relative humidity (%)	73	83	72	62
3pm Temperature (°C)	29.5 (34.67)	31.4 (34.66)	31.4(33.66)	32.4(35.16)
3pm relative humidity (%)	48	46	39	39

Histograms were developed for each of monitored spaces of each house. Figure 1 shows the hours that each space in House 2 was at different temperature bands during the four days (96 hours). The green zones represent temperature bands within the adaptive comfort band (18-28°C). The graph shows that both the main bedroom and the living room experienced more hours outside of the comfort band than the external temperature.

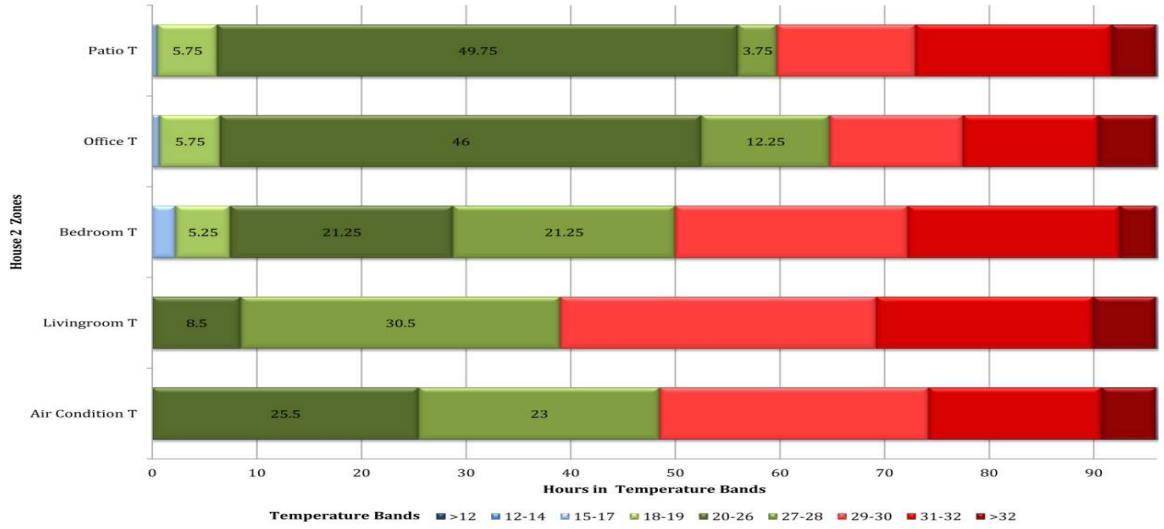


Figure 1: temperature histogram of House 2 Feb 28 – Mar 2, 2012

A comparison of the thermal performance of the main bedrooms of these six houses with each other and the external temperature (Figure 2) shows several important points. With the exception of H1 which was air conditioned overnight, none of the bedrooms cooled to the same extent as the external air. The slow rate of cooling in these rooms would seem to indicate that night ventilation / cooling strategies are either not available (e.g. poor design) or are not being utilised by occupants (e.g. not opening windows overnight). H1 was air conditioned overnight, but not during the day (8am – 5pm). The internal temperature seems to lag approximately 2 hours behind the external temperature, and continues to rise after the external temperature starts to decline. This would seem to indicate that the house design and construction properties are not being effective in limiting heat transfer into the building.

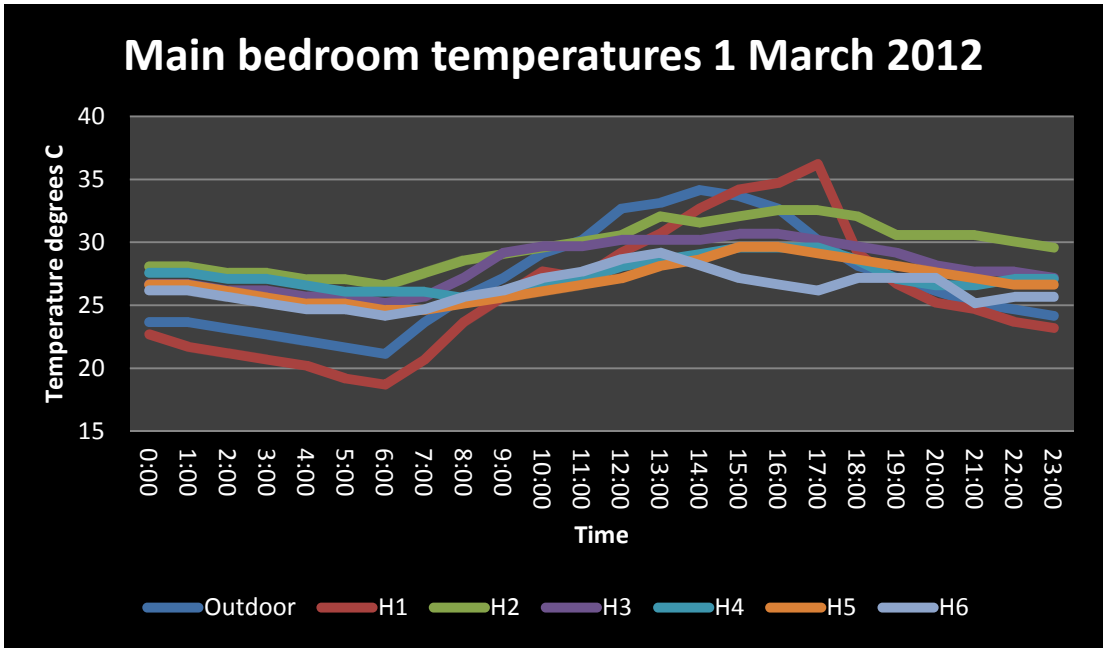
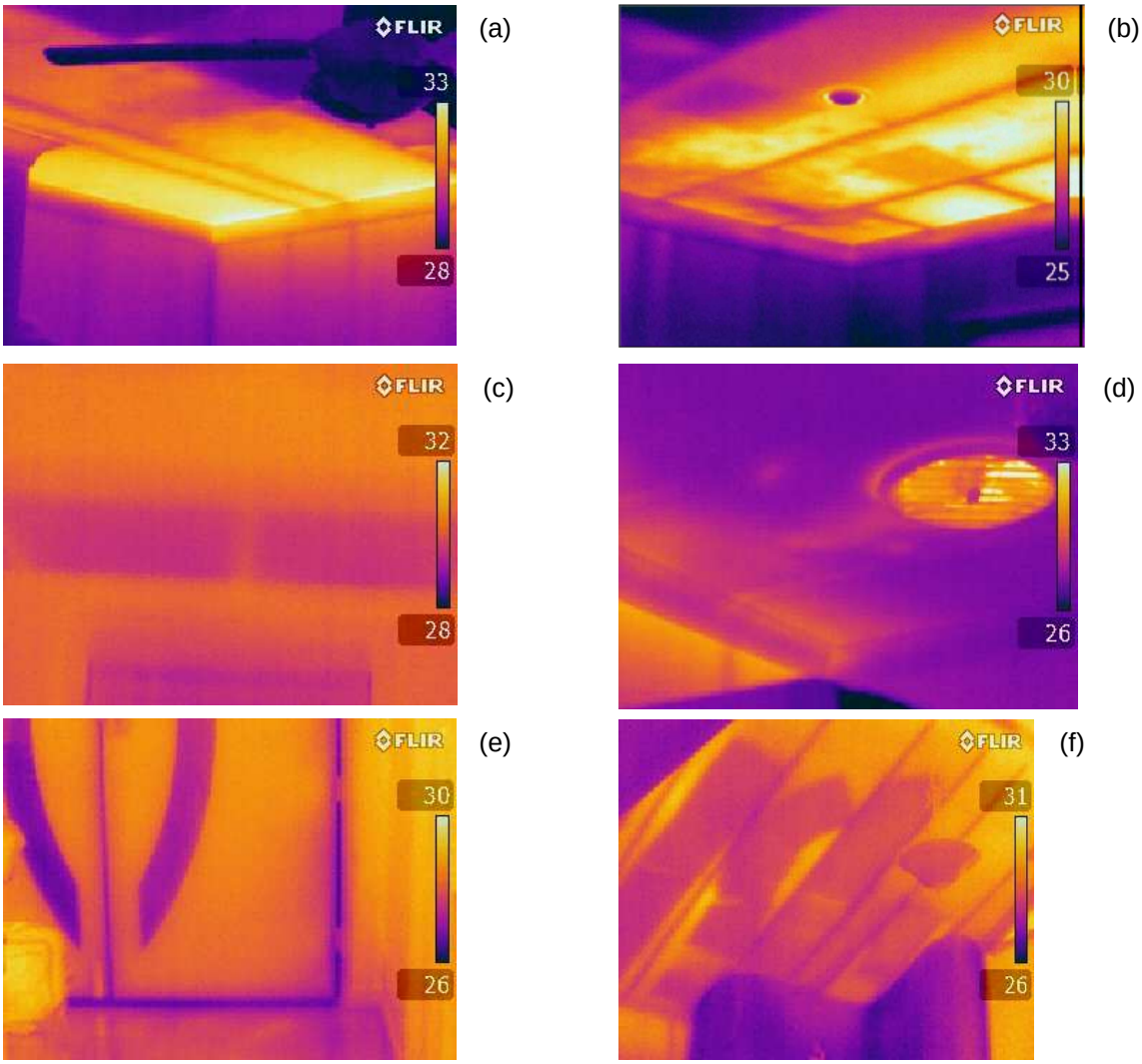


Figure 2: comparison of six bedroom temperatures March 1, 2012

3.4 Thermal imaging

All of the 15 houses and 3 display homes subjected to thermal imaging had issues that would make them non-compliant (minor to serious) with the current building regulations and impact negatively, to varying degrees, on the thermal performance of the building. The common issues relating to insulation and thermal leakage are shown in Figure 3 (a-f).



a) Poor perimeter coverage (typically 300-600mm around perimeter of internal ceilings), with particularly poor coverage in the corners of hip roof designs

b) Patchy (or absent) ceiling coverage in general

c) Entry hallways, utility rooms (e.g. bathrooms, laundry) and bulkheads often not insulated correctly (similar with garage ceilings and walls adjoining main house)

d) Poor insulation around exhaust fans (pictured), lights, roof access covers

e) Leakage around doors (pictured) and windows

f) Two of the homes revealed extensive and serious non-compliance issues that required house owners to seek restitution from the relevant builders.

Figure 3 Common insulation and thermal leakage issues

3.5 Occupant management of thermal comfort

As expected, occupants have different strategies for managing their comfort. Preliminary analysis of the occupant behaviour in six Springfield Lakes houses (section 3.3.) shows that their reported behaviour reasonably matches the assumptions made by NatHERS i.e. that occupants will manage their comfort by firstly using natural means (e.g. window operation), secondly by using mechanical means (e.g. ceiling fans) and lastly by removing excess heat (e.g. air conditioning). The cooling set points of the air conditioners, though, are not reflective of their stated decision points to operate the air conditioner, nor the NatHERS setpoints, but rather appear to be a reflection of government and utility messages that seem to convey that 24-25°C is the optimal temperature for operating air conditioners (Miller, 2012a).

Table 6 Demographic, construction and experiential variables of 6 houses

Indicator	**Range/ Variables**					
	House 1	House 2	House 3	House 4	House 5	House 6
Occupancy	Work from home	Pre-school children at home	Pre-school children at home	Generally unoccupied daytime	Shift work	Shift work
AC use during summer	Day: office & living room; whole house when hot weather predicted	Day: living room when >32°; night – bedrooms	Living room when >28^{0}	Living room when >26^{0}	Living room and main bed when >30°	Living room and main bed when>30^{0}
AC thermostat set point	24°C	24°C	24°C	24°C	25°C	24°C
Use of window openings for cross ventilation	Not in summer	Yes; close when AC on	Yes; close when AC on	Sometimes	Sometimes	Sometimes

4. Discussion

The growth in the reliance on the electricity market to provide occupant comfort by pumping out excess heat has significant economic, ecological and social implications (Miller and Buys, 2012a and c). The expected increase in extreme heat days throughout Queensland, with resultant public health impacts, adds to these concerns. The initial analysis of the results of this study (still in operation) already raises significant concerns about the efficacy of current building regulations and housing industry practices in protecting the health, wellbeing and economic investment of housing occupants and electricity infrastructure. The low level of building documentation (section 3.1), especially relating to the energy rating, appears to indicate a lack of understanding about the importance of those documents in informing potential buyers and current occupants on the thermal performance of the house and hence their own personal thermal comfort. There was no evidence revealed in this study, that occupants, builders or sales agents understood that the star rating system required for building approvals was in any way linked to occupant thermal comfort and associated risks.

The prevalence of houses designed to only meet the minimum regulated performance standards (section 3.2) would appear to add support to findings from previous research: that the housing industry (design, construction and sales) and consumers may (i) misunderstand the intent of regulations (i.e. they represent minimum performance and do not equate to adequate comfort) and (ii) have a very limited perception and experience of the potential and benefits of high thermal performance buildings (Miller, 2012 a,b). Analysis of the simulation results of the display homes in Townsville (section 3.2) showed (a) that the simulation software was poorly and incorrectly used by the industry, misrepresenting the energy performance of the houses, and (b) that the housing industry had not incorporated no cost and low cost opportunities to significantly improve the energy performance of their homes, leading to an under-representation of housing comfort potential to the many display homes visitors.

Over-representation of the thermal performance of the house designs was exacerbated by Queensland regulation that currently permits the 6 star building requirement to be met by a mixture of building envelope efficiency, covered external living area and/or solar power systems. That is, the Queensland government has permitted a level of trade-off of thermal efficiency of the building envelope, for outdoor living areas and renewable energy generation. This regulatory decision appears to have added to market confusion about the differences between building envelope thermal efficiency (and hence indoor thermal performance), occupant options for managing the indoor environment (e.g. using an outdoor living area) and options for reducing the greenhouse gas emissions from electricity consumption (renewable energy). House buyers may think they are obtaining a 6 star house (127MJ/m^2 -Townsville) but in reality the building envelope itself can be as low as 4 ½ stars (168MJ/m^2). This could be considered misrepresentation, and affects both internal thermal conditions and the operational costs to achieve occupant comfort. Added to the above concerns is the strong evidence of very poor industry practices in relation to insulation installation. Of equal concern is that each of these houses has been independently certified, supposedly in accordance with Queensland legislation, as (a) being constructed as designed, and (b) complying with the building regulations, including the energy efficiency requirements. This compliance failure needs further investigation.

The limited performance analysis of the homes to date has already revealed evidence of overheating in summer. The thermal performance of bedrooms in particular needs addressing as our early analysis shows a high use of bedrooms during daytime hours (e.g. shift workers, young children, bedrooms as offices). This multiple-functionality of rooms raises the possibility of changes to the NatHERS protocols and assumptions to treat all rooms as living spaces that are required to meet occupant comfort levels 24 hours per day, eliminating current differences between living spaces and sleeping spaces. Finally, the disparity between the thermostat settings incorporated into the NatHERS protocols and the thermostat settings recommended by government and the electricity industry needs to be resolved. The current practices appear to be contributing to market confusion.

5. Conclusion

The aim of this study was to evaluate the role of various supply chain agents in the realisation of housing thermal performance outcomes particularly in hot summer periods. Preliminary post-occupancy evaluation of twenty-six sub-tropical and tropical homes in Queensland has raised significant concerns about the efficacy of current building regulations in protecting the health and wellbeing of housing occupants, about the ability of the housing industry (design, construction and sales) to deliver minimum requirements and promote higher levels of occupant comfort, and about the way occupants respond to mixed messages (from government, electricity industry and housing industry) about thermal comfort. Data collection for this project will continue to March 2013 and further analysis is expected to contribute to a greater understanding of occupant thermal comfort in Queensland homes.

Acknowledgements: This study is made possible through funding from (i) National Climate Change Adaptation Research Facility(NCCARF) project - *A Framework for Adaptation of Australian Households to Heat Waves*; (ii) Sustainable Built Environment National Research Centre (SBEnrc) project – *Housing Sustainability Performance*; and (iii) Queensland University of Technology / Metecno trial project - *Australian Housing 2025: Maximising the Competitiveness of the Residential Construction Sector and Housing Sustainability Performance*.

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Sustainable Infrastructure Procurement in Australia: Standard vs. Project Practices

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Abstract

The Australian Government and most Australian road authorities have set ambitious greenhouse gas emission (GHGe) reduction targets for the near future, many of which have translated into action plans. However, previous research has shown that the various Australian state road authorities are at different stages of implementing 'green' initiatives in construction planning and development, with considerable gaps in their monitoring, tendering, and contracting. This study illustrates the differences between procurement standards and project specific practices that aim to reduce GHGe from road construction projects in three of the largest Australian road construction clients, with a focus on the tools used, contract type and incentives for better performance.

Keywords: procurement, greenhouse gases, road construction, sustainability, Australia.

1. Introduction

This research aims to understand an important element of current procurement practices in the Australian road construction industry. It seeks to analyse incentives that could be utilised in motivating contractors to improve their greenhouse gas emissions (GHGe) performance in construction and especially from earthworks activities in major road construction projects.

Public road authorities hold key roles in driving initiatives for reducing GHGe throughout the road construction project life cycle (APCC, 2007). The GHGe reduction goals can be achieved by means of a coherent and efficient chain of procurement processes and methods to transform sustainability and climate change policies into proactive initiatives and incentives.

Green procurement policies and practices are being adopted to varying degrees in a number of governments across the world (Brammer and Walker, 2011). For example, most

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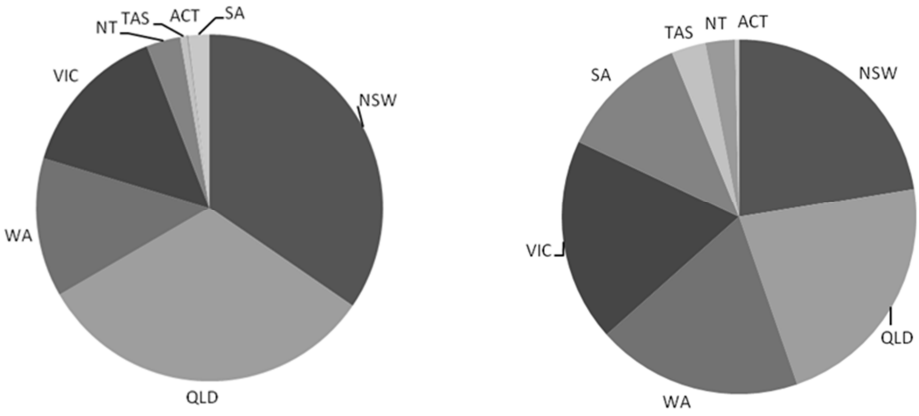
Australian state road authorities have developed advanced policies and strategies to enable reduction of GHGe through their road construction and maintenance procurement (Lehtiranta, et al., 2012).

To ensure the effectiveness of these policies and strategies it is also necessary to determine authority, communication of responsibilities, processes and resources needed to implement sustainable management systems (Tan, et al., 2011). Furthermore, well developed incentive mechanisms will aid this process by placing more emphasis on achieving a client GHGe objective than a contractual obligation alone would (Broome, 2002).

To this end, procurement practices and incentives are being developed and tested to motivate contractors to better perform with regards to their GHGe from construction activities. In fact, several Australian road authorities have responded positively both to recommendations for the inclusion of non-price criteria addressing sustainability in expressions of interest (EOI) for major contracts (Roads Australia, 2010a), as well as to the inclusion of sustainability clauses in major contracts (Roads Australia, 2010b).

However, there remains a lack of adherence to best practices, standardised procedures and guidelines for GHGe assessment and reduction in Australia's road construction industry (Lehtiranta, et al., 2012). This results in irregular application of green initiatives throughout the state project portfolio. The question as to what extent the identified green procurement standard processes are being addressed on a project-by-project basis, remains unanswered.

A deeper understanding of the differences between standard procedures and project specific practices will help road authorities to close the existing gaps to ensure the effective translation of climate change policies into feasible project delivery actions.



(a) (b)

Figure 1 (a) total road expenditure by state/territory, by level of government, 2008-09 prices — all levels of government (2008-09); (b) total road length by state/territory (2010-11) (BITRE, 2012)

This study focuses on carrying out a gap analysis by comparing standard guidelines to project specific contract documentation through case studies. The case studies take place in

three Australian state road authorities: Queensland Department of Transport and Main Roads (QTMR), New South Wales Roads and Maritime Services (NSW RMS) and Main Roads Western Australia (MRWA). These agencies are three of the four largest road construction clients in Australia, contributing to 80% of the AU$16 billion invested by the Australian government in the roads sector in 2009 and are currently responsible for more than 60% of the roads in the country in road length (see Figure 1) (BITRE, 2012).

2. Methodology

The research began with a review of international best practices literature. Based on this analysis, the authors found the most relevant categories as applicable to GHGe from earthworks in Australian road construction. These categories were used as the basis for a detailed document review. The study followed an exploratory approach and aimed to contrast the findings of an earlier study on standard green procurement policies in Australia (Lehtiranta, et al., 2012) with new findings based on project specific practices.

A four-phase evaluation framework for mapping the findings across the road construction project delivery lifecycle was adapted from Lehtiranta et al. (2012) following Matar, et al. (2008). The original lifecycle was modified to include four phases that determine the GHGe from road construction, maintenance and operation. The first phase refers to decisions made before tender at a strategic planning level. The second phase is composed of initiatives, tools and elements that affect project development decisions. The third phase is shaped by processes related to contract formation. Finally, the fourth phase refers to project implementation and entails client-side activities for achieving green procurement targets, documenting the results and learning from the project.

2.1 Data

A further revision of all available standard procurement documents was carried out to include recently released information. Documents studied in the initial review included tender standard documents, manuals, guidelines and templates. Project specific green procurement processes and tools were evaluated through a detailed document review of 12 exemplary projects provided by the three road agencies in Queensland, New South Wales and Western Australia. These case studies were chosen based on project complexity, size (large mass-haul components and over 5 km of road length) and contract type. Specific project details will not be released due to confidentiality agreements. A total of 161 documents were analysed for this study.

2.2 Research Questions

The present study has a particular focus on the GHGe assessment tools used, including considerations of the contract type and incentives for better performance, with an aim to address the following research questions:

- Have the gaps found by Lehtiranta et al. (2012) been bridged by project managers or other leadership roles during the course of specific projects?

- Are the road agencies carrying out GHGe monitoring or benchmarking efforts?
- Does the chosen contract type have an effect on effectiveness of GHGe reduction incentives and requirements?

3. Results

Table 1 shows that there have been initiatives on all levels of the project delivery lifecycle that depend on the experience of the client-side project manager. The case studies demonstrated that individual project managers occasionally place significant weight and effort on reducing GHGe emissions from road construction. It was also found that some road authorities are including clauses that require addressing GHGe reduction at a tender stage. However, this practice has not been integrated into the standard tender documents, nor has it translated into the production of best practice guidelines, thus jeopardising the longevity and industry wide implementation of such practices.

As shown in Table 1, the current standard tender guidelines do not include GHGe calculations, GHGe reduction or earthworks optimisation components applied to all projects. This could represent an opportunity for the road authorities to better balance tender competition by including recommendations for the project managers regarding pre-qualification requirements, non-financial selection criteria and contract clauses related to GHGe and earthworks optimisation applicable to all projects.

3.1 GHGe calculations and benchmarking

Most Australian road authorities have in-house GHGe calculators and many have stated their intentions to create benchmarks for GHGe and long-term goals of raising sustainability benchmarks across road construction project and enable non-price attributes to be assessed as part of tender evaluation processes.

NSW RMS for example has planned action to support the development of nationally agreed methods for measuring and benchmarking road construction GHGe and has set goals of establishing GHGe benchmarks for infrastructure construction (NSW RMS, 2011, p. 68). In fact, NSW RMS has already begun using their in-house GHGe calculator to estimate and analyse past projects (Lambous, 2011).

MRWA has recently begun collecting data from individual projects, having in prior years lacked sufficient data and appropriate systems to monitor emissions from networks and operators. To improve this information gap, some actions under consideration are the comparison of a benchmark to the tender documents with subsequent comparison to the actual GHGe from projects, measurement of GHGe from all contracts or at least a sample (MRWA, 2011, p. 7).

Table 1: Procurement processes implemented by QTMR, NSW RMS and MRWA on a project by project basis vs. standard guidelines.

Project delivery lifecycle		Procurement Processes	Project Specific			Standard Tender Documents		
			Queensland	New South Wales	Western Australia	Queensland	New South Wales	Western Australia
STRATEGIC PLANNING PHASE	Prequalification Requirements	GHGe/carbon calculations						
		GHGe reduction plan			√			
		Mass-haul optimisation						
		Sustainability Rating						
PROJECT DEVELOPMENT PHASE	Tender and contract requirements and incentives	Carbon calculation (road construction)		√	√			
		Scope comparisons based on calculations						
		Mass-haul optimisation plan required/encouraged		√				
		Project plan revision based on GHGe opportunities	√					
		GHGe reduction plan required		√	√			
		GHGe reduction as qualification criteria						
	Non-cost criteria for contractor selection	GHGe/carbon calculations						
		GHGe reduction plan			√			
		Mass-haul optimisation						
		AGIC Sustainability Rating						
PROJECT CONTRACT FORMATION	Contract requirements and/or incentives	Mass-haul optimisation		√				
		Environmental audit	√	√	√	√*	√*	√*
		Fuel consumption monitoring			√			
		Shared costs of emission reduction or offset		√				
		GHGe reduction plan			√			
		GHGe/carbon calculations						
		Sustainability Rating						
PROJECT IMPLEMENTATION PHASE	Project monitoring and control	Database of carbon calculations (BENCHMARKING)						
		Fuel consumption monitoring			√			
		Other GHGe reporting						

* Part of Environmental Management System requested by National Pre-Qualification System for Civil (Road and Bridge) Construction Contracts (PQS) (Austroads, 2004).

Although QTMR has not specifically stated its intention to carry out benchmarking efforts for GHGe from road construction projects, according to the Queensland Government Chief Procurement Office (QGCPO) *Procurement Guidelines* professionals should identify the key sustainability issues, risks and opportunities, as well as the associated 'good and best practice' benchmark, which will assist in defining the desired level of sustainability performance (QGCPO, 2009).

At a national level, the Transport Authorities Greenhouse Group (TAGG) issued the Greenhouse Gas Workbook in 2011. This workbook outlines indicators to be monitored, default factors for missing data, and a step-by-step checklist for calculating GHGe from road construction projects (Dilger, et al., 2011).

The TAGG workbook encourages monitoring of fuel (type and volume consumed by construction vehicles), material type and quantity hauled, haulage distances and other indicators that can be monitored during road construction (Dilger, et al., 2011).

NSW RMS is currently using the TAGG workbook in the pre-tender environmental impact assessment stage to estimate the project GHGe and to propose mitigation initiatives to reduce emissions (Sanchez and Hampson, 2012a). However, this has not been introduced into the standard procurement guidelines as yet.

Some TAGG members are in the process of adopting Carbon Gauge, a GHGe calculator developed by VicRoads (Victoria state road authority) and based on the TAGG workbook (Sanchez and Hampson, 2012a).

3.2 Non-financial criteria and contract type

The more traditional contract types studied, namely construct only, and design & construct (D&C), presented very few examples of non-financial criteria related to: GHGe; mass-haul/earthworks; and fuel usage/planning used for contractor selection.

Although these types of projects require an *Earthworks Plan* (EP) to varying levels of detail, this is usually requested as a post-contract award requirement (all except for one project). Furthermore, GHGe reduction initiatives seem to be requested on a project-by-project basis, based on the experience of the project manager, and are to be addressed through the *Contractor Environmental Management Plan* (CEMP), generally delivered before the start of the works but following the contract award.

It was found that documents of the construct only projects studied from NSW RMS contain more detailed clauses with GHGe and fuel consumption impact than D&C projects. The D&Cs from MRWA require initiatives to reduce GHGe and fuel consumption as standard practice through the request for proposal (RFP).

It was also determined that, although most projects did not present any specific requirements of GHGe reduction considerations for the design, in many cases the mass haulage was a key consideration during pre-tender design selection.

Under alliance projects, some RFPs mentioned minimisation of environmental impact and superior environmental and sustainability performance. However, these documents were rather general and gave little guidance to the contractors on how to address such issues.

However, the New Perth Bunbury Highway (NPBH) project from MRWA carried out under an alliance model does not present any GHGe criteria expressed in the RFP, although the selected contractor did produce a GHGe analysis based on a client request which was publicly available (GHD, 2008). This project was also used as a case study for infrastructure planning and delivery best practices, where the Australian Department of Infrastructure and Transport (ADIT) highlighted that the early involvement of contractors was key to enhancing the chance of success of the project (ADIT, 2012a). In another alliance project studied, the project team was considering climate change impact and GHGe as a core part of the project delivery planning which led to the production of a climate change assessment during the planning stage. This included detailed activities and recommendations to address GHGe from construction activities.

4. Discussion

The need for standard monitoring techniques and requirements that assure accurate GHGe measurement for construction operations, serving for later benchmarking and definition of specific Key Performance Indicators (KPIs) has been noted in previous studies (Sanchez and Hampson, 2012b). Lehtiranta, et al. (2012) also highlighted the need for requirements for detailed earthworks and emissions plans that can be used to measure performance through on-site monitoring of KPIs.

Broom (2002) suggests that performance indicators that can be used as incentives must be realistic and relevant to the project, reflect the state of the technical definition and be easily administered. We propose the integration of requirements for contractors to estimate and subsequently monitor their total fuel consumption and weighted haulage distance (haulage distance per unit volume of material transported) into the procurement process. These two components have a direct impact on GHGe from earthworks in road construction (Hughes, et al., 2011), can be monitored and recorded on-site without the need of costly new infrastructure, and the client could use this information to establish benchmarking systems or weighted non-financial criteria to be used for bid comparison, evaluation and conditional financial incentives.

Alternatively, the use of GHGe calculators could facilitate the comparative analysis of road-building materials and techniques proposed by the contractors on their tenders with respect to the climate change targets of the issuing road authorities (Zammataro, 2010). While the use of benchmark data in negotiation and performance management would be of significant benefit in evaluation and negotiation (ADIT, 2012b).

The inclusion of GHGe estimation as part of the standard tender documentation requirements, using either in-house or internationally available GHGe calculators, would provide a quantifiable parameter that can be directly compared between bids and industry benchmarks. If the implementation of such criteria were enforced, road agencies would also

need to include clauses in their standard contracts that would allow them to monitor and benchmark GHGe from earthworks, particularly in projects with large haulage components.

Additionally, practitioners interviewed by the ADIT (both clients and contracting parties) were reluctant to the idea of nationally standardised contractual arrangements. However, "*tenderers and clients across all jurisdictions agreed that better design definition in the planning and procurement phases would offer significant benefits to traditional contracting; particularly in construct only projects"* (ADIT, 2012b). More detailed requirements for the mass-haul/earthworks plan and best practice guidelines with sustainability and GHGe components could therefore promote minimum levels of project planning and a common language that can be used by both clients and tenderers in tender documentation.

The former recommendation could be integrated into the procurement practices by using the existing TAGG Workbook to combine the benchmarking and best practices development efforts already considered by several road agencies.

Another noteworthy finding was that non traditional contract types that stipulate the involvement of contractors during the earlier stages of the project planning, design and funding, namely alliance and early contractor involvement (ECI), seem to be more likely to serve as useful procurement models for promoting improved environmental outcomes and potentially, GHGe reduction.

The fact that mass haulage was a key point for the pre-tender design selection in many of the case studies analysed reinforces the idea that contract models that allow for more flexibility in the design can in itself be an incentive for the integration of earthworks planning in the design phase due to lower cost with GHGe reduction consequences.

Existing examples in Australia of successful ECI contracts include the MRWA Great Northern Highway Kimberley ECI Project (AU$116 m value, 2007-2009), where the delivery model allowed the maximisation of synergies with the contractors in a complex geographical area (Earth Mover & Civil Contractor Magazine, 2010).

Under this model, the team was able to simultaneously consider social, environmental and economic factors to ensure project works were consistent with sustainability principles. This focus on sustainability led to the inclusion of sustainability incentives in the consequent D&C contract (Earth Mover & Civil Contractor Magazine, 2010), where MRWA included sustainability performance bonus clauses, translated into KPIs such as quantity of concrete wasted and fuel consumption (MRWA, 2007). The project was successfully delivered on schedule in December 2009 and within budget (Earth Mover & Civil Contractor Magazine, 2010)

QTMR also provided an exemplary ECI where the private sector was involved at a stage where the potential to influence the design was limited. However, even minor changes to the geometry and methods of works led to estimated savings of over AU$7 million from avoided mass-haul (600,000 m^3 avoided at AU$12/$m^3$) and approximately AU$100 million due to the cost reduction per cubic metre based on conservative estimates (5.6 million cubic metres

earthworks with a saving of AU$18/m^3) (QTMR, 2012). The collaborative model used also provided benefits in terms of time, risk allocation and conflict avoidance.

Other countries such as The Netherlands have already opted to involve contractors before the route is defined and Environmental Impact Assessments (EIAs) have been carried out (van Valkenburg, et al., 2008). Through this approach, the Rijkswaterstaat (Dutch road authority) has stopped placing tenders with “ready-made” designs focusing on price and has now shifted to open and functional questions during the planning consent. At this stage the contractor still has sufficient freedom in their design and choice of construction method (van Valkenburg, et al., 2008).

Alternatively, because Alliance contracts are based on best value primacy (Walker and Hampson, 2003), this model has the potential for promoting innovation and achievement of more positive outcomes in relation to GHGe and other sustainability issues (Gollagher and Young, 2009). However, it is not clear if the GHGe targets of the clients are included in the partner selection criteria, jeopardising the achievement of the client goals in this area.

Furthermore, because reward and risk allocation mechanisms are determined after alliance partners have been selected (Walker and Hampson, 2003), it is possible that the specific contractual clauses and project objectives regarding earthworks optimisation, GHGe and fuel consumption are determined after the alliance is formed and therefore are not shown on the RFPs. Furthermore, any contractual incentive should also be accompanied by sound monitoring and control systems in order to ensure success relative to quality performance in construction (Chua, et al., 1999).

5. Conclusions

The findings of this research confirm the following gaps found by Lehtiranta et al. (2012) on Australia’s current green procurement practices:

1) lack of established widely used best practices, standardised procedures and guidelines for GHGe assessment and reduction

2) lack of integration between GHGe assessment and management mechanisms including platforms for inter-disciplinary collaboration

3) scarcity of incentives for GHGe reduction in contracts

4) incomplete monitoring, control, and review methods

5) lack of focus on mass-haul optimisation as an environmental management area.

However, the study also shows that project managers are closing these gaps on a project-by-project basis and there is a need to translate these isolated efforts into best practice guidelines and standard procurement documentation for industry wide adoption and improvement.

An area of opportunity found was the *Contractor Environmental Management Plan* (CEMP), which is required in all three states. The CEMP could be used as a tool to motivate better GHGe performance by including carbon emissions in the *air* or *atmospheric* pollution categories and integrating these clauses throughout the procurement process.

Another area of opportunity is monitoring standard techniques and requirements that assure the accurate GHGe measurement of road construction operations that could later be used for benchmarking and KPI definition. There is also a lack of requirements for detailed earthworks and emissions plan. These documents could be used to assess contractor performance through on-site monitoring of KPIs.

It was also concluded that procurement models that stipulate the involvement of contractors in earlier phases of a project can potentially help to better integrate decisions made during the planning phase with the construction activities, and improve sustainability outcomes while achieving other project benefits.

Further research is needed to deepen the understanding of common project practices including contractor perspectives. Therefore, future research should analyse a larger set of case studies from different localities to evaluate the internal contractor processes, drivers and barriers for GHGe reduction initiatives in the road construction industry. Moreover, a comparison of Australian and international best practices would illustrate further possibilities for bridging the current green procurement gaps.

6. Acknowledgements

The authors acknowledge the funding and support provided by Australia's Sustainable Built Environment National Research Centre (SBEnrc) and its partners (2010-2012). Core Members include Queensland Government, Government of Western Australia, John Holland, Parsons Brinckerhoff, Queensland University of Technology, Swinburne University of Technology, and Curtin University.

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Information Provision and Communication Strategies for Improving Earthquake Risk Mitigation

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Abstract

The severity and economic implication of the recent Canterbury earthquake disaster in New Zealand and continual reticence of building owners living in earthquake-prone buildings showed that property owners are unwillingness to adopt appropriate earthquake risk mitigation measures. This unwillingness suggests that the earthquake mitigation information provided and communication strategies may have been ineffective for making informed mitigation decision. This study examines the relevance of mitigation information provided and the efficacy of existing and emerging communication strategies for making informed risk mitigation decisions. Data were collected using structured questionnaire from property owners of earthquake-prone buildings. This study identifies seventeen significant strategies, clustered under five categories that may contribute to successful earthquake risk mitigation in New Zealand, specifically for retrofitting earthquake-prone buildings. These strategies include the provision of a unified safety assessment information system, mandatory disclosure of seismic risks and the use of novel approaches such as the social networks, mass media, reiterating past earthquake experiences and public recognition of pro-social mitigation behaviour are paramount. Subsequent review and adoption of these strategies could communicate relevant risk information to all stakeholders involved in earthquake risk mitigation, leading to informed risk mitigation decisions.

Keywords: Earthquake-prone buildings (EPBs), Earthquake risk information, Communication strategies, Mitigation decisions

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1. Introduction

Given the recency and severity of the Canterbury earthquakes swarm in New Zealand since 2011, it is not surprising that seismic hazard and disaster is a frequent topic of conversation among the residents, visitors and media. According to Paton and Johnston (2006), frequent thought, discussion and information receipt about earthquake risks is necessary to propagate the awareness of earthquake risk and assist people to make decisions and work towards the adoption and implementation of appropriate risk mitigation measures. Likewise, the availability of relevant earthquake mitigation information, and the means of communicating and disseminating this information to property owners and the public, are significant parameters that can be used to influence desired decisions regarding risk mitigation (Keeney and Winterfeldt, 1986; MacGregor *et al.*, 2008). However, the continual reticence of building owners living in earthquake-prone buildings (EPBs) to retrofit their EPBs suggest that the present risk mitigation information provided and communication strategies are ineffective for enhancing their decision to improve the level of earthquake risk mitigation in New Zealand. The aim of this study is to investigate relevance of risk mitigation information provided, and the effectiveness of existing and emerging communication strategies necessary to enable informed risk mitigation decision regarding seismic rehabilitation of EPBs.

2. Earthquake Risk Information and Communication Strategies

The provision and communication of adequate risk information is an important parameter when attempting to explain how people make seismic risk mitigation decision because of its primary objective of providing and sharing information about the hazard, associated risks and appropriate mitigation measures (Paton, 2006). According to Neuwirth *et al.* (2000), the provision of appropriate information about seismic risks and the efficacy of mitigation measures should produce greater rates of willingness to adopt protective measures. Likewise, Lindell and Perry (2004) explained that in order to yield desired outcome of improved earthquake risk mitigation, an effective natural hazard information provision and communication program should consider good quality of information provided, credibility of information source, means of communication and the management of the whole communication process.

Earthquake risk information can be communicated through both informal and formal channels. Several traditional approaches such as printed brochures, warning letters to property owners, regulatory requirements and penalties have been used in communicating earthquake risk information to the public. According to Whitney *et al.* (2004), conventional methods of risk communication have little influence because they are perceived to lack novelty, validity or relevance. Mileti and Fitzpatrick (1993) suggested that conventional methods of risk communication can be improved by using an alternative novel approaches for communicating earthquake hazard and risk information. In addition, previous research suggested that in order to generate an effective response from risk communication, the distribution of earthquake preparedness information and materials should include a mix of passive and proactive approaches that utilizes both traditional and emerging information technologies such as reiterating past earthquake experiences within community networks,

using mass media and policy entrepreneurs (Bourque *et al.*, 2010; Egbelakin *et al.*, 2011). Moreover, Paton and Johnston (2006) established that an effective risk communication strategies implemented at the community level will likely led to risk personalisation that allows people to deliberate mitigation plans at the community level and this could lead to preparedness and are likely will enhance seismic risk mitigation decisions. However, Lindell and Perry (2004) found that providing and communicating earthquake risk information does not necessarily motivate people to adopt mitigation measures or divert significant efforts into assessing alternative sources or channels for providing risk information. A significant portion of people preferred to remain ignorant about natural hazards such as earthquake because of a failure to personalise the risk, when poor quality of information is provided, perceived credibility of information source, inadequate dissemination strategy or perceived incapability of making use of additional information (Lion *et al.*, 2002).

Perception of credibility to the source of risk information impacts seismic mitigation decisions (Whitney *et al.*, 2004). Earthquake risk information is provided through various sources, which include governmental authorities, media, peers, friends and family, and are judged in terms of their perceived credibility. The credibility of information source comprised of three primary characteristics; expertise, trustworthiness and past reliability in communicating risk information (Perry and Lindell, 1990). Generally, governmental authorities such as local council or government officials and earthquake risk mitigation professionals such as engineers are commonly considered as credible source of information (Mileti and Sorensen, 1988). Mass media and peer contacts have also been identified as sources that are perceived as credible. However, there is a growing awareness about the impacts of the media in communicating hazards information to the public (Scanlon, 2009). Likewise, inconsistency and disparity in risk information provided by the different risk provision sources reduce its credibility and quality of information and the ability of the information to assist in making constructive mitigation decisions (Poortinga and Pidgeon, 2004; Paton, 2007). In addition, existing research studies have suggested that using adequate risk communication approaches with sound dissemination plan to enhance earthquake risk mitigation and implementation has an advantage of simultaneously improving people's perception regarding earthquake probability and severity, fatalistic mind sets and improving trust in the efficacy of seismic design techniques for reducing earthquake risks (Paton, 2007; Smith, 2009).

A key issue in earthquake risk mitigation concerns information acceptance, whether existing information provided is relevant and have been effectively communicated to generate enough concern and response that could enhance the likelihood of adopting mitigation measures. Despite the volume of research work on risk information provision and communication, there remains a lack of clarity regarding the provision of relevant information for making informed decision, and the efficacy of communication strategies for increasing the likelihood of property owners' adoption of adequate mitigation measures. An investigation of novel risk information provision and communication approaches such as using the social media, public recognition, reiterating past survival stories in social events, regulatory requirements and risk communication process management, is necessary highlight the efficacy of such novel methods for improving earthquake risk mitigation.

3. Research Method

This paper reports a part of the research findings of a recently completed study undertaken to examine the relevance of earthquake mitigation information provided to property owners, and the effectiveness of existing and emerging communication approaches necessary to facilitate informed risk mitigation regarding seismic rehabilitation of EPBs. Twenty-five factors that include type of risk mitigation information provided, sources of information and communication strategies were operationalised from literature and preliminary interviews, and their level of usage and effectiveness for making appropriate risk mitigation decision was tested in fieldwork.

A cross-sectional survey research design was adopted and data were collected using an online questionnaire through Survey-monkey portal. The population frame of this study comprised identified owners of EPBs. The sampling frame comprised owners of EPBs identified after the enactment of the Building Act (2004) and who may have and have not retrofitted their EPBs, but have all been notified by their local TAs of their buildings vulnerability to seismic disasters since 2004. The sampling frame indicates that responses used in the research were directly from the study population. Respondents were mainly asked to indicate on a five-point likert scale, the extent to which mitigation information provided as well as existing and emerging communication strategies could or have helped them to make informed risk mitigation decisions. The questionnaire was pre-tested in a pilot survey before an industry wide survey was conducted. The data were entered into SPSS for analysis. Preliminary analysis conducted such as analysis of missing data and normality test was conducted for data clean-up and to fulfil normality and goodness of fit criteria. Kolmogorov-Smirnov test conducted showed that all responses to the variables are normally distribute with a p-value larger than 0.05. The mean of each variable was compared by conducting an independent sample t-test (Compeau and Higgins, 1995). A test value of 3 was used to test whether the means were significantly different from a mid-point of 3 on a Likert rating scale of 1 to 5. T-tests were used to identify effective information provision and communication strategies that are likely to enhance building owners' decision to retrofit their EPBs. A relevant mitigation information, source of information and communication strategy is considered significant when $p<0.05$. Industry experts reviewed the findings for confirmation and comments to establish data validity.

4. Sample Characteristics

A total of 510 online questionnaires were administered and 208 surveys were completed representing a response rate of 40.8%. This response rate compares favourably with other studies in earthquake risk management (Ronan *et al.*, 2001; Lindell *et al.*, 2009). The analysis of the questionnaire provides a summary of the respondents' profile and EPBs projects undertaken. A summary of respondents' demographic information and a selected retrofitted EPB projects were provided in Tables 1 and 2. Information summarised in Tables 1 and 2 suggest that most of the respondents are familiar with seismic risk mitigation decision and retrofitting of EPBs projects. For instance, the respondents' geographical distribution indicates that people residing in low to moderate and high risk earthquake prone regions are well represented in the study. Also, the majority of the projects reported are

located in high-risk regions (89%). In addition, most of the buildings have recently been retrofitted; 52% were retrofitted less than a year ago and 32% were strengthened between the last two and four years. Hence, the respondents profile and selected retrofitted EPBs projects indicate that they are well experienced on the subject matter and in a position to provide reliable information.

Table 1 Respondents Profile

Category	Frequency	%
Respondent's Location		
Auckland	46	23
Wellington	63	31.5
Christchurch	51	25.5
Gisborne/Napier	19	9.5
Others: Low seismic risk region	16	8
Others: High seismic risk regions	5	2.5
Personal Experience of an Earthquake Event		
No	*63*	*31*
Yes	*137*	*69*
Years of experience in EPB Projects		
<5years	53	26.5
6-10years	21	10.5
11 - 15 Years	19	9.5
16 - 20 Years	12	6
21 - 25 Years	23	11.5
> 25 Years	26	13
Not Applicable	46	23

Table 2 Characteristics of EPB projects handled by respondents

Category	Frequency	%
Building location		
Auckland	13	6.5
Wellington	60	30
Christchurch	52	26
Gisborne/Napier	38	19
Others: low seismic risk region	9	4.5
Others: high seismic risk regions	28	14
Period of construction		
Prior to 1935	96	48
After 1935	44	22
After 1964	42	21
After 1976	15	7.5
After 1992	2	1
Prior to 2004	1	0.5
Building's historic registration category		
Heritage Category I	75	37.5
Heritage Category II	82	41
Unsure	43	21.5
Building category		
Residential	8	4
Commercial	104	52
Mixed-use (commercial and residential)	51	25.5
Institutional (churches, schools)	28	14
Others	9	4.5
Most recent retrofit period		
<1 year	104	52.0
2-4 years	65	32

5-7 years	18	9.0
8–9 years	6	3.0
>10 years	7	4
Seismic retrofit performance level		
<10% NBS	6	3
10-33%	35	18
33-67%	48	24
67-100% NBS	55	27
Unsure	44	22

5. Significant Earthquake Risk Information Provision and Communication Strategies

Twenty-five factors that include quality of information provided, communication strategies and source of information were investigated, and seventeen were found significant for improving seismic retrofit decision and implementation of EPBs. These seventeen factors were further clustered under five categories (see Table 3). Significant earthquake risk information provision and communication strategies within the context of the research investigation are discussed below.

Table 3: Significant Earthquake Risk Information and Communication Strategies

Code	Information Provision and Communication Strategies	Mean	t- value	p-value
Source of Earthquake Risk Information (SRI)				
SRI1	An earthquake risk mitigation Exhibition	2.01	2.76	0.08
SRI2	Earthquake risk Professionals (e.g. engineer/architect)	2.85	1.94	0.07
SRI3	Government officials	3.96	3.36	0.05*
SRI4	Family/friends	4.13	3.12	0.00*
SRI5	Mass Media	3.73	2.51	0.02*
SRI6	Lessons learnt from past earthquake experience	4.88	3.18	0.01*
Quality of Earthquake Risk Information Provided (QIP)				
QIP1	Provision of sufficient information about exposure to earthquake risks and efficacy of mitigation measures	3.01	4.28	0.04*
QIP2	Providing information about benefits of retrofitting	4.88	3.32	0.00*
QIP3	Information provided about earthquake risks and mitigation was easy to understand	3.09	4.88	0.20
QIP4	Provision of a unified safety assessment information system	4.21	4.28	0.00*
Using Regulatory Requirements (RR) for dissemination information				
RR1	Implementing a building grading system	2.79	3.12	0.00
RR2	Mandatory disclosure of building seismic risks	3.91	3.60	0.00*
RR3	Comprisal of seismic risks in property valuation assessments	4.36	2.11	0.04*
RR4	Sanctions for owners not non-retrofitted EPBs	1.88	1.02	0.08
Risk Information Dissemination and Communication strategies (RIDC)				
RIDC1	Building Earthquake risk notice received from TA	2.03	2.51	0.61
RIDC2	Using social media to disseminate risk information	4.24	3.41	0.00*
RIDC3	Intensify the use of mass media	3.58	2.09	0.04*

Code	Information Provision and Communication Strategies	Mean	t- value	p-value
RIDC4	Reiterating of past earthquake stories and coping strategies	4.01	3.15	0.00*
RIDC5	Introduction of public recognition award	3.79	2.74	0.01*
Risk Communication Management				
RC1	Form of communication	2.88	2.23	0.10
RC2	Frequency of communication	2.39	6.55	0.06
RC3	Quality of communication among stakeholders	4.79	2.74	0.01*
RC4	Quality of communication system	3.61	4.28	0.00*
RC5	Working relationship with owner	4.89	3.55	0.00*
RC6	Extent of managing public image and public relations	3.79	2.74	0.01*

*Significant information provision and communication strategies at 0.05 sig. level

5.1 Source of Earthquake Risk Information

Source of earthquake risk information could significantly influence property owners' decision to adopt appropriate risk mitigation measures. The results presented in Table 3 show four significant sources of earthquake information that would likely influence how property owners make risk mitigation decisions regarding their EPBs. These significant information sources are government officials (SRI3), family/friends, (SRI4), mass media (SRI5) and lessons learnt from past earthquake experience (SRI6). Earthquake risk information provided by government officials, media, family/friends and from lessons learn from past earthquake experience are perceived as accurate and would likely enhance building owners' decision to adopt appropriate risk mitigation measures. This finding shows that respondents assigned a higher level of credibility to these information sources implying a higher level of trust to these information sources. However, it can be plausibly concluded that a lower level of credibility and trust is assigned to risk information provided by earthquake risk professionals such as engineers, which could negatively influence seismic mitigation decisions. This low level of credibility may be related to building failures in the Christchurch earthquake disaster where newer buildings supposedly designed to new seismic standards were significantly damaged. According to Lindell and Perry (2004), when low credibility is accorded to hazard related professionals, people tend to search for other sources of risk mitigation information such as the media and family/friends. Thus, justifying the significance of the positive mean rating accorded to the media and family/friends in this study. Furthermore, the results show that the respondents accepted information gained through past earthquake experience without questioning, but does not intend to use any of this information in near future. The acceptance of information gained from past experience and coping strategies implied that human cognitive and decision-making processes relies more on association and familiarity with earthquake risk issues. This finding emphasise that personal experience produces more vivid memories and testable facts of the disaster event than a pallid description of events or mitigation approaches.

5.2 Quality of Earthquake Risk Information Provided

Analysis of the quantitative data presented in Table 3 provides ample evidence on the relative impact of good quality of risk information on mitigation decisions. Three main factors necessary to maintain a high level of quality earthquake risk information are; providing sufficient information about exposure to earthquake risks and the efficacy of mitigation measures (QIP1); providing information about benefits of retrofitting EPBs (QIP2); and the provision of a unified earthquake safety assessment information system (QIP4). The provision of sufficient information about a hazard and potential mitigation measures increases a person's knowledge about the hazard, influence the level of risk perception and could consequently influence the adoption of adequate mitigation measures. In addition, the results indicate that the when potential benefits are adequately communicated, it may lead to a higher level of perceived benefits ascribed to an expected decision outcome, consequently, leading to higher chances of adopting risk mitigation decision. Therefore, property owners risk mitigation decisions can be promoted by highlighting potential benefits from adopting mitigation measures such increased safety, property value and possible future savings in a future earthquake event. This finding assert several postulations of expectancy-valence models that emphasised the role of perceived benefits in decision-making (Steel and Konig, 2006). Moreover, the findings from the study suggest a lack of provision for a unified earthquake risk information system, where all the stakeholders intending to use the information can access it. The availability of information system would provide quick access to earthquake risk information to property owners and all the stakeholders.

5.3 Regulatory Requirements

Two key potential regulatory requirements emerged in this study with the possibility to effectively facilitate property owners' decision to adopt adequate mitigation measures. These requirements are mandatory disclosure of building seismic risks (RR2) and comprisal of seismic risks in property valuation assessments (RR3) (see Table 3). Mandatory disclosure of seismic risks and comprisal of seismic risks in property valuation assessments through relevant policies would ensure that owners and property retailers are obligated to disclose a building's seismic risk to prospective buyers or tenants at the point of sale or letting in the property market. The increased awareness may lead to informed market stakeholders and consequent improvement of the EPBs market value assessments. Thus, an increase in the property value would provide financial returns at the point of sale or letting to the owners of retrofitted EPBs, leading to the augmentation of their perceived benefits from implementing seismic mitigation measures as discussed in Section 5.2. It is not surprising that the implementation of a building grading system and sanctions for owners of non-retrofitted EPBs as shown by the results is insignificant. The purpose of such a grading system is to "raise awareness of seismic risk issues and ultimately induce voluntary adoption of beyond-code seismic performance standard imposed by the legislation. The grading system involves displaying a letter grade such as A to E on an EPB to denote the level of earthquake risk in the building. Some of the interviewees during the preliminary interview mentioned that the implementation of such a grading system is likely to result in a series of judicial cases where the grading and sanctions will be disputed.

5.4 Risk Information Dissemination and Communication Strategies

Findings from this study show that existing earthquake risk communication strategy has mainly by formal issuance of notice letters by the TAs to property owners and the distribution of brochures, which have been ineffective enhancing owners' decisions to retrofitting their EPBs. To successfully disseminate and communicate earthquake risk information, the findings reveal four novel approaches using social networks such as twitter and face book (RIDC2), mass media (RIDC3), reiterating past earthquake experiences and coping strategies in social functions (RIDC4) and public recognition of pro-social mitigation behaviour (RIDC5). This research finding demonstrated that these novel four approaches can be used to increase the salience of seismic risk by providing accurate information to the public regarding the extent of risk exposure and severity of a potential disaster. These approaches would also help to shape people's perception of risk and personalisation, disaster severity and improve their knowledge regarding the efficacy of risk mitigation measures. In addition, sufficient and appropriate media attention oriented towards effective mitigation measures rather than sensationalism is necessary to provide a favourable atmosphere for adopting earthquake mitigation measures.

5.5 Risk Communication Management

Results presented in Table 3 shows six significant communication management practices that could potentially increase the likelihood of building owners adoption of risk mitigation measures. Presently, only a formal written communication method such as letter and email represent the predominant means of communication. An exploration of regular face-face meeting (RC1 and RC2) may lead to joint ability among the stakeholders to collectively identify risks, proffer mitigation strategies and plan implementation actions necessary to adequately mitigate the risks. Other risk communication management strategies include high quality of communication among stakeholders in terms of communications planning and process monitoring (RC3), exploring quick dissemination of information and novel approaches (RC4) discussed in Section 5.4, and the establishment of appropriate method to generate, collect, disseminate, storage EPB risk information (RC5 and RC6). Effective earthquake risk communication process management would reduce some of the anomalies, such as lack of access to building risk information and poor risk communication process associated with the building safety evaluation process after the September 2010 earthquake in New Zealand. These anomalies contributed to the increased disaster losses in the February 2011 earthquake. Also, it is important for professionals such as engineers and government officials to strive and maintain a good public image and public relations with building owners by paying greater attention to seismic designs recommended approved by regulatory authorities. Having good public relations is particularly important in order to earn building owners' trust regarding the efficacy of earthquake risk-reduction measures.

6. Discussion of Results

Significant earthquake risk information and communication strategies for improving seismic retrofit implementation in New Zealand have been revealed in this study. Effective risk information and communication strategies are needed to explain to those at risk regarding

how seismic hazard and risks are identified, assessed and managed effectively within limited resources. The research findings shows that improving the quality of earthquake risk information provided to building owners, effective risk communication management, using regulatory requirements such as mandatory disclosure of seismic risks and most importantly the provision of a unified safety assessment information system would significantly improve the likelihood of property owners' adoption of earthquake mitigation measures. These findings support PADM's postulation regarding the use of a momentous risk-communication approach for improving earthquake risk mitigation.

The provision of a unified safety assessment information system that offers risk information about the vulnerability of potential EPBs to earthquake mitigation stakeholders and the public is central to bridging some of the related problems associated with seismic risk mitigation decisions. The information system would help other relevant professional groups and property market stakeholders to access any building's seismic risk data and enable all stakeholders to work toward a consensus mitigation strategy. This availability of this information system will help them become aware of commonly encountered issues and imperatives regarding earthquake risks. Evidence from the recent Christchurch earthquakes provides further justification regarding the impact of haphazard information system on the overall earthquake vulnerability in New Zealand. Lack of access to adequate risk information about the performance of buildings in the earthquakes could significantly slow down the reconstruction process in Christchurch. In the CERA report (Canterbury Earthquakes Royal Commission (CERC), 2012). The provision of a safety information system could yield widely accessible and valuable information about the condition of potential EPBs across the country.

7. Conclusion

The objective of this study is to examine the relevance of mitigation information provided, and the effectiveness of existing and emerging communication strategies necessary to facilitate informed risk mitigation decisions. A survey research method adopted revealed seventeen significant strategies for improving seismic retrofit implementation of EPBs. These strategies are categorised in the following five groups; (i) source of information, (ii) quality of information provided (iii) regulatory requirements, (iv) information dissemination and communication strategies, and (v) risk communication process management. The research findings may help stakeholders involved in earthquake hazard and risk management to be better prepared towards the provision relevant information and communication strategies aimed at increasing the likelihood of EPBs owners' adoption of risk mitigation measures. A better understanding of relevant earthquake mitigation information and communication strategies may help the stakeholders to review the existing approaches and could facilitate appropriate channelling of limited resources into the right areas to achieve desired risk mitigation decision.

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Maximising the social value of constructed assets: public-private-innovation at work

Sten Bonke[1], Ib Steen Olsen[2]

Implementing PPI in the Built Environment

The paper presents a new industrial innovation arena in line with present Danish and international efforts towards public private partnerships with generic rules for cooperation and integration of research in innovation processes. The method supports the more traditional way of innovation through a broad-spectrum approach based on utilization of for instance research, users and operation experiences.

Basis is three perspectives: the business system, a cross-disciplinary understanding and an integrative experimental building programme. Research is an important actor in the efforts to create constructed assets which meet social goals. However, it is important to recognize the contextual settings for building research if sector developments in practise are to be achieved. The effect of research depends on other actors in the business system. Clients, regulatory bodies, professional associations and building trade organizations constitute one level in the systemic framework; another is firms – architects, consulting engineers, contractors and suppliers – operating on the individual project level.

The interplay between these actors can be seen as an innovation process as proposed by Winch (2010) where the initiative to new processes or products may originate from one, or several, or from a network of actors. Integrators are actors who undertake a brokering role and promote comprehensive solutions to be used in specific building processes. There is a crucial need for a shift in research and knowledge to a more interdisciplinary focus on practice. This development can be facilitated by integrators such as networks which can cross traditional boarders within technical disciplines, and between technical and social disciplines with a starting point in user needs, and between the construction phase and subsequent operating phase.

In Denmark 30 years use of experimental building projects supported by networks of participating companies as integrators across disciplines and life cycle phases has provided valuable knowledge about this approach to innovation (Bonke & Olsen, 2010).

Keywords: Public-Private-Innovation, Experimental Building, Learning

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1. Introduction

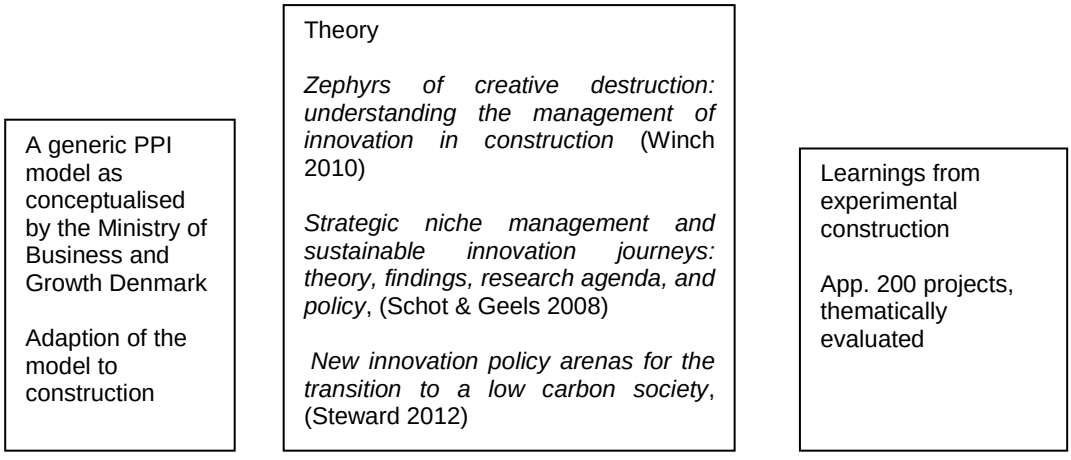
Coming years' development in society will confront the construction sector with daunting challenges. Such challenges concern the implementation of new sources of energy, reductions in energy consumption, increased weight on sustainable solutions, lifecycle assessments in refurbishment projects, more effectiveness in operation of buildings, and better productivity (Kristiansen et al, 2005).

To meet these challenges many western countries have tried, as an approach to stimulate public clients and private companies, to develop new forms of collaboration thus facilitating a comprehensive sharing of different actors' and professionals' knowledge and best practices.

In Denmark the discussions about this approach have been focusing in particular on the interplay between clients, users, designers, contractors and manufacturers – and the track to explore towards better interaction has been much inspired by the concept of experimental building projects. This model grew out of building needs in the public sector, with the first steps taken in the late 1970s followed in the next decades by continuing refinements based on evaluations of experiences from a long national tradition for testing new ideas in real building projects (Bonke et al, 2001; Clausen, 2002; Olsen, 2003). Also other countries, not least Sweden, have thoroughly reported on this approach, often referred to under the term 'demonstration projects', to innovation in construction (Bröchner et al, 1997; Fermenias et al, 2010)

However, in order to convert visions for change into more practical methods and underlining the need for collaboration on a wider basis the Danish government in 2012 published a rough outline for innovation through so called *PPI Public Private Collaboration on Innovation* (in Danish:"OPI Offentligt-Privat Innovationssamarbejde") (Erhvervs- og Vækstministeriet, 2012). Unfortunately, the governmental model is not particularly adapted to innovation in the building sector. Therefore in the following the original approach is reviewed and further developed by inspirations from theory on niche management and from evaluations of cases. This innovation model, or industrial arena, is fully applicable for private clients as well.

Thus, as a point of departure the modelling of *a construction approach* to Public Private Collaboration on Innovation (PPI) will be based on the pillars of recognition as illustrated below:



2. A first step on the road towards Public-Private Innovation

The Danish government has recently taken an initial step towards establishing an operational platform for collaboration on innovation between public clients and private firms. In the spring 2012 the Ministry of Business and Growth Denmark launched their model – an OPI guide (***O****ffentlig-****P****rivat* ***I****nnovationssamarbejde*) as a first step for developing the area. An important aim was to communicate "what it takes from a public authority to gain success through OPI" (Erhvervs- og Vækstministeriet, 2012). The guide is operating with four so-called points of awareness.

2.1 Four points of awareness

First is the issue of *legislation*, for public construction clients particularly important as concerns the law on tender and the EU regulatives. Two other crucial sets of regulatives concern state subsidies and rights.

As a second important point of awareness PPI projects must have *management focus* - that is have priority on responsible management level and be well-anchored in the organisation. Thus, the guide reports, previous learning for instance from cases where the development agenda is organized more in compliance with the aims of the funding bodies than taking into account the basic innovation problem tend to de-couple the PPI project.

Thirdly then, a crucial issue is the *funding*. It is generally hard for public authorities to find opportunities and room for development projects. But PPI may be seen as an investment which may later yield a return – as higher efficiency, quality, growth or the like.

Finally, focus must be on the *organisation* of a PPI project. Emphasis should be put on inter-organisational collaboration, incentives, and new roles for the private firm as well as for the public part.

In the following this model for public-private-innovation will be adapted for construction, as PPI-BUILD. The new model is incorporating previous work with approximately 200 cases of experimental building projects with participation of public clients and private companies. Relevant research based results, i.a. on innovation in a niche-management perspective, is also drawn upon in the process of transforming the model.

3. Innovation in construction – integrating levels and actors

When analyzing the basic factors at stake in innovation the complexity of innovation processes in building products and processes soon become evident (Winch, 2010). In the

research on complex systems dynamics Winch (2010) identifies three “actors” or systems in the innovation process.

3.1 Frameworks and firms

The first system - ”innovation superstructure” - is broadly spoken represented by clients, research, the regulative framework and the professional organisations and associations. The interplay between these is determining the acceptance and use of innovations, and a number of factors may promote or hinder the development of innovations. Such factors being for instance the commitment of public clients, the rules of regulation, the interests and foci of research etc.

Within the second system – in the ”innovation infrastructure” - the development work takes place in firms and projects. Here, decisions are taken on use of innovations, whether they are new or modifications to existing technologies, about adjustments, implementations and exploitations. Also within such firms and project oriented settings a large number of factors may promote and hinder development, for instance sharing of knowledge/ideas, incentives, learning etc.

3.2 Integrators

The interplay between these two systems is performed by a *third system of integrators*, undertaking the task of disseminating and brokering innovations. This interaction between the superstructure and the project oriented level is rather critical for development of innovations. Again, it may promote or hamper development. Innovation will advance as a result of clients’ interests, a creative research environment, favourable associations and entrepreneurial firms. Inertia – or resistance – and lacking initiatives of course have the opposite effect. Winch (2010) indicates that the role as system integrator (or broker) in construction may be divided between consulting firms and contractors. Thus, in fact two separated systems integrators may be exerting influence – one for design and one for production aspects. However, integration can also be “bridged” through professional associations, research or regulation. And also the manufacturing industry can facilitate development when acting in this function.

3.3 Managing innovations

Four central challenges are facing the management of innovations: awareness, champions, professional organisations and the client.

Awareness is created through incentives, rewarding innovation. In construction it may often be relevant to share rewards between the client and the partners in the delivery team. Shifting from lowest-prize bidding towards partnering could be a first step on this road. And innovations require *champions*. Typically, this could be a manufacturer, but also consultants and contractors can play important roles as such. New ideas often originate from niches, then being accepted by the “superstructure system” by the intervention of the integrator/broker. As indicated, in construction it becomes a challenge that the integration of

the champion's idea is divided between the consultant and the contractor. Adding to this, the role of professional *organisations* as integrators are becoming more complicated as new organisations are constantly emerging, claiming to be mouthpiece for the construction community. Finally, the open-minded and competent attitude of the *client* can stimulate the development of innovations as he understands better the proposals from brokers and can himself manage collaborative solutions with consultants and contractors. Learning seems to be a key premise to this.

3.4 The importance of building operation

The last years' development has added another central empirical aspect to these more theoretical perspectives on innovation. Thus it seems evident that the operation of buildings is playing an increasing importance in relation to developing new (resource efficient) technology (Steward, 2012). For instance, a number of surveys show lacking compliance between calculated (energy) savings and actual gains during operation. Consequently, considering building operation will become crucial to PPI-BUILD – thus influencing innovation processes in a much more explicit way henceforward.

4. Free innovation space in the building sector

Innovations can be promoted through establishing of niches, providing shelter for the collaboration on development between technology, user-practices and regulatory settings (Schot & Geels, 2008). Such niches can function as platforms for broader changes towards sustainable development in society.

4.1 Niche Management

Theories and concepts in support of this comprehension of innovation have been elaborated upon since the late 90s under the term "strategic niche management". Much research is concentrating on niche internal processes, such as learning, networking and elaborating on visions. However, recent analyses and experiences also underline the need to pay more attention to external processes, surrounding the niche (Jensen, 2011).

Thus, through external processes the innovation niche is linked to a "socio-technical regime", comprising the marketplace, the branch of industries, research, culture – altogether also often characterized as the sector or the business system. This level is located under a "socio-technical landscape", representing a macro level which is normally rather stable over long time spans.

Niches may be established by clients, firms, users and research. Governments can use and support niches for development of technology which is not profitable in a business perspective, in expectation of realizing certain political goals. Altogether, niche management seems most suitable for innovations characterised by radical, high-risk and long term aspects.

As a consequence niches are often conceived of as obvious frames for development within sustainability and climatic issues which imply substantial changes in markets, for users, in regulatory provisions and the like. Such developments are challenged by the tight interlocking of technology and social changes.

4.2 The internal processes

These processes comprise (1) visualisation and wording of visions and expectations, (2) establishing networks for experiences, exploitation and funding, and (3) a number of learning processes concerning technical issues, user preferences, operational conditions etc.

Internal processes have been elaborated upon in research (Jensen, 2011). For instance, it seems important that expectations are shared by several actors, that they are specific and of high quality. Networks must be wide and comprehend resource persons. Learning processes must not only concern “first order” learning but also be open to changes in assumptions and framework conditions – “second-order” learning. When applying niche management the aim is consequently to prevent innovations from alone optimizing technical aspects to also including social considerations.

5. Experimental building – free space for development

In Denmark by the end of WW2 political focus turned towards the housing situation. In the late 40s and early 50s a number of initiatives were taken, based in the Ministry of Housing (est. 1947), and with the Danish Engineers’ Association as well as with a number of architects as very active co-players. The goal was to achieve a higher level of industrialisation in the production of building components. Thus, industrialised building was developed in a ‘free space’, initiated by the ministry and actively supported by associations and clients. There was a clear vision: the need for housing should be eliminated.

5.1 Establishing experimental building as a free development space

Although several building projects within the development efforts of the 50s and 60s could be characterized as experiments there was not in connection to the individual project established a formal organisation to deal with planning the experimental issues, changing the traditional products and processes, controlling quality, evaluating and disseminating experiences. This for instance is the case with the Bellahøj buildings (1947, varying carcass systems), Engstands Allé (1953, external walls and floor decks as concrete elements), and Rungstedhave (1957, use of hollow decks).

Results were disseminated by means of meetings, articles – particularly in the journal The Building Industry (est. 1950, and soon a central information channel), in reports from the Danish Building Research institute, as regulatory provisions and through so-called “rationalization consultants”. This dissemination was complemented by an active governmental policy, encouraging the exploitation of results, primarily through dialogue with the social housing associations (clients).

Experimental buildings as an approach to development initiatives and innovations was evaluated in a report from the Building Development Council (BUR), established by law in 1971. In the legal framework it was stated that

> "The construction sector has a considerable need for *experimental building* for development and testing of new production methods, new materials, functional designs and qualities. ….. The need will increase along with the standardization of construction because quality improvements as well as flaws will appear in much larger scale than previously" (BUR Byggeriets udviklingsråd, 1974, p.6, our translation)

In 1977 the parliament (Folketinget) decided to grant funding for experimental building projects, to be administrated by BUR. The grant was assigned to a number of conditions which would be influencing developments in the following years. Most significant was the emphasis on the strategy to let experimental building innovate the building as a whole with all its functions, of which the individual materials and components are part. So focus should be holistically on the total product value, for instance as consequences of the energy savings on the indoor climate, on the development of new envelopes, and on housing for disabled persons.

5.2 Characterising experimental buildings

In 1979 as a joint initiative by the Building Development Council, The Building Research Institute and the Building Ministry new and more thorough guidelines on the aims, organisation, evaluation and funding of experimental buildings were published (Byggeriets Udviklingsråd et al., 1979). Experiments were defined by these features:

- ✓ The experiment concerns a total physical frame, not products
- ✓ The experiment may concern form and function as well as organisation
- ✓ The experiment is attached to construction in practice
- ✓ There are certain risks related to the experiment
- ✓ The experiment involves extra costs during planning, production and evaluation
- ✓ Substantial importance is attached to the evaluation and dissemination of results

Subsequently, in 1980 instructions for grants and funding were put forward – stating in concrete terms that

> "an experiment first and foremost is to do something different from customary, at the same time to carefully describe what to do differently, and what the experiment intends to verify or disprove. And further to follow, measure and document what happens. Otherwise it cannot be classified as an experiment" (BUR Byggeriets Udviklingsråd,1980, p.2, our translation)

5.3 Public clients as change agents

An important premise for a successful collaboration – as in experimental building – the parties must be committed and capable of contributing to the development work on the basis of knowledge and experiences. Not least this involves the client, the role of which became more central during this period. Wide circles, including the government, had the notion that clients could and should contribute more actively to the development. As a culmination to this the Danish Association of Construction Clients for public and private clients came into being in 1999. This happened in parallel with a restructuring of the administrative guidelines for experimental buildings, for instance substituting the use of reference groups as dialogue partners with a network of clients and evaluators who were participating in experiments within the same field of subjects.

To further strengthen the use of experimental building the Building Ministry published "Guiding remarks on experiments in construction" (1996) with recommendations based on reports from BUR and later evaluations. With a political prioritization of development subjects visions were formulated, in fact often as a result of previous dialogue with the sector – clients, firms, professional associations, research etc. Through this it became more legitimate and desirable for public clients to participate in experimental building.

In several cases the development work led to ministerial guidelines which were recommended as "best practice", or sometimes converted into legal provisions – or into relaxations of provisions. Thus, one or more experimental buildings could become point of departure for influencing the whole industry. Politically, the goal was clear: the state as a procurer, and the continuing character of public building activities, should be utilized for the changing of processes and products in construction.

6. Adapting and developing the free space

As described above the use of experimental building as a free space for innovation has been adapted and developed over the years. The experiences, and the learning that had been derived, led to a number of research based recommendations in the early 2000 years and onwards. Some of the more important are listed below (Clausen, 2002):

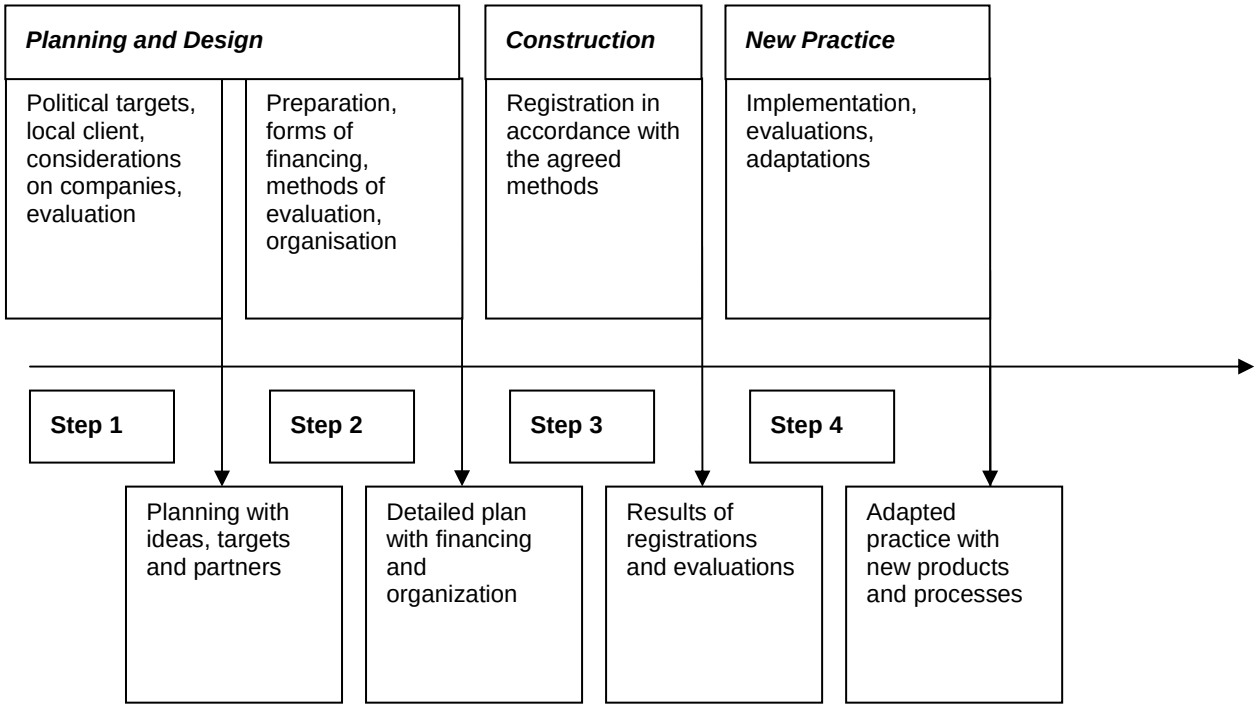
- The handover of the program for the development work to the building *project organisation* should be given greater emphasis. Practical activities should comprise training, education, simulation and social relations. The whole project organisation must have ownership to the experiment.
- Firms involved must consciously relate to their role within a learning situation. Mechanisms for learning to maintain knowledge if staff leaves must be established (or secured by a stable core of staff). Dialogue across firms and professions are crucial.
- Time and space for reflections during implementation must be provided, for instance through phasing. This makes adjustments possible along the way – in the new solution as well as in the social relations ("learning is a process, not alone a result of the innovation or the specific building project").

- It is important to have an emergency plan in place during implementation to handle problems up front. Support for the participants must be available to secure the holding on to elements of development

Then, in 2003, the government in a dialogue with clients and the construction industry concluded on a number of necessary adjustments:

- Concerning the development subjects in experimental buildings a stronger *focus* has taken place on the expense of comprehensiveness
- The experimental buildings organise into *networks*, primarily through their clients. The networks replace previous reference groups and handle transverse conclusions, for instance for departmental guidelines
- The experimental projects and the testing of buildings must be evaluated by external *evaluators*
- Corporation with technical universities has been established with the aim of disseminating results through *education* and textbooks
- Funding for development work in firms and for the evaluation task is *no longer provided*
- Strong *secretariat backup* to the networks has proved necessary
- Reports, guidelines and other information are uploaded to a *homepage*. The need for pamphlets and other types of communication means is however evident.

At the 2010 CIB conference in Manchester an attempt was made to collect experiences and evaluations into an integrated model, while distinguishing between three main phases, Planning and Design phase, Construction phase, and New Practice phase, as illustrated below (Bonke & Olsen, 2010):



As the four steps generally take into account topics as quality assurance, risk analysis and implementation of development work they can also serve as a checklist in a concrete project which involves alterations in traditional practice.

In conclusion, and as illustrated in the figure, the ideas behind experimental building projects have been widely accepted as an adequate model for public-private partnerships (Erhvervs- og Byggestyrelsen, 2009). Within this framework the development process is progressing through the four steps 1) transforming the idea into a proposal, 2) organizing the partnership, 3) development work in parallel with execution of the building project and 4) dissemination and implementation of the results.

As indicated, learned experiences and final results achieved through such processes are made public through reports, articles, courses and seminars. In a number of cases these results have constituted decisive input to new regulatory guidelines which were then typically made compulsory to public and state supported clients.

7. Discussion

Although not verified in targeted research in Denmark, much evidence supports the view that experimental building as a free space for innovations has had probably the greatest importance for the development of industrialised building and for changing building products, processes and procedures in the post-war construction industry. New technology and industrialisation in the 50s and 60s led to radical productivity improvements and capacity growth. Processes and procedures in particular again accelerated from the mid 90s with initiatives on new forms of collaboration, digitalization, lean construction, life-cycle economy, quality management, and benchmarking. The Danish state played an active role on implementing these dimensions.

Nonetheless, it is characteristic that the approach to applying experimental building has generally taken traditional structures and organisation in the industry as given. From this basis the aim was to stand upon existing procedures, to add new perspectives, and to further develop practices thus contributing to solving the challenges in the building sector. An example of this adaptive attitude is the development of new forms of collaboration where the state agreed with the professional associations that there was no need to change existing contractual conditions (*agreed documents*) – minor supplementations would do! Similar observations have been reported Swedish research, stating that demonstrations projects as an innovation approach is suffering deficiencies concerning the strategic need for more radical structural changes (Fermenias, 2004)

Learning and experiences are further reviewed in the following sections, leading to recommendations on the model in the light of the above illustrated Manchester framework.

7.1 The Planning and Design phase

As underlined the conceptualization of a vision – perceptible, acceptable and shared within wide circles of clients, regulative bodies, research and associations – is extremely vital to the

development process. The vision is the key to the sheltered free space within which advancing development and learning can take place and be shared by committed actors.

In the development of the new-forms-of-collaboration case the state launched the initiative for a free space (niche) for interested clients and firms to develop and test new ways of interacting in building processes. Work within the niche was amplified by establishing several spaces in parallel – and phased for learning purposes, with the same vision but in networks of different clients and firms.

In a similar case, focusing on developing flexibility, the vision was again based on state commitment and shared by many actors and parties in the construction sector. This vision was unfolded in a competition, thus involving a wide circle of firms and securing the selection of the most dedicated and qualified partners to enter the free space.

Further, the internal processes in the free space must be underpinned by external processes, linking the niche to the broader industry system on market, sector, research and social relations level. In the cases mentioned this took place through reference groups or networks and public seminars. Here, also the timing of next steps towards funding and planning of the exploitation of results is of course central to maintaining the acceptance of the vision.

7.2 The Construction phase

During this phase important elements are the awareness of parties, champions to take the lead, well-articulated proponents and competent clients. In the emergence of the new-forms-of-collaboration case the call from the ministry provided a breeding ground for an initiative which, after some reluctance, gained tailwind at clients and in particular contractors. The latter – and their professional association – took on the role as champions in close interaction with the state. The free space network on its side undertook the information and follow-up assignments. As indicated, in the flexibility case, the competition and the subsequent development process in the free space, drove forward the winners as natural champions on this development subject.

7.3 The New Practice phase

A decisive element in a successful innovation is integrators or brokers, capable of bridging the free space and practice, and to create broader acceptance of the results. In the new-forms-of-collaboration case the state acted as broker through imposing requirements on the public clients. In the flexibility-case, however, the formalized follow-up was lacking, and the handling and implementation of development results was consequently weakened.

8. The Public–Private-Initiative for the construction industry

In the table below conclusions from the experimental building model are summarized for the PPI-BUILD purpose:

A PPI-BUILD Model in six phases – in comparison with the generic Danish PPI model			
Main phases	**Six PPI-BUILD steps**	**The Danish generic model**	**Remarks to the new model**
Plan with ideas, targets and partners	1. Make the ideas to a visible vision and choose partners. For a public client in accordance with procedures for public procurements. 2. Draw up the lines for a free room for development, a plan for the work and for the evaluation in collaboration with the partners.	A: For the public partner the choice of private partner(s). Two options are possible: a partnership where the partners are chosen after a competition concerning the development work followed by a normal procurement process or a procurement process based on a competition which also contain the development work	1. For the public client it is important – as the initiative is normally is up to client - to choose a competition which underline qualifications. Likewise to get a common understanding of the vision among the partners. 2. The plan must cover original ideas and visions and take into account future possibilities for flexibility.
Detailed plan with funding and organization	3. As development work normally has some cost consequences it is essential to establish funding. 4. A network of knowledgeable and key persons means a lot for the development work and for the later acceptance of results.	B: It is important that the development work is followed by management resources, is prioritized, secured financial and anchored in the organizations. C: The financial benefits have to be evaluated in broad terms – also covering aspects as productivity, quality, sustainability and growth	3. Funding may come from the client, the participating companies, public programs or private organizations. 4. It is important at an early time to consider the later channelling of the ideas to the market and the building sector
Results of registrations and evaluations	5. The vision with the evaluation scheme should form the platform for client and companies.	D: The development work will demand new roles and forms of collaboration sustained by an interdisciplinary approach.	5. In many cases it may be necessary with special observations to get a clear picture of variations between normal practice and the alterations due to the development work.
Adapted practice with new processes	6. The work in the established free room is completed as implementation of the results at the involved partners, as a report and as opening up for marketing and sector discussions.		6. The registrations have to be scrutinized and gathered in a report. Dependent of the funding the report may be published. The wider implementation can be based on the network and a lot of other means as focus meetings, professional organizations, educations and eventually new regulations.

9. Concluding remarks

PPI BUILD supports and further develops the more traditional ways of innovation processes in construction. Typically, innovation is viewed as a technology driven process with dialogues only with few players during the work. The ambition for PPI BUILD is to conceptualize and implement a broad-spectrum approach which contains inputs and involvement from research, users and operation phase experiences in a deliberately

organized way. This approach is in line with open innovation – and is especially suited for more radical changes with the considerable elements of risk, characteristic to construction.

In the further research at DTU Management our plan is to develop and refine conclusions as illustrated in the table above in order pave the way for an adequate and efficient implementation of PPI in the built environment.

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Factors Affecting the Maintenance of Higher Education Institutions (HEIs) Buildings in Nigeria

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Abstract

The process needed to retain Higher Education Institutions (HEIs) buildings; their services and facilities to acceptable standards are recently being challenged by the need to sustain their Utilities and values in Nigeria. The absence of appropriate procurement strategies, maintenance methods, and adequate maintenance budget in the HEIs in Nigeria led to keeping a backlog of maintenance and repairs of their built environments (now in dilapidated conditions) which may impact negatively on staff and learners performance, and reduce their productivity levels. This paper seeks to assess and evaluate the works and service departments in higher education institutions in Nigeria by examining the effectiveness of maintenance works being carried out in connection with identifying the maintenance programme , maintenance schedules and jobs specifications (as maintenance control toolkit) have impacted the HEIs, and Proposing a framework to support key decision makers in Nigeria. Using a case study research strategy, adopting purposive sampling technique to select twelve HEIs, the approach is qualitative using a series of data collection employing semi structured interviews with the Directors of works and services from the selected HEIs . The data analysis employed was the thematic analysis of the data collected. It revealed that, a general shortage of financial resources has allowed a backlog of maintenance and repairs of HEIs Buildings to be built up across both the federal and state type. Furthermore, it identified that, within this context of a maintenance backlog, that the following factors exist, namely-low level of overall maintenance budget; delays in releasing fund (maintenance cash); the adoption and use of assets condition surveys and curative maintenance methods; a shortage of in-house technical staff. Based on the findings a framework is proposed to assist key decision makers to develop enduring solutions to such maintenance challenges to HEIs built environment in Nigeria.

Key words: Backlog , Environment, Maintenance, Procurement, Sustainable.

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Taking from The Polytechnic Ibadan,2012.

Figure 1: HEIs Buildings in dilapidated conditions.

1.0Introduction

Chartered Institute of Building (1990) also defines maintenance and refurbishment as “work Undertaken in order to keep, store, or improve every facility, its services and surrounds to currently acceptable Standards and to sustain the utility and value of the facility”. The British Standard (BSI,1993) defines building maintenance as combination of any actions required to retain an item in, or restore to acceptable conditions. Alan(1998,p.74-90) defines defects as “ugly spots on both old and new buildings, and such spots reduce the commercial values of the assets as well as their service years”.

David (1999,p.122) defines facilities or assets management “as managing a facility to maximise profit or returns on investment to give value for money expended.” He explained further that frequencies of maintenance works on a building or asset depends on many factors, such as quality of materials used, quality of workmanship, frequency of use, nature of use, the age of the asset, ecological factors, nature of activities within and around the asset-for example activities that can cause vibrations to occur, such as mining, heavy traffic –vehicle train and air craft movements. David (1999) classifies asset maintenance into three, namely- preventive, predictive and corrective depending on the type of maintenance strategies adopted and used by the individuals or corporate organisations concerned. He explains further that repairs of damaged or worn-out parts of a building is curative and maintenance is preventive. He classifies repairs into two, namely minor and major repairs.

1.1 **Justification of the Study**

A cursory look at some Higher Education Institutions buildings in Nigeria, especially those built more than five years ago, suggests that they are not well maintained .It is suspected that some Higher Education Institutions (HEIs) have not considered budgeting for maintenance at all. In Nigeria, ownership of Higher Education Institutions (HEIs) can be categorised as being Federal government owned, state owned, and those in private ownership(for the purpose of this study emphasis is on Government owned). In South Western Nigeria (comprising of six states), there are fifteen Higher Education Institutions (public owned).This evidently shows the commitment of the Nigerian gover nment towards ensuring better quality of life for its citizens. However, meaningful skills and knowledge need to be imparted to learners in a very conducive environment. In addition the workplace for academic and other faculty staff must also be conducive. The study needs to evaluate current approaches to asset maintenance in Higher Education Institutions and develop a strategic framework for (HEIs) Works and services departments in HEIs in Nigeria.

1.2 Aim of The Study

The study needs to assess the constraints of Higher Education Institutions works and services departments in Nigeria with a view to evaluating their procurement strategies, maintenance methods, budgets, assets sustainability, and the influence of culture in the execution of projects. The study aims to propose a theoretical strategic framework on asset management in Higher Education Institutions in Nigeria.

1.3 Objectives Of The Study

*To establish current theoretical approaches to assets maintenance management

*To assess and evaluate works and services departments constraints in relation to procurement strategies, maintenance methods, budgets, effective maintenance management, and the influence of culture.

*To develop a theoretical asset maintenance strategic framework for HEIs in Nigeria.

*To validate the framework(through interviews and by attending workshops).

2.0 Research Methodology

Dainty(2008) asserts that there are four philosophical paradigms, namely-1-Ontology,-ii-Epitemology,-iii-Axiology,-iv-and Rhetorology. The author explains further that, the selection of any philosophical paradigm should consists of the three essentials, such as Ontology, Epistemology and Methodology. Crotty(1998) explains that there are three essentials namely, Ontology which is study of being and concerns with what is the nature of existence with the structure of reality, such as “meaning”, and realism, epistemology means reality-that is, what it means to know, and that is a way of understanding and explaining how we know what we know and methodology is the strategy, plan of action, process or design underlying the choice and use of particular method and linking the choice and use of methods to the desired outcomes.

2.1 Mixed Method

For the purpose of this study, both the qualitative and quantitative approaches(mixed method research design based on pragmatism) would be adopted and research questions shall be drawn to ensure that the study achieves its objectives. However, for the purpose of this presentation, the researchers used semi-structured interviews(Qualitative) to collected the data been presented now.

2.2 Methodology and Data Collection strategy

In the whole study, both the hard and soft paradigms shall be used. The first phase of data collection shall be carried out by conducting semi-structured interviews(qualitative) for the Directors of works and services departments of the selected HEIs in Nigeria. The second phase shall be by administration of questionnaires(quantitative) for the users of the HEIs built environments. The researchers intend to use triangulation method. Robson(2002) asserts that, triangulation when used removes the bias of the researchers, enable an in-depth knowledge and understanding of the study area, encourages wider coverage, helps in validating the results of the research and finally enhance results credibility.

2.3 Research Design

Bryman and Bell(2003,p.32) define “research design as the ways in which the data will be collected and analysed in order to answer the research questions posed and to provide a framework for understanding the research”. The study sampled twelve HEIs out of the entire fifteen of them (Federal and State owned), with one respondent in each HEI(One-Director of works and services) sampled.

2.4 Sources of Data

For the purpose of the study, the researcher used both primary source and secondary source of data collection.

2.5 Limitation of Methodology

The study shall be limited to the selected HEIs buildings in six states of the South Western part of Nigeria. The study shall use semi-structured interviews (qualitative) for the Directors of works and services and surveys for the users of the assets.

3.0 Current Theoretical Approaches to Asset Maintenance Management.

3.1 Maintenance Strategies

Chika(2008) asserts that, no single maintenance method and strategy can effectively provide needed remedies to both natural and artificial defects on buildings. The author recommends the use of a planned maintenance method which is termed as Planned Preventive Maintenance. Olanrewaju et al.,(2011, p.263) asserts that “there is a need for shift from maintenance management principles to value-based initiatives”. This argument is calling for an improvement in maintenance management processes.

3.**2 Procurement Strategies**

Barret and Baldry(2003)describe procurement as the process by which a user employs a separate organisation under a contract to perform a function or to be performed by in- house staff. They conclude that HEIs as Corporate entities cannot stick to adoption of a particular procurement strategy in order to achieve quality of work done and ensure effective project delivery.

Brian and Brook(2009,p.44) assert that, "the choice between in-house and outsource services is not always clear cut". They argue that, the organisation management must consider first the issue of costs. RICS(2009) agrees that, a high degree of expertise is one of the advantages of outsourcing. The report further explains that, in-house technical staff(direct labour) carries out specialist work, especially where breakdowns have to be attended to immediately or where security is a high priority. An investigation must be made into the value of the project before a decision is taken as to which of the two strategies or combination is to be adopted and use (RICS,2009).

3.**3 Maintenance Methods**

David(1999) classifies building maintenance into three, namely-1-preventive,-2-predictive-3- and corrective maintenance methods. The author explains further that, repairs or replacements of works can be minor or major. Chika(2008) recommends the use of planned preventive maintenance method, while Justine and Keith(2008,p.361) assert that, "in the United Kingdom a stock condition survey(combination of predictive and curative) is the common tool used to assess the need for maintenance. In addition, (Oyewande,1992;Taiwo,2010 and Akinpelu, 2002) recommend the use of preventive maintenance method as a measure to avert eventual collapse of buildings. RICS(2009) asserts that the combination of preventive and corrective maintenance methods are needed for facilities to be durable and perform well. Iwarere and Lawal(2011) assert that, all public facilities can be utilised efficiently and effectively if a combination of preventive and corrective methods are employed.

3.**4 Techniques of Maintenance Budget** Estimation and Percentage

David(1998,p.215) asserts that, "an annual maintenance budget of about two to four percentage of the Agency annual budget needs to be allocated to the department of works and services for minor repairs and replacements". Justine and Keith(2008,pp.362-363) assert that "maintenance needs are determined by considering the physical conditions of the assets components in compliance with the Decent Home Standard". They assert that, budgetary and specification standards are the challenges being faced in the restoration of assets to normalcy. Olanrewaju, et al.,(2011) assert that, most HEIs based their maintenance budget estimates on the previous year's budget plus allowances for the coming year's budget. RICS(2009,pp.12) in its report that, "maintenance budget should be set up by taking information from the condition surveys and in particular from the prioritised schemes of works".

3.**5 Surveys on Users Satisfaction**

Emmit and Gorse(2006) assert that, any fault or defect discovered should be recorded and reported for immediate and appropriate actions(correction of the defects).

3.**6 Quality Control of Maintenance Projects**

Emmit and Gorse(2006) assert that, quality of completed building projects are determined by design process, quality of materials, components and works undertaken. Soderholm et al.,(2007) assert that, quality management aims to increase customers' satisfaction. Brian and Brook(2009) assert that, works and services departments should have a quality system in place and have their project designs, planning and execution stages accredited under ISO9000/9001:2008. RICS(2009) asserts that, many organisations now formally put quality management regimes in place to conform with ISO 9000:2000-now updated to ISO9000:2008.

3.**7 Sustainability of the Built Environment**

Project performance is considered in terms of cost, time and quality(Ding,2005 and Patermann,199). Alameda(2002) asserts that, sustainability development can be divided into three types, namely-1-build for durability,-2-make the environment safe-3-and use materials from sustainable resources. Sustainable development is a development that meets the needs of the present without compromising the ability of future generations to meet their own needs(Ugwu and Houpt,2007). Spilans(2009) asserts that, the three fundamental aspects of sustainability developments are-i-environmental,-ii-economic-iii- and social. RICS(2009) asserts that, many organisations have put in place local strategies in environmental sustainability, material sourcing, waste disposal and energy management policies in an attempt to set up a framework to achieve a sustainability operation.

3.**8 Use of Maintenance Control Toolkit**

Olowoake(2006,p.3-9) asserts that the use of maintenance control toolkit, such as maintenance schedule, maintenance programme, job specification and facility register make maintenance project planning, execution, monitoring and evaluation efficient and effective and reduce maintenance costs.

4.0 **Research Questions**

4.1 Which of the procurement strategies do you adopt and use for-1-maintaining building structures -2-domestic equipment-3-and other services provided?

4.2Which of the maintenance methods do you prefer to use-and why?

4.3How do you estimate your annual budget-and what percentage is it of the Institution overall budget?

4.4How often do you carry out a survey on users satisfaction of the built environment that your department manages?

4.5How often do you ensure the delivery of quality in your projects-and how do you improve on it?

4.6What are your department programmes in sustaining the assets that you managed?

5.0 Summary of Current Work Done and Findings on Semi-Structure Interviews(Qualitative) Conducted for Directors of Works and Services of the Selected Twelve HEIs in Nigeria.

The outcome of the recent semi-structured interviews (qualitative) conducted for the Directors of works and services departments of the selected twelve HEIs in Nigeria revealed as follow: All the twelve departments of HEIs in Nigeria adopt and use outsourcing for large and complex maintenance projects, and in –house technical staff for supervision, monitoring and controlling of such projects. In addition, they all use in-house technical staff for small and simple maintenance projects.

*Majority of HEIs works and services departments don't use planned preventive maintenance method, instead, they prefer the use of conditions survey and curative maintenance methods-due to paucity of maintenance funds and delays in releasing same where available.

*Many of the HEIs works and services departments base the estimation of their annual maintenance budgets on consideration for the previous year budget and the prevailing market prices of materials, components and labour plus a percentage or lump sum increase, while some of them use budget forecasting.

*Almost all of the HEIs works and services departments in Nigeria don't carry out surveys on users satisfaction. They rely on letters of complaints from the assets users.

*In general, design of new maintenance projects are carried out by Commissioned Consultants. Such projects are executed via outsourcing, while the in-house technical staff carry out the supervision monitoring and controlling of the projects materials, components and workmanship.

6.0 **Suggestions**

*The HEIs works and services departments should on yearly basis prepare and attach their maintenance schedules and work programme with their departments annual budgets for their HEIs management approval and release of maintenance funds to time. The department should also create a quality control unit within-comprising of seasoned professionals from the consulting firms and the in-house technical staff (Olowoake 2006;Olanrewaju et al.,2011)

*The HEIs works and services departments should endeavour to carry out reconnaissance surveys of their built environment with a view to identifying likely problematic areas, do the costing, prepare and attach annual maintenance schedules and works programmes for the approval and release of maintenance cash by their HEIs managements(Olowoake 2006;RICS,2009).

*The HEIs works and services departments should twice in a semester (at the beginning and the end) carry out surveys on users satisfaction of the buildings they use. This is necessary to get to know the needs and feelings of the users(David,1998;Justice and Keith,2008;Olowoake,2006;RICS,2009).

*The HEIs works and services departments should create a project control unit within, and the duties of the unit is to supervise, monitor and control maintenance projects materials,

components and workmanship in order to ensure cost saving, quality deliveries of projects within time limit (Olowoake,2006).

*The HEIs works and services departments to sustain built environment effectively, they should endeavour to prepare and use environmental sustainability toolkit-such as – maintenance schedules, work programme, facility register, history record, maintenance planning and others (Brian and Brook,2009; Chika,2008;RICS,2009;Olowoake,2006;Iwarere and.Lawal,2011).

7.0 **LIST OF PARTICIPANTS(DIRECTORS OF TWELVE SELECTED HEIs IN NIGERIA**.

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7.2 Wahab, S.(2012) Lagos State Polytechnic, Ikorodu, Nigeria.

7.3 Oyediran, A.T.(2012) Obafemi Awolowo University, Ile-Ife, Nigeria.

7.4 Oyebanji,M.(2012) The Polytechnic, Ibadan, Nigeria.

7.5 Olaniyan,S.(2012) University of Ibadan, Nigeria

7.6 Layode,K.(2012) Yaba College of Technology, Lagos, Nigeria.

7.7 Ayeye,O.(2012) University of Lagos, Nigeria

7.8 Adenuga,O.(2012) Tai Solarin University of Education, Ijebu-Ode, Nigeria.

7.9 Ogunbadejo, O.A.(2012) Federal Polytechnic, Ilaro, Nigeria.

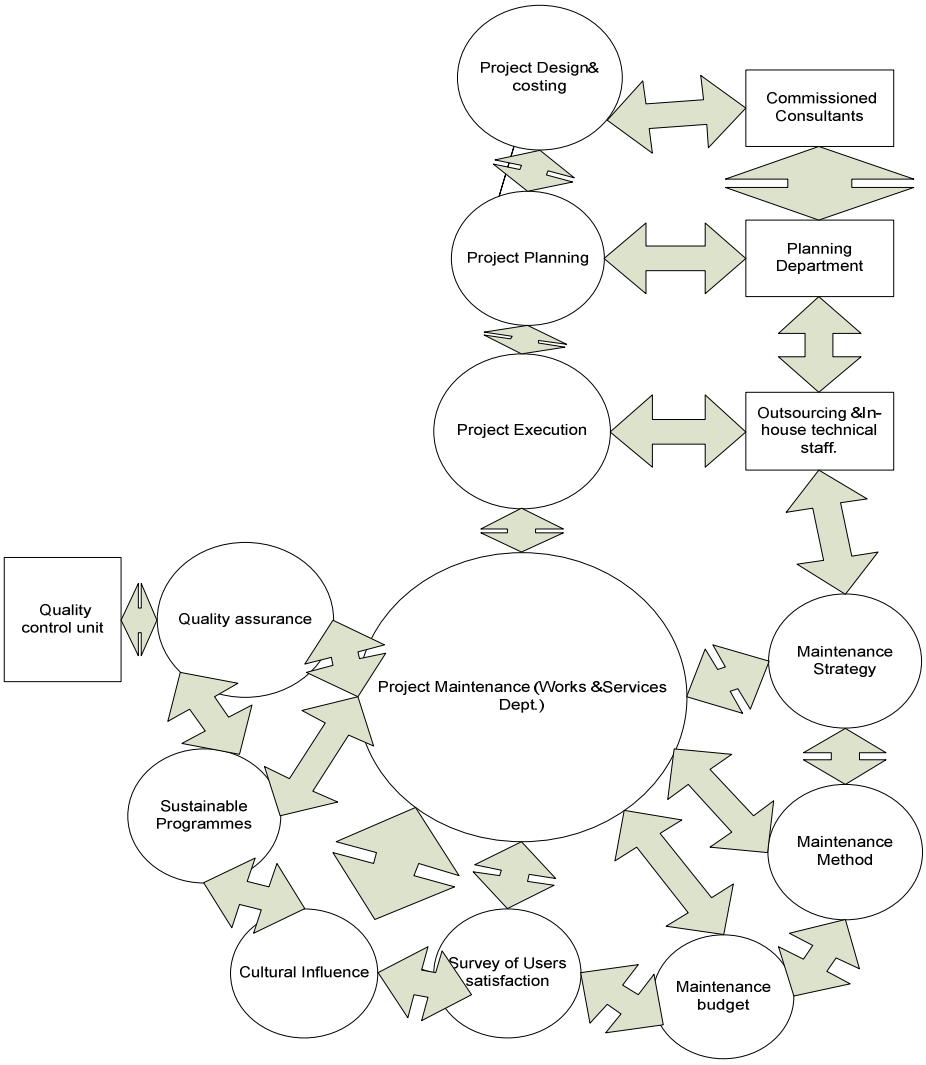
7.10 Williams, S.T.(2012) Olabisi Onabanjo University, Ago-Iwoye, Nigeria.

7.11Oyekunle, F.A.(2012) Olabisi Onabanjo University, Ago-Iwoye, Nigeria.

7.12 Banjo,O.T.(2012) Federal University of Agriculture, Abeokuta, Nigeria.

8.0 A Theoretical Framework Designed to Support Assets Maintenance Management *of* Higher Education Institutions (HEIs)Buildings in Nigeria.

Figure 2: Culled from the semi-structured interviews-2012.



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Payment Scenario in the Malaysian Construction Industry Prior to CIPAA

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Abstract

This report is literature reviews undertaken to re-establish the state of payment problems in the Malaysian construction industry. The findings from this study will be used as a guide for further survey to measure the situation of the payment problems before the enactment of Construction Industry Payment and Adjudication Act (CIPAA). There are journals selected to be included in this study. The purposes of the journal were to discover the financial issues of late and non-payment problem related to the causes of delay in construction projects. Most of the research in the journals was carried out by adopting a combination of document analysis, law cases and review of act and statue. The possible solution to overcome the issue to the late and non-payment in construction projects were also highlighted in the journals. Based on the discussion, this research gives a general view and provides a comprehensive result of the "Payment Scenario in the Malaysia Construction Industry Prior to CIPAA". The result in this paper covered the factors contributed to the late and non-payment problem in construction industry, impact of late and non-payment and also the possible solution towards late and non-payment problem in construction industry.

Keywords: payment, contracts, legislation, delay, adjudication

1. Introduction

Payment problems are old age issues that permeate the Malaysian construction industry. So often, contractors and parties in the construction industry complain either not getting paid or payments have been unduly delayed by the employer. The issues of late and non-payment are paramount to the construction industry as compared to other industries. This is due to the following facts; unlike many other industries, the duration of construction projects are relatively long, the size of each construction project is relatively large and each progress;

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payment sum involved are often relatively large, payment terms are usually on credit rather than payment on delivery, services are rendered before progress payment is made, and products become fixtures disabling removal.

A failure of the contractor in getting regular and timely payment could result in project delay, reduced profitability and in the extreme case the company may go into liquidation. It will also have a knock-on effect on the entire construction value chain because when clients do not pay the main contractors on time, the sub-contractors, suppliers, hirers and everyone in the construction value chain will suffer.

In addressing the issues on payment in the construction industry, the government has introduced the Construction Industry Payment and Adjudication Act (CIPAA). CIPAA is expected to come into operations in early 2013. The act applies to all construction contracts made in writing and that which relates to construction work carried out wholly or partly within the territory of Malaysia. Under CIPAA, a statutory right has been created for unpaid parties to demand for payment for work done.

In preparing to measure the success of CIPAA, a detailed and more accurate study needs to be undertaken in re-establishing the state of payment problems in the Malaysian construction industry. The findings from this study will be used to measure the success of CIPAA in addressing the payment problems before and after its enactment.

1.1 Introduction on CIPAA

The Construction Industry Payment and Adjudication Act 2012 (CIPAA) was recently gazetted. CIPAA is a speedy dispute resolution mechanism. The process is quick and relatively cheap, particularly in comparison to litigation and to those arbitrations that have somewhat unfortunately, for whatever reason, been allowed to become more time consuming and costly than they should have been.

The construction industry, in particular, the Construction Industry Development Board (CIDB) and Master Builders Association Malaysia (MBAM) and other related promoters have been instrumental in getting the government to enact this piece of legislation since 2003 to address the cash flow problems plagued by the industry. The primary objective of the Act is to address cash flow problems in the construction industry. It removes the pervasive and prevalent practice of conditional payment (pay when paid pay if paid) and reduces payment default by establishing a cheaper and speedier system of dispute resolution in the form of adjudication. The Act also provides for the recovery of payment upon the conclusion of the adjudication process in addition to a host of other remedies such as a right to reduce the rate of work progress or to suspend work or even to secure direct payment from the principal.

It offers a relatively simpler, cheaper and faster process compared to arbitration and/or court proceedings by virtue of express provisions prescribed by the proposed Act itself. The adjudicator’s decision is regarded as void and that they cannot recover their payment if they fails to make a decision within forty five (45) working days from the completion of the reference by the parties who fail with the decision. The decision is temporarily binding in that

it can still be subjected to an arbitration or litigation in court i.e. if either or both the parties so desire. In the interim, the parties need to still comply with the adjudicator& decision and pay the disputed amount unless the decision is stayed (by application made to High Court). CIPAA applies to every "construction contract" (as defined by the Act) relating to construction work carried out wholly or partly in Malaysia. It therefore affects both local and international contracts that fall within the ambit of the Act.

CIPAA identifies the particular construction contracts which are included within its scope. Generally, these encompass construction work contracts and consultancy services contracts. More importantly, CIPAA only applies to contracts which are made "in writing". The Act applies equally to the Government of Malaysia as well as the Private Sector. CIPAA is wide ranging and covers inter alia, the building industry, the oil and gas industry, the petrochemical industry, telecommunication, utilities, infrastructure, supply contracts and consultancy contracts.

Findings of this study may assist the government and relevant parties in addressing problems associated to late and non-payment in an effective and timely manner to create a win-win situation for all parties in the Malaysian construction industry. It is hoped that the government and relevant parties will adopt and implement the necessary plan of action in order to minimise disputes on payment in any construction project, so as to create a friendly and enjoyable working environment for all parties and to improve the payment flows in the Malaysian construction industry. The result of this research may be of significance to the introduction of a legislation known as the Construction Payments or Security of Building Payment Act, which already enacted in many advanced countries.

2. Identification of Late and Non-Payment Problem

A delayed payment by a party who is involved in the process of payment claim may have an influence on the supply chain of payment in whole. According to the Construction Industry Working Group on Payment (2007), problems in payment at the higher end of the hierarchy will lead to a serious knock-on cash flow problem down the chain of contracts.

The previous research done by Hasmori et al. (2012) stated that client’s employees are wrongfully holding the payment and most of the time they do this to obtain some kind of “gift” from contractors once they pay out the payment. According to Ye and Abdul Rahman (2010), identified clients deliberate delay for their own financial advantages, delay in releasing of the retention monies to contractor and wilful withholding of the payment for personal reasons are the cause of the paymaster’s withholding of payment.

Based on result analysis by Ye and Abdul Rahman (2010), contractors in Malaysia perceived that delay for few day less than 5 working days is acceptable and accepted late payment from the clients as they are always at the mercy of the clients. This could be due to the inherent culture of late payment in the Malaysian construction industry that the contractors perceived late payment for a few days were acceptable.

According to Ye and Abdul Rahman (2010), delay in certification by parties involve in the project might also cause of late payment issues. The parties involve may delay in approving the application for payment claim due to certain reasons which may arise because of his own or other parties involve.

The journal/ paper/ report that included in the report of Payment Scenario in the Malaysia Construction Industry: A Literature Reviews and a Report of Industry Responses 2012 are as follows, Table 1:

Table 1: Factors contributed to late or non-payment in construction

Factor	Description	Author
Paymaster's Poor Financial Management	1. Cash flow problems because of deficiencies in client's management capacity 2. Client's ineffective utilization of funds 3. Scarcity of capital to finance the project for instance, client's need money to roll 4. Poor cash flow because of lake of proper process implementation 5. Financial failure due to bankruptcy or winding up paymaster other business activities 6. Overlook the ripple effect of economic downturn on cash flow 7. Client's poor financial and business management	Abdul-Rahman et al. (2011); Hasmori et al. (2012)
Paymaster's Withholding of Payment	1. Withhold of payment by client	Hasmori et al. (2012)
Conflict among the Parties Involve	1. Contractor's misinterpretation of client's requirement of variation order 2. Heavy work load of consultant to do evaluation for variation order 3. Argument of the amount to be paid 4. Non-payment for certified sums	Abdul-Rahman et al. (2009)
The Use of Pay When Paid Clause In Sub-Contractor	1. The sub-contractor will only be paid after the main contractor himself has received payment from the employer	Ab. Halim et al. (2010)
Local Culture / Attitude	1. Delay for few days less than 5 working days is acceptable and accepted late payment from the clients as they are always at the mercy of the clients.	Hasmori et al. (2012); Abdul-Rahman et al. (2006)
Short of current year's project	1. Over deduction of the sum payment 2. Bank line of credit constantly borrowed to the limit	Hasmori et al. (2012); Supardi, A. et al. (2011); Ab. Halim et al. (2010)
Delay in certification	1. Delay in valuation and certification of interim payment by consultant 2. Involvement of too many parties in the process of honouring certificates 3. Issuance of payment certificate by party not in construction contract	Supardi, A. et al. (2011)
Disagree on the valuation of work done	1. Inaccuracy of valuation for work done 2. Unpaid of work done due failed on defect work 3. Decreased in productivity 4. Unclear instruction and miscommunication due to language barriers 5. Verbal instruction given is not confirmed in writing 6. Work carry out by contractor does not comply to the specification	IMohamad et al. (2012)

Contractual Provisions	1. Contract agreements do not bring any justice to both main contractors and sub-contractors 2. Disrespectful from parties involve regarding to the contractual provisions effectiveness	Ab. Halim et al. (2010)
Technical Problems	1. Delay in processing for approval 2. Delay in receiving progress payment from client 3. Absence of a comprehensive business plan 4. Wrongly calculated claims 5. Without using the right procedures 6. Claims without adequate supporting documents 7. Errors in submitting claims 8. Failure to identify technical problem and remedial action to be taken 9. Insufficient information and poor documentation on work progress 10. Inexperience of site supervisor and contractor's representative 11. Unclear material description and details in specification and drawing 12. Actual quantities does not match as stipulated in Bill Quantities (BQ) 13. Incomplete claim document	Ab. Halim et al. (2010); Abdul - Rahman et al. (2009)

3. Impact of Late and Non-Payment

Haseeb et al (2011) identify the four major factors which caused the delay in construction and these are client problem, service provider problem, sources problem and universal problem. Based on the survey results, client factor is identified as a major factor causing the delay in construction with the inability to make payment due to economic background and lack of financial arrangement for the project (Hasseb et al., 2011). In addition, the breakdowns of equipment and labour disputes caused the delay in completion of the project.

Delays in construction projects lead to serious consequences that may retard the development of the construction industry and influence the overall economic condition of a country (Abdul-Rahman et al., 2009). According to Abdul-Rahman et al. (2009), delay in the completion of construction projects could be the greatest cause for extra cost and loss in financial return or other benefits from project. Thus, delay is costly for both owner and contractor. To the owner, a delay means loss of potential revenue, whereas to the contractor, a delay means increased costs in overhead.

Payment has been an issue of major concern in the construction industry and majority of contractors reported that they have went through late payment situation in government funded projects whilst more of them affirmed the same situation in private funded projects as told by Hasmori et al (2012).The late payment issues in the construction industry is a global phenomenon and in Malaysia the impact of this problem had cause a massive destruction to the country's economic and this have tarnish the good image of the construction industry. The impact of late and non-payment are described in Table 2.

Table 2: Impact of Late and Non - Payment

Impact	Description	Author
Creates negative chain effect on other parties	The construction payment blues have domino effects. A delayed payment by one party may affect the whole supply chain of payment of a construction project. For instance, if an employer delays in making payment to the contractor this in turn will result in contractor's delay in making payment to the sub-contractors and suppliers.	Mohamad et al. (2012)
Results in delay in completion projects	Late payment causes cash flow problems which in turn can affect the overall progress of works. Financial problem is confirmed by the top management as the main cause of delay in addition to manpower shortage.	Abdul-Rahman et al. (2009) Haseeb et al. (2011)
Leads to bankruptcy or liquidation	Late payment may affect the financial status of the contractor. It will influence a company's cash position.	Ab. Halim et al. (2010)
Project delay	A failure of the Contractor getting regular and timely payment could result in project delay, reduced profitability and in the extreme case, the company may go into liquidation	Judi and Rashid (2010)
Affect the contractors reputation	Frequent late payments could result in loss of reputation, trade credit constraints, and reduced credit ratings	Hasmori et al. (2012)
Profitability of the project	The profit margin is small and this situation can led a player to go on bankruptcy and there goes another project on abandoned list	Hasmori et al. (2012)

4. Potential Solution of Late and Non – Payment Issues

Regarding cash flow management, Abdul-Rahman et al (2011) suggested that the clients to be trained on cash flow management and financial management whereas the contractors should accessing risk management in managing material, transportation, labour and maintenance. Apply payment bond with bank and client is also the suggestion that should be taken in account.

Contractor need to be smart in accepting the contract and to choose a good paymaster (Abdul-Rahman et al., 2011). Before any payment is being certified, it is a contractual responsibility of the committee to also monitor whether the claim is made in accordance to the terms, product delivery and other criteria prescribed. In fact, 98 percent of such processing can be completed within 10 days. If the payment is late, the finance officer must inform the reason for the delay in writing (Hasmori et al., 2012).

Legislation should be amended to give a clear message to constructors and clients as to clarity the payment matters and refund procedures said by Abdul-Rahman et al. (2011). Termination at common law can only take place where one party commits a breach of contract, and that breach amounts to a repudiatory breach. A party is said to have repudiated a contract if he expressed by his words or conduct that he does not intend to be bound by the contract or to perform his obligations. Normally, refusal by the Employer to pay sums due is clearly a default and Contractor can take action based on such reason. But, failure to pay one installment out of many is not ordinarily sufficient to amount repudiation.

Hasmori et al. (2012) said that the remedies to overcome the late and non-payment is by adopting a new way of payment method among developers or clients whom wrongfully

withholding the payment. Penalties shall also be given personally to the employees if they are found wrongfully withholding the payment. Table 3 show the potential solutions of late and non-payment issues in construction industry.

Table 3: Potential solutions of late or non-payment issues

Solution	Description	Author
Financial Management	1. To conduct training on cash flow management and financial management 2. Accessing risk management in managing material, transportation, labour, and maintenance. 3. To apply payment bond with bank and client.	Abdul-Rahman et al. (2011)
Contractual Matters	1. To be smart in accepting the contract and to choose a good paymaster. 2. Determining the contract with the Employer 3. The development of principles of modern construction contracts 4. There should be a specific clauses in the contract related to managing construction failure.	Abdul-Rahman et al. (2011); Hasmori et al. (2012)
Legislation	1. Legislation should be amended to give a clear message to constructors and clients as to clarity the payment matters and refund procedures. 2. A right to a speedy dispute resolution mechanism 3. A right to suspend work 4. A right to regular periodic payment. 5. Applying charges to overdue payments. 6. A right to a defined time frame for payment 7. Collection period (CP) in 48 days. 8. A specific agencies or bodies must be existed for the party involved to set guideline in resolving that matters.	Abdul-Rahman et al., (2011); Judi and Rashid (2010)
New way of payment method	1. Adopting a new way of payment method among developers or clients whom wrongfully withholding the payment.	Hasmori et al., (2012)
Local Attitude	1. Fundamental change in the mind-set towards timely payment and statutory enactment to deal with payment in construction industry	Hasmori et al. (2012)
Technical Issue	1. The detail and proper procedures of claim issuance to resolve matters arising 2. The relevant provisions of construction failure should be stated in separate clause due to its scope of event.	Mohamad et al. (2012)
Financial institution	1. Reduced interest rates/bank fees for businesses with robust cash flow management 2. Extension of credit facilities on a temporary basis 3. Seasonal repayment/ payment based on money flowing into the business 4. Repayment holidays 5. Slow or delayed start to repayment terms 6. Access to free/ heavily subsidised cash flow software	

Figure 1 illustrates the framework of the study which includes the factor, impact and solution of late and non-payment in construction industry.

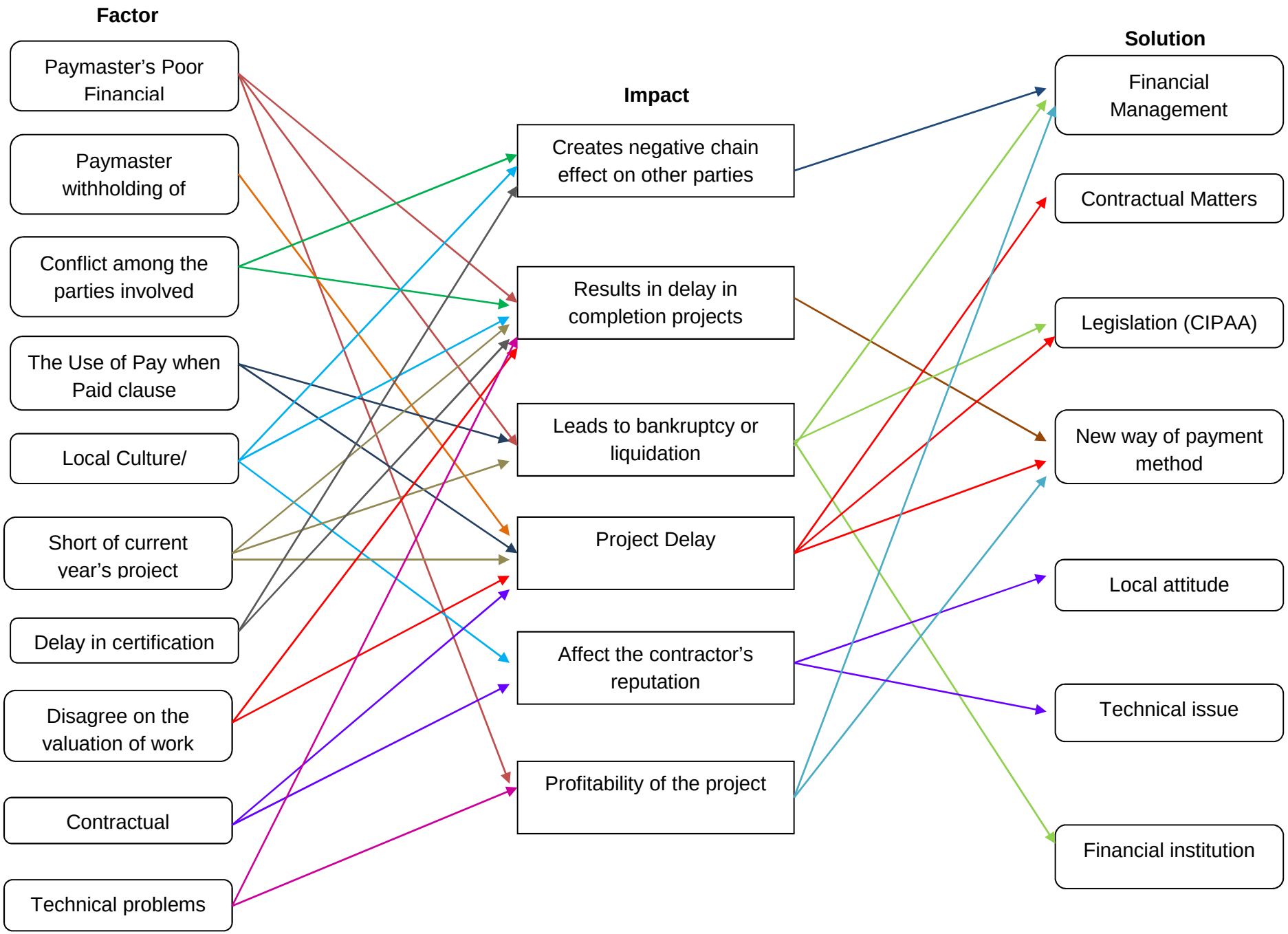

Figure 1: Framework of the study

5. Conclusion

The literature described above show that there are ten (10) factors that may contributed to the late and non-payment in Malaysian construction industry. The most significant factors that may contribute to the late and non-payment are short of current year's project and technical problem. The problem caused late and non-payment in current year's project include over deduction of the sum payment and bank line of credit constantly borrowed to the limit. The technical problem that may be the causes to the late and non-payment problem are mostly because of delay in processing for approval, delay in receiving progress payment from client, absence of a comprehensive business plan and wrongly calculated claims.

Based on the survey done by researcher mentioned above, the impact of those factors in late and non-payment problem are creates negative chain effect on other parties, results in delay in completion projects, leads to bankruptcy or liquidation, project delay, affect the contractors reputation and profitability of the project. The worst impact that may be happen when late and non-payment occur is the profit margin is small and this situation can led a player to go on bankruptcy and there goes another project on abandoned list.

The factors and impacts of the late and non-payment can be solved through financial management, contractual matters, legislation, new way of payment method, local attitude, technical issue and financial institution. Based on the survey done by the researcher, financial management is the best way to resolved late and non-payment issue.

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Perception of Procurement on Successful Infrastructure Project Outcomes in Pakistan

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Abstract

In Pakistan, the need for infrastructure is immense while resources, capitals and commodities are scarcely found. This paper explores the methods used in Pakistan to procure infrastructure projects. With the help of archival analysis, in depth case interviews and in light of the literature it discusses the advantages and disadvantages of the methods of procurement used in public sector in Pakistan. The findings reveal that there are two distinct methods of infrastructure project procurement in public sector in Pakistan i.e. the traditional method and the non-traditional method (Public Private Partnership (PPP)). The driving forces for the non-traditional method in comparison to the traditional method are also limited. This paper also discusses the perception of procurement in delivery of successful project outcomes in Pakistan. In addition it provides an analysis of the challenges a developing country like Pakistan face while adopting modern procurement methods and systems; how enabled is the environment in Pakistan to accept new and innovative forms of procurement.

Keywords: Infrastructure Projects, Procurement, Pakistan.

1. Introduction

In Pakistan the need and demand for infrastructure is massive while the resources in Pakistan are not ample to meet this demand (Noor *et al*., 2012). Not only there is limited fiscal space, there are also huge gaps in public sector capacity to build and operate infrastructure (IPDF, 2010). Procurement of infrastructure projects poses challenges that are not found in other areas of public procurement, the primary reason is that infrastructure is highly complex and customized therefore it requires not only economic but also political, social and environmental

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considerations from a long term perspective (World Bank, 2009). How to use the limited public resources wisely remains an important challenge for governments especially under fiscal pressure (Estache and Limi, 2011). The Government of Pakistan (GoP) estimates that less than half of the infrastructure investment needs can be met with public funds under the Medium Term Development Framework (MTDF) of the Government of Pakistan (IPDF, 2010). The country needs to embark on implementing different forms of procurement to meet its infrastructure needs (Noor *et al*., 2011). The public sector in Pakistan has taken some steps but there is still more to be done (Noor *et al*., 2012). A combination of policy reforms, institutional support, incentives and financing modalities are required to encourage private-sector participation in financing, constructing and managing infrastructure projects (IPDF, 2010). In Pakistan, construction sector is an important sector and although it is not working to its fullest potential, it is still of prime significance to the country (Azhar *et al*., 2008). They state that it is among the largest sectors that generates employment within the country as well as a key driver for economic development of Pakistan. Furthermore, according to them, similar to many other developing countries, Pakistan is also facing critical project management related issues. They also suggest that procurement is a major factor for cost overruns in projects in Pakistan. Saqib *et al*. (2008) found out that procurement related factors such as project delivery system, project bidding method and project contract mechanism were rated as most significant factors and procurement related factors were rated among the top five critical success factor categories in Pakistan. They suggest that there is a need for further study on procurement in Pakistan which will be useful in implementing projects successfully. Much research remains to be done on the links between procurement of projects and its effective implementation in Pakistan (Khan *et al*, 2008). They expect that further research within Pakistan could reveal more prospective information on the existing mechanisms of procurement of projects in Pakistan and the means for improving the implementation of projects to achieve successful outcomes for the benefits of all the stakeholders and general public (Noor *et al*., 2012). The aim of this paper is to give a holistic view of the types of procurement of infrastructure projects in Pakistan, the perceptions about procurement and its impact on successful delivery of project outcomes and the challenges a developing country like Pakistan face in implementing new and innovative forms of procurement as well as how enabled is the environment to accept these new forms of procurement.

2. Methodology

The methodology for this research employed qualitative research techniques. The research was carried out in two stages. In the first stage, archival analysis was conducted of government documents and reports including reports by international organisations, policy documents and literature. As a result,it was found that there are two different methods of procurement used for procuring infrastructure projects in public sector in Pakistan i.e. the traditional and the non-traditional methods. This also facilitated in identification of potential case study projects based on the type of procurement method used. During the second stage, case studies were selected based on archival analysis. A total of 6 public sector organisations had been selected as organisational case studies and 8 projects had been selected among these organisations as

project case studies. A total of 24 respondents participated from these 6 organisations. The case studies were analysed using qualitative content analysis techniques of the in depth interviews. Cross case analysis had also been carried out based on looking at the similarities and differences across similar as well as different methods of procurement.

3. Types and Use of Infrastructure Procurement in Pakistan

Figure 1 below provides a diagrammatic explanation of the different types of procurement arrangements and methods for infrastructure projects in Pakistan.

The infrastructure procurement in Pakistan can be broadly classified in two distinct methods of procurement i.e. the traditional method and the non-traditional method. Within the traditional method the normal practice in public sector in Pakistan is to use the general contracting i.e. Design-Bid-Build. In case of no-traditional methods of procurement for infrastructure projects in the public sector in Pakistan the three main types of contractual arrangements are BOO which is under policy recommended for procuring thermal power projects in addition to it being used by the first private sector airport in Pakistan. BOT is most widely used for infrastructure projects across the public sector in Pakistan especially in case of transport sub-sector as almost all the case study projects in this sector have been procured through this arrangement. The only one BOOT project is in the hydropower sector in Pakistan and it is the only BOOT project so far in infrastructure projects in public sector in Pakistan. From the respondent responses, it was quite evident that the predominant method of procurement in case of infrastructure projects in almost all the organisations was that of traditional method of procurement. This is illustrated in the Figure 2 below that all organisations utilise traditional form of procurement except Organisation 2 which employed only non-traditional method of procurement as per government and policy guidelines and is specialised organisation in case of non-traditional form of procurement in Pakistan (Noor *et al.*, 2012).

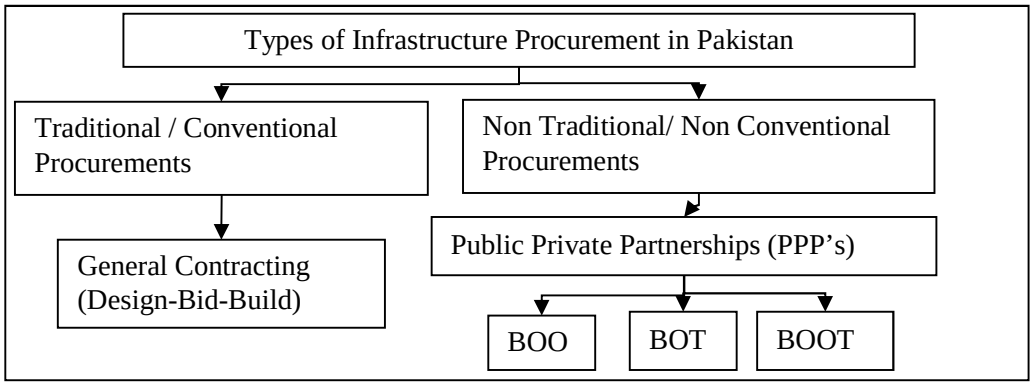

Figure 1: Types of Infrastructure Procurement in Pakistan - Source: Noor et al. (2012)

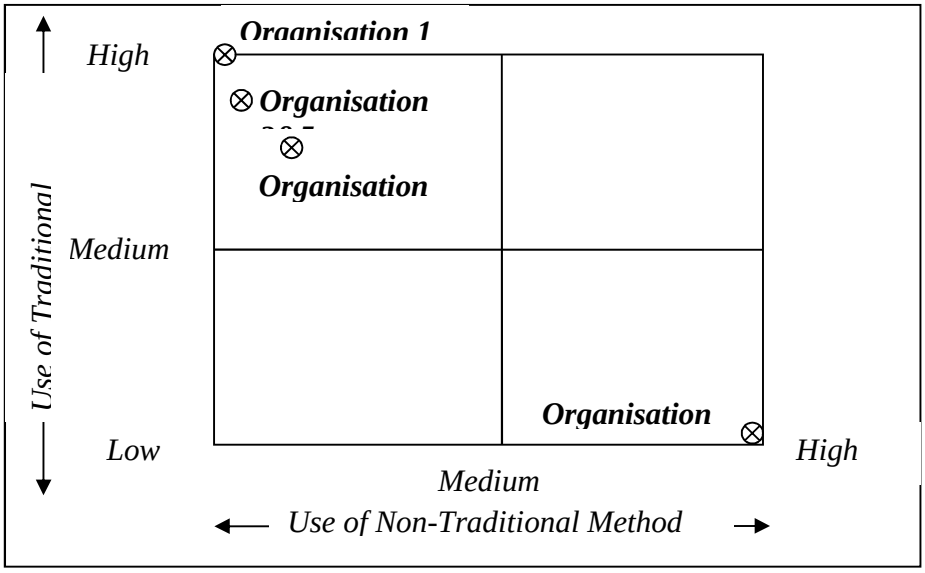

Figure 2: Predominant Use of Method of Procurement across Cases - Source: Noor et al. (2012)

4. Advantages and Disadvantages of Different Types of Procurement in Pakistan

The following sections have been adapted from a study conducted by Noor *et al.* (2012) which discusses the advantages and disadvantages of traditional and non-traditional methods of procurement in light of literature and in the context of Pakistan based on interview responses during case study interviews.

4.1 Traditional Method

General contracting or as it is usually known as design-bid-build is the traditional approach to procurement in construction.The advantages of the traditional method in Pakistan have been reported to be the relative comfort with the approach and ease of use for the public sector organisations, with relative price certainty and targeting at least cost, having fair amount of competition and to a degree transparent which are mandatory for public procurement under the government regulations. The disadvantages have been reported to be cumbersome, time consuming, often resulting in delays in project execution and resulted in adversarial relationship often ending in legal disputes. Both advantages and disadvantages broadly conform to the literature on traditional method of procurement such as Francis and Sidwell 1996; Hughes *et al*. 2006; Morledge *et al.* 2006; Walker and Hampson 2003 and Murray and Langford 2009. This can also be depicted in the force field analysis diagram such as in figure 3 below. Considering the advantages being the forces driving the traditional method and the disadvantages being the restraining forces, also evident from section 3 and figure 2 above, the traditional method of

procurement is the predominant method and is in high use hence it can be inferred that the driving forces are stronger than the restraining forces.

4.2 Non Traditional Method (PPP)

Duffield (2008) defines Public-Private Partnerships' (PPPs) as a contracting arrangement in which a private party, normally a consortium structured around a Special Purpose Vehicle (SPV), takes responsibility for financing and long term maintenance or operation of a facility to provide long term service outcomes. In Pakistan as stated earlier in section 3, Public-Private-Partnership (PPP) is considered as a non-traditional procurement method. The driving forces and advantages of the non-traditional method of procurement and especially Public Private Partnerships in Pakistan have been reported to be the need for efficiency and finances. The restraining forces and disadvantages to this particular method have been reported to be lack of understanding of the method of procurement, the project revenue issues, the long gestation period of PPP projects, resistance to change and the suitability to the present environment of the country. These factors broadly conforms to the literature by authors such as Hughes (1989); Walker and Smith (1995); Merna and Smith (1996); Chu (1999); Walker and Hampson (2003); Hughes *et al*. (2006); Morledge *et al.* (2006); Miller *et al.* (2009) and Murray and Langford (2009). Regarding the issue of lack of understanding as explained by authors such as Nahapiet and Nahapiet (1985); Naoum(1994); Nam and Tatum (1997); Slaughter (1998); Luu *et al*. (2005); Shields (2005) and Miller *et al.* (2009), stress is on the need and the importance of understanding of procurement as well as the increase in the level of understanding with experience and expertise. This lack of understanding as reported was not specific to clients alone but also contractors, consultants and private parties have exhibited the same in case of Pakistan which corresponds to what Naoum (1994) and Luu *et al.* (2005) have stated. It is also interesting that resistance to implement change (Shields, 2005) has also been observed in case of Pakistan. Suitability to the specific environment and the influences of environmental factors such as regulatory, legal, political, economic, cultural, financial etc in which it is being administered conforms to the literature. Although the literature does not particularly elaborated these in the context of developing countries, the findings do confirm that these issues are having a profound negative impact on the applicability of this type of procurement in Pakistan. Considering the above the same can be depicted using a basic force field analysis as done in figure 4 below. Considering section 3 and figure 2 above, non-traditional method of procurement is seen as a sparingly used method. Hence it can be inferred that the restraining forces are stronger than the driving forces in the case of non-traditional method in Pakistan.

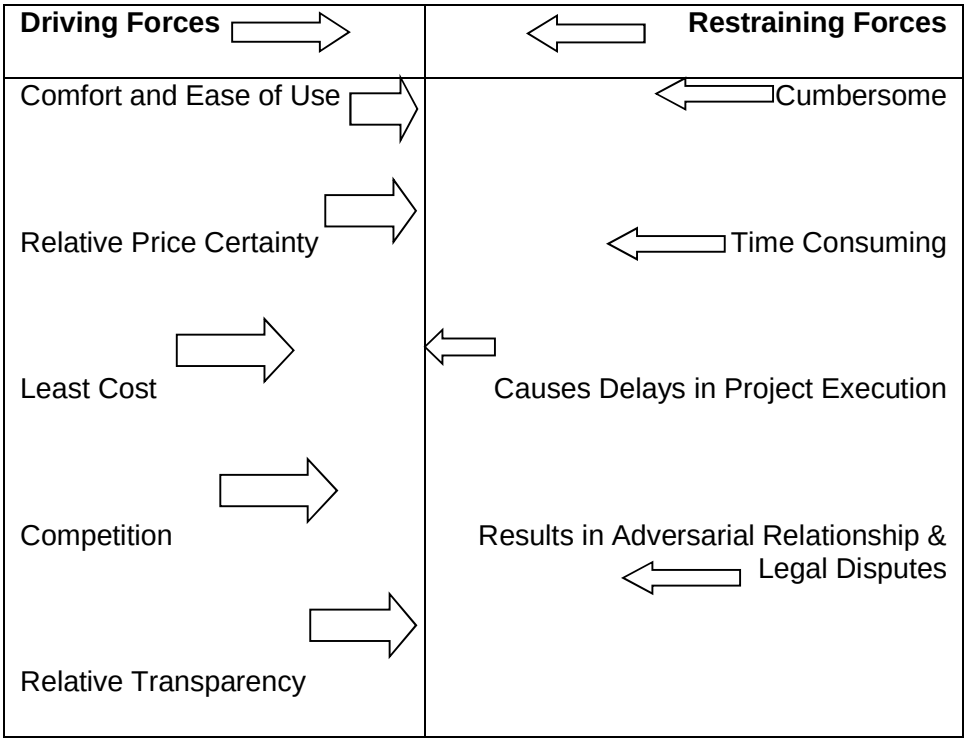

Figure 3: Force Field Analysis of Traditional Method in Pakistan - Source: Noor et al. (2012)

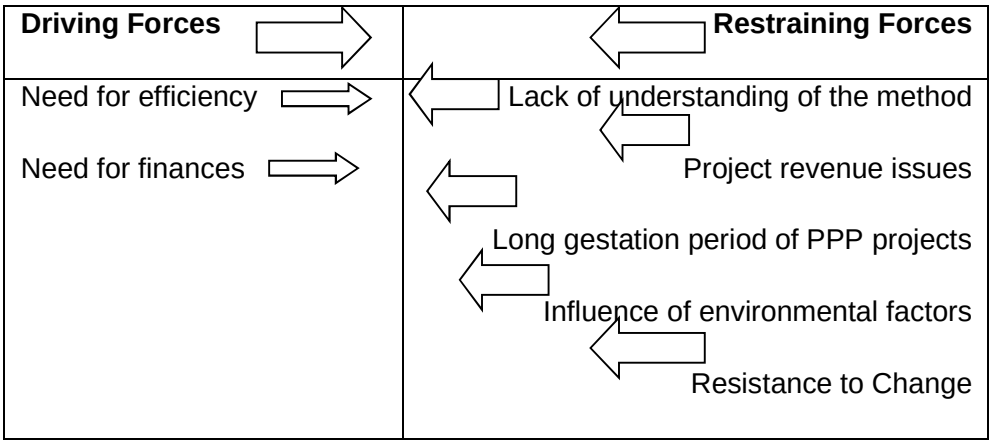

Figure 4: Force Field Analysis of Non-Traditional Method in Pakistan - Source: Noor et al. (2012)

5. Perception of procurement practices in delivering successful project outcomes

Success was defined and perceived as meeting all the major objectives of the project as envisaged prior to execution when the project was constructed and completed. In totality the respondents perceived that procurement had a direct impact on successful outcomes of the project. As it was unanimously stated that the project procurement processes and methods directly impacted the successful outcomes of the projects in the organisations investigated, It was perceived that all the criteria, guidelines and rules etc. were designed to achieve successful project outcomes. It was felt if the process of procurement is followed in letter and spirit there would be no problems in its effective implementation. The criteria for pre-qualification and award of contracts in theory was perceived to be tailored in such a way that these are built in the process for one reason alone i.e. to achieve successful project outcomes. The procurement systems in the organisations studied had a direct relationship and impact on performance and success of the project.

In addition procurement planning and project planning were perceived to be instrumental in achieving successful outcomes. If project planning and especially the prime governmental project document i.e. PC-1 (stands for Planning Commission template 1) was properly prepared in their experience, such projects usually reached successful conclusions. It was felt that for successful implementation both political and organisational will and loyalty including personal will and loyalty to the project, were imperative i.e. how loyal and willing all the project stakeholders are to the project. It was reported that there was much room for improvement in the process and rules which would lead to successful implementation of projects. The due diligence of the process of procurement was also reported to help in identifying who is best suited to handle the project.

6. Challenges in adopting modern procurement methods for developing countries

As Riley and Lewis (2008) state that uncertainty results in large part from imperfect information, the institutions in a society are those that reflect the quality of the information that is available. They further state that adopting new and different procurement processes has a direct relationship with uncertainty. They assert that the greater the uncertainty, the more rigid and limiting the institutional arrangements tend to be, and in the context of construction, the more difficult it becomes to adopt a new and different procurement process that minimizes transactional and enforcement costs. They further state that “the smaller the uncertainty facing the decision maker, the more flexible the institutional arrangements, and the greater the scope for initiative. Hence, developing countries tend to limit the scope for initiative in public sector contract letting (almost always to the lowest competitive bid) whereas more developed countries experiment with various of the newer formats that even allow negotiation (PPP, PFI, BOOT, BOLT etc)” (Riley and Levis, 2008: P?). The same can be inferred from this research in case of Pakistan that the external environmental uncertainties are quite extensive and massive.

Infrastructure procurement has been found in Pakistan to have forward and backward linkages to a range of external environmental issues and barriers identified during this research. It has been found and can be summarized to state that the current situation of the economy, the instability of the political scenario, the immaturity of organizations and institutions, law and order situation or security situation, legal and institutional frameworks, risks and contract management practices, the level of understanding of other procurement form all are not conducive at the moment towards effective implementation of other forms of procurement. There is weak rule of law and justice; economic situation, policy, political instability, decision making abilities etc; all of these have increased the cost of working with public sector in Pakistan. Although it may be noted that these factors and higher uncertainty affects of the above mentioned factors have had a negative impact on the public sector , they have, on the positive side, pushed the organisations to find other innovative methods of financing and procurement. There is limited number of enablers for implementation of other forms of procurement and large number of impediments. A study funded by the Asian Development Bank in 2007 was targeted in Pakistan for finding private sector constraints to infrastructure investment and resulted in finding of substantial impediments, however efforts for removal of these impediments have had limited success till date.

Overall, there is a need to investigate and explore processes of infrastructure procurement in Pakistan as according to the World Bank study (2007) which states that in Pakistan different processes need to be explored which focus on efficient delivery of the end product, especially large mega infrastructure projects at cost, in time, with quality and functionality (World Bank, 2007).

7. Conclusion

Infrastructure procurement is a fairly complex phenomenon and requires innovation, specialty of skills, expertise including policy, regulatory, financial and governance instruments in place to tackle different eventualities. Although most of the factors driving infrastructure procurement process are common across the globe, it should be granted that local solutions to local problems should be pursued. There is a dire need to innovate in the procurement of infrastructure projects in Pakistan. The Government of Pakistan realises that all infrastructure needs of the country cannot be with public funds, but the fact of the matter remains is how to attract, retain and build investor confidence from the private sectors; how to get the knowledge and understanding of the principles and prerequisites of project finance; what policy measures are required and how to maintain a consistency in policies; how to increase the efficiency regarding management and governance of procurement processes; how to develop a regulatory framework that addresses every aspect of procurement; etc. The policy, regulatory, financial and governance instruments at present in the country are at the stage of infancy regarding new and different procurement forms. They need to evolve to the growing needs of the time. Merely incorporating what has been successful in other countries will not bare fruitful results. A longitudinal study investigating and comparing costs for traditionally procured projects and non-traditionally procured projects might be also worth further investigating. Further research is

required that might more rigorously explore the policy environment on how procurement is supposed to be and how currently it is actually being procured in Pakistan. At policy level, stability and clarity in policy frameworks is required. The unstable political environment of the country, instability in policies, use of political pressure and influence are impediments to the procurement and successful implementation of projects. Measures are needed to reduce the impact of negative political factors and increase the impact of positive political factors such as political will.

There is a need to reduce the higher uncertainty of environmental affects as there are limited number of enablers for implementation of other forms of procurement and large number of impediments which need to be reversed. The concept of partnering, alliances and principles of supply chain management need to be explored, understood and adopted within the context of Pakistan in public sector infrastructure procurement.

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Critical success factors in multi-organizational design and construction projects

Pavni Sahni Kohli[1] and Sebastian Macmillan[2]

Abstract

The IDBE masters programme at Cambridge attracts early mid-career built environment professionals from across architecture, engineering, surveying, project management, and construction law. Their first assignment is to write a critical and reflective 5000-word account of a construction project in which they have been engaged. They are asked to report on their own actions and those of others, and on the outcome as they see it. Since the course started in 1994, some 292 case studies have been submitted. From this rich data source, 15 cases have been selected for detailed investigation. They are from different authors and organisations, and have been selected primarily for the authors' reflections on people-based issues like teamwork, leadership, communication, design integration, and collaboration among different disciplines.

The writers are not briefed to focus on *critical success factors* but the case studies have been analysed against a set of 31 critical success factors drawn from the literature. The expectation was that projects judged by the authors as having weaknesses in terms of delivery or quality would lack vital attributes found in more successful ones. However, the pattern across the case studies is less clear with examples where despite good leadership, commitment, honesty, credibility, well-defined responsibilities, and high degrees of technical skill, the outcome is nevertheless judged by the writer as low-performing. At the same time, a set of ten factors that all the better-performing cases shared have been identified: the setting of a challenging task; commercial awareness; technical skills; social skills; attention to team building process; interdisciplinary working; client focus; change management and flexibility; passion and enthusiasm; and motivation. The results have implications for the IDBE course syllabus.

Keywords: case studies, success factors, interdisciplinary collaboration, motivation, social skills.

1 Introduction and objectives

This study draws upon an original database of 292 case studies submitted over an 18-year period by students of the *Interdisciplinary Design for the Built Environment* (IDBE) course at the

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University of Cambridge. As part of their course-work, every student is expected to prepare a case study where they review and assess a recent project in which they have been involved. The main purpose of the assignment is an educational one of encouraging the writers to reflect critically on a project with which they are fully familiar and have most of the facts at their fingertips. Critical reflection and effective communication are among the key aims of the course itself. The case study briefing to the students in the Course Handbook includes requiring them to describe and reflect upon the decisions and actions of the participants, to gauge the strengths and weaknesses of the process followed, and to evaluate the outcome. The aim of this analysis is to undertake a cross-case comparison, to report on the factors that the authors identify as critical to project performance, to offer some generalisable lessons about project success, and to assess the course syllabus against them. Because of the scale of the task in comparing cases, just 15 cases from the 292 have been chosen. The selection of projects was made before any detailed analysis was undertaken. Author and project details are given in Table 1. The projects ranged from a $1bn project down to just £4.5m. The median value is £30m. Projects were selected according to the following criteria:

- *Detailed coverage of teamwork and process issues including collaboration across professional disciplines:* as opposed to a more technical focus.

- *Completion:* the project (or part of it reported upon) had been constructed; none of the projects was a design-stage only case study.

- *Size and type*: domestic-scale projects were omitted, the smallest in value is US$4.5m.

- *Location*: while IDBE students come from all over the world, selected projects were limited to those in UK and US.

Table 1 Summary of the 15 projects chosen for analysis

CS	Discipline of author (and project role if different)	Project location	Project type	Cost US$ 000s*
9	Civil engineer	US	University science complex	1000
7	Architect	UK	Multi-storey office	160
5	Structural engineer	UK	Multi-storey office	150
11	Structural engineer	UK	Multi-storey office	100
14	Project Manager	US	Media centre	72
15	Mechanical engineer	US	Art museum	50
13	Mechanical engineer	UK	School	36
4	Mechanical engineer	UK	School, library and housing	30
3	Structural engineer	UK	Sports stadium	30
10	Architect (project manager)	US	Industrial scale bakery	20
8	Building Regulator (client and end user)	UK	Council Offices	10
1	Structural engineer	UKI	University research building	10
12	Building Regulator	US	Food production facility	5
6	Architect	UK	Agricultural college	5
2	Mechanical engineer	UK	Low carbon housing	4.5

*Some of these cost figures are estimates based on floor areas

2 Literature Survey

There are many definitions and explanations of when a project is a success, and success for one stakeholder or group of stakeholders does not necessarily represent success for others. For example, a prizewinning architectural project may have been highly challenging technically leading to expense and delays. As Jugdev and Müller (2005) state 'project success is ambiguous and highly context dependent'. Nevertheless, several authors offer descriptions of success. Ashley (1987) describes it as 'results much better than expected or normally observed in terms of cost, schedule, quality, safety, and participant satisfaction'. Tuman (1986) sums it up as 'having everything turn out as hoped . . . anticipating all project requirements and having sufficient resources to meet needs in a timely manner'. A more comprehensive definition is given by De Wit (1986) who argues: 'The project is considered an overall success if it meets the technical performance specifications and/or mission to be performed, and if there is a high level of satisfaction concerning the project outcome among: key people in the parent organization, key people in the project team, and key users or clientele of the project effort'.

Accepting that success is relative, is it nevertheless possible to determine common factors that contribute to its achievement so that organisations and individuals can become more aware of them, and universities can address them in their teaching? The topic of CSFs has attracted considerable interest from both academic and professional communities, and numerous studies have been conducted that seek to define 'critical success factors' (CSFs), especially within information systems, R&D, and various engineering environments. Table 1 shows some descriptions from the literature.

Table 2 Some descriptions of critical success factors from the literature

Rockhart (1979)	CSFs are a means of identifying the essential elements that need to be addressed for organisations to implement change more effectively. Within a project context, CSFs can be described as the factors that the manager needs to keep a firm eye on to achieve a successful delivery.
Anderson et al., (2006)	The implication is that if critical success factors are not present or taken into consideration, problems will be experienced which may act as barriers to success.
Jugdev and Muller (2005)	Project success is ambiguous and highly context dependent. Consequently, what is considered to lead to success is coloured by personal perception and by the circumstances under which the judgement is made.
Cooke-Davies (2002)	The question of which factors are critical depends on answering three separate questions: What factors lead to project management success? What factors lead to a successful project? And what factors lead to consistently successful projects? Cooke-Davies distinguishes between project success (measured against the overall objectives of the project), and project management success (measured against traditional measures of performance such as cost, time and quality). A further distinction is between success criteria (the measures by which success or failure of a project will be judged) and success factors (those inputs to the management system that lead directly to the success of the project).
Fortune and White (2006)	These authors demonstrate there is lack of consensus about what factors affect project success. They found the three most cited factors to be support from senior management; clear and realistic objectives; and the production of an efficient implementation plan.

Researchers concerned with the production of the built environment have identified several critical frameworks for success. The most basic comprises the widely accepted trio of time, cost and quality which, at its most elementary, is an assessment of whether a project meets the budget, the timetable and the technical specifications (Phua, 2003). Certain success criteria are concerned with the delivery team and its procurement and management procedures such as project partnering, construction contracting methods, planning and project management (Chua et al,1994). Equally from the perspective of clients and other building users, lie issues of whether qualitative and quantitative client expectations, plus those of the wider stakeholder community, have been met. Without the inclusion of these issues, the measurement of success is incomplete, and normative frameworks will be inadequate to guide management (Zwikael and Globerson, 2006).

In construction management, Chan et al (2004) propose that CSFs can be sorted into five independent groups which they term: *human related factors* (experience, client characteristics, project team), *project factors* (type, complexity, size), *project procedures* (procurement, tendering), *project management actions* (communication system, planning and control mechanisms) and *external environment* (social, economical, political).

In their study of a multi-disciplinary engineering consultancy in the UK, Koutsikouri et al (2008) state that there are few studies of the design phase of construction projects that use the framework of critical success factors. She and her colleagues summarise the organisational setting as often multidisciplinary and characterised by creativity, iteration and the uniqueness and temporality of project arrangements. They note that the challenges faced by project participants are many and varied, there is high dependence on diverse skills, often difficulty in developing a shared vision, and limited time to locate relevant knowledge. They identified that it is vital in design projects involving different professional disciplines to include soft skills, that is, the subjective dynamics of people and social processes, such as passion and enthusiasm, creativity and innovation, and culture and values. These, they show, are all of particular importance within multi-disciplinary design projects. Drawing on research into project management success factors by Fortune (2006) as well as other sources, they developed a framework of CSFs and applied it to projects in the consultancy they studied.

IDBE case studies are not limited to a single engineering design consultancy but are spread more broadly across wider disciplines. Nor are they limited to the UK but are international. The student authors do not necessarily share even among themselves a single definition of design, which is an ambiguous term even within the built environment let alone more broadly across manufacturing and the creative arts. Nevertheless the framework of critical success factors used by Koutsikouri and her colleagues has been adopted for this study. The list of factors is shown in column 2 of Table 3 (below).

3 Data Analysis

In an iterative process, each of the 15 projects was subjected to an independent review and evaluation by the first author of this paper. The text of each case study was scrutinised to identify references to the 31 CSFs, and the relevant content from the original case study referring to each CSF was pasted into a table. This resulted in a table for each of the case studies comprising 31 rows. Next, the first author of this paper assessed the case study writer's comments about each CSF and allocated a score against each one on a scale of 1-5 (5=high) interpreting as faithfully as possible the original case study author's perception of how strong or weak the project was with respect to that factor. Tables 4, 5 and 6 contain selections of the case study text *in italics* and the scores allocated. In all 15 cases also, the original student author's overall perception of the project outcome from their own perspective was rated by the first author of this paper on a scale of 1-5; again this is a subjective interpretation but at least by a single researcher to achieve a level of consistency. Just as projects are likely to be evaluated differently by different stakeholders, it has to be admitted that the research method adopted here is not an objective process but a subjective one, whose aim is to identify whether there are common patterns across this set of case studies.

Although the case studies were not written around the 31 factors, in practice detailed examination yielded a mention of almost all of them. The scores allocated were tabulated and the cases were then ranked by total score. Trends and patterns in the data could then be identified and investigated. The overall ratings made by the first author of this paper were also tabulated. The results are given in Table 3 which divides the projects into three broad categories of low (four projects), medium (6 projects) and high (five projects) ratings. Where there is no mention of a factor in the original student case study, table 4 shows n/a (not applicable).

Table 3 Rating ascribed to each CSF in each case study

	CASE STUDY NUMBER:	*8*	*3*	*14*	*12*	*6*	*1*	*5*	*9*	*2*	*13*	*4*	*11*	*15*	*10*	*7*
	OVERALL SCORE	**1**	**1**	**2**	**2**	**3**	**3**	**3**	**3**	**3.5**	**3.5**	**3.5**	**4**	**4**	**4**	**4.5**
A	**Goals and Objectives**															
1	Defined project goals	2	2	1	2	4	2	2	4	4	4	5	3	2	4	5
2	Shared project vision	2	2	2	3	2	2	2	4	4	4	5	4	3	4	4
3	Defined roles & responsibilities	1	1	**4**	1	2	2	4	4	2	4	3	2	3	4	5
B	**Performance Monitoring**															
4	Project management practices	1	1	2	2	2	2	3	4	2	3	3	3	4	4	4
C	**Decision Makers**															
5	Quality of leadership	1	1	1	4	2	2	3	2	2	4	3	2	3	4	4
6	Team selection & composition	1	1	1	1	2	2	4	4	2	4	3	na	2	4	4
7	Commercial awareness	3	1	1	**5**	2	3	3	2	2	na	4	5	3	5	5
D	**Transformations**															
8	Technical skill	1	2	**4**	2	2	2	4	2	2	3	3	4	4	5	5
9	Social skills	1	2	1	2	1	3	2	n/a	2	4	na	4	4	5	4
10	Team Building process	1	1	1	2	1	2	**1**	n/a	3	4	4	4	4	5	4
11	Creativity and innovation	1	2	2	1	5	3	3	4	5	4	3	4	4	2	4
12	Effective teamwork	1	1	2	4	1	2	2	3	3	4	2	4	4	3	4
13	Time management	3	2	2	2	3	2	3	4	3	2	5	4	2.5	5	3
E	**Communication**															
14	Rich Communication	1	1	2	1	2	2	2	2	3	3	3	4	3	4	4
15	Knowledge sharing	1	1	1	3	2	2	2	4	4	2	3	4	2	4	4

16	Management of expectations	1	1	1	**4**	2	3	3	2	2	2	3	3	4	4	4
17	Feedback on progress	1	2	1	1	2	2	2	na	3	3	2	2	5	4	4
F	**Environment**															
18	Organizational structure	1	2	3	3	2	2	2	4	2	3	2	2	3	2	4
19	Culture	n/a	2	3	1	1	n/a	3	2	4	n/a	4	2	3	n/a	n/a
20	Physical environment	n/a	1	n/a	n/a	2	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	4
I	**Boundaries**															
21	Relationships	3	1	3	2	2	3	2.5	2	2	2	2	4	4	4	3
J	**Resources**															
22	Sufficient resources	2	1	2	2	3	3	4	5	4	3	3	4	3	2	3
23	Appropriate technologies	1	3	1	na	2	2	3	4	4	4	4	4	4	3	5
K	**Continuity**															
24	Client focus	1	1	2	**5**	3	5	4	4	2	5	4	4	5	4	5
25	Mutual trust & understanding	2	1	1	2	2	2	2	2	2	2	2	2	4	3	3
26	Change management & flexibility	1	1	1	2	3	4	3	2	3	2	4	4	4	5	4
27	Motivation	1	2	1	1	4	4	2	3	4	4	4	4	3	4	4
28	Challenging task	1	2	**4**	2	4	4	4	4	3	3	4	4	4	4	4
29	Passion and enthusiasm	1	1	2	2	4	2	2	2	4	4	3	4	4	3	4
30	Shared values	1	2	1	2	1	2	2	2	4	2	2	2	4	**1**	4
31	Recognition and appreciation	1	0	4	1	4	4	3	4	5	4	4	4	4	2.5	4
	TOTAL	39	44	57	65	74	75	81.5	85	91	92	96	100	106	108	122

4 Findings

As table 3 shows, the 15 projects occupy a spread of performance achievements. At the extremes, the least successful projects show a relatively uniform pattern of low performance across all, or almost all, of the critical success factors. At the other extreme, the most successful projects showed fairly consistent good performance across the board. The factor 'physical office environment' was rarely referred to in the original case studies and does not seem to have been a significant issue in this set of case studies. 'Culture' was also rarely mentioned.

In tables 4, 5 and 6, a selection of direct quotes from the original case studies are presented *in italics* under the various CSFs to demonstrate some of the process that has been followed in the analysis; other summary observations about each CSF made by the first author of this paper are given in normal text.

4.1 Low and medium performing projects

The main trend shown by the low performing projects was uniform low ratings across all or almost all factors, although the data do contain examples of projects that are not uniform. These have been highlighted in table 4. So for example, case studies 12 and 14 exhibited a high quality of leadership from the client side, good commercial awareness and rigorous client focus.

Table 4 Case studies 12 and 14 – low performing overall but good in parts

CS no.	CSF	Analysis including original quotes from the case study *in italics*
CS12	a. Quality of leadership (**4**)	This project ranked in bottom four according to overall performance. However, it had high scores in some factors: a. "*Client's agent was dedicated and honest, high credibility, very experienced with excellent negotiation skills and ability to solve problems quickly and effectively.*"
	b. Commercial awareness (**5**)	b. "*Quick cost effective construction was first priority, knowledge of building inspector used in lieu of architect to save money.*" Although there was much focus on commercial awareness, this was the

	c. Client focus (**5**)	only thing the team was focusing on. Very little attention to creativity and innovation, an architect was not used in order to save money. c. "*Client brief of cost control was followed religiously by the team, clients expectations met perfectly (ON TIME), the agent dealt with the problems competently."* The strong client demanded extreme cost cutting and time management; this resulted in other factors being completely sidelined and effecting the morale of the team.
CS14	a. Defined roles and responsibilities (**4**) b. Technical skills (**4**) c. Challenging task (**4**)	Overall the project did not perform well**.** However, it had high scores in some factors, a. these were clearly defined among consultants and [the consultant's] team. b. "*All consultants sufficiently experienced but were not integrated into the project well, [The consultant] decided on use of evidence based design in lieu of industry standards which was ill-matched for such a technical project."* c. "*Very technical building, broadcast and data infrastructure needed to run through entire building, needed more coordination, time and effort between design team and owner to achieve architecture support for the facility and design of such unique elements."*

Projects with medium performance similarly showed considerable variety across the individual factors. Table 5 shows examples including quotations where the medium projects still score highly. One interpretation is that despite generally low scores, the seven CSFs highlighted in Table 3 (*defined project goals*, *creativity and innovation*, *sufficient resources*, *client focus*, *motivation*, *challenging task* and *recognition and appreciation)* can raise an otherwise weakly performing project to make it moderately successful.

Table 5 Projects with moderate performance but showing some high scores in CSFs

CS no.	CSF	Analysis
CS1	Client focus (**5**)	There was constant focus on client needs. "*The client expressed gratitude to design team for sensitive way cost savings had been made, with little detrimental effect on space*"
CS2	a. Creativity and Innovation (**5**) b. Recognition and appreciation (**5**)	a. According to the author, it was an "*innovative, award winning design by high profile star architect Renzo Piano."* b. The team was motivated to give its best as the building was in the national register of historic buildings and afforded them much recognition and appreciation.
CS5	a. Defined roles and responsibilities (**4**) b. Team selection and composition (**4**) c. Team building process (**1**)	a. The team was composed of experienced experts and each had a clearly defined role d. One factor that stood out is 'Team building process': *"There was no effort towards team building exercises, everyone worked in isolation and people were not proactive in building relationships with each other."*
CS9	a. Defined project goals (**4**) b. Shared project vision (**4**) c. Defined roles and responsibilities (**4**)	a. The main goals were to achieve high quality and complete the project on schedule. *b.* The project benefited from a strong vision statement: "*The [University] Campus initiative report and a series of other documents present the aspirations, benchmarks and clear vision that the redevelopment of a former industrial zone into a university extension will have direct benefit for the entire community."* *"Also aim to lead by example in terms of sustainable development and construction."* c. "*Clearly defined by organograms in [the consultant] and [the client's representative] to direct progress of the masterplan. They in turn appointed [the project manager]."*
CS13	a. Goals and objectives (**4**) b. Defined roles and	a. "*High aspirations for the school to achieve specialist status in music and IT.'* b. Initially the roles and responsibilities were clearly defined but later on there were communication problems: "*The specialist needs required*

	responsibilities (**4**) c. Team building (**4**) d. Creativity and innovation (**4**) e. Effective interdisciplinary team work (**4**)	*specialised consultant appointments-causing large number of consultants on the project. However, development of specializations led to breakdown of understanding between the different participants--neither the design team nor the specialists were aware of the task the other needs to undertake. With no one spanning the gap-continual breakdown in communication occurred."* c. *"Kick-off meeting (internal to the consultant) to introduce all design team members to the scheme and to each other, this brought the members together at an early stage and develop a sense of belonging before turning up together at external meetings."* d. "*Architect, known to be perfectionist, brought in innovative measures based on extensive research and forced consultants to think out of the box."* e. *"...seen in design of structural systems where architect and structural engineer brought opposite ideas but adapted well to solving new problems ... the whole team bonded over the differences in opinions and the fact that a satisfactory situation was reached in the end."*
CS6	a. Creativity and Innovation' (**5**) b. 'Recognition and appreciation' (**4**)	The project was moderate success, but scored high in these two factors: a. A very creative and dominant architect: "... *brilliant renowned architect who was tenacious about his design*. [He defined the goal] *to build a beautiful building which matched his vision."* b. It was a very prestigious project with much scope for recognition for the team. Both these factors kept the design team motivated and passionate to deliver their creative vision.

4.2 High performing projects

Table 6 summarises five high performing projects in terms of the original authors' observations tabulated against CSFs that were met to a high level. The most successful projects showed high ratings in almost all factors but most significantly in the two areas:

- *Transformations* - technical skills, social skills, team building process and effective inter-disciplinary teamwork

- *Continuity* – client focus, change management and flexibility, challenging task and passion and enthusiasm.

This suggests that the most successful projects focused on the core issues of creating a strong team by team-building exercises and creating open channels of communication. Secondly they maintained constant client focus and kept the team motivated by offering challenges tasks. This ensured that the team was open and flexible, and managed changes well.

Another factor in which successful projects rate highly is *commercial awareness* which means that the commercial value of the building was paramount. Often this led to tight control on spending and ensured the projects did not go over budget. As a result clients were satisfied and deemed the projects a success. Another prominent factor is *management of expectations*, which is closely linked with client focus.

Table 6 High performing projects

CS no.	CSF and grade	Analysis
CS4	a. Defined project goals (**5**) b. Shared project vision (**5**) **c.** Time management (**5**)	a. [The project goal and vision] "*... was to deliver the project on a strict deadline."* b. Time was managed strictly to achieve this goal – "*...completed on very strict deadline, everyone did whatever it took to complete on time for the Ashes."*
CS7	a. Defined project goals (**5**) b. Commercial awareness (**5**) c. Technical skills (**5**) d. Client focus (**5**) e. Defined roles and responsibilities (**5**)	a. *"The goal was to make the project a commercial success, give flexibility and choice to client."* Clearly defined roles and responsibilities: "*... the architects and project managers prepared a full program complete with aims and objectives and delegated work to architects, contractors, sub-contractors."* b. "*... was a common thread as each decision reflected on commercial value of the building.*" c. "*... excellent technical skills, best consultants in their field were used."* d. "*... maintained throughout by [the architects], this was the reason for three design options so that the client could have flexibility and choose what they liked.'*" The clients prepared a detailed report with aims and objectives, this set out the roles of each consultant. Moreover they selected the best consultants in the field and provided them with sufficient resources. The consultants in turn maintained clear client focus throughout.
CS10	a. Commercial awareness (**5**) b. Technical skills (**5**) c. Social skills (**5**) d. Team building process (**5**) e. Time management (**5**) f. Change management and flexibility (**5**)	*a. "Strong focus throughout, bankers always a part of meetings and advised on costs and budgets*." *b.* "*Key problem areas were quickly identified - like HVAC and interior/exterior finishes, and simplified to reduce time and cost (6 weeks saved). Simple solutions like retaining a well finished concrete surface rather than painting with epoxy high gloss saved thousands in material and labour costs."* *c.* "*Skills like listening carefully helped form an understanding of the project.""* *d.* "*The team was motivated by quick response to design discussions, sketching by day, drafting by night and presenting next morning helped to consolidate the design quickly."* *e. "... eye on agreed objectives and weekly score of them, constant focus on objectives and deliverable dates resulted in project completed before time."* *f.* By architect when client adamantly purchased and assembled non-suitable windows which leaked and caused mildew, the architect tried an innovative spray on sealant which worked very well. So there was flexibility despite non-cooperative client.
CS11	a. Commercial awareness (**5**) b. Transformations (**4**) c. Interdisciplinary team work (**4**) d. Client focus (**4**) e. Change management and flexibility (**4**)	a. As client and contractor were the same the focus was on this aspect. Primary goal was to have maximum net lettable area. The architect was sidelined after the initial stage to focus on building fast. b. *"[The engineers] maintained a practical outlook and the perception of hard work by undertaking rework, this established a good relation with the contractor."* Innovative solutions to the horizontal loads problem in the building - this reduced maintenance and increased net lettable area. *c.* "*This was seen between [the engineering consultants] and fabricators, it limited abortive work and maximized profit. Working closely with fabricators minimized errors."* *d.* The team worked to woo the high profile client in order to win further work. *"[The engineering consultants] absorbed design and co-ordination role, usually the domain of the architect but necessary here as contractor passed information directly to them they maintained open communication channels and provided innovative solutions quickly."*
CS15	a. Transformations (**mostly 4**)	a. Highly professional and experienced staff, interdisciplinary meetings held regularly and allowed everyone to discuss ideas and resolve problems

	b. Continuity (**mostly 4**)	together, helped to avoid breakdown of relationships despite difficult client. *"Workshops and team building process helped communication, this was later seen in the way team handled constant changes and took them in their stride."* *"Inter-disciplinary meetings were held regularly and allowed everyone to discuss ideas and resolve problems together."* b. *"The team maintained rich communication and despite frequent changes attempted to maintain flexibility and keep work on track.* They also had shared values: *"To see the project successfully to its end and ensure client is happy."*

5 Findings

In broad terms, projects whose authors report on them positively overall are achieved when most of the critical success factors are also present. And conversely, when little attention is paid to these factors, projects in this study have been reported by their case study authors as underperforming. This is only to be expected and neither of these findings is a surprise. What is more valuable is to assess whether, within the framework of 31 critical success factors, it is possible to identify those that appear to be essential to high performance. According to the present analysis there are ten success factors that appear to be *crucial* for high performance, in that each of our high performing case studies scored highly with respect to each of these ten. These are highlighted in table 4 and listed in table 7 below.

Table 7 Crucial success factors in the IDBE data set

Decision Makers	**Transformations**	**Continuity**
Commercial Awareness	Technical skills Social skills Team building process Effective interdisciplinary team working	Client focus Change management & flexibility Motivation Challenging task Passion and Enthusiasm

A key question then becomes: 'how are these *crucial factors* rated in those projects judged as of medium success?' Here the pattern is not clear cut. As table 4 shows three of the ten *(client focus*, *motivation* and *challenging task)* were fairly highly rated in the set of medium performing projects but the other seven were not; and meanwhile the factors of *defined project goals*, *creativity and innovation*, *sufficient resources*, and *recognition and appreciation*, were highly rated in the medium performing projects, though they are not among the ten *crucial factors* of high performing projects.

The expectation of this analysis was that as projects are rated more and more successful, then more and more of the CSFs would be met at higher and higher levels. That simple pattern is not entirely evident in Table 3. In part this is undoubtedly due to methodological limitations of this study, and specifically the subjective nature of our interpretations of others' project descriptions and evaluations. But equally, it reinforces the line taken by Koutsikouri et al that 'simply attempting to identify and classify CSFs is not enough in understanding how project success

can be achieved in complex projects.' Built environment projects involve complicated procedures and processes, and the ***degree of integration across factors*** may be equally or more impactful than success against each judged separately.

A further finding relates to the application of the CSF framework devised by Koutsikouri et al. While their study was based upon interview data from only one organization, it has been applied beneficially here to a diverse sample of multi-organizational built environment projects and been found to offer an insightful assessment system for these as well. Despite the fact that the IDBE case studies were not written in accordance with the framework, and nor were the original case study authors questioned, a mention of almost every factor was found in each of the 15 cases. This illustrates the potential of the CSF framework in a wider context.

6 Conclusions

Clearly every construction project is unique, and it is neither possible nor desirable to propose a single universal formula that will guarantee a successful outcome for every project. Nevertheless this study has usefully applied *a framework of critical success factors* and found it to be an analytical tool that has helped to pinpoint strengths and weaknesses of each of these 15 projects.

In the context of the IDBE masters course, from which the case studies have been taken, arguably the ten crucial factors from the high performing projects should be at the core of the course to deliver to its students. Fortunately IDBE is already strongly focused on some of them – in particular ***social skills***, ***team building process***, ***interdisciplinary team working***, and ***client focus*** (as part of a broader concern with design for use and skills in stakeholder engagement). ***Change management and flexibility***, and ***motivation*** are delivered but to a lesser extent. As the students are experienced professionals, there is little emphasis on the course in ***technical skills*** other than those in connection with the sustainability agenda. Students are set ***challenging tasks*** in the studio design projects, and those taking the course are invariably ***passionate*** and ***enthusiastic*** which is why they want to take the course in the first place. Measured against the crucial success factors, the largest gap in the course syllabus is ***commercial awareness*** and this is a skill to which the course needs to pay more attention.

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Analogy-Based Ranking of Delay Causes: An Outlook for Future Projects

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Abstract

Business competition has intensified in many world countries. With such increasingly competitive environment, companies –including those operating in the construction industry– need to seek opportunities outside their home market. Recent construction industry statistics show this trend to be on the rise, despite the increased level of uncertainty that comes along. With an aim to help Egyptian contractors expand their business, the paper presents a study on predicting the causes of schedule delay in potential out-of-country projects, especially in politically unstable and/or economically underdeveloped countries. Novelty of the research comes from developing a "ranked" project-specific list of schedule delay causes for any "future" project into consideration. Development of such list depends on partial analogies with past project cases, whether completed by the company or others working in the industry. For a new project in a given country/region, the list conveys the potentially significant causes of delay specific to the project under study, while taking into account the dominant country and project conditions. The paper provides an overview of the research methodology and study implementation. The research utilises a global list of schedule delay causes, created after scanning a large pool of completed projects in Africa, the Middle East, and the Far East. A process is then devised to handle both quantitative and qualitative data sources. The qualitative approach is adopted in case of incomplete, inaccessible, or unreliable past project records. In the latter case, knowledge of the experts who participated in these projects was used. Finally, means to merge the outcomes of both quantitative and qualitative analyses were sought. The paper also details the indexing system used for identifying the partial analogies between the new project and those past experiences contained in either the qualitative or the quantitative data sets.

Keywords: internationalization, risk, schedule delay, qualitative and quantitative analyses, analogy.

1. Introduction

Business competition has been on the rise in many world countries. With such increasingly competitive environment, companies –including those operating in the construction industry–

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are pressured to seek opportunities abroad. Despite the uncertainties, statistics clearly show an upward trend for the internationalization of construction.

In 2010, the top 225 international contractors generated US$383.7 billion in revenue from construction projects outside their home countries (ENR 2011). Twenty two of these top contractors were from the US. The total international revenue generated by those US contractors was US$44.9 billion, up from US$24.9 billion only five years earlier (ENR 2006, ENR 2011). What may come as a surprise is that out of this US$44.9 billion, 36% associates with projects in the Middle East and Africa. Such market remains attractive despite the political situation in some countries (ENR 2011). A more interesting example concerns Egyptian contractors. Only three showed up on the top 225 international contractors list, with total international revenue of US$1.95 billion in 2010. However, their international revenue jumped eight folds from a mere revenue of US$245 million back in 2005 (ENR 2006).

Diversification into new markets still comes with a hefty price. Companies simply have to learn how to deal with a different set of uncertainties and risks, which are not common in the company's home market (Artidi and Gutierrez 1991, Ramcharran 1998, Hastak and Shaked 2000, Shore and Cross 2003, Gunhan and Artidi 2005, Ozorhon et al. 2007).

To shed more light on the subject, this paper presents a study on schedule-related project risks in politically unstable and/or economically underdeveloped countries. Study was initiated to help Egyptian contractors better understand the causes of schedule delay encountered in projects abroad, especially those in countries of the latter types.

2. Literature Review and Study Contribution

Causes of schedule delay have been a topic for interest for a long time. Some studies focused on identifying the main causes of delay in certain project types while others were specific to the country of execution. Other researchers discussed the delay analysis methods and proposed ways to mitigate the prospective delay. For instance, Wang et al. (2004) utilised feedback from 31 industry professionals to develop a framework for construction risk mitigation in developing countries. Other studies which made use of a larger sample size such as the ones conducted by Abd El-Razek et al. (2008) and Lo et al. (2006) were limited to their home countries, Egypt and Hong Kong, respectively. Yet, with the myriad of studies in literature, none managed to develop a comprehensive approach for ranking delay causes in prospective future projects, while addressing both quantitative and qualitative data sources in an integrated manner. This paper attempts to fill such gap.

The main contribution of the study stems from how a "ranked" list of potential delay causes specific to a "future" project into consideration is developed, figure 1. Utilising a generic list of delay causes, partial analogies with past project cases, e.g., projects 1 through 12, are used to deliver a ranked list of delay causes specific to projects into consideration, e.g., projects KLM and PQR. As per figure 1, projects 1, 2 and 3 are irrelevant to target project PQR, whereas projects 10, 11 and 12 are irrelevant to target project KLM. In other words, no partial analogies can be drawn from these source projects to the target project into consideration. The resulting list of delay causes then becomes available to the contractor

prior to project execution. It gives insight on what should be watched for in that particular project. Risk mitigation strategies can be decided upon in accordance with the significance of delay causes.

It is worth mentioning that analogies can be made, whether the source data is qualitative or quantitative in nature. The paper particularly elaborates on the way each type of data sources is dealt with.

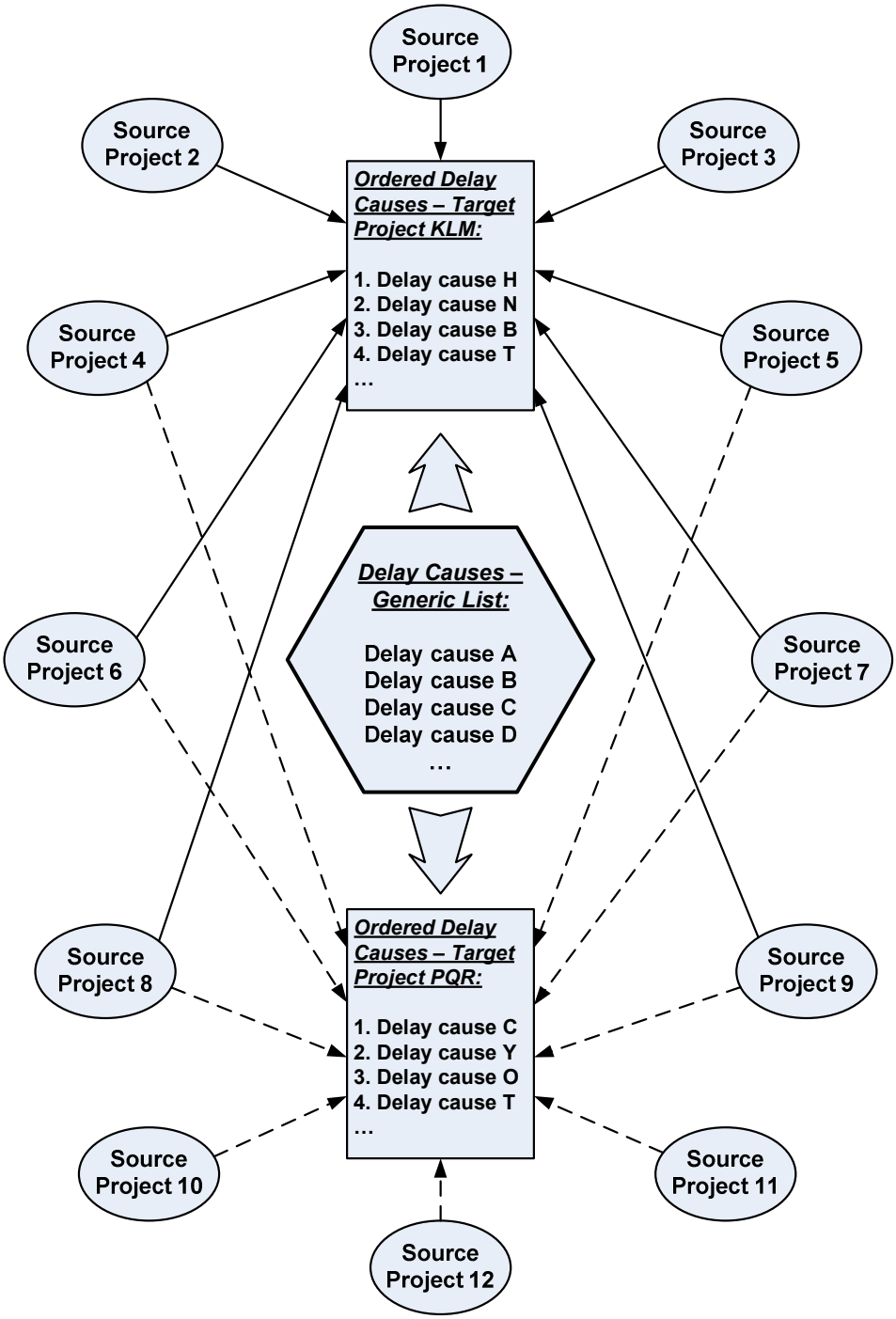

Figure 1: Ranking of delay causes according to partial analogies with past projects

3. Research Methodology

A five stage generic process was adopted to implement the research idea, figure 2. This same process can also be applied by interested construction companies for their own international operations.

Stage 1 involves the establishment of the project pool (or in other words, the source data to use for the research method implementation). When project data is properly archived, a review of the relevant documents is performed with the aim of highlighting delay cases/scenarios. To prepare for the following steps of the methodology, the schedule impacts and number of instances a given delay cause occurs are meticulously recorded. Another approach has to be adopted when only incomplete, inaccessible, or unreliable project records exist. In the latter case, semi-structured interviews and/or questionnaire forms are employed to solicit the knowledge of those who participated in managing the source projects. It is important to include such data pool, in order not to exclude a significant source of data for study implementation. Stage 1 ends with the categorization of projects according to the country/region and type of work.

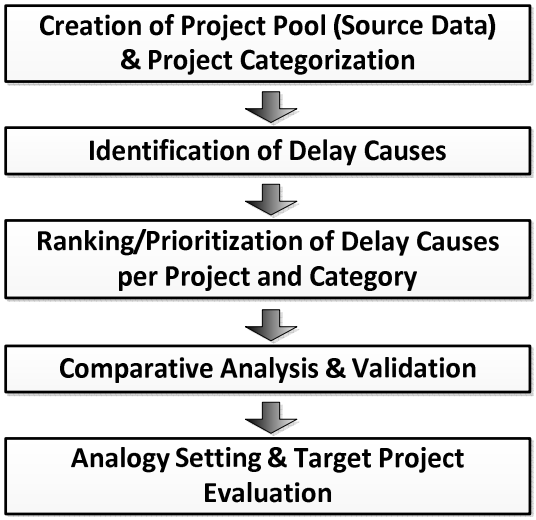

Figure 2: Research methodology

Stage 2 involves identifying and listing the delay causes for each project, whether the source of data is qualitative or quantitative. For standardization purposes, a global list of schedule delay causes is devised and each project is annotated with the delay causes specific to it.

Stage 3 proceeds with ranking the delay causes for each project. It then utilises the categorization of projects to identify and rank risks per each category. Besides identifying commonalities in delay causes within the category, differences from one category to another could be pointed out. With such knowledge, a comparative analysis is conducted to signify the similarities and differences, stage 4. Validation of the results using test cases is necessary to assure the quality of outcomes.

Last step utilises the delay causes that have already been identified, categorized, and ranked, as per the previous steps, to evaluate any target project into consideration. Using partial analogies with past project cases, an outcome in the form of a project-specific ranked list of schedule delay causes for the target project is produced. Research specifically adopts case-based reasoning (CBR) as the computational platform of choice to prioritize the list of delay cause for future projects.

Implementation of the research methodology, for both quantitative and qualitative data sets, is elaborated on in the next sections. Emphasis is on the identification, categorization, and ranking of delay causes.

4. Quantitative Approach

This approach requires full access to archived files of past out-of-country projects. To be able to detect the delay scenarios/causes, and measure their impacts and how frequent they occur in numerical terms, several companies were approached with a request to access their completed project databases. Due to restrictions on the proprietary information and the poor record keeping by some, the implementation by authors had to be limited to data from few companies with the majority of projects from one well-known international contractor. Thus, the results obtained, part of which will be presented at the end of this section, cannot be considered conclusive of the Egyptian construction industry. Moreover, this led to emphasizing the qualitative approach as complementary to the quantitative counterpart.

For each candidate project, the delay scenarios were identified. To streamline the identification process, a global register for schedule delay causes was developed as the identification progressed from one project to another. This register includes all schedule delay causes possible, where each project exhibits some of these causes. This guarantees a common reference in study implementation. Also projects were organised in categories according to project region/country and/or type of work, e.g., Roads in Sub-Saharan Africa.

Review of project baseline and update reports was fundamental in measuring the delay impact factor, DIF_{ijk}, for each delay scenario, eq. (1).

$$DIF_{ijk} = D_{ijk} \,/\, T_{jk} \quad \text{.....(1)}$$

Where, DIF_{ijk} is the impact factor for delay cause *i* in project *j* under category *k*, D_{ijk} is the delay (in time units) resulting from delay cause *i* in project *j* under category *k*, whereas T_{jk} is the total time/duration for project *j* under category *k*. Unlike many studies in literature, the measurement of D_{ijk} made extensive use and comparisons of actual project plans and baselines, critical path and update reports, etc. This also led to the exclusion of many projects that did not fare the bill, or in other words, had to be analysed qualitatively.

A combined list for each category *k* was developed to showcase the delay causes detected in the source projects under this category. The DIF_{ijk} values were then summed up to estimate a collective impact factor for each delay cause at the category level, CIF_{ik}.

The frequency of occurrence, and thus the probability, P_{ik}, for each delay causes was further tracked as per eq. (2).

$$P_{ik} = Q_{ik} / N_k \text{.....(2)}$$

Where P_{ik} is the probability of occurrence of delay cause *i* under category *k*, Q_{ik} is the frequency or number of projects under category *k* where delay cause *i* occurred, and finally N_k is the total number of projects under category *k*.

An expected value index, EV_{ik}, for each delay cause *i* under category *k* can be estimated as the multiplication product of P_{ik} and CIF_{ik}, according to eq. (3) as follows:

$$EV_{ik} = P_{ik} * CIF_{ik} \text{.....(3)}$$

Outcome of the above methodology was a prioritized list of schedule delay causes per category, a sample of which is illustrated in table 1.

Table 1: Prioritized causes of delay for Airport Aprons in Afghanistan

R_{ik}	Cause of Delay	EV_{ik}
1	Change orders	2.64
2	Removal of debris	2.11
3	Demining	1.90
4	Theft at harbor	0.50
5	Unavailability of mobilization area	0.40
6	Unclear scope of work	0.25
7	Lack of coordination	0.25
8	Lack of sufficient data	0.14
9	Lack of access to batch plant site	0.10
10	Lack of good documentation	0.10
11	Unavailability of permanent power connection by government	0.09
12	Occupation of site by client	0.09
13	Gate access delays	0.05
14	Regulatory issues at harbor	0.02
15	Strike	0.02
16	Bad weather	0.01

5. Qualitative Approach

The qualitative approach allowed a much more diverse group of projects in Africa, the Middle East, and the Far East, to be investigated. Semi-structured interviews were conducted with 19 experts who participated in 38 projects that took place in the target regions. With schedule impacts in mind, experts were asked to rank the causes of delay in

each international project they participated in. Estimation of CIF_{ik} in this approach is based on the ranking of delay causes in projects under any targeted category *k*. An average rank, R_{ik}, for each delay cause *i* under category *k* is based on 1) the number of times this delay cause was associated with a project under this category, Q_{ik}, and 2) The relative impact of the delay cause as indicated by its ranking in the list. This average rank is calculated as per eq. (4).

$$R_{ik} = \sum_{j=1}^{N_k} R_{ij} \ / \ Q_{ik} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Where R_{ij} is the rank for delay cause *i* in project *j* (R=1 being the top-rank delay cause). Finally, CIF_{ik}, which represents the relative impact of the delay cause *i* under category *k*, is taken as the reciprocal of R_{ij}. Table 2 shows an example of a prioritized list of causes of delay categorized according to project region. In this context, CIF_{ik} is utilised to calculate EV_{ik} as per the generic eq. (3).

Table 2: Prioritized causes of delay list in Sub-Saharan Africa

R_{ik}	Cause of Delay	EV_{ik}
1	Cash flow problems	0.5
2	Regulatory issues at the customs	0.375
3	Lack of equipment with reasonable rental prices	0.31
4	Bad weather	0.25
5	Unclear scope of work	0.125
6	Lack of qualified subcontractors	0.125
7	Change orders	0.1
8	Strikes	0.08
9	Site obstructions	0.08
10	Delays in site possession	0.08
11	Re-routing	0.06
12	Lack of co-ordination	0.06
13	Poor planning/Estimating	0.06
14	Bribery/Corruption	0.05
15	Lack of supply of primary resources	0.05
16	Delay in shipment	0.05
17	Fluctuation in prices/exchange rates leading to work stoppages	0.05
18	Re-work	0.04
19	Procurement administrative issues	0.04
20	Security issues	0.03

It is to be noted that the rank of a delay cause *i* under category *k*, that is R_{ik}, is recorded and used for merging the quantitative and qualitative analysis results. The same eq. (4) was applied for quantitative data to unify the method of measurement. Table 3 shows the exact

same example used in table 1 organized using eq. (4). EV_{ik} is again calculated using the generic eq. (3). Further details are presented in the following section.

Table 3: Table 1 causes of delay for Airport Aprons in Afghanistan prioritized using Eq.4

R_{ik}	Cause of Delay	EV_{ik}
1	Change orders	1.0
2	Removal of debris	0.5
3	Demining	0.33
4	Theft at harbor	0.14
5	Unavailability of mobilization area	0.125
6	Unclear scope of work	0.1
7	Lack of coordination	0.08
8	Lack of sufficient data	0.06
9	Lack of access to batch plant site	0.05
10	Lack of good documentation	0.05
11	Unavailability of permanent power connection by government	0.04
12	Occupation of site by client	0.04
13	Gate access delays	0.04
14	Regulatory issues at harbor	0.03
15	Strike	0.03
16	Bad weather	0.03

6. Merging Qualitative and Quantitative Data

In order to benefit from the enhanced quality of the quantitative data and the large coverage of the qualitative data, a merging approach is proposed. The merging enables knowledge to be leveraged from both approaches, thereby enhancing accuracy and coverage of the prediction, figure 3.

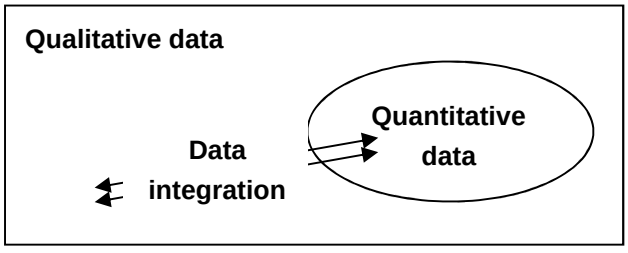

Figure 3: Qualitative and quantitative data merging

In study implementation, projects were generally categorized according to the project region/country (*R*) and type of work (*W*). This classification reflects on earlier studies in delay

analysis and risk classification, e.g., Hastak and Shaked (2000) and Wang et al. (2004). The adopted categorization and outcomes of both quantitative and qualitative analyses were used to develop a common/global index, GEV_{ik}, for delay causes under category *k*. This index can be calculated according to eq. (5).

$$GEV_{iRW} = EV_{iR} * EV_{iW} \text{.....(5)}$$

Where EV_{iR} is the expected value index for delay cause *i* in region *R* (i.e., category *k* is equivalent to region *R*), and EV_{iW} is the expected value index for delay cause *i* in work type *W* (i.e., category *k* is equivalent to work type *W*).

When the merging approach is utilized, EV_{iR} is calculated based on the rank value reciprocal similar to the qualitative approach methodology (eq. (4)).

To exemplify, let us assume a construction company is considering an Apron Project located in Sub-Saharan Africa. Table 2 provides information for the sought type of work (*W*), which is Apron Projects, whereas table 3 is reflective of project region/country (*R*), which is Sub-Saharan Africa. Thus, the value of GEV_{ik} for delay cause "change orders" – based on Tables 2 and 3 – shall be equal to $EV_{iR} * EV_{iW}$ = 1 * 0.1 = 0.1. Obviously, in merging the qualitative and quantitative data, all needs to be in sync. That is why the calculated EV_{ik} values of table 1 was not utilised. Table 3 was used instead.

Finally, the research took into consideration that quantitative data is more reliable; therefore a multiplier is used to augment the weight of results derived from quantitative analysis. Another used multiplier accounts for the level of confidence in qualitative data/interviewer for more results precision

7. On-Going Research

Further works include estimating a multiplier to account for own company circumstances. This can contribute to the re-prioritization of delay causes as defined by eq. (4). Such multiplier can be derived from semi-structured interviews with high profile experts within the companies in concern. Further works also includes introducing a case-based reasoning (CBR) model to enhance estimating the similarity between the contractors' upcoming projects and the projects available in the case base.

8. Conclusions and Recommendations

This paper presents three distinct yet complementary approaches to quantify the expected delay causes on construction projects. The quantitative approach was based on actual delay durations calculated from an in-depth assessment of delay causes from construction schedules and narratives. This approach can be used when the company has a large number of well-documented construction schedules. The qualitative approach is based on interviews with 19 experts and covered 38 projects in Africa, the Middle East, and the Far East. Based on the ranking of delay causes from these data sets, expected values of delays were calculated for various project types and regions. This approach can be utilized when

companies do not have reliable construction schedules, but have access to experts with sufficient knowledge on delay causes. For companies that can capitalize on both types of data (qualitative and quantitative), a data merging approach is proposed. This technique is able to leverage the advantages of both approaches (accuracy and coverage) to enable construction companies to better predict the expected causes of delay on international construction projects. This improved prediction can result in 1) the development of more effective risk response plans, 2) more reliable estimation of contingencies, and 3) establishment of more efficient project control procedures.

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Harmonisation of Construction Health and Safety Laws in Australia

Manikam Pillay[1]

Harmonisation of Construction Health and Safety Laws in Australia

For over four decades all states and territories in Australia have maintained their own and separate set of laws for the management of health and safety risks in construction. This resulted in at least ten different sets of health and safety legislation. Responding to calls for national uniformity, a harmonised set of laws wer issued in 2011 by the Federal Government, in the form of Model Work Health and safety Act and Regulations. These, together with industry-specific codes of practice, are expected to provide construction organisations their first ever common set of standards and benchmarks across the states and territories they operate in. However, the objectives of harmonisation appear not to have been fully realised because the harmonized legislation have not been adopted by all states and territories. This paper traces the development of health and safety laws in Australia, and briefly examines the application of these laws in the three states of New South Wales, Queensland and Victoria. It concludes with a discussion on what the laws mean in terms of managing health and safety risks in the Australian construction industry.

Keywords: Harmonisation, **Work Health and Safety Act, Work Health and Safety Regulations, Codes of Practice, Construction Health and Safety**.

1. Introduction

The current Constitution of the Federation of Australia does not give the Commonwealth a general power to legislate for health and safety, hence each of the six states, two territories and the Federal Government has developed its own set of health and safety laws for protecting workers health and safety (National Research Centre for OHS Regulation). For this reason health and safety protection of Australian workers were, for over four decades, were based on myriad of laws. Historically, these were derived from the British system of laws and, in early days were largely prescriptive and relatively easy to comply with because they told duty-holders what they were required to do to comply with the laws (Johnstone 2004; 2008). There were, however, also a number of shortfalls and limitations of these forms of legislation. For example, they included a mass of detailed and technical rules which were often difficult to understand by those who the laws were designed to protect; many standards were developed ad hoc to resolve problems as they arose, and concentrated mainly on factory-based physical hazards (resulting in uneven coverage across the industries), the specification standards did not encourage employers to be innovative in terms of seeking

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cheaper or more cost-efficient solutions (Gunningham and Johnstone 1999; Johnstone 2004). They also ignored the now well-accepted view that many hazards do not arise from the static features of the workplace but from the way work is organised. The traditional factory legislation created a climate of dependence on state regulation, with little involvement by workers, unions, health and safety representatives or committees.

1.1 Early reforms

The first major reforms, initiated in the 1970's, followed the recommendations of the Robens' Report (National Research Centre for OHS Regulation ; Productivity Commission 2004). The two major changes involved streamlining the traditional by creating a more unified and integrated system by consolidating existing legislation for health and safety under a single 'umbrella' statute, and the creation of "a more effectively self-regulating system promoting the involvement of workers and management, at workplace level, working together to achieve, and improve upon, the OHS standards prescribed by the state" (National Research Centre for OHS Regulation). The initial reforms involved moving away from prescriptions to performance standards (Bluff, Gunningham et al. 2004; Johnstone 2004).The laws focussed on fostering safe and healthy working environments and safe work systems (National Occupational Health and Safety Commission (NOHSC) 2002) and included a three-tiered structure; a principal act, subordinate regulations supported with codes of practice (Johnstone 2004; Tuck and Pillay 2012). The reforming Acts placed broad 'general duties' of care on parties who had a significant influence on health and safety, including employers, self-employed persons, persons in control of workplaces, employees, designers, manufacturers and suppliers of plant and substances, and erectors and installers of structures. The standards were moved from the Acts into subordinate regulations, which also included a number of processes (such as consultation, identification of hazards, assessment of risks, and methods of controlling risks) that needed to be followed in achieving(Johnstone 2004; 2008). To assist the industry comply with the Act and the regulations codes of practice (CoPs) which were either hazard-based, process-based or systems-based were also developed and issued as guides (Gunningham 2007; Tuck and Pillay 2012).

In spite of these reforms, the costs of work-related injuries and diseases were still relatively high (>$20B) with over 200 000 workers staying away from work at any point in time, 270 000 forced to change jobs or reduce their hours of work because of work-related injuries, and industries such as mining, construction, transport and agriculture having relatively poor safety performance in comparison to other industry sector (Productivity Commission 1995). There were a number of reasons for this relatively poor state of health and safety, including:

(a) 'apathy' arising from uncoordinated proliferation of standards, complex standards, failure to keep pace with technological, social and economic changes, and to formally and consistently involve workers and unions,
(b) unclear legal rights and responsibilities, leading to confusion,
(c) too much legislation, with over 150 statutes across the country,
(d) inflexible regulations,
(e) weak encouragement of best practice approaches,

(f) inconsistency between jurisdictions, inefficient mandate standards and inadequate and unhelpful codes of practice, and

(g) enforcement that was not directly aimed at preventing injury and disease by deterring non-compliance with the laws (Productivity Commission 1995).

Over the years further developments occurred leading to the development of 'new generation' health and safety laws that were more streamlined, with elements of goal-setting, performance-based and process-based approaches included (Gunningham and Johnstone 1999). However, while the legislation still followed the common three-tiered approach, there were still many differences in structure, details, coverage, and matters between the Acts, regulation and CoPs (Johnstone 2008; Tuck and Pillay 2012). For example, by 2009 there ten principal health and safety acts; one for each of the six states and two territories, one for maritime industry and another covering commonwealth employees (Table 10).

Table 1 A summary of health and safety acts in Australia as at December 2009

Jurisdiction	Act
Commonwealth	Occupational Health and Safety (Commonwealth Employees) Act 1991
	Occupational Health and Safety (Maritime Industry) Act 1993
Australian Capital Territory	Work Safety Act 2008
New South Wales	Occupational Health and Safety Act 2000
Northern Territory	Workplace Health and Safety Act 2007
Queensland	Work Health and Safety Act 1995
South Australia	Occupational Health, Safety and Welfare Act 1986
Tasmania	Workplace Health and Safety Act 1995
Victoria	Occupational Health and Safety Act 2004
Western Australia	Occupational Safety and Health Act 1994

Empirical research on the impact of the reformed Acts and health and safety performance does not exist in Australia. Studies from Britain, however, suggest there is some evidence that legislation was a primary driver for initiating improvements in health and safety management at the organisational level (David 2004), although there is little peer-reviewed research on the direct effect of legislation on workplace injuries (Health and Safety Executive 2009). The differences between states have been frequently suggested to place increased burdens of costs to organisations that operate across more than one state, as well as on state governments that are charged for enforcing (Access Economics 2009). Hence calls for more uniformity and harmonisation have been part of the Federal government's agenda for at least the twenty years (National Research Centre for OHS Regulation).

1.2 Initial attempts at harmonisation

The move towards national harmonization under the gambit of 'uniformity of health and safety' was first initiated in the 1990s by the National Occupational Health and Safety Commission, and later by the Australian Safety and Compensation Commission (Safe Work Australia 2012). In early days this included National Standards and National Codes of Practice in a number of key health and safety focus areas. These National Standards did not have legal status and were not enforceable unless they were adopted by the states and territories through formal instruments such as Acts and regulations. As there was no binding agreement nationally on how and when National Standards should be adopted, the level of consistency achieved was varied. For example, across the building and construction industry there were at least nine Acts which applied to health and safety of workers; with an additional "30 statutes that relate to some aspects of the industry's operations; and at least 20 principal regulations, and another 34 other regulations, most of which have some application to the industry," (Cole 2003). In essence this created a system of law that was deemed to be fragmented, disjointed and uncoordinated, inequitable, wasteful and inefficient (Cole 2003; Productivity Commission 2004).

1.3 Later attempts at harmonisation

In 2006, the Council of Australian Governments (COAG), through the recently established Australian Safety and Compensation Council, began reviewing the national health and safety framework to improve national consistency and identify priorities for harmonisation. In 2008 the Workplace Relations Ministers Council agreed to the use of model legislation as an effective way to proceed to harmonisation, leading to the signing of an Intergovernmental Agreement for Regulatory and Operational Reform in Occupational Health and Safety (IGA). The IGA established the principles and processes for cooperation between the Commonwealth, states and territories to implement model legislation, complemented by consistent approaches to achieve compliance and enforcement by the end of 2011. This was the first attempt at committing towards harmonisation of health and safety laws within a set timeframe for the development and implementation of a complete and fully integrated package comprised of a model Act, supported by model Regulations, model Codes of Practice and a National Compliance and Enforcement Policy (Safe Work Australia 2012). The process commenced under the Labour Government of the (then) Prime Ministership of Kevin Rudd and continued under the current Gillard Coalition Government. A draft Model

Work Health and Safety (WHS) Act was released by SafeWork Australia for public comment in 2009, and a Model Work Health and Safety (WHS) Bill declared in 2010 following an extensive consultation process, and a final version made available on the Safe Work Australia website. A draft Model Work Health and Safety Regulation (WHSR), supported with a number of Draft Codes of Practice were also issued in 2010 and 2011, followed by a public consultation process in 2011 and 2012. The Federal government expected the Model WHS Act to be adopted by all states and territories by the end of 2011 and the model WHS Regulations by the end of 2012, so that by the beginning of 2013 all building and construction workers across the country will be the covered by the same set of health and safety standards and benchmarks.

However, at the time of writing this article, this objective has not been achieved because the Acts and Regulations have not been fully adopted as expected. This certainly appears to be the case in the state of Victoria. The Bailieu government has argued that Victorian workplaces were already the safest, with the lowest workers' compensation premiums; and adopting the harmonised laws would add to the regulatory burden of compliance, particularly for small and medium-sized businesses, without any perceived gains (Bailieu 2012; WorkSafe Victoria 2012). What this means is that workers across some states may not necessarily be provided with the same set of health and safety protection, and building and construction organisations across some states could be subjected to higher than normal costs of complying with health and safety laws (Stewart-Crompton, Mayman et al. 2009; Productivity Commission 2010).

2. Introduction

In this section the health and safety laws as they relate to the building and construction industry in the states of New South Wales, Queensland and Victoria are critically examined.

2.1 New South Wales Health and Safety Laws

The New South Wales government enacted a new set of work health and safety (WHS) laws to replace the Occupational Health and Safety Act 2001 from on 1 January 2012. In taking this stance the NSW state government has argued the new Act provides greater consistency, certainty and clarity, and make it easier for building and construction organisations to understand their workplace health and safety duties; moreover, companies operating in several states are expected to develop health and safety policies and procedures that could be used nationally (WorkCover Authority of New South Wales 2012). The legal framework is a three-tiered structure comprised of a WHS Act 2011 (NSW), WHS Regulations 2011 (NSW), and supported with a series of codes of practice, illustrated in Figure 1. The NSW WHS Act 2011 has an 'object' of providing for a balanced and nationally consistent framework to secure the health and safety of workers and workplaces (New South Wales Government 2012). The NSW law is largely performance-based and mirrors the Model WHS Act 2011, including an extended objective to include welfare (in addition to health and safety), is concerned with risk minimisation. The NSW WHS Regulations similarly mirrors that of the Model WHS Regulations 2011 in terms of matters covered.

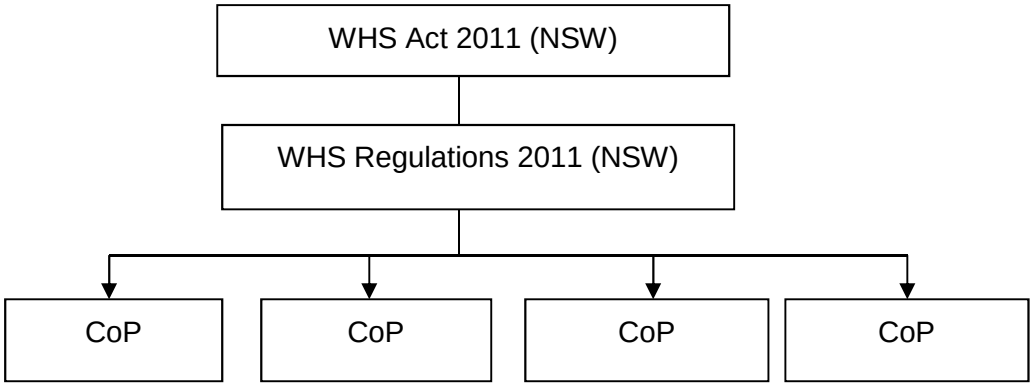

Figure 1: Legal framework for WHS legislation in NSW

2.2 Queensland Health and Safety Laws

The Queensland government also adopted a new set of work health and safety (WHS) laws to replace the Work Health and Safety Act 1995, comprised of a WHS Act 2011, WHS Regulations and supported with guidance materials and industry standards (Figure 2).

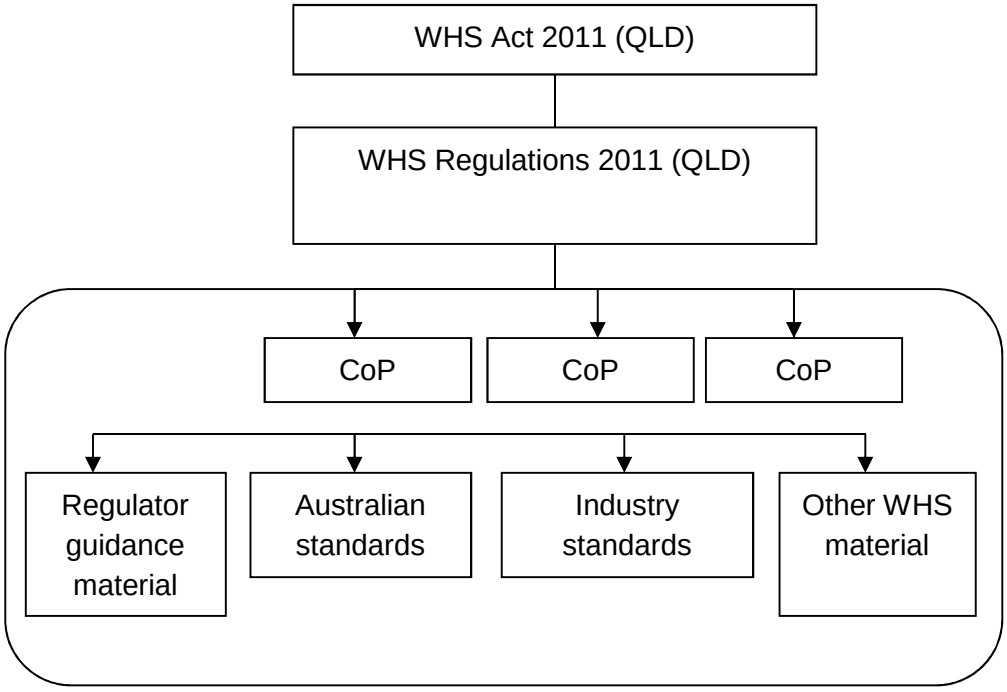

Figure 2: Legal framework for WHS legislation in QLD

The new Act provides a framework to protect the health, safety and welfare of all workers at work and of all other people who might be affected by the work (Workplace Health and Safety Queensland 2012). The new has a similar 'object' of providing for a balanced and nationally consistent framework to secure the health and safety of workers and workplaces. It is also performance-based and mirrors the Model WHS Act 2011, including an extended objective to include welfare (in addition to health and safety), and is also concerned with risk minimisation (Workplace Health and Safety Queensland 2012). The WHSR 2011 specifies the way in which a duty under the WHS Act must be performed and prescribes procedural or

administrative matters to support the WHS Act, such as requiring licences for specific activities and the keeping of records (Workplace Health and Safety Queensland 2012). The WHSR 2011 is authorised under section 276 of the Work Health and Safety Act 2011 and section 165 of the State Penalties Enforcement Act 1999 (Queensland Government 2012). However, unlike NSW, the legal framework includes two additional types of guidance material in the form of (i) CoPs and (ii) regulator guidance material, Australian / industry standards and other WHS material (Queensland Government 2012). The latter three appear not to be part of the NSW framework

To a large extent the regulations are very similar to the Model WHSR 2011 and the WHS Regulations 2011 (NSW). Most of the prescriptions specified in the previous Workplace Health and Safety Regulations 2008 is expected to be moved into the CoPs, allowing business operators some flexibility, while drawing a “line in the sand” regarding acceptable and unacceptable levels of safety (Queensland Government 2012). In adopting the harmonised laws the Queensland state government believes that safety standards will not be lowered as the national codes of practice have evidentiary status under the WHS Act 2011, and construction organisations can choose to adopt other ways that provide a level of safety equal to or better than those set out in the CoPs.

2.3 Victorian Health and Safety Laws

Unlike the previous two states, the state of Victoria has not adopted the Model legislation, and currently has its own standards. The legal framework includes the Occupational Health and Safety Act 2004, Occupational Health and Safety Regulations 2007, Compliance Codes, WorkSafe Positions and Non-statutory guidance (Figure 3).

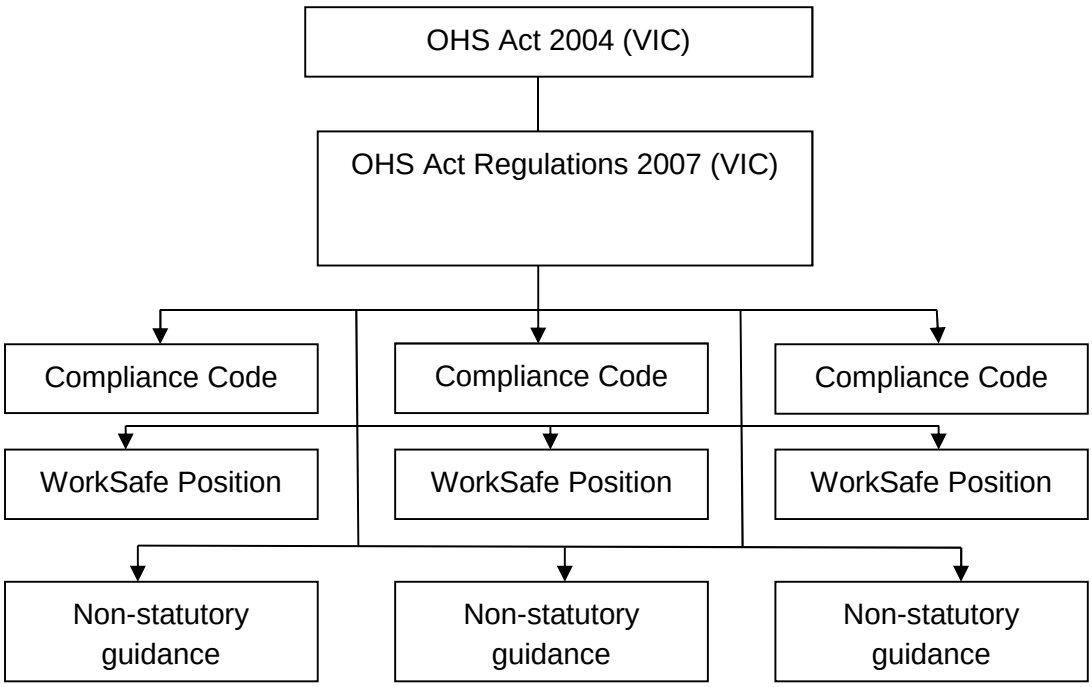

Figure 3: Structure of Victoria’s health and safety laws

Similar to the WHS Acts of NSW and Queensland, the OHS Act sets out the key principles, duties and rights in relation to health and safety. Unlike NSW and QLD it has four objects which include:

> (i) to secure the health, safety and welfare of employees and other persons at work; and
> (ii) *to eliminate, at the source, risks to the health, safety or welfare of employees and other persons at work; and*
> (iii) *to ensure that the health and safety of members of the public is not placed at risk by the conduct of undertakings by employers and self-employed* persons; and
> (iv) *to provide for the involvement of employees, employers, and organisations representing those persons,* in the formulation and implementation of health, safety and welfare standards having regard to the principles of health and safety protection

The central focus of the Victorian Act is the elimination of risks at its source, protection of workers and members of the public, and the involvement of unions and employer associations in setting health and safety policy and standards at workplace level. In contrast, the NSW and QLD WHS Acts have one main object, '*to provide for a balanced and nationally consistent framework to secure the health and safety of workers and workplaces*.' The OHS Regulations, similar to NSW and Qld, specify the way in which a duty imposed by the Act must be performed, or prescribe procedural or administrative matters to support the Act. Compliance Codes are similar to the CoPs in the Model, NSW and Queensland Acts, and provide practical guidance to duty holders, so if organisation complies with them they are 'deemed' to be in compliance with the Act or regulation duty covered by the Code. However, Compliance Codes are not mandatory, and a duty holder may choose to use some other way to achieve compliance.

WorkSafe Positions are guidelines made under Section 12 of the OHS Act that explain how WorkSafe Victoria will apply the Act or regulations, or exercise discretion under a provision of the Act or regulations. In the main they are aimed at providing certainty to organisations and other affected parties.

Non-statutory guidance includes information published by the regulator and is aimed at building people's knowledge and awareness of health and issues, risks to health and safety, and the disciplines and techniques that can be applied to manage and control risks. These are not mandatory, nor provide any "deemed to comply" outcomes for duty holders. Their main role is to inform the 'state of knowledge' regarding a health and safety issue.

3. Legal Requirements for Construction Health and Safety

The legal requirements for construction health and safety are not covered in the Acts but forms part of the regulations. These are found in Chapter 6 (NSW and QLD) and Chapter 5 Part 5.1 (VIC), and include duties of care

a. in relation to (i) construction work and (ii) high risk construction work,
b. for consulting with the designers of structures,
c. requiring designers to provide a written report on health and safety,

d. relating to safe work method statements (SWMS), excavation work and trenches,
e. for written WHS management plans, signage and ensuring compliance with other Regulations,
f. for general construction induction training and issuing of construction induction cards.

There are, however, a number of differences between the NSW, QLD and VIC regulations.

For example, the regulations in NSW do not require a PCBU to keep a record of their reasons for using lower end administrative control measures such as relying on training to prevent falls from height in high risk construction work. Similarly, the person having management and control, including a principal contractor in Victoria, is also not required to keep such a record. This has been considered to be a diminution of the existing standards in Queensland which require administrative controls to be used in combination with higher order control measures for a fall risk greater than 2 metres. The Queensland WHS Regulation 2011 hence requires a PCBU to document why higher order controls such as edge protection were not used (Workplace Health and Safety Queensland 2012). In VIC and NSW the main test for adequacy of risk control measures for work at heights depends on meeting the test of 'reasonably practicable'.

3.1 Risk Management of Construction Health and Safety

The ways by which risks can be managed are explained through a number of CoPs; an important one is the CoP for risk management of construction work. The main steps involve delineating construction work from high risk construction work, identifying hazards, putting in control measures to eliminate or minimise risk, and reviewing the control measures (Safe Work Australia 2012). Where high risk construction work is involved, there is a need to develop safe work method statements, and health and safety plans where a construction project ($A250K) is involved.

3.1.1 Identifying Construction and High Risk Construction Work

Construction work includes any work carried out in connection with the construction, alteration, conversion, fitting-out, commissioning, renovation, repair, maintenance, refurbishment, demolition, decommissioning or dismantling of a structure, and include any installation and testing carried out in connection with any of the above activities (Safe Work Australia 2012). The laws also distinguish between normal and high risk construction work, the latter includes a list of nineteen activities. In order to identify all hazards associated with the construction work safety managers and coordinators would need to think beyond construction hazards by considering other things such as (i) confined spaces, (ii) falls, (iii) high risk work, (iv) demolition work, (v) electrical safety, (vi) plant and structures, (vii) hazardous chemicals, (viii) asbestos, and (ix) manual handling (Safe Work Australia 2011; Safe Work Australia 2011; Safe Work Australia 2012).

3.1.2 Risk Control

Once hazards have been identified, they need to be controlled. Here, the regulations across all states are similar in that there is no requirement to undertake any assessment of risks

which were previously required in both NSW and QLD (this requirement was removed from VIC in 2007). Currently, risk assessment are only required if the construction work involves asbestos. Because the regulations require that risks be eliminated, minimised or reduced so far as is reasonably practical, the CoP recommends risks be eliminated first. If this cannot be achieved then means of minimising risks through substitution, isolation, engineering, administrative and personal protective equipment need to be considered (Safe Work Australia 2012). The CoP for construction work provides a range of examples which can be used. While the code points to examples, the effectiveness or otherwise of these various approaches is questionable.

3.1.3 Safe Work Method Statements

Safe Work Method Statements (SWMS) compulsory risk control measure when 'high risk construction work' is involved (Borys 2012; Safe Work Australia 2012), therefore forms the backbone of high risk construction safety management (Pillay, Borys et al. 2011). They were first introduced in Australia as part of the national Standard for Construction Work (National Occupational Health and Safety Commission (NOHSC) 2005).The regulations require that (i) SWMS be prepared before the work commences, (ii) all work must be carried out in accordance with the SWMS, and (iii) they be revised when control measures are revised, if changes are made to the way work is done, and following an incident (Safe Work Australia 2012). A SWMS (i) enables supervisors, workers and any other persons at the workplace to understand the requirements that have been established to carry out the high risk construction work in a safe and healthy manner, (ii) sets out the work activities in a logical sequence, and (iii) identifies hazards and describes control measures (WorkSafe Victoria 2008; WorkSafe Victoria 2008; Safe Work Australia 2012). Beyond this, research by the author suggests that they are also important in (i) planning work and resources, (ii) initiating interactions between supervisors, workers and contractors, (iii) making people aware of the hazards, risks and means of controlling them, and (iv) acting as a source of reference (Pillay, Borys et al. 2012).

3.1.4 WHS Management Plans

The regulations require that all construction projects (which are valued at >$250 000) have a written WHS management plan before the project commences (Safe Work Australia 2012). Such a plan generally sets out arrangements for managing health and safety risks across the project's life cycle, hence ensures risks associated with a complex construction project are managed, as there are usually many contractors and subcontractors involved and circumstances can change quickly from day to day. The expectation is that if he construction project involves high risk construction, SWMS are included as a risk control strategy in the plan.

4. Conclusion

The harmonisation of health and safety laws in Australia, whilst not achieving the objective of a nationally consistent set of rules for safety in general, is an important and a necessary first step towards improving health and safety performance of the construction industry. The

current laws across the three states are consistent in terms of the duty of care requirements, and the guidelines issued by the regulators point organisations towards a systematic approach through definition of construction work (to avoid confusion between what it is and what it is not!), delineating of high risk construction work from other works, a risk management approach that can be uniformly applied across other types of construction work (in that there is no need for risk assessment unless there is asbestos on site), and documentation in terms of SWMS (for high risk construction work and WHS management plan for construction projects). The latter can be useful risk management strategy that can be applied to most construction work.

5. Acknowledgments

The author wishes to thank the anonymous reviewers for their comments in improving the paper.

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Model of Housing Delivery System based on Community-based Housing Development in Surakarta City, Indonesia

Winny Astuti[1]

Abstract

Slums and squatter settlements have become obstacles for the growing city development where urbanization level is increasing. Most of urban poor live in slums and squatter settlements that are characterized as high building density, semi-permanent housing, and inadequate infrastructure and services. In Indonesia, there are two regular types of housing supply, namely direct government provided–stated as formal housing, and community based housing –labeled as informal housing. Community-based Housing Development (CBHD) is a government housing initiative, which encourages community empowerment through Community-based Organization (CBO). The CBHD model has believed to be an instrument for poverty alleviation since it encourages community inclusion, empowerment and security. The CBO organized the community to carry out tasks related to problems of poverty in their settlements and to communicate their problems to the city government. The Government of Surakarta, a middle-size city in Central Java, Indonesia, has initiated the CBHD through several programs, such as Improvement of Substandard Houses (RTLH) and Relocation Program. This research aimed to identify the characteristics and model of CBHD in Surakarta. Qualitative research has been conducted through in-depth interview to key informants in the government's institutions as well as in the CBO. It is found that the program is initiated mostly by the government with the aim of increasing achievement of development indicators such as poverty indicators and slum clearance indicators. The City Government through the Mayor Regulation consequently initiates development of the CBO in the form of POKJA and SUB-POKJA. The involvement of community is seen only as an instrument for achieving government development goal, rather than the goals of achieving the empowerment, improved quality of life and social cohesion of community. Therefore, the model of CBHD in these case study areas can be classified as instrumental model.

Keywords: Community-based, Housing, Development, Slums, Indonesia

1. Introduction

Slums and squatter settlements has become one of the indicators of urban poverty as the fact that most of urban poor lives in slums area. Those difficulties in escaping poverty are partly caused by community institutions in the slum area that do not give opportunities for

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community inclusion, empowerment and security (The World Bank, 2002). These three elements of community capacity are somehow important to promote urban have-nots' self esteem and establish their way out of poverty.

In Indonesia, the informal delivery system based on community empowerment has been contributed to almost 90% of housing delivery system in Indonesia (Silas, 2005). According to Turner (1987) in Astuti (2012), three fourth of housing for the poor is provided by the poor itself due to their limited access to the formal delivery system with their local knowledge and resources. If the communities have opportunities and access for housing provision, they may have the capacity to build five times more than the capacity of government or the private sector, according to their capacity and levels of amenity. Community-based Organization as an important element in community-based development has 2 important and strategic roles as follows (Turner (1987) in Astuti (2012)): (1) ***to help people to organize*****,** which is generally done for helping community to articulate their needs and generating access to their own resources; (2) ***to act as mediators*****,** which is to act as a intermediary between community and/or community-based organization in negotiation with other public agency as well as the government as a resources for settlement development efforts.

In community-based development, participation is one of the instruments to enhance community empowerment in community-based planning project. There are at least four intensity in participation (Bamberger and Shams, 1989) as follows: (1) *Information sharing*, where the project designers and managers or even government may share information with beneficiaries to facilitate collective or individual action in order to enable target groups to understand their project tasks better; (2) *Consultation*, when beneficiaries are consulted at key issues at some or all stages in a project cycle; (3) *Decision making*, when the beneficiaries have a decision-making role in matters of project design and implementation; and (4) *Initiating action*, when beneficiaries are able to take initiative in terms of actions or decisions of the project. According to Kruks, (1983) in Mikkelsen (2001) there are two kinds of objectives of development project related to community participation. Firstly, **transformational participation**, in which participation is seen as instrument or facilities for achieving higher goals or self-fulfillment and sustainability and secondly**, instrumental participation,** where participation only placed as methods for achieving specified target, generally government target for the donor projects.

2. Surakarta as a Study Area

2.1. Characteristics of Surakarta

In Surakarta the popularity of the CBHD system has been increasing under the era of Mr. Joko Widodo, widely recognized as Jokowi, Mayor of Surakarta for 2005-2015. Slums and squatter settlements have become strategic issues of Surakarta. Several strategies, which have been developed to overcome these issues, are mostly based on the Community-based Housing Development (CBHD) towards Surakarta without Slums 2015. In the policy level, CBHD combines strategies stated in *RPJMD* (*Rencana Pembangunan Jangka Menengah Daerah;* Medium-terms Regional Development Plan) of Surakarta 2010-2015 with the Poverty Alleviation Strategies through the support and cooperation of related Government

Working Units and all parties of development under the coordination of TKPKD ((*Tim Penanggulangan Kemiskinan Kota / Daerah;* Coordination Team of Urban Poverty Alleviation *)*.

Surakarta is a municipal city located in the core of SUBOSUKA region, Central Java, Indonesia. It is surrounded by three regencies, i.e. Boyolali, Sukoharjo and Karanganyar. With the area of 44.04 square-km, it is dominated by developed areas with the population of approximately 600.000 people. The levels of poverty were as high as 22% covering 125,600 urban poor people (TKPKD, 2011). The Government of Surakarta stated that in 2006, there were 6612 substandard houses spread in 5 districts of Surakarta. Of these numbers of household, 1571 of them live in squatter settlements along the government land and illegal land such as rail land and riverbank area.



Figure 1. Maps of Surakarta, Central Java, Indonesia

2.2. Housing and Human Settlements Policy based on CBHD in Surakarta

In order to overcome the problems of slums and squatter settlements, the government of Surakarta has developed housing delivery system through CBHD. Basically, there are two policies; firstly, **Improvement of Slums Area**, which includes rehabilitation and renovation of substandard houses constructed on a land with certified property right; quality improvement of substandard houses and their neighborhood and rehabilitation and renovation of substandard houses constructed on a group parcel of illegal land. Secondly; **Resettlement (relocation) of Settlements** located along riverbank areas to legal and certified land and standard housing construction (see Figure 2)

Community-based housing development is initiated through establishment of the Mayor Act, which imply the development of Community-based Organization in form of POKJA (*Kelompok Kerja*; Community Working Groups) whose role is to be the mediator between the government and the communities in the implementation of the program.

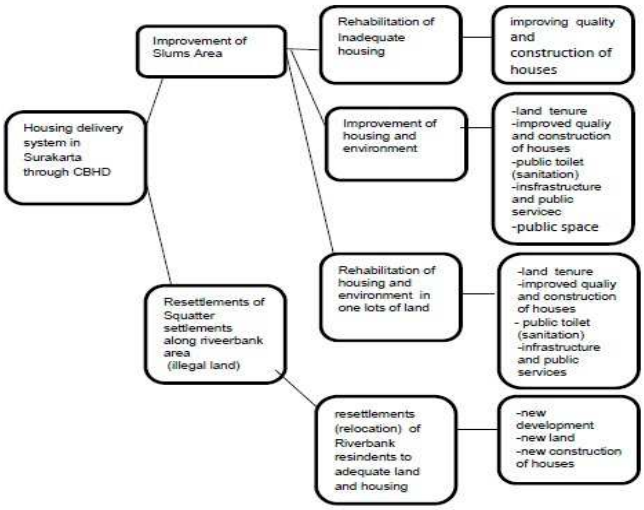

Figure 2. Housing Delivery System based on CBHD in Surakarta City

Sources : Analysis from the result of interview survey with several government units and POKJA. 2012

3. Research Methodology

The research was conducted in qualitative method and inductive approach. In-depth interviews were addressed to several government institutions related to CBHD whose involved in the lesson-learned of CBHD in Surakarta as follows: Planning an d Development Board of Surakarta City (BAPPEDA); Board of Community Empowerment, Woman empowerment and family Planning (BAPERMAS PP and KB); Board of Public Services "*Griya Layak Huni*"; Consortium of NGOs; and Department of Public Works.

Whereas representations of Community-based Organizations interviewed in this research were POKJA RELOKASI in *Kelurahan* Pucangsawit and POKJA RTLH in *Kelurahan* Kratonan. Analysis of Model of CBHD was analysis from the variable of firstly, **transformational participation,** with indicators of empowerment; community capacity in planning and decision making; sustainability. Secondly **instrumental participation**, with the indicators of; top down procees; output program is for the government goals; domination role of the government

4. Results and Discussion

4.1. Characteristics and Model of CBHD Implemented in Surakarta

Model of CBHD in Surakarta is positioning CBO in the form of POKJA as the center of development. This study determines two case studies of implementation of Rehabilitation/renovation of Substandard Houses (RTLH program) in *Kelurahan* Kratonan and Relocation Program of Settlements along Riverbank Areas in *Kelurahan* Pucangsawit to Mojosongo.

In the case study of RTLH Program, POKJA RTLH is a Working Group in the community level, which was formulated by the Head of *Kelurahan*. This has roles for communication and intermediary role between community as the beneficiary and the local government in the

Kelurahan levels as well as in the City Levels. In order for conducting communication role, there are three development committees were developed. (1), Development Committee in the city level; (2) Development Team in the *Kelurahan* level; and (3) POKJA RTLH for distributing the Aids in the Community Level.

POKJA RTLH has organization structure of Head of POKJA, Secretary and Treasury. There are three main tasks of POKJA RTLH. Firstly, POKJA has to conduct community need assessment and propose the community development planning to the City Government through the Development Team of RTLH Program in the Kelurahan level. Secondly, POKJA needs to coordinate, consult and report the implementation of RTLH program periodically to the City Government (Government Unit of DKRPPKB) through the Development Team of RTLH Program in the *Kelurahan* Level. In the implementation of program, POKJA RTLH also has to give consultation to people related to housing construction and any neighborhood development problems (based on interview with the head of POJKA RTLH Kratonan, 2012).

Whereas in the Relocation Program, POKJA RELOKASI was formulated based on the Mayor Act 2007, which states that there are two levels of POKJA RELOKASI. The first is POKJA INDUK (the Main POKJA), which is based on *Kelurahan* and was established by the Mayor. The second is Sub-POKJA, which is based on RW (*Rukun Warga*; Community Unit) level. Sub POKJA was established by Decision Letter from Government Unit of DKRPPKB (*Dinas Kesejahtaraan Rakyat, Pemberdayaan Perempuan dan Keluarga Berencana*; *Board of Community Empowerment, Woman Empowerment and Family Planning*). Organization structure of POKJA as well as Sub POKJA consists of Head, Secretary, Treasury and members.

In implementation of program, Sub-Pokja in the RW level has to coordinate to POKJA in *kelurahan* Level; the Government Unit of DKRPPKB (changing name to BAPERMAS, PP and KB since 2011); and the Ministry of Community Welfare in a National level through the Mayor of Surakarta. Organization of the Relocation program is therefore systematic, simple and unbureocratic in order to transfer community need assessment to the relevant actor and interest. Pokja's role of intermediary and communication had been conducted well during the implementation. This can be seen trough the transfer of community demand to the interest group. Below are the explanations of the two programs in this research i.e. RTLH Program and Relocation Program

4.1.1. Rehabilitation/renovation of Substandard Houses (*RTLH* Program) in *Kelurahan* Kratonan

Rehabilitation/ renovation of substandard houses (RTLH) is a part of program towards Surakarta Slums Clearance in 2015. This program was based on the government report, that in 2006, there were 6612 substandard houses spread in 5 districts of Surakarta. Until 2011, renovation of 4.986 houses has been carried out and and there were 1250 houses left to be targeted next in 2012.

Targeted area for RTLH Program in *Kelurahan* Kratonan was located in RT (*Neighbourhood Unit*) 01, RW (*Community unit*) 06. In 2007, after establishment of The Mayor Act no 13/

2007 regarding Mechanism for Obtaining Aids for Housing Renovation, the process and mechanisms of CBHD applied in this area was as follows: (a) **Formation of POKJA,** which has been stated in The Mayor Act 2007 as the requirement for obtaining Aids for housing rehabilitation/ renovation (RTLH Program). This was followed by the formation of Village committee and POKJA committee to run the program; (b) **Preparation of Site Plan and Project Proposal,** which was conducted by POKJA through community forum. The proposal was therefore submitted to the City Government through DKRPPKB with approval of *Kelurahan*; (**c) Approval of Aids for Housing Rehabilitation and Renovation,** as the data of the targeted beneficiaries verified, DKRPKB agreed to distribute the aids for housing rehabilitation and renovation of a two-million-rupiah grant for each house and a 7.5-million-rupiah micro finance loan for each household from BUKOPIN Bank through BLUD (Local Service Unit of Houses). The grant was originated from UN Habitat fund. All financial budgets was then centrally managed and administered by POKJA. The Mayor, Mr. Jokowi later gave visit to the location with several Government Working Units delegations such as Department of Public Works (DPU), The National Agrarian Bureau (BPN), City Planning Board (DTRK), Park Planning Office (DKP), and other parties. This visit led to the agreement to support the program by synergizing internal programs of those government working units; (**d) Implementation Stage,** where the development was carried out under the coordination of community and POKJA. There were two construction works which were conducted in parallel. Firstly, the construction of houses and secondly, legalization of land tenure, provision of infrastructure and services supported by related Government Working Units (SKPD). Furthermore, there were aids for economic development or improvement of home-based industrial development. And finally, **(d).Preparation of Accountability Report,** where reporting all activities in every stages, as an obligation of POKJA, after the construction carried out and other form of aids distributed .(see Figure 3)

Community-based Housing Development is usually resulted in development of housing and environment quality as well as community development. The results of RTLH program in Kelurahan Kratonan, which can be accepted by the beneficiaries are as follows. **(1). Improvement of housing quality**. By the Government's grant of Rp 2 Million for each house, people's houses have a little improvement. For people who need to have more improvement, they can borrow the housing mortgage loan from BUKOPIN Bank for Rp 7.5. million along 5 years repayment. **(2). Improvement of the neighborhood environment,** which has also been conducted by Integrated Management of Slum Improvement's Program by support of several government units as follows: BPN, which has conducted certification and land security of tenure to people's land as an ownership land, which previously was the government's state land; DTRK which has developed Detailed Engineering Design of houses and issued the Building Permit; DPU, which has constructed drainage and pedestrian corn block; PDAM (Local Corporate of Clean Water; *Perusahaan Daerah Air Minum)* which has distributed clean water suppy and public toilet; PLN (National Power; *Perusahaan Listrik Negara*) which has improved electricity supply system to the neighborhood; and DKP, which has provided neighbourhood community park and Street Electricity. By the housing and neighborhood development, the area of Kratonan is right now well prepared facing the flood. **(3). Economics enhancement,** as the people received the economic development from the Government Unit of Economic Affairs through the program of Small and Medium Business development, capacity building of business management

and Aids for some units of Street Vendor's Vehicles .Results of the RTLH Program in Kelurahan Kratonan can be seen in Figure 4.

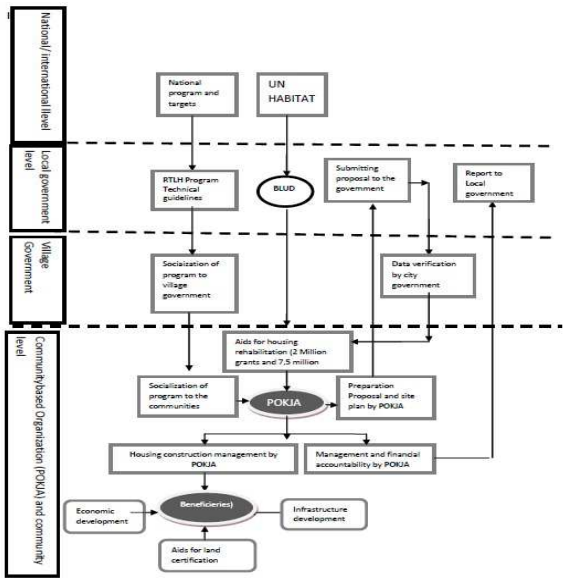

Figure 3. Process and Mechanisms of RTLH Program

Source: Analysis based on interview survey, 2012



Figure 4. Program of RTLH is resulted in security of tenure; improvement of housing construction quality; improvement of environment and economic development

Sources : Field survey, 2012

4.1.2. Relocation Program

Relocation program were developed due to the fast growing number of illegal houses along the riverbank area, where this area is restricted as residential and therefore should be relocated to the area for residential uses according to the Master Plan. The riverbank area is classified as a disaster-prone area, which is periodically facing flood due to overflow of Bengawan Solo River in rainy season. This disaster, the great one happened in 2007 flooded approximately 6.368 houses spread in 12 Kelurahan and 3 districts of Surakarta, 1.571 houses were located on the riverbank area of Bengawan Solo River .

Pucangsawit is one *Kelurahan* in Surakarta, where Relocation Program for 268 houses of the riverbank area were implemented (Bapermas, 2012). Most of people was relocated and resettled in Kelurahan Mojosongo distributed in 6 spots of residential area in Ngemplak Sutan (112 houses), Solo Elok (89 houses), Donohudan (36 houses), Mipitan (8 houses), Kedung Tungkul (18 houses), and Sabrang Lor (5 houses).

Table. 1. Number of Victim of flooding disaster as a target for Relocation Program in Surakarta

No	Name of Village (*kelurahan*)	Location of Victim		Total Number of Flooding Victim
		Riverbank area	Outside Riverbank area	

1	Pucang Sawit	300	624	924
2	Sewu	363	222	585
3	Sangkrah	294	248	542
4	Semanggi	339	194	533
5	Joyosuran	57	897	954
6	Jebres	218	257	475
7	Gandekan	0	20	20
8	Jagalan	0	991	991
9	Sudiroprajan	0	75	75
10	Ps. Kliwon	0	7	7
11	Kedung Lumbu	0	133	133
12	Joyontakan	0	1129	1129
	TOTAL	**1571**	**4797**	**6368**

Sources : BAPERMAS, 2012

Figure 5 shows the mechanism for Relocation of Pucangsawit *kelurahan's* community to *Kelurahan* Mojosongo, as follows (Astuti, 2012): **(a) Socialization to the targeted community,** which was conducted by The Mayor of Surakarta. This action was aimed to give general overview and to build up community knowledge upon high risk living on the riverbank area; (**b) Formation of POKJA and Sub-POKJA of Relocation,** which were formed as a response to the establishment of The Mayor Act 2007 .The role of POKJA was preparing proposal, coordinating sub-POKJA and community in the implementation of program and maintaining communication link with the local government. Whereas Sub-POKJA was directly coordinate with community in distribution of grants; **(c) Data Identification of Grant Beneficiaries** was conducted by POKJA and Sub-POKJA followed by collected administration requirements for receiving aids for relocation. The Relocation grants included grants for obtaining land for Rp 12 million; grants for new housing construction for Rp 8.5 million and grants for public infrastructure for Rp 1.8 million. (**d). Inquiry of Destination Land for Resettlement** was done by sub-POKJA together with the beneficiaries in order to look for land which was suitable for residential development in affordable price. As a requirement for having grants for land purchase, the land should have land title from the National Agrarian Bureau (BPN). **(e) Proposal Preparation for Relocation Grants** was therefore **prepared by** POKJA and Sub-POKJA to the City Government through DKRPPKB for obtaining construction grants of Rp 8.5 million for each house. **(f) Building Destruction and Removal,** was therefore conducted to free the riverbank area from any residential development. Some people was recycling some building materials to be reused in the construction of new houses in the destination area of relocation. And finally, **(g) Self-help Housing Construction** of houses on the destination area of resettlement land. The Government Working Unit provided urban infrastructure such as local street, sanitation system, electricity power, water supply. Social programs were in the form of assistance of environment awareness to the local community towards sustainable management of the area.

Results of Relocation program are as follows*:* **(1) This program has increasing acess of land security of tenure for residential development.** By the grants of Rp 12 Million for each people in obtaining parcel of land suitable for residential development, beneficiaries are no longer stay on the hazardous area of flooding along riverbank area with insecure residential status. Therefore, they are very happy and antusias in obtaining the grants from the government and in overall proccess of program implementation. By land security of tenure, the people have a right to effective protection by the state against forces evictions. **(2), The program has increased the access of adequate houses in an affordable price.** By Grants of Rp 8.5 million for construction of new houses in the new area of relocation, they have their houses be more durable and adequate enough as standard houses than their previous houses constructed along the riverbank area. It means that this is a part of poverty alleviation in terms of increasing access to land secure tenure and adequate houses in an affordable prices. **(3). The program has improved the infrastructure in the neighborhood area**. Beneficiaries also has received Grants of Rp 1.8 million from the City Government for development of infrastructure in the neighborhood area, by Integrated Management facilitated by the City Government. In fact, Relocation Program has been succeed to invite and generate inter-organizational networks and integrated works among the Government Units; private sector, community and NGS's cooperative works for increasing neighborhood quality. BPN of Surakarta was issuing land certificate for land secure tenure in a new area; The Bureau of Local Public Services (BLUD) *Griya Layak Huni* helped facilitate warranty for people in obtaining housing mortgage loan from the Bank for housing construction; PDAM helped in distributing clean water supply services; PLN have distributed electricity services; DPU provided infrastructure development; and DKP provided local community park in the new area (see Figure 6)

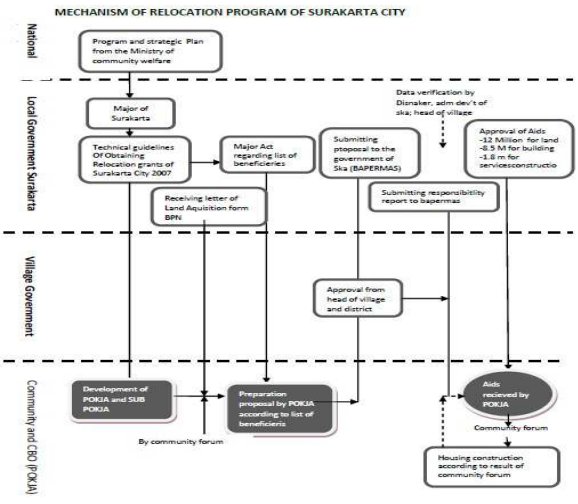

Figure 5. process and Mechanisms CBHD in Relocation Program

Source : Technical Guidelines of Relocation 2007 and Interview with POKJA RELOKASI, 2012

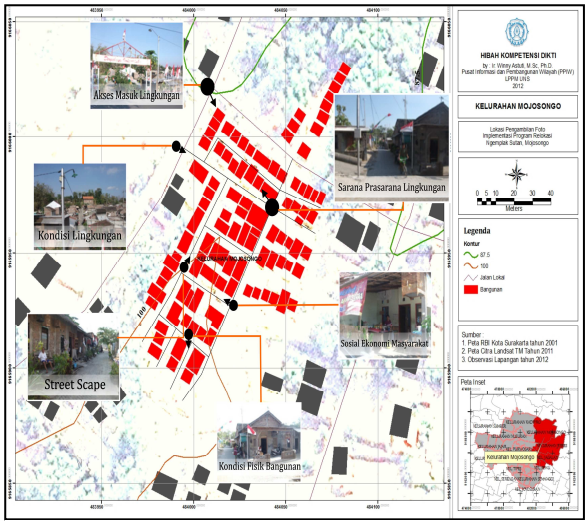

Figure 6. Location of relocation program in Kelurahan Mojosongo

Source : Field survey, 2012

4.2. Model of Housing Delivery System based on Community-based Development

Table 2. Model of Housing Delivery System based on Community-based development in Surakarta

Components of CBHD	Community-based Housing Development Sub-market	
	Renovation of substandar Houses (RTLH program)- KRATONAN	**Relocation Program - MOJOSONGO**
National Policy	- Ministry of Public Housing gives conducive circumstances for development of CBHD and allocates National Financial Budget (APBN) for housing renovation	- Ministry of Community welfare gives conducive circumstances for development of CBHD and allocates National financial budget (APBN) for relocation
Function of Local Government	- As a part of the City government target of "Surakarta slums clearance 2015" - Set up the mechanisms for people participation in project management through the Mayor Act - Through the Mayor Act, Local government shared information with beneficiaries in order to facilitate collective action - Planning and overall management are conducted by the local government	- As a part of government target for solving problems of squatter settlements along riverbank area stated in Medium Terms Development Plan - Set up the mechanisms for people participation in project management through the Mayor Regulation - Through the Mayor Act, Local government shared information with beneficiaries in order to facilitate collective action
Function of Community-based organization	- CBO (POKJA) Involves in planning (proposal), implementation, maintenance, distribution of budget but not in overall management and utilization of project	- CBO (POKJA) Involves in planning (proposal), implementation, maintenance, distribution of budget but not in overall management and utilization of project
Function of *Kelurahan* and District Government	*Kelurahan* and district government only gave approvals	*kelurahan* and district government only gave approvals
Intensity of participation of community	- The community received shared information from the local government to have collective action - All lists of beneficiaries have been stated in the Mayor act, therefore no initiative	- The community organization received shared information from the local government as well as encouraged consultation related to the targeted location for relocation land destination
Extent of participation	- All households beneficiaries were involved in the project especially in the building construction stage	- Community involved through the community forum, but all of the project management was done by CBO (POKJA)
Community Empowerment	- Increased capacity of community in managing housing construction - Community involved in implementation, maintenance, and utilization of result of the project, but planning and overall management were conducted by the local government	- Community capacity was not directly increased since they were only involved in the community forum. Empowerment were only done for the CBO (POKJA) related to its function in preparation of proposal, financial management and reporting accountability report
Results of Program	- Improved land tenure - Improved housing construction - Better provision of infrastructure - Developed economic for small and medium home-based industries	- Land security of tenure in the new area - New construction of houses - Infrastructure development

Sources: Analysis of Researcher according to interview results and other sources, 2012

Table 2 shows that in 2 case studies, it was found that the programs had been set by the local government in order to achieve the development goals and achievement as stated in the Medium Terms Development Plan of Surakarta as "Surakarta Slums Clearance 2015"

and Squatter Clearance. Establishment of Mayor Act and Technical Guidelines in the Renovation Program (RTLH) as well as Relocation program indicated that the government tried to elaborate the collective action from the community through CBO (POKJA), which was formed to run the program. In terms of the extent of participation, the RTLH program demonstrated higher participation because it generated participation of overall households since the aids for housing construction were directly distributed to the households. Whereas in the Relocation Program, all the management related to implementation, maintenance, monitoring and report for responsibility report was conducted by the POKJA. The beneficiaries people had only been involved in utilization of program, apparently there was no direct empowerment developed in this program.

In these two case studies of community-based housing delivery system sub markets above, it was found that these programs **did not generate transformational participation** and empowerment yet, since the participation was only seen as an instrument for achieving government development goals, rather than the goals of empowering and increasing the quality of life and the cohesion of the community.

5. Conclusion

Community-based Housing Development (CBHD) as development based on empowerment of community is believed as one of the strategies in poverty alleviation. Therefore, this becomes instrument for achieving government's goals in poverty alleviation in slum's settlement. In the case of Surakarta, the program based on CBHD required the government to form the Community-based Organization (CBO) in the form of POKJA, whose function was clearly stated in the Mayor Act of Technical Guidelines for implementation of the project. The POKJA has roles for generating communication internally with the communities of targeted beneficiaries and externally for mediation of communities with the government and other parties involved in development project.

Related to the two case studies, in the RTLH Program), community was empowered through involvement of communities in implementation, maintenance, and utilization of the project results even though planning and overall management were conducted by the local government. Whereas in the Relocation Program, the capacities of communities were not directly increased for they had only been involved in the community forum. Empowerment had only been affected to the CBO (POKJA) for its function in preparation of proposal, financial management, and reporting accountability report. Therefore, in the two case studies, these include in the instrumental model. These did not generate transformational participation, where empowered community; increased quality of life and enhanced cohesiveness of community. Community participation was only seen as instrument for achieving government mission and goal for Solo Slum Clearance 2015 and Poverty Alleviation Goals.

Acknowledgement

1. Directorate General of Higher Education (DIKTI) Indonesia for fully financial support to this research; Rector; and Head of LPPM Sebelas Maret University
2. Head of BAPPEDA; Head of BAPERMAS; and Head of BLU '*Griya Layak Huni*";
3. Consortium of NGOs of Surakarta; POKJA Relokasi Pucangsawit; POKJA RTLH Kratonan; Reseach team and all parties, which can not be mentioned one by one

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Building Information Modelling: An International survey

Matthew Gray[1], Jason Gray, Melissa Teo, Seokho Chi, Fiona Cheung

Building Information Modelling (BIM) appears to be the next evolutionary link in project delivery within the AEC (Architecture, Engineering and Construction) Industry. There have been several surveys of implementation at the local level but to date little is known of the international context. This paper is a preliminary report of a large scale electronic survey of the implementation of BIM and the impact on AEC project delivery and project stakeholders in Australia and internationally. National and regional patterns of BIM usage will be identified. These patterns will include disciplinary users, project lifecycle stages, technology integration–including software compatibility—and organisational issues such as human resources and interoperability. Also considered is the current status of the inclusion of BIM within tertiary level curricula and potential for the creation of a new discipline.

Keywords: BIM, AEC Industry, implementation, survey, integration, project delivery

1. Introduction

No one would dispute that we are living in a 3-dimensional (3D) world. If time or money is included one could even say that our world encompasses four or five dimensions. Extending this approach, we can think of a world of up to n-dimensions. However, the building industry has been trapped in the 2D-3D realm for decades (Campbell 2007), first on paper, and more recently using Computer Aided Design (CAD). Recent advances in technology have allowed the Architecture, Engineering and Construction (AEC) Industry to keep up with the multi-dimensional real world. The tool that has allowed them to do this is Building Information Modelling.

Building Information Modelling (BIM) is now considered the ultimate in project delivery within the AEC Industry (Azhar et al. 2008), and has the potential to revolutionize the industry (Gerrard et al. 2010). It is a process involving the generation and management of digital representations of physical and functional characteristics of a facility. The resulting model becomes shared knowledge-resources to support decision-making about a facility from the earliest conceptual stages, through design, construction, operational life and eventual demolition (National Institute of Building Sciences buildingSMART alliance 2012). Thus it is a singular central system suitable for the entire project process. It involves the co-ordinated efforts of all consultants being combined within one highly detailed model with all elements required for a building project (Azhar et al. 2008). This breakthrough technology is responsible for the complex collaboration systems now in place within many organisations who have integrated BIM as their preferred project delivery method.

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Building Information Modelling has been under considerable scrutiny over this last decade. A number of papers have been published outlining challenges and limitations but it seems there has been little progress over the years as the same concerns are repeatedly mentioned. These concerns include interoperability, irrelevant data, integrated design, and legal issues around intellectual property and data ownership.

One of the most common items of discussion is software interoperability. Where there is a market, there will be competition. With competition, these competing software vendors continuously try to out-do each other and to maintain a hold on the market through individuality, resulting in a large number of different software packages (see Çetiner 2010 for examples). Programs like Autodesk Revit and Graphisoft Archicad have created their own file types, with the idea that if one software developer developed a new tool that had substantial benefit over the competition, a user couldn't then just open their project file into another program. Users are then limited to one program, unless they were to spend twice the time to develop the project in both programs. A lack of comprehensive BIM standards mean that multiple BIM software products lack the ability to produce interoperable files" (Smilow 2007), and therein lies the problem. Often professionals who utilise different software cannot fully collaborate on a BIM project as even though there are methods of using third party programs to convert to a common file type to be able to move from one to the other and back again. Typically this process strips most of the information from components, and may degrade parts of the 3D model so that they may not appear as a smooth curve anymore, or polygons—building blocks of a 3D model—may disappear altogether. While this competitive behaviour by software developers is expected or promoted within a free-market economy, it can hinder consultants and project teams, and in turn the uptake of BIM by industry.

Furthermore, many disciplines that require the processes of analyses then face the issue of BIM models containing too much of the wrong sort of information. Poerschke et al. (2010) express concerns regarding the sheer volume of irrelevant data that needs to be processed even when only “particular, abstracted information" is needed for modelling tools.

Another point to consider is the limitations of the design phase within BIM. Some significant drawbacks stand in the way of a fully integrated project. Coates et al. (2010) argues that BIM “…concentrates rather too much on providing means of representing the final form of the design, whereas designers also need a continual stream of abstraction, advice and information…”. Most designers still prefer to use pen and paper to sketch out ideas and many prefer the freedom of physical model building as current BIM tools fail to allow "personal nuances in the design process" as well as accommodate for the "ambiguities of early design" (Coates et al. 2010).

However, beyond the software realm itself, BIM has raised many more issues in terms of legalities (Smilow 2007), with concerns over who has legal ownership of the digital models of collaborative projects, and whose intellectual property it may be. As BIM leads into a new method of team collaboration, team dynamics must make developments and new definitions for individual responsibility and liability (Boos 2010). As the use of BIM increases, these issues may continue to grow in importance, although some claim that as use has increased, fears of these issues have become less (Young et al. 2009).

There have been a number of surveys in recent years that have attempted to quantify just how much impact BIM is having, and how widely adopted it has become. A US survey (Dean 2007) found that as many as 70% of industry participants are either using BIM, or plan on adopting it in the near future. A survey of American architects, engineers and contractors indicated that 62% of BIM users claimed they would use BIM on at least 30% of their projects in the following year and 45% of users said they expected to use BIM on at least 60% of projects (SMART 2008), while a 2009 survey found the US uptake rate at 48%, compared to 28% in 2007 (Young et al. 2009, 5). In contrast, Gerrard et al. (2010) found that in 2007 only 25% of Australian firms were using BIM. This is far less than the literature on BIM seems to intimate. But is BIM used the same way by all these professionals?

The question remains of what practitioners understand BIM to be and to what degree BIM is utilised. For some time, many considered BIM to merely be a 3D model of the project as an improvement over 2D drawings, but little more. The industry started to see 4D modelling and as such, the limits of what was possible grew.

Technology has advanced significantly in the past five years. Take for example the rise of Facebook, iPhones (and other smart phones), and tablet computing. These technologies have been disruptive in their adoption, and increased from a zero base to become ubiquitous. It is conceivable that other technologies, such as BIM, may have undergone similar rapid transformations. Use of BIM in the USA appears to have risen from 28% to 48% between 2007 and 2009. It is possible that similar rises in use have occurred in Australia and other countries since 2007.

To gauge how much the use of BIM has changed a research project has been initiated that has as its first objective an update of the level of adoption of BIM in Australia. Beyond this, the project also plans a similar worldwide survey, something that appears to be missing from the literature. The project ultimately aims to gain a thorough understanding of BIM with regards to its functionality, extents of its strengths and weaknesses, and identify its opportunities and threats. The intent of the surveys is to develop a coherent picture of the professional practitioner's point of view of the technology, as well as update and benchmark the level of use of BIM within Australia and on a wider global scale. These data will also be broken down to identify the areas where BIM is utilised within a project lifecycle by each discipline. The study is particularly designed to address the impact of BIM with regards to the first principles of project management, namely time, cost and quality.

At the time of writing, preliminary data only have been collected from the surveys. This paper therefore reports on the methodology being adopted, the rationale and expected outcomes from the work, and in particular attempts to present a coherent conceptual framework for the potential utility of BIM based around a first principles analysis of literature from the perspective of project time, cost and quality.

1.1 Uses of BIM

The uses of BIM can vary through wide scope of works. Current BIM modelling can function to an *n*th dimension of works – these progress more as technology evolves and as the BIM process is refined. A preliminary list of BIM uses may include:

- Design Visualisation

- Design assistance and constructability review
- Site Planning and Site utilisation
- Scheduling and Sequencing (4D)
- Cost Estimating (5D)
- Integration of Subcontractors and supplier models
- Systems coordination
- Layout and fieldwork
- Prefabrication
- Operations and Maintenance (including as-built records)

(Campbell 2007)

One of the strengths of the approach is the reduction in tedious computation from 2D drawings for many tasks (Smilow 2007), obviously a 'step in the right direction' for building project delivery. Such a change is likely to have a significant impact upon the time for any project.

1.2 Time

One crucial question is what effect has BIM implementation brought on project delivery time? There is no doubt that this question cannot easily be answered without first hand case study analyses conducted on BIM. Reddy (2008) examining a number of case studies, and Azhar et al. (2008) based on 32 major projects that employed BIM both found that that BIM can influence time management with a 7% reduction in time for project completion. There is a perception that it helps to deliver projects on time (Suermann and Issa 2009, 2007), but it is not clear that this is actually the experience of the industry. Some claims of time savings are from vendors of BIM technology (Carroll 2007), while others derive from extensive surveys of industry practitioners in the USA (Young et al. 2009). This same study also reports potentially significant cost savings.

1.3 Cost

Most authors tend to point out the theoretically viable economic benefit of BIM implementation. Nonetheless, there is very little empirical evidence within current academic literature of project cost savings. Some authors attempt to attribute figures, such as an "average BIM return on a given investment [of] 9.486%" (Azhar, Hein and Sketo 2008) or reports that "…a cost differential as small as 2% in increased construction costs results in savings of more than 10 times that investment in reduce energy consumption, waste management, and other costs of operation. This doesn't even factor in the reduced waste of both time and materials during the construction process" (Reddy 2008).

Azhar et al (2008) reports that a 2007 study by the Stanford University Centre for Integrated Facilities Engineering (CIFE), based on 32 major projects that employed BIM, found cost benefits including a reduction of unbudgeted change by 40%, accuracy of cost estimation

brought to within 3%, time taken to produce a cost estimate reduced by 80%, and clash detections resulting in savings of as much as 10% of the contract value.

Perhaps the most compelling evidence for the cost effectiveness of BIM comes from a 2009 US study (Young et al. 2009), with two thirds of over 1,000 BIM users seeing positive return on investment (ROI). Most telling from this study, businesses that actually measured their ROI found substantially greater benefits than those who simply estimated the benefits; 57% of companies who directly measured the benefit found a ROI of 10 percent or greater, compared to 36 percent of companies who simply estimated ROI (Young et al. 2009, 4).

If these benefits are repeated across the industry, BIM would appear to be a sound investment. Two obvious questions are: is this benefit being seen in markets outside of the USA, and are there similar impacts being seen on project quality.

1.4 Quality

The importance of an integrated design system within BIM is continuously emphasised and proven through current academic research. Benjaoran and Sdhabhon (2010) detail the BIM's integrated design tools which identify project-specific safety hazard and provide best practices to eliminate corresponding hazards and design clashes. "Traditionally, safety is managed separate from the construction" (Benjaoran and Sdhabhon 2010). Construction management is thus fragmented from safety management and tends to disregard safety constraints within the construction process, ultimately leading to a disjointed planning phase. "The 4D CAD model is an innovative integration tool between construction and design. It combines two separated information sources – a construction scheduled and a 3D CAD model into one integrated system." (Benjaoran and Sdhabhon 2010). This is achieved through the development of a holistic and automated systems tool that integrates safety into design planning and control processes. The system is supported with database that encapsulated and accumulated safety knowledge including both in explicit and implicit form. Its unique ability to "represent construction activities as virtual 3D objects can effectively convey space information" (Benjaoran and Sdhabhon 2010) and assist designers during the Schematic Design (SD phase to plan accordingly, continuously re-iterating the planning schemes.

According to the planners, the 4D CAD visualisation of the workflow allowed subcontractors to make early decisions to avoid congestion and work space conflicts; thus planning the workspace effectively between different construction trades. It was further mentioned by planners that 3D-4D modelling, unlike 2D drawings, does benefit the planning for the work tasks performed at height, thus helping the contractors to plain into the production adequate lifting aid devices of heavy materials as well as the lifting of workers themselves in order to perform their work tasks at a proper working height (Rwamamara et al. 2010). Such issues highlight the potential of BIM to mitigate planning errors and reform the project delivery process, thus improving project quality.

Rwamamara et al. (2010) state that "construction work activity is information-intensive and the number of documents increases proportionately with the project size." As project size increases, so does the complexity. Waly and Thabet (2003) made use of "advancements in computer graphics to develop 4D tools that enable graphic simulation and visualization of the construction process."

In addition, Popov et al. (2006) states that usually an "architecturally – design part of a design is dissociated from an economic one strictly therefore a designer (Architect or Constructor) having no tools and often even no possibilities (for instance due to time restrictions) for unbiased pricing of a structure and comparison of variants, simply makes no price evaluation at all." Therefore it can be stipulated that a designer (from the Schematic Design (SD) phase) will be able to design within realistic constraints and provide economically viable solutions. This information can therefore be exported about operations and resources from estimates and scheduling applications such as Microsoft Project – therefore creating a smooth transition (Popov et al. 2006).

Contrastingly Coates et al. (2010) argues that although significant potential lies within the BIM implementation and its relation to design, huge developments are required for better alignment with architectural tools and the design process. "For an Architect BIM concentrates rather too much on providing means of representing the final form of the design, whereas designers also need a continual stream of abstraction, advice and information to facilitate in the move from information to the distillation of knowledge" (Coates et al. 2010, 58). Nonetheless Coates et al. also acknowledge the advantages of BIM to the architectural design process such as the use of the BIM for 3D printing of physical models as well as the creation of animations and virtual environments. Coates et al. (2010), however concludes strongly with a detailed list on the areas for developments with regards to improving the misalignment of BIM with the design process:

- Better alignment with the architectural thought processes
- Improved intuitive operation, reduce the mental overhead of using the system
- A building method of information collection, evaluation, structuring and sharing
- Further develop of BIM linking it more effectively to real world capture and feedback and customer feedback technologies
- Providing a greater range of models and abstractions to assist with the creative process
- Further development of BIM using total emersion technologies
- A built in learning and error correction system
- A better system of tailoring issued information to meet the needs and capabilities of the recipient
- Better integration with other practice business systems, combining, aggregating and visualizing business data
- Better integration with contextual information and GIS systems

(Coates et al. 2010)

It seems clear that BIM has the potential for improving project quality for some disciplines more than others. One of the things that needs to be assessed is whether practicing professionals actually see these quality improvements on their projects. This can really only be assessed by asking them directly.

2. Methodology

This research is a part of a larger BIM study conducted by the same research team (QUT ethics committee approval number 1200000555). It intends to combine data gathered through this survey with data collected from face-to-face interviews. Extensive literature analysis has shown both these approaches valid for gathering data on the use of BIM. This immediate research consists of an electronic survey that is conducted online with invitations emailed directly to individual within construction firms, initially within Australia and then internationally, including Korea, China, Indonesia, the UK, Canada, Brazil, India and the USA. Translation of the survey from English means email invitations will be sent out in stages as translations are complete.

The literature review and analysis has been integrated into the research methodology to form a strong basis of knowledge as well as to identify knowledge gaps in the overall knowledge base of BIM's theoretical knowledge. In addition the qualitative information acquired from the literature analysis has been influential towards presenting a theoretical frame working model (see Figure 1) which outlines the overall system's integration of BIM's functionality within the AEC industry professionals. This has effectively identified the differences between theoretical BIM notions to real world scenarios and relative BIM performances.

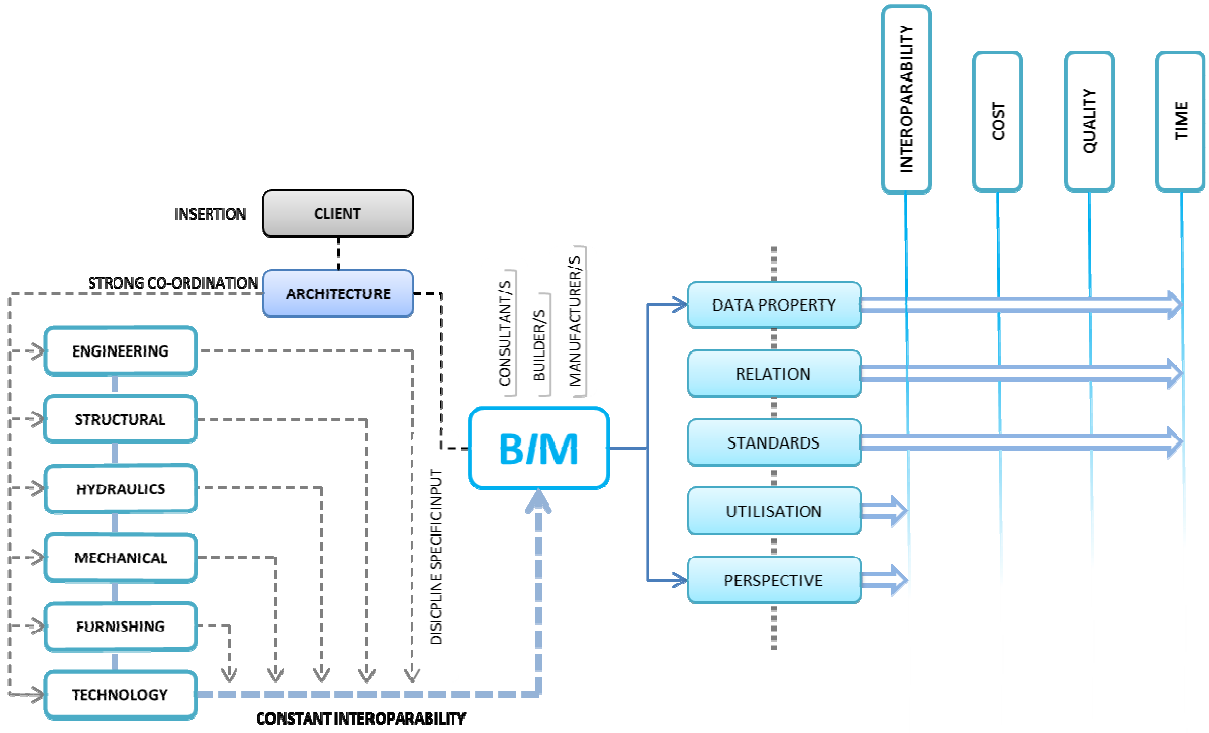

Figure 1: Conceptual framework of BIM as a tool connecting disciplines with project outcomes

The discrepancies identified within the literary analysis as well as the lack of current information on BIM (especially within Australia) are the basis for the nation-wide electronic survey. There are and have been a number of surveys and studies of BIM. The Royal Institute of Charted Surveyors (RICS) are currently conducting in-depth BIM research which includes a survey released on October 2012. RICS's survey presents more emphasis on the overall systems of BIM with regards to surveying and housing markets. Consequently,

neglecting the overall understanding of BIM's influence on the entire AEC industry. This knowledge gap is effectively covered by this research. Therefore justifying the primary aim for this research study and establishing the potential contribution that can be made by this research study.

This survey seeks to obtain information from all AEC related disciplines (architects, engineers, surveyors, contractors, project managers etc.) on their *current* use of BIM. This will allow the study to encompass a broad view point and identify the effects of BIM on the AEC industry. The structure of survey is designed to collate data from both BIM-Users and Non-Users. The start of the survey contains general questions put in place to gather demographical information from the participants. The survey is then broken into two sections; BIM Users and Non BIM users, with many more questions for BIM users. It includes a range of qualitative and quantitative questions that allow the consenting, voluntary participants to provide information on issues such as – the duration of BIM use; scope of works with BIM use; building types that BIM has been utilised for; identification of strengths, weaknesses and potential improvements. Most questions have emphasis put on project lifecycle phases, such as: Design; Documentation; Construction Logistics and Operation and Maintenance, as shown in ***Figure 2*** . This broad range of questions will allow this study to identify the extent of BIM use within the current AEC industry with relation to project delivery.



Figure 2: Example of question layout of online survey

The Non-BIM users section contains questions which allow this study to draw justified conclusions on the lack of BIM integration for various reasons behind this as well as their willingness to adapt for the BIM revolution.

This extensive questionnaire is currently within its Phase 1 of data collection (230 participants engaged). At the completion of data collection this survey will reach more than a 1000 participants world-wide. This method of data collection is intended to provide valuable information to feed into the literary qualitative analysis. The survey also complimented the integration of qualitative research with a series of 'open ended' questions to allow the participant to provide responses which were not restricted. This can be used to gain an in-depth understanding on to the quantitative data collected as well as to draw conclusions between the pre-survey qualitative analysis.

The aim of this approach is not to reiterate existing systems of BIM use, but to gain a more in-depth understanding on the use of BIM and provide up-to-date information on its overall systems relationship with the AEC industry. The fundamental reasons for using a combined, qualitative and quantitative research methodology is due to its ability to base factual up-to-date data (quantitative) collected while integrating the concepts and knowledge base acquired from the qualitative literary analysis. This can further assist in comparing the up-to-date qualitative information gathered from the survey in identifying the line between the theoretical potential of BIM to real world scenarios.

3. Results

At the time of writing only very preliminary results have been obtained, with a total of just ten completed surveys, with another 35 people who have 'clicked through' the survey without completing any responses. Part of the rational of this survey was to canvass all construction firms and individuals to get an appreciation of total use within the industry, not just the opinions of those who use BIM. Of the 10 respondents almost half have identified as not using BIM. This is consistent with the pattern reported by Young et al. (2009) It will be very interesting to see whether this pattern continues as more responses come in. There has been a lot of excitement about the potential of BIM, but the reality might not match the rhetoric (Gerrard et al. 2010), at least in Australia. These responses have come from eight different professions, including: steel detailer, building designer, tradesman, quantity surveyor, interior designer, structural engineer, draftsman architect and construction manager. All have more than ten years experience in their profession.

With this low number of responses, drawing sensible conclusions is difficult. However some responses are consistent with patterns already seen in the literature and are likely to be reiterated by further respondents. These are shown below.

- Software most used is Autodesk Revit, Autodesk Navisworks, and Tekla Structures.
- Three of four BIM users find it highly effective compared to 'traditional methods'
- Estimated costs of implementing BIM are between 2 and 15% of total project costs
- BIM is used most during the documentation stage of the project
- The most consistent improvements in Time, Cost and Quality of a project are during the construction/logistics phase.
- During the Design phase, BIM is most effective for visualisation
- During the Documentation phase, BIM is most effective for modification and overall accuracy.
- Most BIM training is Company Funded, and focuses primarily on Software
- Of the four BIM users one apparently had a bad experience, and commented that there was a "...Significant addition of time" to the project, significant organisational costs "...with no immediate benefits", "Significant cost in hardware and poor performance of software", and that "genrally [sic] the BIM process is done poorly by most ".
- This same respondent feels that "More integration is required between software manufacturers - especially Autodesk products", and that "Due to the additional planning stages of BIM projects onsite operations are generally overtaking the BIM process in construction program".
- This user concluded with advice to others: "Understand the process is HUGE and you are not an expert". Other users had slightly difference advice: "Never give up. It makes sense and will be adopted. Be patient and concentrate on data [not on] the tools. Do not let yourself be cornered into exclusive propietary [sic] solutions." and "It works".

- Of non-BIM users, one had never heard of it, while two others stated there was no demand for it.

More extensive results will be presented in due course, including results from international respondents.

Ideally BIM should be regarded as “the entire process of exchanging, re-using and controlling project information being generated during the lifecycle of a building project and not just a simple information model” (Ham et al. 2008). This notion is illustrated within Figure 1. With plenty of room for improvement, BIM has currently affected the organisational structuring of many building project processes. The BIM approach provides architects with the opportunity to regain lost ground in respect to their traditionally status as leaders (Khemlani 2007), as it enables enhanced control, co-ordination and management of building projects. Having said that, the BIM process is still at a very young stage and just like organisations in the retail sector before them, BIM adopters will need to go through a managed process of change which encompasses not only their internal organisation but also the way they interface with their external supply-base and clients (Dawood and Iqbal 2010). Currently the majority of the UK market is still working lower level processes, with the most significant benefits experienced by moving to higher levels of BIM adoption (Dawood and Iqbal 2010, 7-14), something reiterated by in the USA (Young et al. 2009).

4. Conclusion

A wide range of institutions and industry bodies are conducting BIM research. This research project has the ability to stand out from the rest and effectively contribute to the overall body of knowledge, as it will update the knowledge of BIM use in Australia, last assessed in 2007 (Gerrard et al. 2010), as well as making an international assessment of current industry practice. While data do exist for the US and UK as recently as 2012, this study extends the knowledge of use across international boundaries and across disciplinary boundaries. Dta collection for this project is still within its preliminary stages, but over the early months on 2013 a substantial amount of data will be gathered and analysed.

5. Acknowledgements

The authors acknowledge the substantial assistance provided by our research assistants Rashan Senanayake and Marko Matkovic, particularly in populating the project bibliography, compiling the survey and producing the framework diagram. Professor Martin Skitmore helped to initiate the project and provided timely guidance to the research team. The School of Civil Engineering and the Built Environment, Queensland University of Technology is acknowledged for providing seed funds that allowed our RA’s to be employed.

6. Appendix—Survey Questions

1. PRELIMINARY

What is your profession? (Please check all that apply)

How many years of experience have you had in your profession?

Where is your current workplace based?

Have you used BIM on any projects you have worked on?

2. BIM USERS

What is your current definition of BIM?

How long has your organisation been using BIM?

How often have you had external requests to use BIMs?

From who have you had requests for BIM?

On what percentage (%) of projects have you used BIM in the last year?

Within these project types, what is the average project size on which you have implemented BIM? Nominate all types that apply

Which BIM software have you used?

How effective has BIM proven to be in comparison to utilising more traditional methods (CAD, Hand drawings etc.)?

What aspect/s of BIM do you use?

What project changes/results have you experienced having used BIM?

What are the estimated costs of implementing BIM on your project (of total project costs)?

What is the extent of BIM's involvement/implementation within the main stages of a project?

In the main stages of a project, how has BIM affected the **COST**, **QUALITY** and **TIME** of:

Within the **DESIGN** phase how effective has the implementation of BIM proven to be?

Within the **DOCUMENTATION** phase how effective has the implementation of BIM proven to be?

Within the **CONSTRUCTION/LOGISTICS** phase how effective has the implementation of BIM proven to be?

Within the **OPERATION AND MAINTENANCE** phase how effective has the implementation of BIM proven to be?

What is your overall level of satisfaction with your BIM experience?

Who is mostly responsible for co-ordinating the BIM on a project?

Which discipline/project party has intellectual property ownership of the BIM in a project?

With all building projects there are legal concerns which impact the process. With regards to BIM integration were there any legal concerns?

Were there any organisational issues involved in the BIM process?

What is the competancy level of BIM users within your organisation? (Total must add up to 100%)

Do you have any BIM training systems in place?

What is your BIM training focussed on?

How often does your organisation provide training?

To what extent should BIM be integrated into Tertiary Studies Curriculum?

Were there any challenges with the initial take up of BIM?

Any suggested improvements to:

What advice would you pass onto to new BIM users?

Would you recommend implementing BIM on building projects?

To what extent would you recommend the implementation of BIM within the building types below?

To what extent would you recommend the implementation of BIM within the Project sizes listed below?

To what extent would you recommend the implementation of BIM within the Project lifecycle phases listed below?

Any Additional Comments?

03. NON-BIM USERS

What is your current definition of BIM?

What are your reasons for not employing BIM?

Are you considering the implementation of BIM within your organisation?

What aspects of BIM do you plan on utilising?

Have you had any external requests for BIMs and from whom?

Any Additional Comments

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Climate Change Study on Coastal Settlements and Traditional Architecture in Madura Island, Indonesia

Ispurwono Soemarno[1], Muhammad Faqih[2], Wahyu Setiawan[3]

Abstract

Various studies on the phenomenon of global warming and climate change have been done. The results among other things are the rise of sea water levels and the change of air temperature. Such conditions would supposedly affect coastal settlements and its socio-economic as well as cultural future of the Madurese. The influence may also arise against existing Madurese traditional architecture. This study is aimed to understand the effects mentioned above.

The method used in this study is a series of field observations and interviews conducted in four regencies in Madura Island. Changes observed are the natural phenomena associated with climate change, including the indication of sea level rise and preventive actions as well as the current condition of Madurese traditional architecture.

This paper is a preliminary result of the overall study. The indication of sea level rise are found in three observed areas. Meanwhile, the changes of Madurese traditional architecture found in this study are mainly due to densification process. All the results are expected to be the subject of further studies to gain the anticipation of possible negative impacts through adaptation efforts.

Keywords: climate change, coastal settlements, Madurese traditional architecture

1. Background

Madura Island is situated on the north of East Java, separated by Madura Straits. The majority of Madurese is devout Moslem society, while the main livelihood of Madurese is fishing. Fishermen settlements are scattered along the coast of this island. Other livelihoods are trader, tobacco farmer and salt maker.

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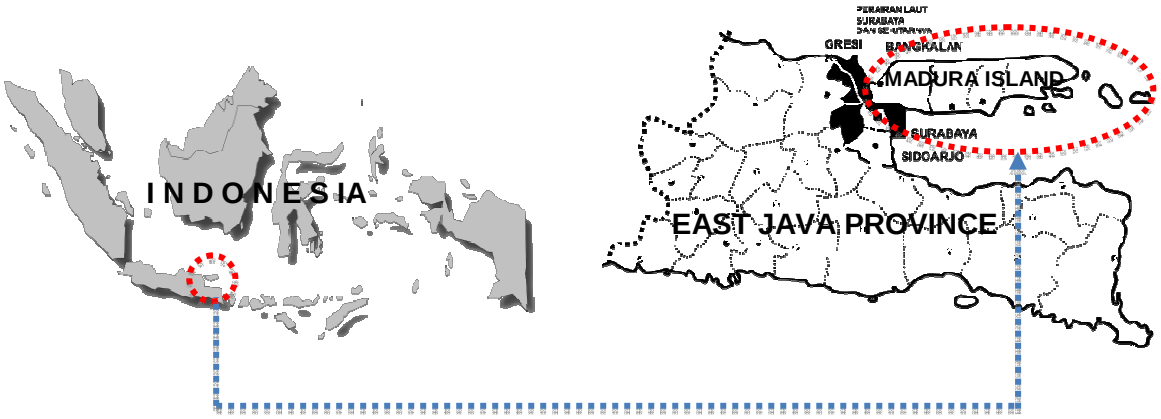


Figure 1: Indonesia and Madura Island

Administratively, Madura Island consists of four regencies, from west to east respectively: Bangkalan, Sampang, Pamekasan and Sumenep.

The Madurese has its own traditional architecture that is slightly different compared to Javanese architecture. In order to boost Madurese socio-economic development, the Indonesian government built Suramadu Bridge, which connects Surabaya in East Java and Madura Island. This 5.438 meter long bridge is completed in 2009.

This study is conducted in relation to the climate change phenomenon. It is an observation process aimed if Madurese clearly comprehends such phenomenon and whether it affects Madurese built environment, especially its traditional architecture. Interviews were conducted with related stakeholders. The questions raised to the staff of local environmental authority office among other things are whether they aware and comprehend the climate changes basic issues and their implication in Madurese context. Other information obtained include the locations of the Madurese traditional architecture that still can be found within the regencies in Madurese island. The next step is visiting the sites and comparing them with the theory of traditional architecture based on existing literatures. Furthermore, information related to climate change research results are also used to analyze the existing conditions in the study areas.

2. The Literatures and Field Findings

2.1 The Madurese Architecture

In 1986, Wiryoprawiro carried out a study on traditional architecture in Sumenep, Madura. Historically, Sumenep Kingdom existed in Madura Island in the past. This explains a variety of old kingdom buildings in Sumenep.

Tulistyantoro (2005) described his study on aspects and significance of the Madurese settlement. He explains that in the case of residential home extended family is adherent. The house is located on the North side, with *langgar* or *mushala* (a small mosque) located at the West end, while cattle sheds are located on the South. The layout of the kitchen was

originally adjacent to the cattle sheds, but many kitchen layouts then shifted to the side or back of the house. In addition to cooking activities, the kitchen is also functioned as a place to store crops or agricultural products. The courtyard, which is formed and located in the middle of these buildings, is called *tanean*. A long courtyard is called *tanean lanjang*.

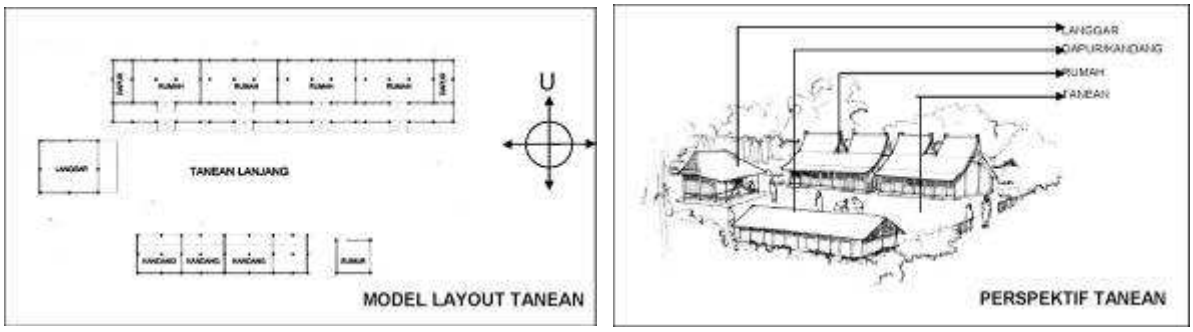
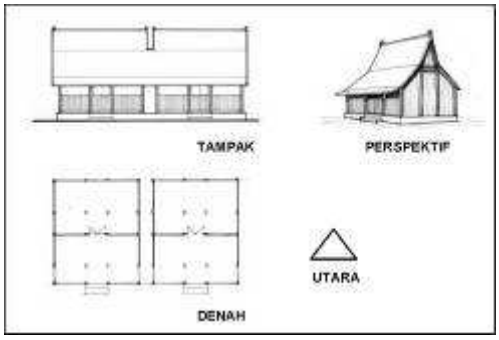


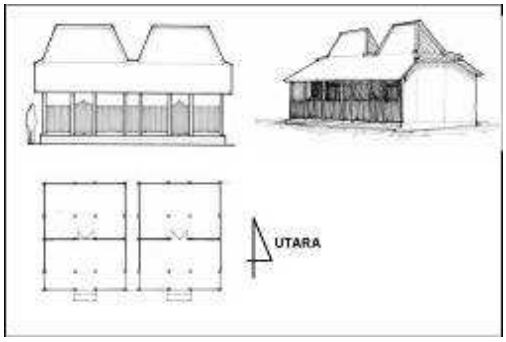
Figure 2: A courtyard is formed and situated among buildings within a Madurese settlement

Dwelling is the main residence, usually only has one door toward the front. This building is a space to sleep with a full wall on four sides. In addition, there is an open porch with a half-wall that serves well as a sitting room or area to receive guests for women. Dwelling floor height is around 40 cm above the surrounding land. Ground floor material is earth, plaster or other materials such as terracotta. The doors are generally made of wood, and roof materials are palm leaves, thatch or tiles depending on the economic viability of its inhabitants. The form of floor plans, location of the main mast, and shape of the roof can distinguish building form. Based on the floor plan, the building is divided into *slodoran* and *sedana*. *Slodoran* consists of one room with two doors and a porch with one exit. *Sedana* has two rooms and two doors but only has one porch with one exit. Based on its main column, a building can be divided into *bangsal* and *pegun*. *Bangsal* has similar shape of Javanese *joglo* beheaded on either side, while *pegun* is shaped pyramid-like that has overhang on the front and rear part. Both types have the same structure of four main columns, but *bangsal* always has ridge with dragon tails shape.

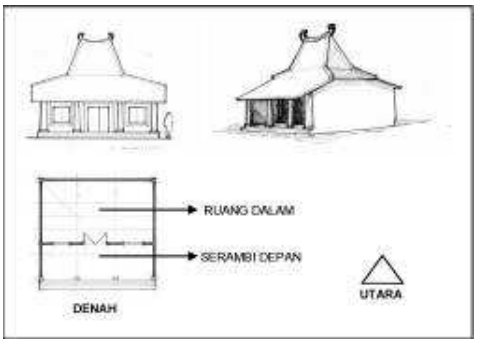
From its form, roof can be differentiate into *pacenan*, *jadrih,* or *trompesan*. A roofed shed house is called *pacenan* (derived from the words *'pa-china-an'*). *Jadrih* is a roof type on a house with two ridges; while *trompesan* is a roof type that consists of three segments.



a) Trompesan roof type



b) Pegun roof type



c) Pacenan roof type

Figure 3: Trompesan, pegun and pacenan roof types

2.2 The Climate Change factors

Climate change is a term refers to large changes in temperature, precipitation snow, or wind patterns lasting for decades or more. It is believed as real and urgent challenges that are affecting people and the environment worldwide. Climate change generates significant change on earth, including air and ocean temperatures rise, snow and ice melt, and the rise of sea levels. In this study, the observation on sea level rise is chosen as a method used in detecting the climate change at the study areas. Other climate change indicators indicated above require a long time to measure; especially air and ocean temperature rises, in order to acquire significant results. Declining in fish catches by the fishermen could also be resulted by the climate change phenomenon. However, several other factors have to be taken into account to get valid study results.

The study of Bappenas RI (Indonesian National Development Planning Agency) in 2010(b), pointed out that land temperature increase only 0.5^0 C in wet months (December to February) for the period between 1904-1994 (with Jakarta as the sample), while during the dry months (June to August) there is an increase of 1.5^0 C. In terms of sea level rise due to climate change in Indonesia, Bappenas RI (2010a) stated that the result in comparing the average of sea level during the period 2001 to 2008 and the period 1992 to 2000 shows a sea level rise between 2 - 12 cm with an average increase of 6 cm in a period of 7 years.

In architectural aspects, change in building material used or comfort in building interior might also be the results of the climate change. These cases also need several factors to be considered valid as climate change implication. In this study, change in building floor level or building relocation are due to the rise of sea levels.

2.3 The Field Findings

The interviews and discussions are carried out with related parties in four environment regencies (Bangkalan, Sampang, Pamekasan and Sumenep) offices in Madura Island. The results of these actions are mostly having none or barely related directly to climate change implication. The awareness of climate change consequences is still somewhat limited among staff in the environmental offices in all regencies in Madura Island.

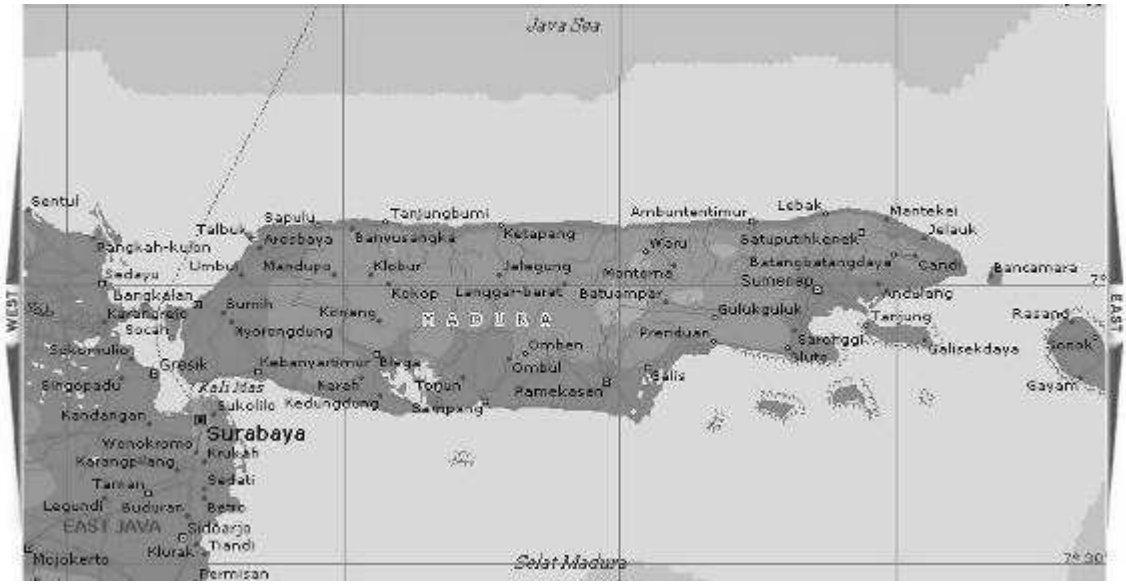


Figure 4: Madura Island

There are four locations in northern coast of Madura and one in southern coast surveyed in this study. They are Sepulu and Tanjungbumi in northern Bangkalan regency, Ambunten and Pasongsongan in northern Sumenep regency, and Camplong in southern Sampang regency. The findings in those field survey areas are described below.

The observations, associated with the presence of Madurese traditional architecture conducted in Bangkalan regency, are barely found any group of buildings that form a complete residential area with its *tanean lanjang*. This fact is consistent with the study results conducted by Sharvina (2012) in Labang district, southern part of Bangkalan. She has not found any Madurese settlement completed with tanean lanjang pattern there. However, some Madurese traditional buildings still exist in Sepulu, a small district at coastal area in northern part of Bangkalan.



a) b)

Figure 5: a) Fishermen village at Sepulu district; b) A traditional house found at Sepulu

From Figure 5b) above, clearly seen that one traditional house has been surrounded by other, relatively, new buildings. This densely populated village resulted on the need of more land to build their dwelling. This need is also shown in the following figure 6 a) & b) which showed an attempt to enlarge the coastal area through reclamation efforts.



a) b)

Figure 6 a) & b): A reclamation effort to get 'new' land for dwelling

On the other hand, it is clearly seen that tidal water level has increased in this area. This is demonstrated by the construction of embankments to protect the area from high waves. A broken house located right on the beach is also found. The information from the field stated that the inhabitants moved to another place that is considered as 'safer place' from the threat of rising sea level at this beach. These situations are shown in Figure 7 a), b) and c).



a)

Figure 7a): The embankment, which gives protection from waves



b)



c)

Figure 7b) & c): The broken & abandoned house

Furthermore, at this survey area, a wall was built with the purpose of a protection from the ocean tides. It is apparently made several times in different times. This can be indicated from the different materials used for that wall. This fact indicates the increase of tidal waves from time to time at this survey area.



Figure 8: A protection wall against tidal waves that was built in different phases

In addition to the circumstances above, it has been found two buildings with Madurese traditional architecture character at this survey area. One building stands next to a new building. There is an open space in front of the second building. This space might be part of *tanean lanjang* in the past. (Figure 9a) and 9b)).



a) b)

Figure 9a) & b): Two buildings with traditional architecture character at the surveyed area

In Camplong district, part of Sampang regency, at the southern coast of Madura Island, a protection wall was also found. However, it is not as high as the one in Sepulu, northern part of Bangkalan regency. The coast settlement situation in Camplong and the waves protection wall can be seen in the following Figure 10.



a) b)

Figure 10 a): Fishermen settlement at Camplong coast; b) The waves protection wall

In Camplong study area, some Madurese traditional architecture buildings are found. Some of these traditional buildings are situated at the same site. The existence of *tanean lanjang* still can be seen here, even though some buildings have changed their function. It is shown in the following Figure 11a) & b). Both figures were taken at the same location and from the opposite direction.



a) b)

Figure 11 a) & b): Both figures show the existence of tanean lanjang as described above

In Sumenep regency, two locations are chosen as the survey study areas, namely Ambunten and Pasongsongan. Both districts are situated at the northern coast of Madura Island. At Ambunten, local inhabitants describe the increase in sea level. They showed their graveyard that has been eroded underneath due to the reason above. They also explained that within the last five years, the level of tides is increased. They supported their story by showing the sign of previous water level tide.



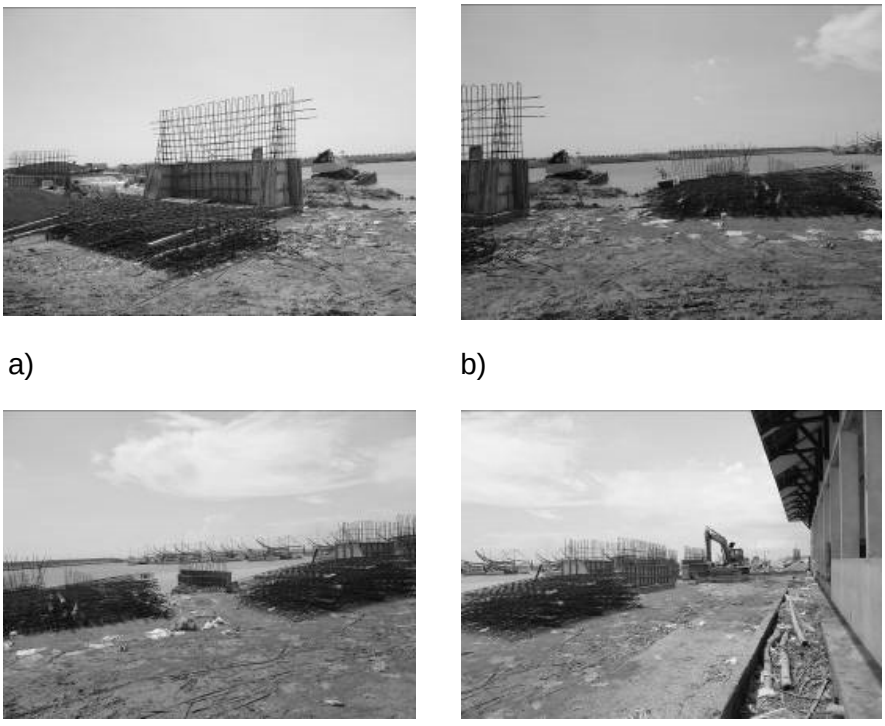
Figure 12: Eroded graveyard land at Ambunten



a) b) c)

Figure 13 a), b) & c): All three figures above show the gradations of sea level rise points at Ambunten coast

At Pasongsongan district, the sea level rise was very clear. During the interview phase, a staff of Local Government Development Board explained that in Pasongsongan district, the Public Works Department was in the process of building a wall protection against the tidal waves. During the field survey, some parts of the protection wall were being prepared. Moulding of these reinforced concrete walls were also in forming process. Some of the preparation works can be seen in the following figures.



a) b)

c) d)

Figure 14 a), b), c) & d): The tidal waves retaining wall preparation process

3. Conclusion

From all the discussions described and figures presented above, some conclusions of this climate change study on coastal settlements and Madurese traditional architecture can be drawn as follows:

- The sea level rise is clear in all Madura coastal areas. This is evident with the construction of retaining walls in some places in the survey areas.

- The shifting of buildings to a higher location and the erosion happened on a cemetery site at the study areas also proved the sea level rise.

- The sea level rise on the northern coast of Madura, however, is higher than the south coast. The large area of Java Sea in compare to Madura Straits might be the reason of these differences.

- Some Madurese traditional architecture buildings are still exist throughout the island. Meanwhile, the concept of *tanean lanjang* is barely found. It might be in the extinction process. The main reason of this process is the scarcity of land while the population is always increased over the years throughout the island.

In light of the findings above, some task actions that could be carried out by the government including:

- Provide periodic explanation to the public about a variety of negative consequences that may arise due to the phenomenon of climate change, and efforts to address them.

- Continue to take necessary actions against disasters caused by the sea level rise and protect the coastal settlements from the risen tidal waves.

- Preservation the remaining Madurese traditional architecture buildings and encourage Madurese society to rebuild the building compound with *tanean lanjang* concept. It might not be an easy process. Some government incentives in the form of property tax might be needed to preserve the traditional architecture treasures.

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Navigating the future of roads – considering potential impacts of environmental and social trends on road infrastructure

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Abstract

Providing mobility corridors for communities, enabling freight networks to transport goods and services, and a pathway for emergency services and disaster relief operations, roads are a vital component of our societal system. In the coming decades, a number of modern issues will face road agencies as a result of climate change, resource scarcity and energy related challenges that will have implications for society. To date, these issues have been discussed on a case by case basis, leading to a fragmented approach by state and federal agencies in considering the future of roads – with potentially significant cost and risk implications. Within this context, this paper summarises part of a research project undertaken within the 'Greening the Built Environment' program of the Sustainable Built Environment National Research Centre (SBEnrc, Australia), which identified key factors or 'trends' affecting the future of roads and key strategies to ensure that road agencies can continue to deliver road infrastructure that meets societal needs in an environmentally appropriate manner. The research was conducted over two years, including a review of academic and state agency literature, four stakeholder workshops in Western Australia and Queensland, and industry consultation. The project was supported financially and through peer review and contribution, by Main Roads Western Australia, QLD Department of Transport and Main Roads, Parsons Brinckerhoff, John Holland Group, and the Australian Green Infrastructure Council (AGIC). The project highlighted several potential trends that are expected to affect road agencies in the future, including predicted resource and materials shortages, increases in energy and natural resources prices, increased costs related to greenhouse gas emissions, changing use and expectations of roads, and changes in the frequency and intensity of weather events. Exploring the implications of these

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potential futures, the study then developed a number of strategies in order to prepare transport agencies for the associated risks that such trends may present. An unintended outcome of the project was the development of a process for enquiring into future scenarios, which will be explored further in Stage 2 of the project (2013-2014). The study concluded that regardless of the type and scale of response by the agency, strategies must be holistic in approach, and remain dynamic and flexible.

Keywords: road, future, trend, strategy, transport

1. Introduction

A range of factors are placing an increased amount of pressure on Australia's road network such as changes to weather patterns, road material resource shortages, the changing usage and expectation of roads and transport, population growth and urbanisation, and increases in energy and resource prices. The Organisation for Economic Co-operation and Development's (OECD) Economic Survey (2010) described Australia's increased congestion in its transport infrastructure as an 'infrastructure deficit'. While on the other hand, research suggests that in the developed world the use of cars has peaked and demographic and digital change are impacting traditional movement patterns, resulting in a lesser need for road network expansion and rather a greater sharing of existing road space (Brookings Institution Metropolitan Program, 2008; Newman & Newman, 2006; Newman & Kenworthy, 2011). These ever-changing trends and pressures demand that road agencies be mindful of this rapidly changing world and proceed with informed and transparent approaches. A number of new technologies and processes may need to be adopted in order for Australian road agencies to respond to the pressures associated with the future of roads and remain at the cutting edge of best practice on road planning, assessment, building and management.

Long-term planning and resilience-building is urgently required in response to emerging issues related to environmental impacts, carbon legislation, economic risks and social demands, to provide reliable and effective road networks into the future. Particularly relevant in Australia, where 814,000 kilometres of road network spans a wide range of geographic areas (see Figure 1), the cost of road construction in Australia is estimated to be in the order of $17.5 billion per year (Bureau of Infrastructure, Transport and Regional Economics, 2009). The road maintenance cost is estimated to be in the order of $5 billion per year and rising. This rising maintenance task, in which the cost is estimated to be in the order of $5 billion per year and rising (BIS Shrapnel, n.d.), was made clear by the forensic work of BIS Shrapnel in 2012 who revealed that for every $100 of net assets in Australia, we are only spending $1.44 on maintenance (Hart, 2012), which has resulted in years of under spending in maintenance on roads, public rail.



Figure 1: Major Australian road networks

It is critical to understand the direct environmental impact of roads because of their role in our society and the scale of the infrastructure we have built to date. It is also important, and more challenging, to consider the indirect environmental impact of roads through their end-use as transportation corridors, and how this might be addressed through strategic directions for transport infrastructure. For example, roads support an automobile industry that employs millions of people and sells a copy of its product every 1.5 seconds (Worldmeters.info, n.d.). Road infrastructure also supports vehicles that combust 310,000 barrels of oil every day in Australia and emit 17 percent of Australia's greenhouse gases, in turn threatening global climatic stability, local ecology and agricultural industries (Australian Bureau of Statistics, 2010).

The use of roads has become a core part of an economies activity, for example a cup of coffee can be based on nearly 30 different transport related activities. However, while the economic benefits of road construction and use are well known, the environmental impact and associated future economic impacts are typically underestimated. For example, each kilometre of road constructed, and associated infrastructure, requires large quantities of aggregates, concrete, asphalt and steel to be sourced, transported and placed. A typical two-lane bitumen road with an aggregate base can require up to 25,000 tonnes of material per kilometre, showing why aggregates are the most mined resource in the world. The emissions from the mining, transportation, earthworks, and paving associated with road construction, as well as emissions from road users, makes it one of the greatest contributors to climate change – some 22 percent of global carbon dioxide emissions (InterAcademy, 2007).

2. Method Summary

This report outlines the commencement of an approach developed by the SBEnrc working closely with the Western Australian and Queensland road agencies. It outlines findings on a number of key trends affecting the future of roads and will highlight the potential impacts on social well-being. It will begin an exploration into developing strategies to ensure that roads continue to deliver social needs and that a transparent and deliberative approach to road policy issues may enable Australian road agencies to maintain their global best practice edge.

This project presents the findings of a research project as part of the Sustainable Built Environment National Research Centre (SBEnrc) in Australia. The research has included findings from a global literature review, four stakeholder workshops, and extensive research based collaboration with industry. The project is supported by Main Roads Western Australia, QLD Department of Transport and Main Roads, Parsons Brinckerhoff, John Holland Group, and the Australian Green Infrastructure Council (AGIC).

Table and diagrams shown in this paper were sourced from the findings of SBEnrc stakeholder workshops, hosted by Main Roads Western Australian in Perth on 12 July 2011, and Queensland Department of Transport and Main Roads in Brisbane on 9 September 2011, facilitated by Curtin University and Queensland University of Technology. The second series of stakeholder workshops was held in each respective city on 27 April 2012 and 13

April 2012. Of the 75 participants, Government employees were well represented on behalf of the project partners while a range of industry associations, private, public and academic professionals contributed towards the breadth of analysis and range of discussions.

The 2011 workshops were aimed at learning from the experiences of participants, identifying a range of challenges the research team must consider, and gaining a strong understanding of how the research can directly support and enhance industry and government practices and policies. Hence, the workshops were a valuable opportunity for the research teams to engage with the project partners and experts in the field to ensure that the projects are well informed and guided towards tangible outcomes.

The 2012 workshops were structured around a new methodology developed by the research team to explore future trends related to roads and sustainability in order to consider a range of possible strategic responses. The process has been succinctly summarised below in Figure 2, based on an inverted triangle to demonstrate the progression of the process, starting with a highly complex idea or goal (i.e. planning for the future of roads) and narrowing down to tangible outcomes (i.e. identifying strategies to respond to specific future risks). Each stage of the process was designed to deliver specific outputs for the research investigations and industry partners.

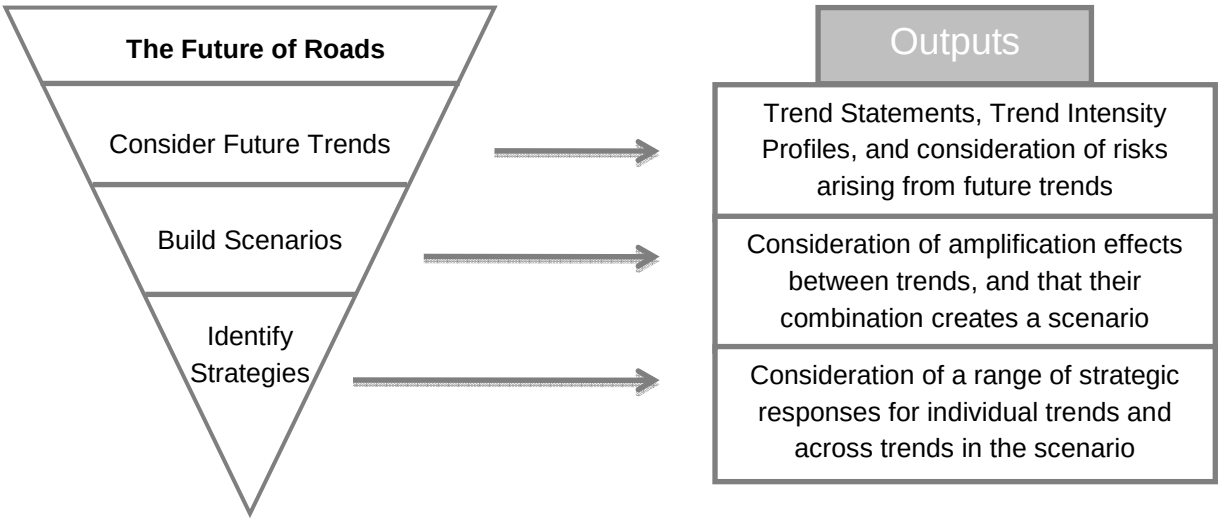

Figure 2: Workshop process for considering the future of roads

3. Discussion – Trends

A new range of complex social, economic and environmental pressures will face road agencies and the transport network, presenting challenging implications for society. Global trends are emerging that can inform the context of these issues and allow further investigation for agencies. An early understanding of the social, economic and environmental trends affecting the future of roads will enable the development of strategies to ensure that road agencies can continue to deliver road infrastructure that meets societal needs in an environmentally appropriate manner. The following section uncover the global

emerging trends and investigate finding from road industry workshops and proposes some of the key trends and processes for addressing their impacts.

3.1 Emerging global trends

A lead article in the September 2012 edition of the Economist examined an emerging global trend revealing the term ‘peak car’. It describes the concept of car use peaking in the world’s developed nations (Economist, 2012) and reflects on an Australian Government report examining the phenomenon and the effect on government road and transport policy. Factors considered to be significant were underpinned by social influences, including the use of digital mediums instead of travel, online shopping, changes in demography with a preference towards more urban living and the reduced attraction of automobiles, and other factors including increased fuel costs and climate policy. Meanwhile road agencies are absorbing what this means for the road network and their approach to road building, operations and maintenance, as they attempt to resolve increasing congestion due to the ‘infrastructure deficit’ outlined in a 2010 OECD report on Australia, and the political cycle of new public infrastructure.

The dominant global perspective illustrates that an opportunity exists to transform the way road infrastructure is conceived and harnessed, to assist society to respond to a range of environmental and social pressures. Innovations in the construction, road use and management in order to manage these changes can now be seen. The most provoking global trends are those developing from new influences of technology, vehicle ownership patterns and maturing network expectations of informed citizens. Emerging global trends identified during the literature research are listed below in more detail:

- Community expectations regarding road space and use are changing. A US study described that 75% of youths would rather own a smart phone than a car reinforcing we have moved from the age of ownership to the age of access. Car ownership is declining while public transport use, walking and cycling is increasing and people are moving to higher density locations which support reduced car dependence. This is reflected in metropolitan areas across the globe where there is a move towards citizens reclaiming space that was for cars and car parking (see Figure 3);

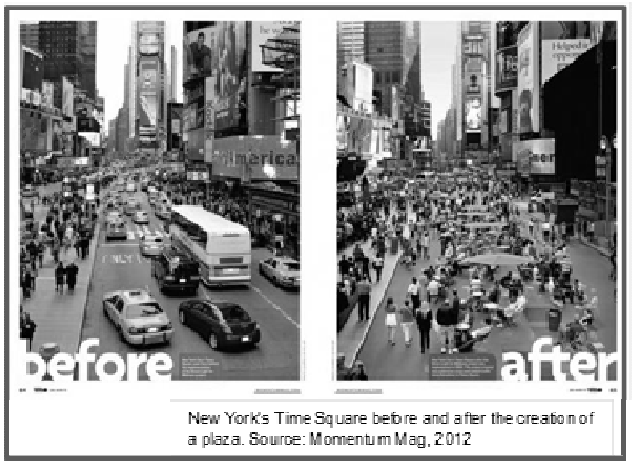

Figure 3: The reclamation of space in New York’s Times Square

- Vehicle design including the size, shape and fuel use is evolving, with manufacturers changing the power source of vehicles away from fossil fuel and the subsequential implications of roadside infrastructure to service these changes;

- Roads have the potential to generate and also provide electricity with commercial businesses exploring the solar potential of roadways, harnessing of the energy produced by the motion of traffic and using magnetic energy to charge electric vehicles while they are driving;

- Existing transport infrastructure can be used more efficiently. Many innovations look at how existing road infrastructure could be used more efficiently, exploring behaviour change policies, parking restriction policies, different technological innovations, such as driverless vehicles to assist congested traffic flow, managed lanes, innovative congestion or road user charging and prioritising public transport within established road corridors; and

- Raw aggregate alternatives for use in pavement construction are emerging to reduce increased extraction and transport costs due to the poor accessibility of quarries and strict aggregate quality guidelines. Wastes are increasingly being repurposed for use in road construction, evident in India whereby the incorporation of recycled plastic bags have been shown to improve performance under excessive solar heating. Furthermore, roads are being used as repositories for carbon, and insitu-stabilisation techniques (like using natural rubber additives) are gaining credit for its adaptable sustainability solutions.

3.2 Emerging trends for Australian road agencies

In the coming decades the design, construction, operation and maintenance of roads will face a range of new challenges. Many of these will bear little resemblance to challenges previously faced - a result of a growing number of interconnected environmental, social, and economic pressures or trends. For instance, environmental pressures will include the impacts of climate change on rainfall patterns, temperature profiles and accelerated maintenance cycles; economic pressure will include greater road freight demand, resource shortages (aggregates and water) and predicted increases in energy prices globally; and social trends will include a shift to lighter vehicles, smart phone technology influences on mobility, population pressures, and political pressure to adapt to climate change.

Drawing on the findings of SBEnrc Stakeholder Workshops in 2011 hosted by the partner road agencies and facilitated by Curtin University and QUT, Table 1 below shows the results of an exploration potential global trends. Participants identified both positive and negative changes in order to conceive the future global environment for the road industry. Participants were asked to identify the most influential increasing pressures, listed first and highlighted with an asterisk.

Table 1: Proposed list of both positive and negative changes used to conceive the future global environment for the road industry (drawn from stakeholder workshops)

Potential trends affecting the future of roads (drawn from stakeholder workshops)	
– *Climate change – *Rising price of oil – *Increased community action – *Decreasing access to resources (aggregates) – *Population growth – *Increased freight – *Maintenance costs – *Increased community expectations of transport network – *Employment and skill shortages – *Global financial crisis – *Water scarcity – A price on carbon – Technology innovation, e.g. smart roads for driverless cars – Rapid urbanization and densification – On-line shopping – Increased use of social networking – Increased use of smart phones and applications – Increased frequency and intensity of extreme weather events	– Growing environmental awareness and cooperation – Modal shifts to rail and public transport – Biodiversity degradation and collapse – Loss of agricultural land – Increased automation – Waste reduction and harnessing – Growing middle class – Peaking of food production – Alternative fuel sources – Changing world powers – Pressure for intergenerational responsibility – The influence of the government – Decentralisation – Congestion increases or decreases – Globalised tourism – Health costs and impacts – Changing lifestyles affecting mobility – New transport paradigms – Short political cycles – Methods of energy generation

Note: Information, recommendations and opinions expressed are not intended to address the specific circumstances of any particular individual or entity. This table has been produced for general information only and does not represent a statement of the policy of the participants of the stakeholder workshop, the SBEnrc, or the SBEnrc partner organisations.

The list revealed distinct trends emerging in the form of overarching themes. The themes common to both workshops were climate change leading to extreme weather events, the rising price of fossil fuels, water scarcity and the increased importance of the community as a key stakeholder. Participants of the Queensland workshop identified population growth and the changing influence of the governments as particularly important, which reflect specific pressures to Queensland. Interestingly, Western Australian (WA) stakeholders identified resource shortages as a key global change, whereas Brisbane participants listed accessibility issues leading to the shortage of aggregate resources rather than a decreasing supply. It is proposed that this reflect on the state's long history of resource shortages and changing outlooks within the road construction industry on the long-term viability of resource use in Western Australia.

3.3 Identification of potential trends by stakeholders

In consultation with road agency partners, the above list was developed into ten trends for further exploration. The research team investigated each trend to establish a series of 'trend statements', which analysed information about the trend profile, timeframe and risks. The list of ten trends is as follows:

1. Roads require more frequent and costly maintenance
2. More extreme weather events and sea level rise require a more resilient road network
3. Oil based road surfacing becoming unfeasible
4. Demand for new infrastructure due to an increase in active and public transport
5. Aggregate shortages
6. Road freight increases in size & quantity
7. Funding constraints on new projects & on maintenance of existing infrastructure
8. Road and public transport infrastructure reaches capacity
9. Electric & alternative fuel vehicles mainstreamed
10. City planning densification requirements along rail lines & for infill development
11. Information technology and smart phones influence transport and mobility patterns

It is understood that this list is not conclusive; however it serves as a useful base from which to analyse the impacts to road agencies, consider the amplification of trends when combined, and make preliminary steps into scenario planning. Within the professional experience of the practitioners present in the 2012 workshop series, the stakeholders confirmed the trends as suitable representations, alongside reaching a consensus for the addition of technology, smart phones and intelligent transport systems (ITS) as being influential to road agency roles in the coming decades.

Drawing on the findings of 2012 series of SBEnrc stakeholder workshops road industry representatives from the public and private sector, along with academic and industry associations considered a short list of emerging trends and its effect on state roads in the coming two decades. The agreed top four in each state are shown in Figure 4.

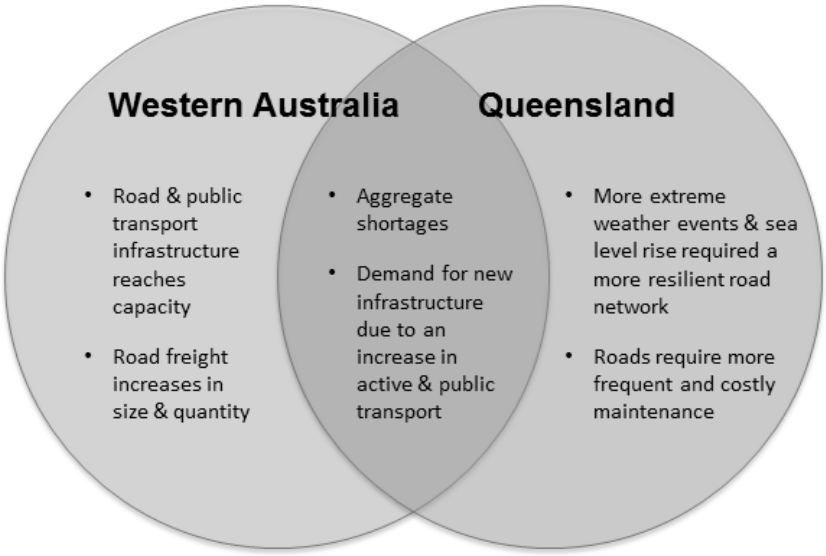

Figure 4: Future trends selected for consideration by SBEnrc partners and stakeholders as part of the 'Future of Roads' workshops in Brisbane and Perth, 2012

Reflecting on the trends selected the research team suggest that there are some key reasons why particular trends are important to each state. Both Queensland and Western Australia are experiencing increased infrastructure demands as a results of mining booms, putting enormous pressure on natural resources to service these requirements, evidenced by the '*aggregate shortage*' trend being selected with the most votes in both states. A changing social culture, population growth, and growing congestion in both capitals, Brisbane and Perth, have given rise to a greater number of trips by walking, cycling, and public transport, putting pressure on existing infrastructure, evidenced by this trend being selected in both states. The recent extreme weather events during the summer of 2011 have clearly cemented the concern regarding climate change impacts on roads in Queensland, and this is shown through the appearance of the trend '*increase in extreme weather events*'.

The stakeholders were provided with a process to reach agreement on emerging trends relevant to the road network and that set the platform to identify strategic responses. These strategies can be developed in the short-term to combat the risks and build resilience in our road networks. This is known a scenario planning, and a unique methodology was developed for a workshop style framework to breakdown the complexity. Scenario planning enables decision makers to overcome preconceived ideas discuss strategies for the future and develop informed strategies that combat risk. Scenarios are not predictions; rather they provide support for informed decision-making, enabling analysis of decisions, the understanding of relationships between issues, and the challenging of cultural norms and assumptions. They are part art and part science enabling foresight for decision makers. This will be explored further in the ongoing research however insight into scenario planning can be discovered by adding an extra dimension to the list of trends and begin considering them in combination whereby they may amplify the trend over time and the associated risks, examples of which include:

- 'More extreme weather events' leading to increased damage of main roads and 'roads requiring more frequent maintenance;'

- ‘Aggregate shortages’ leading to increased costs of aggregates and ‘more costly road maintenance’ in Queensland;

- ‘Road freight increases in size and quantity’ leading to increased design strength requirements for road pavement, contributing to ‘aggregate shortages’ in Western Australia;

- Trends that may reduce impacts of another include; and

- ‘City planning densification along rail lines and infill development’ alleviating the impacts of ‘road transport infrastructure reaching capacity.’

4. Conclusion

Roads will always be a focus for any city or region due to their economic and social importance. Perhaps for the first time in a century there may be a confluence of factors that are causing road agencies to fundamentally rethink how road infrastructure is made, how they are shared, and how they are managed. It will be important for the road and transport agencies to maintain a transparent and innovative approach to these emerging global and local trends, and the results so far suggest that road agencies in Australia are up to the challenge.

As agencies look into the coming decades they are increasingly finding that the conditions that have shaped their operations over the last two decades will look very different to conditions in coming decades. The research reveals how industry stakeholders can continue to participate in the process of risk and strategy analysis associated with current and future trends, to develop a platform for informed and transparent decision-making in the identification of powerful strategies to address the future of roads and combat risks to road infrastructure.

Implications for state and federal agencies

This research proposes to state and federal agencies that there is a changing role for road agencies, and importantly, the structural shift that is occurring within them, which is leading them potentially focus less on new infrastructure and more on maintenance and enhancing the efficiency of existing roads. The outcomes of this research enable road agencies to identify emerging trends that impact on the state road network, and develop strategic responses that enable road agencies to combat risks and build resilience. This aligns with the desire of both QTMR and MRWA to adopt a more holistic planning framework that accounts for social, economic and environmental drivers and outcomes. The Government benefits from the project’s research include:

- informed policy and management decisions for a resilient road network;

- greater insight into changing roles for road agencies and leverage points for action;

- a scenario planning methodology to stimulate responses and identify leverage points for strategic action; and

- more informed targeting of funding for future research.

Implications for industry

In such a competitive industry, firms are seeking to develop approaches that differentiate themselves from their competition, delivering cost-effective, innovative solutions addressing multiple objectives. With this in mind, it is important for industry to connect with research institutions to ensure that emergent areas for innovation are quickly investigated, understood and integrated into project offerings. This research project has sought to contribute to the conversation around 'sustainable road infrastructure', providing an extensively researched context to inform future innovation. Industry benefits from this project include:

The outcomes of the 'Future of Roads' project provide industry with a number of benefits, including:

- a better understanding of emerging options to reduce greenhouse gas emissions associated with road construction;

- improving strategic positioning;

- providing guidance on areas of specialisation for product innovation for reducing the environmental impacts during road construction; and

- understanding market gaps and resultant business opportunities.

Implications for future research

There has been little focus nationally or internationally on assisting road agencies to understand the potential future risks of trends related to the changing expectations of road users, climate change and resource availability despite trends that suggest major reassessment may be needed. This research project highlights that methods are available to inform medium to long-term planning and resilience-building to provide reliable and extensive road networks in future. Road agencies around the world have been oriented mostly to building roads, ignoring the changing circumstances; however there are conflicting trends about car use and public transport that mean they must now redefine their role. Australian road authorities are pioneering how to investigate the pressures facing the future of roads and consider how a strategic response can be informed.

Further research into the environmental and social trends affecting road infrastructure is required to enable determination of the hierarchy and urgency of strategies required to navigate the future of roads. This second phase of research is currently under the final stages of consideration by the Sustainable Built Environment National Research Centre (SBEnrc, Australia) and interested road agency research partners (existing and new).

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The development of a simple multi-nodal tool to identify performance issues in existing commercial buildings

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Abstract

Australia's building stock includes many older commercial buildings with numerous factors that impact energy performance and indoor environment quality. The built environment industry has generally focused heavily on improving physical building design elements for greater energy efficiency (such as retrofits and environmental upgrades), however there are noticeable 'upper limits' to performance improvements in these areas. To achieve a step-change improvement in building performance, the authors propose that additional components need to be addressed in a whole of building approach, including the way building design elements are managed and the level of stakeholder engagement between owners, tenants and building managers. This paper focuses on the opportunities provided by this whole-of-building approach, presenting the findings of a research project undertaken through the Sustainable Built Environment National Research Centre (SBEnrc) in Australia. Researchers worked with a number of industry partners over two years to investigate issues facing stakeholders at base building and tenancy levels, and the barriers to improving building performance. Through a mixed-method, industry-led research approach, five 'nodes' were identified in whole-of-building performance evaluation, each with interlinking and overlapping complexities that can influence performance. The nodes cover building management, occupant experience, indoor environment quality, agreements and culture, and design elements. This paper outlines the development and testing of these nodes and their interactions, and the resultant multi-nodal tool, called the 'Performance Nexus' tool. The tool is intended to be of most benefit in evaluating opportunities for performance improvement in the vast number of existing low-performing building stock.

Keywords: Energy efficiency, building performance, indoor environment quality, occupant satisfaction, whole of building performance evaluation

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1. Introduction

The built environment has a significant impact on the sustainability and liveability of our cities. Commercial buildings in particular are responsible for considerable flows of energy and resources, in part because many existing buildings were designed and constructed before sustainability was a primary concern. Similarly, commercial buildings have a significant impact on the health and well being of occupants, who spend an increasingly large proportion of their time indoors. But many of these buildings were designed and built before the health and productivity became common and explicit design goals. The result is a glut of older inefficient buildings that are not providing a high quality environment for their users.

There has been limited focus on improving the performance of older existing commercial buildings, yet these buildings typically represent the vast majority of the building stock in many cities. Australian cities have approximately 21 million square metres of commercial office space spread across nearly 4,000 buildings (PCA, 2008), most of which, if measured by net lettable area, consists of low-grade office buildings (Davis Langdon, 2008). As the performance of much of this low-grade stock has yet to be improved there is growing interest in cost-effective energy management options. Further, tenants themselves are increasingly demanding high performance spaces that contribute to improved occupant comfort and satisfaction whilst also maintaining good environmental performance (Colliers International, 2012). There is consequently a significant opportunity to improve the sustainability of our cities by focussing on refurbishing these buildings for energy efficiency and human health objectives.

Significant efficiency gains are possible through isolated upgrades to building plant and equipment, such as HVAC, lighting, and office equipment. However, there are also numerous opportunities to improve performance through a focus on improving existing equipment and integrating building systems. Additionally, there is also a resurgent awareness of the potential for occupants to take a more proactive approach to energy efficiency and individual comfort. The last few decades have also seen an increased awareness of the importance of occupant feedback in contributing to improved building performance, as evidenced by the increased use of post-occupancy evaluations. However, a number of barriers have prevented the widespread improvement of existing buildings, including high perceived capital cost and the problem of split incentives. Another significant barrier is that building managers and facilities managers often simply lack sufficient information to help determine where to begin and how to consider whole-of-building performance when investigating upgrade options. As user needs change, buildings may also be used in ways that differ from their original design intent, and this often has impacts on energy consumption and indoor environment quality. Furthermore the energy consumption profile of buildings may vary over time as office fit outs are modified, equipment ages, and tuning and maintenance is neglected.

The issue is further complicated by the fact that efforts to improve environmental performance do not necessarily result in improvements to indoor environment quality or health and productivity (Leaman *et al*. 2007; Kato and Murugan, 2010). For example,

increased day-lighting can reduce reliance on artificial lighting, but can increase the potential for glare if not well executed or if occupant controls are not available for individual adjustment. This is of particular concern as energy and maintenance costs represent only about 4-5 per cent of total costs over a building's life cycle, while occupants' salaries are around 85 per cent (Collins *et al,* 2008). It is thus highly counterproductive to focus on energy efficiency in isolation to the building occupants. Improving the energy performance of buildings in a way that also supports a productive workplace is a complex issue that is still not yet well understood, yet it represents a key strategy in transitioning towards a healthy and low carbon society. Australia faces a challenge in improving the performance of existing commercial buildings, and in light of the challenges and opportunities mentioned above it is clear that it will require an integrated approach and a greater level of collaboration between building stakeholders.

As such, this research project focused on developing a low cost, low complexity resource to assist efforts to improve existing commercial buildings. The research project, supported through the Sustainable Built Environment National Research Centre (SBEnrc) examined how the energy performance of existing commercial buildings could be improved while maintaining high a quality indoor environment conducive to a productive workforce. The research focused on identifying issues being faced by the industry in optimising the performance of commercial buildings, through a whole-of-building approach. This was based on the rationale that in order to improve both energy performance and productivity there is a need for a holistic approach that involves communication and cooperation between the many stakeholders and sub-contractors involved in operating buildings. Such an approach challenges standard practices and requires a new framework that brings together various areas of building operation and management that often occur independently.

2. Methods

This mixed-method, industry-led research project comprised literature review, workshops, evaluation trials, and case-study analysis as detailed below.

2.1 Literature review

A review of literature was conducted by the research team to investigate the current state of green building in Australia and the impacts of 'green' design on occupant health and productivity (Hall, 2010). This provided background knowledge of the industry and potential areas for further investigation, and provided a basis for the subsequent stakeholder engagement process. The literature review revealed a number of important issues faced by industry:

- Existing buildings are significant users of energy and large emitters of greenhouse gases.
- Indoor Environment Quality (IEQ) in buildings can have significant impacts on the comfort, health and productivity of occupants.
- Addressing inefficiencies in existing buildings represents a significant opportunity for energy savings.

- Buildings can be built to the highest efficiency standards using leading edge technology, but the way they are managed and used can profoundly influence their performance.
- Productivity improvements are of keen interest to the market but can be difficult to quantify in practice.
- Buildings are complex systems with many stakeholders involved, and there is often a lack of communication between the various parties.

2.2 Workshops

Three stakeholder workshops were held in the early stages of the project with 50 key stakeholders to identify areas of interest for the project to develop (SBEnrc, 2011). The workshops were facilitated using the 'Community Social Learning' (CSL) methodology designed by Emeritus Professor Valerie Brown, ANU (Brown, 2008). The CSL methodology is designed to guide participants through a process to identify key issues, as well as enabling and disabling factors, that relate to a given enquiry area. Participants were asked to vision their ideal green buildings and then consider the enablers and disablers to achieving these visions. Participants then identified what could occur to enhance the enablers, and reduce the disablers, that were relevant to the research project.

Stakeholders indentified the a key disabler for the ideal green building to be split incentives, lack of feedback loops and continuing communication/education, perceptions/fear of change, a lack of knowledge and education professionals, short term focus on capital expenditure over long term benefits, and lack of quantifiable evidence. When asked how to overcome these disablers, stakeholders discussed the need for a standardised post-occupancy evaluation for buildings that can be used across the commercial buildings sector (rather than using a different one for each building), as there is some trepidation towards single building evaluations. Also raised was the need to measure indoor environment factors, quantification of occupant experience, measuring and mandating building performance, and offering incentives to upgrade buildings.

Some other key outcomes from the workshop were:

- *A focus on existing commercial buildings:* The need for further attention on existing and older buildings was emphasised over the focus on new design given the dominance of this building type in the sector.
- *A holistic approach to energy management*: Much discussion also revolved around understanding how buildings are being managed and used by building managers and occupants, as no matter how efficient the building is designed to be if it is not being operated correctly it will not perform.
- *Options for enhancing stakeholder collaboration in buildings*: There was interest in seeing the project consider the various stakeholders within a building and their relative contributions to improving building performance
- *Consideration of the impact on productivity of energy programs*: Particularly the link between energy management initiatives and productivity. Understanding that productivity is difficult to quantify in practice, a focus on indoor environmental quality and occupant perceptions of their own productivity could be considered as an acceptable proxy.

2.3 Development and trial of the Performance Nexus

The research included three evaluation trials as part of the tool development process, comprising existing commercial buildings in Brisbane and Perth. The intention of these trials was to develop and test the 'Performance Nexus' framework. The first trial employed an occupant experience questionnaire and basic IEQ monitoring with a handheld device in order to evaluate a traditional low-cost post-occupancy evaluation procedure. The trial was undertaken in a commercial building in Brisbane. The second trial involved use of the project-specific occupant survey and conducting basic handheld IEQ measurements in addition to detailed indoor environment quality analysis by an environmental services contractor. A pre- and post-occupancy evaluation was conducted on a tenancy in Perth undertaking a Green Star Interiors retrofit. Data was gathered from this building for three nodes; 'Occupant Experience', 'IEQ', and 'Design Elements'. Data from this trial is currently being analysed.

Following this trial it could be seen that some of the biggest communication barriers came between owners, tenants, and building managers. At this point the *Performance Nexus* was expanded beyond consideration of IEQ, design elements, and occupant experience to include building management, corporate culture and the legal and non-legal agreements in place between tenants and owners. An expert team at Queensland University of Technology assisted with the development of these areas in line with the growing use and trend of green leases in Australia. Targeted surveys/checklists were thus developed and refined for each of the five nodes of the *Performance Nexus*, namely; Design Elements; Building Management; Agreements and Culture, Occupant Experience; and Indoor Environment Quality. The intention of tools was to target information to specific stakeholders to identify key systems and practices and potential areas for improvement, as shown in Table 1. The questions were discussed with multiple project partners in the area of building management to ensure the answers would inform improving the buildings energy performance in a way that created a productive workplace.

Table 1: Lines of questioning across the Performance Nexus

AUDIENCE	Design Elements	Building Management	IEQ	Occupant Experience	Agreements and Culture
Base Building	Building Owner	Building Manager	Building Manager	Occupants	Building owner
Tenancy	Tenancy Representative	Property Manager	Tenancy Representative	Occupants	Tenancy Representative

The surveys were constructed so as to help identify key factors and interrelationships between the nodes to help identify opportunities for improvement. The *Performance Nexus* is particularly valuable as a pre- and post-retrofit evaluation tool that can highlight the impacts of retrofits on a workplace, identify areas that may need improvement, and identify relationships between areas that could be strengthened. The surveys are intended to serve as a freely available tool that can be used to inform upgrade initiatives. The final surveys were trialled in an owner-occupied local government building in Western Australia. The Occupant Experience, Indoor Environment Quality and Agreements and Culture

questionnaires were fully completed. For both this trial, and the post-occupancy trial of the tenancy building, building management was the most difficult stakeholder to engage and complete the questionnaires. Data from these trials is currently being analysed to determine the linkages and reliability of questioning methods. The next step would be for a final review of the survey methods, and peer reviewed scoring to the survey questions.

2.4 Case studies

In addition to the actual trial of the *Performance Nexus*, a series of publicly available case studies on existing building retrofits were selected and analysed using key criteria from the *Performance Nexus* nodes to identify key features of the building performance improvement process:

- *QV.1, 250 St Georges Tce, Perth, WA*
- *60 Leicester Street, Carlton, VIC*
- *201 Charlotte Street, Brisbane, QLD*
- *115 Batman Street, Melbourne, VIC*
- *500 Collins Street, Melbourne, VIC*
- *40 Albert Rd, South Melbourne, VIC*
- *Trevor Pearcey House, ACT*
- *500 Bourke Street, Melbourne, VIC*
- *187 Melbourne Street, Brisbane, QLD*
- *182 Capel Street, Melbourne, VIC*

An initial desktop review was conducted to determine buildings that had completed retrofits considering multiple nodes of the *Performance Nexus*. This was followed by interviews with key personnel involved in the day-to-day operation of the building, such as building managers and facilities management staff. Interviews were conducted by phone and/or email during August and September 2012. The aim was to explore multi-node and cross-node interactions and distil key lessons that could inform a greater understanding of high performance buildings. The next step involved examining the collection of case studies to identify key lessons that could potentially be transferrable beyond that building to inform a whole-of-building consideration of performance.

3. Results and Discussion

Initially, the research project began by looking at the relationships between design elements, indoor environment quality, and occupant satisfaction. Together, these three areas constitute a standard post-occupancy evaluation framework that provides a reasonable understanding of how certain design elements can impact the internal environment and building occupants. However, it became apparent that it was also important to focus on stakeholder agreements, organisational culture, and building management practices in order to more fully understand the performance potential of commercial buildings. Recently, innovative leasing arrangements are beginning to emerge in Australia and internationally, intended to support high performance objectives (Roussac and Bright, 2012). Tenant agreements may be used to align tenant and owner objectives, and also make various stakeholders accountable for using, managing and maintaining a building effectively. This node therefore looks at what specific areas of commercial leases can encourage or inhibit building performance from both an energy and IEQ perspective. It has also become apparent that the organisational culture of stakeholders within a commercial building, and the communication between all the various parties involved, has a significant impact on performance outcomes and should therefore be considered.

Experience from the trials undertaken during the project suggests that there is often insufficient communication between owners, tenants and building managers, yet successful implementation of any energy efficiency initiatives depends increasingly upon close collaboration between these parties. The Nexus thus included wider consideration of building management, corporate culture and the legal and non-legal agreements in place between tenants and owners to help identify where these could be strengthened. There is also a re-emerging awareness of the key role of occupants in contributing to energy efficiency outcomes. Even the most efficient design elements will not deliver high performance outcomes if they are not being used as per their design intent. The occupant experience questionnaire was thus further refined to include consideration of the education and training that occupants had received to facilitate improved individual comfort and energy efficient operation of the building. For example, instead of just asking if occupants are satisfied with the amount of light, the questionnaire asked if occupants have received any training on how to use lighting systems and shading elements properly, and if they understand how to adjust design elements or use controls. It is possible to compare the results of the Occupant Experience questionnaire to the results of the Building Management and Agreements and Culture questionnaires in order to highlight any communication or information breakdowns.

Analysis of the case studies suggests there is often a focus on installing more efficient technologies in order to improve energy performance, but that the contribution of good building management practices to achieving high performance outcomes are often not given as much coverage. There is an underutilization of occupant surveys and indoor environment quality monitoring as tools to inform better building design and management. Additionally, there is still a lack of focus on using tenant agreements to contribute to improved building performance. There are many opportunities to improve performance by taking a more holistic approach to identify interrelationships between existing building systems and procedures and aligning them for improved performance.

3.1 Addressing multiple nodes in a whole of building approach

When refurbishing a building for energy efficiency there is often a focus simply on installing better design elements in order to improve performance, however if these building systems and technologies are not adequately maintained and operated the entire system will be sub-optimal and may have negative impacts on energy, IEQ and occupant satisfaction. Therefore, it is important to consider other factors that can contribute to improved building performance, such as building management practices, tenant agreements, and occupant education and feedback processes, which when combined represent key factors in understanding building performance.

Improving the energy performance of buildings in a way that also supports a productive workplace is currently not yet well understood. However, providing a framework to assist efforts to revitalise existing buildings such that the dual objectives of energy efficiency and occupant satisfaction are achieved represents a key strategy in transitioning towards a healthy and low carbon society. The resultant '*Performance Nexus'* tool for commercial buildings provides such a framework and is intended to save industry time and reduce the complexity and cost involved in performance improvements. As a pre- and post-retrofit evaluation tool, it can help highlight the impacts of retrofits on a workplace, identify areas that may need improvement, and identify relationships between areas that could be

strengthened. The tool helps guide users through a holistic approach to the building evaluation process, and ensures that key metrics and considerations are included in the process, shown in Figure 1 and Table 2. In summary, the key performance areas are as follows:

- **Design elements**: This node of the *Nexus* focuses on key existing energy efficient design elements within a building and on appropriate additional retrofit technologies that could be considered. The node considers monitoring and control technology; lighting; heating, ventilation and air-conditioning; plant and equipment; building fabric; and the tenancy design and fit out.
- **Building Management**: This node of the *Nexus* considers the way design elements are used and maintained, and how information from the other *Nexus* nodes is used in decision-making processes. The node considers operation and management practices, reporting and evaluation, maintenance and cleaning, commissioning and tuning, management personnel, communication and education, and procurement.
- **Occupant Experience:** This node provides an occupant experience questionnaire that can be used to gather feedback and information from occupants about the building and tenancy. It is important to identify problem areas that are contributing to dissatisfaction in order to rectify the situation, and occupants are often an underutilised source of information. The node considers perceived productivity; communication and reporting; training, education and guidance; and the use of controls.
- **Agreements and Culture:** Agreements can be in two forms, namely ‘hard’ and ‘soft’. Hard agreements include legal agreements such as green leases that affect the occupants of buildings, while ‘soft’ agreements include other non-legal arrangements that can support high performance objectives. This node considers lease agreements; ratings, mandates and incentives; commitments and targets; organisational culture; and communication and education initiatives.
- **Indoor environment quality:** Indoor environment quality can have a significant impact on occupant health and productivity. This node considers basic IEQ monitoring, advanced IEQ monitoring, IEQ management programs, health and well being, and reporting and communication of results.

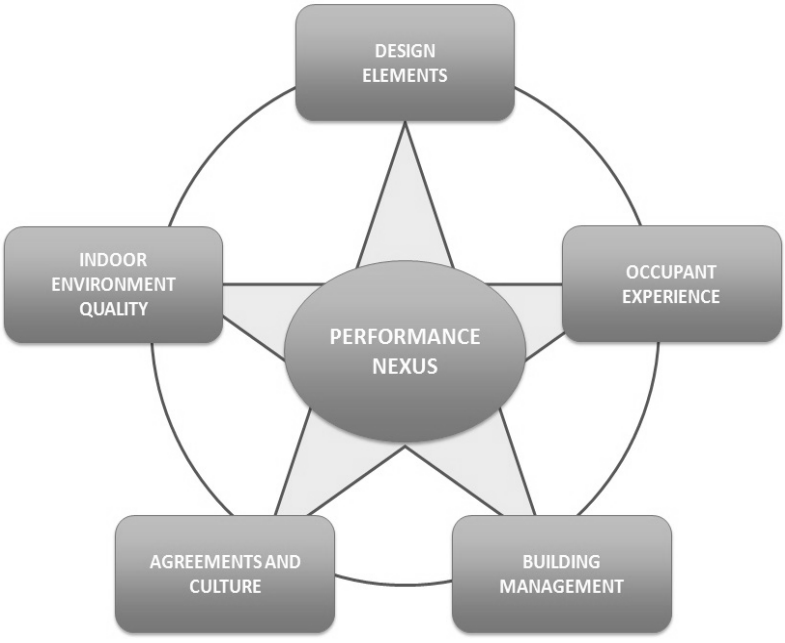

Figure 1: Performance Nexus tool, highlighting the multi-nodal considerations in a whole of building approach to improving performance

Table 2: Summary of considerations for each node of the Performance Nexus

Node: DESIGN ELEMENTS	
- *Monitoring and Control Technology* - *Lighting* - *HVAC* - *Other plant and equipment* - *Building Fabric* - *Tenancy design and fit out*	- *Focusing on physical technologies and systems in the building, this node can inform design of both new buildings and retrofits.* - *Design elements have a large role in the building's energy demand profile, and a focus here can achieve significant energy consumption reductions that, if done holistically, may also improve indoor environment quality and occupant satisfaction.* - *The design elements will be a key determinate of the type and scope of the building's management practices.* - *Design elements are increasingly operated and affected by occupants (e.g. with individual lighting controls and operable windows).*
Node: BUILDING MANAGEMENT	
- *Operation and management practices* - *Reporting and evaluation* - *Maintenance and cleaning* - *Commissioning and tuning* - *Management personnel* - *Procurement*	- *Building management can directly impact the energy performance of a building, while indirectly impacting the indoor environment quality and occupant experience.* - *Substantial reductions in energy can be achieved using existing technology, focusing on the way design elements are used and maintained, and how information from other nodes is used.* - *Building management is often a combination of automated systems, routine schedules and user interfaces.*
Node: OCCUPANT EXPERIENCE	
- *Occupant satisfaction and perceived productivity* - *Communication and reporting* - *Training, education and guidance* - *Use of controls*	- *When considered with the other nodes of the Nexus , occupant experience may be the most accessible way to inform efforts to create a productive workplace.* - *Although interpretation of survey results in the workplace is difficult, it can increase understanding about the potential response of occupants to changes to reduce energy demand.* - *Engaging occupants in the design of energy conservation initiatives is also a way to increase occupants' support for and involvement in such programs to assist in their implementation.*
Node: INDOOR ENVIRONMENT QUALITY (IEQ)	
- *Basic IEQ monitoring* - *Specialised IEQ monitoring* - *IEQ management programs* - *Health and well-being* - *Communication of results*	- *The indoor environment quality can have a significant impact on occupant health and wellbeing that may affect productivity. Initiatives to reduce energy consumption need to ensure they don't negatively affect IEQ.* - *Monitoring and considering key IEQ parameters can provide valuable insights that enhance energy demand reduction programs.* - *Consideration of IEQ covers a number of parameters, including air quality and ventilation, acoustics, lighting and thermal comfort.*
Node: AGREEMENTS AND CULTURE	
- *Lease arrangements* - *Organisational Culture* - *Communication and education* - *Ratings, mandates, and incentives* - *Commitments and targets*	- *This covers the types of binding and non-binding agreements between the various building stakeholders such as owners, building managers, facilities managers, service providers, tenants and occupants.* - *It considers emerging legal instruments such as green leases that can underpin greater energy conservation and improved IEQ (e.g. covenants to repair, break clauses, relocation notices, rent and rent review clauses, and gross / net leases)* - *It also considers social aspects including organisational culture and communication practices.*

3.2 Enquiry methods for node evaluation

The *Performance Nexus* has been designed to consider both the base building and tenancies through the use of structured surveys. The Design Elements node of the *Nexus* can act as an anchor point with each element being examined across each of the other four nodes. Structuring the *Nexus* in this way enables building stakeholders to assess what design elements are in place, investigate how these are being managed and what other agreements and systems are being used to support performance objectives, and also to consider how effective these are through the IEQ and occupant experience components, as shown in Table 3 for the case of lighting.

Table 3: Example of application of each node of the Nexus to 'lighting'

Design Element	IEQ	Occupant Experience	Building Management	Agreements and Culture
Is the lighting system energy efficient?	*Are the lux levels sufficient and suitable for tasks?*	*How satisfied are occupants with light levels and lighting controls?*	*Is there a maintenance schedule for lighting?*	*Is there a fit out guide in place for lighting systems?*

The *Performance Nexus* can be used to identify links between the five key performance areas and to generate strategies for improvement, as illustrated in Table 3. Table 4 shows a sample of how each of the key performance areas in the *Performance Nexus* can be harnessed to enhance energy efficiency initiatives.

Table 4: Sample of interactions between various nodes of the 'Performance Nexus'

DESIGN ELEMENTS This node focuses on the effectiveness of the lighting design as it has a major impact on occupant satisfaction and energy demand in the building. Electric lighting is a large user of energy and also generates waste heat which places additional load on building HVAC systems, estimated to account for up to 15-20 per cent of cooling demand.	
BM	Ensure lighting controls are in accessible locations with clear labelling or occupants will not use them. Consider reducing maintained artificial illuminance levels in general office areas and providing task lighting.
AC	Consider the inclusion of specific energy and IEQ performance requirements for lighting in tenant leases. These can be supported by education on use of lighting controls and how this impacts building performance.
OE	Consider the occupant experience of the level and quality of light as improved lighting can increase individual productivity though increased working speed, reduced error rate, and improved concentration.
IEQ	Check the actual lighting levels at workstations horizontally and vertically to assess compliance with guidelines for workstations and general areas. Supplement with task lighting where required to improve productivity.
BUILDING MANAGEMENT This node focuses on the processes to ensure design lighting levels are maintained, as cleaning lights can improve output by as much as 25-30 percent. Poor maintenance and management of installed luminaires can negate the benefit of any retrofits.	
DE	Ensuring high efficiency lighting is maintained with correctly matched lamps and ballasts can reduce energy consumption. Commissioning ensures correct equipment compatibility for optimal efficiency.
OE	Ensuring lighting quality is monitored and faulty lamps replaced reduces disruption to staff and avoids negative impacts on productivity and occupant experience. Appropriate lighting layout and design can reduce glare and reflections that may affect visual amenity inside the building.
IEQ	Good building management practices such as regular cleaning of lamps, luminaires and surfaces can increase light output, potentially avoiding the need for lighting retrofits or facilitating de-lamping options.
AC	Implement policies to ensure contractors and maintenance staff are informed of correct lighting components and replacement schedules.

INDOOR ENVIRONMENT QUALITY This node focuses on the impacts of lighting design and maintenance on the quality of the indoor environment. This is important as the costs of low productivity and illness in a workplace can be 100 to 200 times the cost of energy bills, with just a 1% productivity change in Australia equating to AUD $1.2 billion.	
DE	Encourage increased natural day-lighting over artificial lights using correct tinting on windows and external or internal shading as this reduces energy consumption.
OE	Encourage increased natural day-lighting as studies have shown that this can lead to increased worker productivity, reduce absenteeism, Increased vitamin intake, and mood improvements.
BM	Ensure lights and windows are adequately maintained to maximise light levels and consistency. This can be done through schedules that can also include checks on wattage and fixture conditions.
AC	Consider policies for restricting after-hours light use, providing adequate labelling and mapping of light switches, and providing clear reporting procedures for complaints on lighting.
OCCUPANT EXPERIENCE This node seeks to identify if occupants know how to use available lighting controls including light switches, external shadings, internal blinds, and desk task lighting. Effective use of lighting controls by occupants can reduce energy consumption by more than 30 percent.	
DE	Consider the inclusion of occupant controls in the design as this can dramatically reduce energy demand with occupants turning off lights that are not in use and reducing lighting levels to meet task requirements. Providing some degree of control over lighting levels also has a large impact on satisfaction.
IEQ	Measure lighting levels to ensure that they are within recommended task lighting requirements, as users may have differing tolerance for lighting levels that may change if they are informed about recommended levels.
BM	Check occupants are aware of correct communication channels to report lighting issues. Good communication with occupants and prompt response to lighting complaints and can avoid dissatisfaction and distraction.
AC	Consider policies that ensure minimum task lighting standards are met as per appropriate guidelines and design standards. Provide education to ensure occupants understand how to operate the lighting system to improved energy efficiency and individual comfort.
AGREEMENTS AND CULTURE This node investigates if the organisation considers sustainability or energy efficiency as part of their core strategy and if this focus is embedded in the culture.	
DE	Consider policies that require the use of efficient lighting technologies to ensure that replacements are in line with the design intent, such as part of 'repair and alteration' clauses in lease agreements.
OE	Building organisational culture around sustainability can assist encouraging occupants to take ownership and more responsibility for their actions which impact performance.
IEQ	Consider policies that require compliance with minimum lighting levels to ensure that appropriate lighting is provided and daylighting is harnessed where appropriate.
BM	Consider policies that set minimum requirements for maintenance schedules to ensure efficient operation of lighting, such as part of 'repair and alteration' clauses in lease agreements. Consider policies for after-hours lighting use, adequate labelling and mapping of light switches, and reporting procedures for complaints.
BM: Building Management DE: Design Elements OE: Occupant Experience **IEQ: Indoor environment Quality AC: Agreements and Culture**	

4. Conclusion

This project focused on creating a tool, the *Performance Nexus*, to assist efforts to improve the energy performance of existing commercial buildings while fostering a productive environment, considering five key interdependent areas of building performance; namely 'Design Elements', 'Building Management', 'Agreements and Culture', 'Occupant Experience' and 'Indoor Environment Quality'. The tool has been developed through research, stakeholder workshops, and trials on buildings, to identify the key metrics and

considerations related to building performance that need to be considered when designing an intervention. The research took into account a range of key factors influencing the energy performance of buildings, including the actual physical design elements, the way the building is operated and maintained, the experience of occupants, legal and non-legal agreements and the quality of the indoor environment. The project suggests that the tool is a low cost, low complexity approach that can be used to encourage the greening of existing commercial buildings with a focus on energy efficiency and enhanced productivity. The project's research output includes an accompanying workbook to guide building stakeholders through a process of identifying issues preventing their building from operating at an optimum level for energy efficiency and for the health of occupants.

5. Acknowledgements

This paper has been developed with funding and support provided by Australia's Sustainable Built Environment National Research Centre (SBEnrc) and its partners. Core Members of SBEnrc include Queensland Government, Government of Western Australia, John Holland, Parsons Brinckerhoff, Queensland University of Technology, Swinburne University of Technology, and Curtin University. This project has been supported by the following partners, acknowledging the key persons contributing to the project: Western Australia Government Department of Treasury and Finance (Carolyn Marshall and Anna Evers), Queensland Government Department of Public Works (Lee Wade and Stuart Greirson), Parsons Brinckerhoff (Shaun Nugent, Darren Bilsborough and Alan Hobson), John Holland Group (Fin Robertson and Scott Fraser), Townsville City Council SolarCity Program (Greg Bruce and Mark Robinson), QED Environmental Services (Joseph Sholtz), HFM Assets (Damien Moran), and the Green Building Council Australia (Romilly Madew, Andrew Aitken).

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Biophilic Urbanism: Harnessing natural elements to enhance the performance of constructed assets

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Biophilic Urbanism: Harnessing natural elements to enhance the environmental and social performance of constructed assets

Creating climate resilient, low-carbon urban environments and assets is a policy goal of many governments and city planners today, and an important issue for constructed asset owners. Stakeholders and decision makers in urban environments are also responding to growing evidence that cities need to increase their densities to reduce their footprint in the face of growing urban populations. Meanwhile, research is highlighting the importance of balancing such density with urban nature, to provide a range of health and wellbeing benefits to residents as well as to mitigate the environmental and economic impacts of heavily built up, impervious urban areas. Concurrently achieving this suite of objectives requires the coordination and cooperation of multiple stakeholder groups, with urban development and investment increasingly involving many private and public actors. Strategies are needed that can provide 'win-win' outcomes to benefit these multiple stakeholders, and provide immediate benefits while also addressing the emerging challenges of climate change, resource shortages and urban population growth.

Within this context, 'biophilic urbanism' is emerging as an important design principle for buildings and urban areas. Through the use of a suite of natural design elements, biophilic urbanism has the potential to address multiple pressures related to climate change, increasing urban populations, finite resources and human's inherent need for contact with

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nature. The principle directs the creation of urban environments that are conducive to life, delivering a range of benefits to stakeholders including building owners, occupiers and the surrounding community.

This paper introduces the principle of biophilic urbanism and discusses opportunities for improved building occupant experience and performance of constructed assets, as well as addressing other sustainability objectives including climate change mitigation and adaptation. The paper presents an emerging process for considering biophilic design opportunities at different scales and highlights implications for the built environment industry. This process draws on findings of a study of leading cities internationally and learnings related to economic and policy considerations. This included literature review, two stakeholder workshops, and extensive industry consultation, funded by the Sustainable Built Environment National Research Centre through core project partners Western Australian Department of Finance, Parsons Brinckerhoff, Townsville City Council CitySolar Program, Green Roofs Australasia, and PlantUp.

Keywords: Emerging process, sustainable urban design, biophilic urbanism

1. Introduction

Cities around the world are growing rapidly in size and number, as they provide unprecedented economic and social opportunities. The importance of both the scale and density of cities in creating these opportunities is now well understood (Glaeser, 2011; Newman and Kenworthy, 1999). However, in achieving such scale and density, urban areas are becoming increasingly abstracted from nature, and urban residents are more disengaged from the natural world than potentially at any other period in human history. Within this context, the last two decades in particular has seen an emergence of research into how experiences of nature affect human health and wellbeing. A growing body of evidence suggests that humans have a psychological, physiological and emotional need for regular experiences with nature, manifested in a range of neurological and physical responses (Kellert *et al,* 2008). This research is of interest to planners, developers and citizens for the potential to create more liveable, economically viable and functional urban environments (Reeve *et al,* 2011). There is also increasing evidence of a range of direct and indirect benefits from using nature as a design principle, addressing pressures related to climate change, increasing urban populations, and finite resources (SBEnrc, 2012).

Consequently, the principle of ‘biophilic urbanism’ is appearing in the design and retrofit of buildings and cities around the world. The term has been recently defined as an emerging design principle for buildings and urban areas, featuring a suite of natural design elements that address multiple pressures related to climate change, increasing urban populations, finite resources and our inherent need for contact with nature. The principle directs the creation of urban environments that are conducive to life, delivering a range of benefits to stakeholders including building owners, occupiers and the surrounding community (SBEnrc, 2012).

Research undertaken as part of the Sustainable Built Environment National Research Centre's (SBEnrc) 'Greening the Built Environment Research Program' (2011-2012) investigated biophilic urbanism, and how to enable its broader application in Australia. The research was informed by industry and government stakeholders, as well as by leading academics and practitioners in the field. The research specifically sought to identify ways in which nature was being integrated into the built environment around the world, and what benefits this was providing. Key barriers to the use of biophilic urbanism in Australia, as well as strategic opportunities were identified via stakeholder workshops. This formed the basis of an inquiry into city-scale case studies around the world for policies, programs, and initiatives that support the use of biophilic urbanism, and lessons that could be learnt to inform efforts to overcome barriers and enhance opportunities in Australia.

This paper outlines the findings from this research project, including an overview of the literature on the theory of biophilia; evidence of links between human health and wellbeing, and experiences of nature; and how nature is being integrated into urban environments around the world to provide a wide range of benefits. An emerging process for encouraging the application biophilic urbanism is then presented, along with key considerations for policy and decision makers.

1.1 The theory of biophilia

'Biophilia' is a concept that has been explored by researchers for several decades, beginning with the German psychoanalyst Eric Fromm in the 1960s, and popularised by Edward O. Wilson in 1984, in his book *Biophilia.* In this, Wilson suggested that humans have 'an urge to affiliate with other forms of life' (Wilson, 1984, p85) that can be explained through evolutionary processes of survival and natural selection. Humans display positive psychological and physiological responses towards certain forms of nature that have historically been vital for human survival (Wilson, 1984; Kellert & Wilson, 1993). Researchers have explored these ideas since. There is general consensus that human's material needs for nature, such as for food, water and shelter, have led to aligned psychological, emotional and spiritual needs (Beatley, 2009; Wilson, 1984; Kellert & Wilson, 1993; Lohr, 2007).

Over the last few centuries, there have been significant shifts in the way humans live. With widespread urbanization, over half the world's population lives in cities. In reaction to industrialism of the 19th century, cities reduced in density throughout the 20th century, often rationalized in terms of seeking to be closer to nature (Mumford, 1961). This 'urban sprawl' has brought a range of issues, including increased dependence on the car and a growing ecological footprint from sprawling cities (Newman and Kenworthy, 1999). However, this pattern appears to be reversing and urban densities are rising again after 100 years of decline (Newman and Kenworthy, 2011). Young people especially are moving back into cities and are choosing not to use cars; the rationale for this is now being led by the health profession who instead of seeing suburbia as natural and healthy, now see it as having bred a generation of obese and unhealthy people who have lost the ability to walk (Newman and Matan, 2012). In parallel to this pro-urban movement there has been a new emphasis on how nature can be more directly and effectively brought back into this dense, urban

environment. This is the driving force for biophilic urbanism as it is most clearly being articulated and demonstrated in dense cities and central areas.

1.2 Links between experiences with nature, human health and well-being

Recent research has shown that urban nature (biophilic urbanism) provides multiple benefits, including reduced crime, increased psychological wellbeing, reduced stress, depression and anxiety, enhanced productivity, enhanced healing from illness, increased immunity, increased attention recovery and cognitive abilities, and developmental benefits to children (see Reeve *et al,* 2011). As Timothy Beatley highlights, even small doses of nature, such as a window view of trees and parkland, pot plants in buildings, a short walk in a park, or rooftop gardens can produce benefits (Beatley, 2009). This is an important finding, as injecting nature into an existing built environment will require taking advantage of opportunities to vegetate smaller space, while always seeking ways in which to provide 'more intense and protracted exposure to nature' where possible (Beatley, 2009, p212).

In addition to these health and wellbeing benefits, biophilic urbanism is also being shown to address many significant challenges in urban environments, including climate change, resource shortages, population growth and global financial crises. Biophilic urbanism has been shown to: provide reduce energy demand for heating and cooling; manage stormwater runoff; improve air quality; reduce congestion by encouraging walking and cycling; increase property values and stimulate the economic development and rejuvenation of urban areas; sequester carbon and reduce carbon emissions; enable urban food production and enhance food security; and increase urban biodiversity (Reeve *et al,* 2011).

Ideally, biophilic urbanism can be considered on multiple scales: at the building, neighbourhood and city level, with natural design features, or 'biophilic elements' integrated into the urban environment across all three. Table 1 outlines some of the key biophilic elements commonly used today in cities at various scales, and highlights the principle benefits provided by each. Urban environments and constructed assets at each of these scales are designed, developed and owned by a range of public and private stakeholders, increasingly in partnerships with each other. These stakeholders often have different, if not divergent, motivations and considerations in their investment decisions. As may be evident upon closer inspection, many of the benefits listed in Table 1 may not flow directly to the stakeholder responsible for investment decisions related to introducing a biophilic element into a built environment assets. Further, many of the benefits are accrued over long time periods, or would need widespread application of biophilic urbanism to be realised. These issues highlight some of the complexity involved in the application of biophilic urbanism.

Table 1: Overview of biophilic elements, across scales of application

Element		Forms	Specific Benefits	Common Benefits
Building	Indoor Plants	- Pot plants in buildings - Indoor living walls, including pots within a frame (also see Green Walls) - Indoor planted vegetation, such as atriums and large planted installations	- Reduces illness - Increases productivity - Improves air quality	Revitalises urban environments

	Green Roofs	- 'Intensive': Soil deeper than 200mm and vegetation up to the size of trees - 'Extensive': Soil up to 200mm with ground cover vegetation	- Improves building energy efficiency - Water management - Space efficiency - Food production - Sound insulation - Increases roof/wall lifespan - Vertical urban farming	Reduces urban heat island effect Improves air quality Improves microclimate Sequesters carbon/ reduces greenhouse gas emissions Increases biodiversity Improves water cycle management Provides amenity Enhances well-being/ reduces stress Recreation Reconnects with nature Revitalises cities Increases property value Enhances tourism
	Green Walls	- Internal and external green walls - Include: vegetation directly attached to infrastructure (such as ivy), panel systems with substrate (such as preplanted panels with soil), and container or trellis systems.		
Neighbourhood	Green Verges	- Street trees and canopies - Shade planting for buildings - Green streets and alleys that create cool pervious greenways - Rain gardens and bio-swales integrated into stormwater management plan and consisting of pervious channels - Green permeable sidewalks	- Encourages walking, and cycling - Reduces building cooling/ heating energy use - Water management - Food production	
	Green Islands	- Urban parks and gardens placed close to transportation routes - Community farms close to homes - Residential backyards - Lawns and gardens (public and private)	- Encourages walking and cycling - Food production - Increases community cohesion	
City	Green Corridors	- Green corridors (biodiversity corridors) reaching outside the urban area - Highway crossings and migratory routes - Backyard commons - Vegetated buffer zones along coastal areas	- Links biophilic elements - Encourages walking and cycling	
	Urban Farming	- Large scale community gardens and urban farms - Urban and peri-urban agriculture	- Food production - Employment and education	
	Waterways, and water sensitive urban design features	- Wetlands (natural and constructed) - Ponds and lakes - Rivers and streams - Vegetated swales, drainage corridors, infiltration basins, etc. - Oceans and associated coastal vegetation	- Water management, treatment and storage - Protects downstream water bodies	

(Reeve et al, 2012a)

2. Emerging process for biophilic urbanism

This emerging evidence of the potential of biophilic urbanism to address multiple pressures on urban systems and provide a host of benefits has not yet resulted in its mainstream, intentional use. Its use around the world remains *ad hoc* and largely disconnected. As part of the SBEnrc research project, two stakeholder workshops were held in the early stages of the project to identify current barriers and opportunities for biophilic urbanism in Australia. Key barriers that were found included (Reeve *et al,* 2012a):

- **Limited local research and data** on biophilic elements, preventing decision makers from making informed and justifiable decisions. Biophilic elements are vulnerable to financial pressures if the full economic and social value isn't demonstrable.

- **Benefits and costs of biophilic urbanism are unequally borne** (split incentives) by various government departments and between stakeholders such that the costs may be paid by a department, organisation or individual that doesn't recoup the full benefits.

- A "**silo effect**" restricts holistic governance, and exacerbates split incentives. A **lack of mandatory requirements** makes biophilic urbanism a 'beyond compliance' addition to building and planning. **Existing regulations and planning requirements** generally don't support the inclusion of biophilic urbanism elements.

- **Cultural disconnection from natural environments** causes ignorance of the benefits of experiences of nature and a lack of support for policies to increase urban nature.

- **Traditional economic models** that do not value **externalities** disempower decision makers from including biophilic elements in urban and building design.

Several existing opportunities were also identified, many of which mirrored the barriers:

- **Some supportive and adaptive policies** and **building/design standards** that encourage and enable beyond compliance performance to drive innovation.

- **Leadership in various levels of government** and a willingness to trial and/or introduce supportive policy measures. Creative leadership responsive to community expectations rather than political cycles and traditional economics.

- **Existing social capital**, including community groups, community gardens and community appreciation of and pressure for biophilic urbanism. Community leaders and change agents assisting in educating their community, establishing norms and supporting political processes.

- **The private sector** can provide funding, leadership and 'biophilic entrepreneurship' to develop demonstration sites.

- A growing number of **demonstration sites** showcasing the multiple benefits of biophilic urbanism and driving new norms in urban design.

- Interest in **new valuation techniques and metrics** to value externalities in evaluations of biophilic urbanism, which in turn may enable access to finance.

To enable widespread use of biophilic urbanism in Australia, strategic ways of overcoming these barriers and enhancing the opportunities needed to be found. A method of 'learning by example' was developed in consultation with project stakeholders (see Reeve *et al,* 2012b) involving an investigation of five global cities that are forerunners in this field. This provided

insights into the experiences, processes and outcomes of increasing the application of biophilic urbanism and into addressing the barriers and opportunities identified for Australia. By looking across these five case studies of forerunning cities, an understanding of the important processes and steps leading to the application of biophilic urbanism has been developed. This takes into account the contextual circumstances of each city, and highlights important precedent factors that influence a city's ability to introduce policies and other initiatives to encourage biophilic urbanism.

The findings from this investigation have been distilled into the emerging process shown in ***Figure 1***, with further detail given below. The process is not presented as an endpoint. It is part of an ongoing evolution of understanding and experience of how to encourage and enable biophilic urbanism. As the historical, cultural, political, economic, geographic, demographic (among other) factors differ between each city, no one process or pathway is likely to be appropriate for all cities. This process has been developed with reflection of the barriers and opportunities that were found to exist in Australian cities (however again, these will differ between each individual city in Australia), and the learnings from the case-study cities relevant to these.

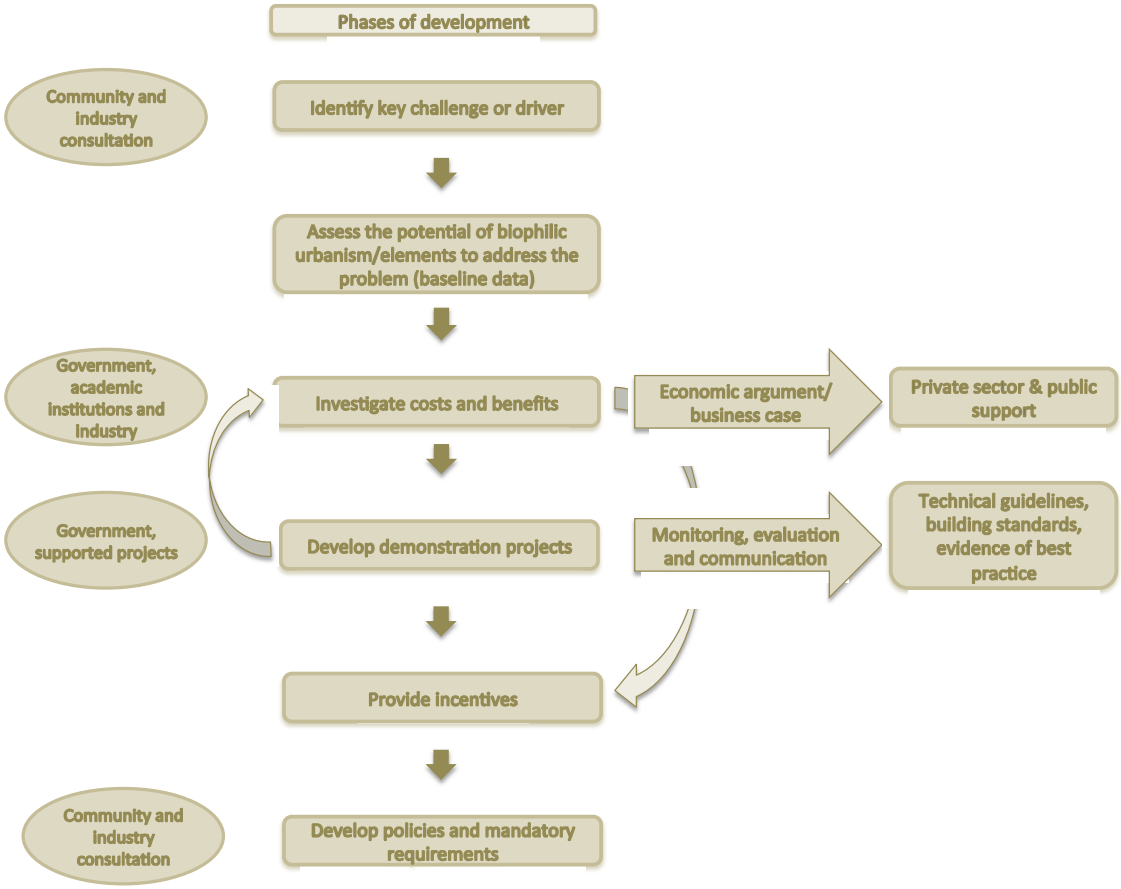

Figure 1: Emerging process for enabling the application of biophilic urbanism

1. ***Identify the key challenge(s) and driver(s):*** Identify key challenges faced by the city that can be addressed by biophilic urbanism, especially where there is an existing conversation in government and public domains about the need to address this. There is

a long ‘menu’ of benefits provided by biophilic urbanism, however it can be more effective to focus discussions of biophilic urbanism on areas of existing concern. This ‘piggybacking’ reduces the need to make a case for action, may facilitate cost/benefit analysis and data collection where existing work is being done in this area, and ensures that the way in which the biophilic element is implemented throughout the city optimises the outcomes of particular concern to that city. While taking an issue-specific focus is important, a *whole-system perspective* is also necessary when comparing the costs of biophilic elements to conventional systems.

Common drivers to date have included stormwater management, to increase urban amenity, economic revitalization of derelict urban areas, enhanced international competitiveness, countering the loss of biodiversity and ecosystem services, and to a lesser extent, mitigating the urban heat island effect.

2. ***Develop baseline data:*** Gather initial evidence of existing policies, programs and requirements, as well as environmental conditions. This will help to ensure that any mechanisms developed will be strategic, targeted, transparent and minimize unintended consequences. Data is also needed on the potential application of biophilic elements. For example, an inventory of all available and appropriate roof space for green roofs; a breakdown of land-uses throughout the city, and of government, commercial, residential and other property ownership. This informs the strategy development by identifying the scope for application of any initiatives, and the target audience.

3. ***Assessing the costs and benefits:*** An economic argument is important to gain support from the community and private sector, as well as from decision makers within the government. From a government’s perspective, an economic argument gives some basis for understanding the extent to which biophilic urbanism will reduce their existing financial liabilities (for instance, for stormwater management), and to develop appropriate incentives that reflect this value. From the public, and private sector, perspective, this is a business case to assist in decisions of whether to include biophilic elements in their building developments themselves.

   It may not be possible to develop a full cost-benefit analysis due to the large number of externalities and unquantifiable benefits. Considering the costs and benefits that can be quantified, however, may indicate whether there is sufficient public good to pursue a strategy to encourage biophilic urbanism/elements. Such an investigation provides a starting point for discussions around green roofs by answering high-level questions, such as what are the societal benefits, what are the city-wide benefits, and what are the benefits to individual building owners.

4. ***Demonstration:*** Develop demonstration and pilot initiatives to test, refine and develop local data for biophilic elements. Municipal buildings, and participating commercial buildings, can be used. Monitoring, evaluation and communication of the benefits and performance of elements needs to be an integral part of demonstration project strategies. This should lead to technical guidelines, standards and locally relevant evidence of best practice.

Demonstration of biophilic elements is vital, as many of the benefits are difficult to quantify. It has been found that where citizens have personal experiences with biophilic elements, they inherently understand and value the benefits and are generally supportive of policies and programs to increase their application.

5. ***Provide incentives:*** Financial incentives are generally necessary to encourage private property owners to integrate nature into their property, especially for more costly biophilic elements. Economic modeling done elsewhere suggests that biophilic elements provide an array of public benefits, which can typically justify such incentives. As biophilic urbanism becomes more mainstream, achieving economies of scale, it may be possible to refine eligibility for incentives to promote particular outcomes such as innovation and greater public benefits.

6. ***Policies and programs***: Policies, mandatory requirements and broad programs to require and encourage biophilic urbanism/elements are the final stage of this process. Extensive community and industry consultation has been found to reduce opposition to new policies and programs for biophilic urbanism. It also ensures that these are balanced and meet the needs of the community, and creates a sense of ownership and inclusion that has in some cities underpinned community and volunteer projects that enhances the biophilic benefits and reduces municipal costs for implementation and maintenance of the biophilic elements.

   Performance based policies and standards can drive innovation and improve outcomes. These can require more work in ensuring that a biophilic element does indeed meet the performance requirements, however the requirement to do so results in greater transparency, and by measuring and evaluating outcomes, can help communicate the benefits of the biophilic elements and drive continual improvement in these.

   Integration and consistency across policies that encourage or require the use of a biophilic element can be achieved through several mechanisms, including: high level policy or vision that provides a process for issue-specific policies, plans and programs; a senior political champion, who sets the agenda and enables inter-departmental cooperation; Multi-departmental advisory boards, or other instituted mechanisms for cross-departmental communication and collaboration; creating a position, such as a sustainability officer, with power to direct other departments on relevant policy and program areas.

2.1.1 Additional considerations for policy development and implementation

In addition to the process, there are a number of findings from the case study cities that provide important insight into the process of encouraging and enabling biophilic urbanism. The relative importance of these findings will differ between cities.

Program and policy development: There were a number of consistent, important precedent factors common to many of the case study cities that were found to enable biophilic urbanism program and policy development, including:

- *The role of champions and advocates:* To a large degree, the efforts of an individual or group of individuals was of fundamental importance in catalyzing a process of developing demonstration projects to provide evidence and experience with the biophilic element, and enable techniques and technologies to be refined and adapted to the climate and circumstances of the city. In several cities, this included a political champion, who helped overcome the 'catch-22' of cities lacking experience or evidence of the performance of biophilic elements to justify their use, with this in turn preventing them from being able to develop demonstration sites to gain experience and evidence.

- *A visible 'crisis' or challenge:* In most case study cities, a crisis or challenge was the impetus for the city to consider biophilic urbanism as an urban design principle. This includes combined sewer overflows and national pollutant discharge limits in the United States, a need to remain internationally competitive and attractive to investors (Singapore), or to balance increasing urban density and development requirements with public expectation for urban greenspace (Berlin). Such a crisis or challenge typically provides an economic, social, political and/or environmental imperative to move away from the *status quo* of urban design, and helps overcome resistance to such change. Making present and future challenges more visible to politicians, business and the public may assist in enabling biophilic urbanism.

Policy mechanisms: In terms of the policy mechanisms implemented in case study cities, some common considerations and findings included:

- *Fee-bate systems:* Feebate systems can put a price on what is otherwise a market externality, such as stormwater runoff, the urban heat island effect, or loss of visual amenity in cities. Several case study cities introduced separate charges for such externalities (in particular for stormwater runoff). This provided encouragement to private property owners to reduce their individual contribution to such costs, and provided the city with dedicated funding to also address the issue.

- *Financial Incentives:* Financial incentives were found to be typically necessary to encourage private property owners to integrate natural design features into buildings and/or to preserve additional greenspace, at least until economies of scale and evidence of the benefits developed. Such incentives were justified on the basis of the public benefit such design features provide. Conditions for receiving such incentives generally ensured good design that enhanced the public benefits.

- *'Biotope Factor'*: Berlin's biotope factor requires any new, or substantial re-development, include a given proportion of green space. Various biophilic elements are given weightings, depending on the degree to which they meet the city's green space objectives, enabling developers to determine the most effective mix of elements for each development. The mechanism has been adopted by cities around the world, as it is found to increase innovation and be effective in its application.

- *Performance based requirements:* Performance based mandatory requirements to include biophilic elements into the built environment tend to result in greater innovation,

provide greater transparency, and ensure that elements are functional rather than 'tick box' inclusions. These can require greater work in evaluating designs and assessing performance.

- *Requirements for new build and significant renovation:* Mandatory requirements have only been introduced for new build and significant renovations in the case-study cities considered. It would appear to be politically too difficult to otherwise require existing buildings to retrofit with biophilic elements.

- *Offset mechanisms*: Offset mechanism can balance development needs with ecological preservation. It is generally considered a last-resort mechanism, to be used if conservation of the original ecosystem is not possible.

Economic argument: In terms of developing an economic argument, or cost-benefit assessment to support the use of biophilic elements in cities, the following findings emerged from the case study cities.

- *Externalities in urban environments:* Many costs associated with urban environments are often not fully recognised, such as the urban heat island effect, increased stormwater runoff, a lack of visual amenity and green space, and a loss of biodiversity. The costs related to these urban issues are often aggregated into many different municipal, state and federal budgets. As such, governments and citizens are often unaware of their extent of such costs, nor of the financial benefits thus possible by mitigating these issues.

- *Recognising unquantified benefits:* Many benefits of biophilic urbanism cannot be readily quantified for a range of reasons. This includes many of the social, healthy and well-being, and environmental benefits described in this paper, some of which evidence suggests that these may indeed be economically significant. Hence, most cities justified the use of biophilic urbanism based on a partial cost-benefit analysis with quantifiable benefits, however in comparing the use of biophilic urbanism to conventional urban design and infrastructure approaches, recognised the wide array of additional benefits provided.

3. Conclusions and recommendations

Biophilic urbanism has the potential to provide significant benefits in cities, including a wide range of social, psychological and wellbeing benefits to residents, as well as functional and economic benefits to the city as a whole. There is an emerging body of evidence that demonstrates and to an extent quantifies these benefits, and provides insights into the underlying mechanisms that produce them. Despite this, their use in Australia and internationally remains *ad hoc,* constrained by a number of key barriers.

To address some of these barriers, an in-depth investigation of forerunning cities that have to some degree introduced policies, programs and initiatives to encourage the use of biophilic urbanism was undertaken. This provided insights into factors that have led the

development of such policies, programs and initiatives, and what can be learnt from these experiences to help cities elsewhere similarly increase their use of biophilic urbanism. An emerging process is suggested, based on these insights, and within the particular context of the barriers and opportunities to biophilic urbanism in Australian cities, as identified by relevant stakeholders. The emerging process will continue to be developed, informed by growing experience with and understanding of the application of biophilic urbanism in Australia and internationally.

Future work by the research team and others will investigate applications of biophilic urbanism to develop metrics that describe their performance across a range of benefits. This will inform a process for assessing biophilic elements, with a specific focus on building-scale elements. Capacity building training and educational materials will also be developed to enable industry and government to cost- and time-effectively evaluate the value of biophilic elements, and ensure they are well designed to maximise all possible and desirable benefits.

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Loss estimation methods utilised by stakeholders involved on residential post-canterbury earthquake reconstruction

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Abstract

The importance of natural disaster economic loss estimations is paramount, in terms of assisting policy makers in mitigation decisions, risk assessments and tracking losses as they occur. Historically the New Zealand construction industry and associated affiliate stakeholders has not employed a systematic method to estimate, or record the losses that have occurred as a result of natural disasters. Therefore records are lacking. The Canterbury earthquake of February 22nd 2011 in particular, was the most significant natural disaster in New Zealand's history, with economic loss occurring at all levels of the New Zealand economy. There have been numerous complexities around how to measure this loss, and what should be included or excluded in the estimates. Government's direct intervention in respect of residents' red zoned properties has added a further complication when trying to establish realistic loss estimation methods and data storage. Loss estimations have historically relied heavily on insurance data collected after large scale events. This exploratory research aimed to investigate the loss estimation methods / evaluative processes utilised by stakeholders involved in the post-disaster residential sector of Christchurch, and compare the findings to the reviewed literature. Semi-structured interviews were conducted with six selected participants from five insurance and project management companies in Christchurch. The findings suggested that there is a lack of regulation, no systematic framework, nor any consistency of process within the New Zealand construction industry, or their associated stakeholders.

Keywords: loss estimation, canterbury earthquake, residential sector

1. Introduction

This research topic resulted from sighting a number of publications following the 4th September 2010 earthquake in Christchurch, such as the $2 billion initial estimate (EQC 2011), and then subsequently after the 22nd February 2011 earthquake, reports of $10 billion, which was later increased to $20 billion (TVNZ, February 28, 2011). From the media

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reports it was unclear as to what the estimates included, excluded, or how the figures were even derived. The main source of data for economic loss estimates has been insurance information according to Walton (2004), and following the Canterbury Earthquake(s) there have been 302,000 claims lodged with the Earthquake Commission EQC as at April 2011(Mathewson 2011). A complicating factor due to EQC involvement was that there are now multiple claims on individual properties, due to each major earthquake (Sept2010,Feb22,June13 2011) being treated as separate event, from an insurance perspective. Residential housing represents a substantial percentage of loss as a result of the Canterbury Earthquakes. The concept of economic loss estimation is broad and dependent on many factors such as time, geographic context, and the needs of the end user (Cochrane, 2004). For the purpose of this research the scope was limited to the residential sector only, due to insurance data being a main source of direct economic loss information. Research literature on the topic of loss estimation frameworks following natural disasters suggested that no consistent framework or relevant inclusions *et al*. were used in New Zealand. This, despite the issue being raised over 25 years ago by Ericksen (1985) and although this reference was in respect of flood losses, the principle remains relevant to any and all natural disasters. The research involved stakeholders engaged in Christchurch residential reconstruction work, where a sample of employees representing Insurance Companies and Project Management Companies were selected using a purposive non-random sampling technique. For the purposes of clarification, the following key terms are noted and explained in brief.

Direct Loss: "Direct losses as those that result from the physical destruction or damage to buildings, infrastructure, vehicles and crops" (Committee on Assessing the Costs of Natural Disasters 1999 p35).

Indirect Loss: "Indirect loss is any loss other than direct loss [which occurs as a result of a natural disaster]" (Cochrane 2004 p291).

Intangible Loss: "Intangible losses are those with no market value" (Bureau of Transport Economics 2001 p61).

Natural Disaster : "A natural disaster occurs when a natural hazard event causes damage to property or harms people" (Bureau of Transport Economics 2001 p5).

2. Literature Review

The selected literature on the topic of loss estimation included available and relevant New Zealand literature, most however were overseas publications.

2.1 Loss Estimation overview

From the literature reviewed there is no consistent approach to economic loss estimation in New Zealand, Australia or the US. This statement was supported by the findings from Walton (2004), The Bureau of Transport Economics (2001) and the Committee on Assessing the Cost of Natural Disasters (1999). The challenge is in defining a consistent dataset for

estimating disaster losses and identifying which data should be included in the estimates (Committee on Earthquake Engineering 1990). The literature had consistent themes but varied on how losses were calculated and what information was included and excluded. “Some measure only direct losses whereas others purport to include indirect losses”(Committee on Assessing the Costs of Natural Disasters: 1999 p8). Economic loss estimates are important in making informed mitigation decisions, for example, “it would be difficult to gauge the cost-effectiveness of public policy decisions such as relocating residents out of earthquake-prone areas without loss information” Despite this “little is known about the economic costs of natural disasters” (Bureau of Transport Economics 2001 p3). Even though there was no agreed framework within the reviewed literature, losses were generally broken up into two broad categories being ‘direct loss’ and ‘indirect loss’, and then further broken into measurement subcategories of ‘intangible’ (non-market values) and ‘tangible’(market values). These same classifications were proposed by Handmer (1985), Smith *et al.*(1995) and supported by Walton (2004). There were, however, existing frameworks from overseas sources, namely the *Economic Costs of Natural Disasters in Australia,* and *the Impacts of Natural Disasters: A Framework for Loss Estimation.* This software based Loss framework followed a similar classification system of breaking the losses into two categories, direct loss and indirect loss. Natural disaster loss estimation software developed over the past two decades has provided an integrated framework and incorporated geographic information systems (GIS) to display spatially referenced data such as population, building types and infrastructure (Strasser *et al.* 2008 p1). The development of *HAZUS* (Hazards United States), provided an integrated framework for loss estimation. This framework used mathematical formulae and information on building stock, economic data and GIS to display shaking from an earthquake (Committee on Assessing the Costs of Natural Disasters 1999). The outputs of the model included direct and indirect economic losses displayed as dollar losses, and although the model was originally developed for earthquake assessment it has been expanded to include flood loss and storm loss. Examples of earthquake software have included HAZUS, KOERI-loss (Kandilli Observatory and Earthquake Research Institute), SELENA (Seismic Loss Estimation using a logic tree approach), and a relatively new ‘Riskscape’ programme which is a New Zealand application developed by the National Institute of Water and Atmospheric Research (NIWA) and Geological and Nuclear Science (GNS) to predict losses and early assessment of natural disasters (King & Bell, 2006). In New Zealand much is known about earthquakes due to past research by GNS and the Geonet system. Riskscape uses information from systems such as Geonet and formulates the impacts that may result from natural disasters much like HAZUS. Development of the Riskscape programme began in 2004 and currently this New Zealand application is limited in scope as it only has a direct loss output. Asset inventories are used as base data to the estimates; this includes bridges, buildings and pipeworks (Riskscape, 2010). Riskscape has two levels for estimation and uses synthetic data. Level 1 determines damage through the modified Mercalli (MM) intensity scale based on past earthquake data, to assess how buildings react based on the type of building and distance from the centre of the earthquake The output is based on algorithms which model how assets perform in a natural disaster. There has been ongoing research in this field in New Zealand by Dowrick & Rhoades (2005, 2010) and a specific model is under development for the Canterbury region (Stirling *et al.*2008). Level 2 has more engineering input with the analysis of specific design spectra within a specific building class (King & Bell, 2006). Riskscape has “the potential to

become a nationally applied hazard and impact assessment tool enabling a standardised approach across the country" (Riskscape 2011).

2.2 Direct Loss Estimation and Measurement

There are different ways in which direct loss can be calculated, either based on imperial data (collected data), or synthetic data (based on likely impacts). Imperial data collection of direct losses can be divided into two groups, 'Primary data' collection which is most often surveys of businesses and households and the other is 'Secondary data', such as tabulated insurance claims, small business loans and various other sources (Brookshire *et al.* 1997) "There is little debate over the classification of direct economic loss which is the easiest to classify, they are losses that result from the physical destruction or damage to buildings, infrastructure, vehicles and crops" (Bureau of Transport Economics 2001 p15). The Edgecumbe Earthquake publication by Butcher *et al*. (1998), highlighted one of the potential problems with the data utilised, as a significant amount of money was involved in restoring chimneys, when in fact this may not have been earthquake related damage, and more likely general wear and tear; This would overstate the loss.

2.3 Indirect Economic Loss and Measurement

Indirect Economic Losses which are caused by natural disasters are losses resulting from the consequences of physical destruction. These have not been measured, studied, or modelled to the same extent as direct losses, despite the fact that indirect economic loss can have more of an impact than the direct economic loss in large events (Committee on Assessing the Costs of Natural Disasters 1999). New Zealand could incur significant indirect losses due to an open economy that is vulnerable to 'capital flight', with speculative investors withdrawing their investments from the New Zealand Economy (Cochrane1995 p68).

2.4 Intangible (non-market)losses

The importance of intangible loss is generally accepted, however they are often not measured, and are therefore discounted in the evaluation of natural disasters (Bureau of Transport Economics 2001 p88). Cochrane (2004 p291) supported this statement, stating that "Non-market losses are never estimated. Disaster losses are almost exclusively limited to impacts measured by market values".

2.5 Timing and Measurement of Losses

There are a number of issues associated with measuring economic losses. Issues such as the use of replacement value vs. depreciated value (Ashley 2007 p197) also ignoring post-disaster liabilities, ignoring non-market losses, double counting, differentiation between gross and net values and confusing data as to whether post disaster economic trends are a product of the event or another unrelated factor (Cochrane 2004 p290). Often the effects are measured over a shorter period to reflect the full range of outcomes from the event "indirect flood loss estimation due to business interruption cannot be estimated over a single point in time but has to be regressed over the full recovery period" according to Ashley *et al*. 2007

pp197-198). This was further reiterated by the Committee on Assessing the Costs of Natural Disasters 1999 p18), when stating that, “Timing of the estimate also has an impact on the estimate. Measuring the losses of natural disasters takes time. In the case of earthquakes, the extent of the damage to houses or businesses have suffered may take weeks to establish. Initial loss estimates may understate actual losses, potentially by wide margins”

2.5.1 Ignoring Post Disaster Liabilities

Loss accounting often fails to account for the region’s liabilities or borrowings, and the cost of indebtedness could be missed if measured over a too short a period, as long-term these liabilities could have impacts on the region and economic growth (Cochrane 2004 p291).

2.5.2 Double Counting

Double counting is a common problem in loss estimation. Cochrane (2004 p290-291) suggested that double counting is endemic and that it is very easy to make the mistake of double counting disaster losses. “It is commonly asserted that total damage is the sum of direct damage (damage to building and contents) and lost value-added. Double counting exists here because value-added includes the services of capital, whereas direct damage should reflect the cost of replacing the depreciated portion of such capital.

2.6 Summary

The reviewed research was focused mainly on direct loss estimation, and the areas of most contention were those around the classification and measurement of indirect and intangible losses. Indirect loss data has proven difficult to collect, which has led to attempts to model the indirect losses using synthetic data. Intangible losses are rarely measured and are therefore excluded from most loss estimates. This is attributed to there being no market or agreed way of measuring them, such as health effects or loss of heritage buildings.The focus recently, has been around integrated frameworks with the development of software such as HAZUS and Riskscape a New Zealand application. This is still in development and does not have the capability to provide an indirect economic loss output. The development of a framework has been hindered due to the complexities and the debate over exactly what information should be included or excluded in a framework. Three measurements that can alter the result significantly are the timeframe in which the loss is measured; the unique nature of the event; and the geographic context of the loss estimate. Further to this there are measurement limitations which need to be addressed such as double counting, identifying the impacts on loss estimation by the uninsured, and replacement versus depreciated values. New Zealand has not measured the economic losses that result from natural disasters consistently in the past. Instead, the focus has been on understanding the event, and this is shown by the extensive works conducted by Dowrick & Rhoades (2005, 2010). The type of economic modelling used is dependent on the end user for example, insurance companies are only interested in insured loss, and not in the losses incurred by the ‘uninsured’.

3. Methodology

Following the 2010 and 2011 earthquakes in Christchurch, loss estimation occurred across several sectors, both locally within Canterbury and nationally on a scale never before witnessed in New Zealand. Although extensive research has been conducted in the field of loss estimation, there was only a limited amount of published knowledge related to the research question being explored, and little or no information about the specific loss estimation methods actually used in New Zealand. The scope of this particular research was deliberately restricted to residential housing and the insurance sector due to the level of remaining uncertainties in other post-disaster claim sectors. The research was exploratory, confirmatory and applied, exploring the methods stakeholders employed to estimate economic losses following natural disasters. The methodology was confirmatory in accord with the findings of Walton (2004) and the Bureau of Transport Economics (2001) which stated "there is no consistent approach to loss estimation and storage of that information." The participant sample was non-random and purposive, as the participants were deliberately selected for their known attributes. Knowledge of the topic was seen as a key factor to the success of the qualitative data collected. The six selected participants from the five project management and insurance companies sampled, were in managerial roles, had an overview of the respective company's processes and were involved in the loss estimation of residential housing following the Christchurch earthquakes. All were interviewed to compare and contrast the findings with the reviewed literature. Face-to-face semi-structured interviews were undertaken, and given the potential sensitivity of the information, the structure of the interviews focussed on methods and processes rather than on actual, and therefore commercially sensitive, statistics. The data collected data were then analysed and organised into categories. The findings were compared and contrasted across the various stakeholder participants' responses, and with the findings from the reviewed literature.

4. Results/Findings

4.1 Initial Estimation Method

Of the five companies sampled, only the two Insurance Companies (A & B) and two Project Management companies (D&E), used a form of initial estimation to establish an indicative cost of the loss incurred on a residential property. Company A used their own historic insurance information using 'a basic average of historical data over a period of time' to establish a likely cost based on the insured' s description of the damage. Company C then set the estimation level which was based on factors such as the post-disaster property zoning (red, green, orange, blue-green). Similarly Company B used a computer based programme where the cost was calculated using their own empirical insurance data. Company D & E's estimation methods used primary data collected from on-site inspections combined with secondary cost data from various market sources, and established an initial estimate of the loss. This was later used to evaluate residential repair options. This method was more intense than the method employed by the insurance companies as it was based on surveys from the actual damage and current market rates rather than historic data and costs. The insurance and project management companies considered that historic data bore little or no relevance to the (unique) earthquake events of 2010 and 2011. In effect then the

five companies sampled all used different methods to conduct loss estimates. This was in line with the main findings of the literature where there was an inconsistency in industry around loss estimation methods, due in the main to a lack of an agreed and common framework. Both Company A and B stated that the initial estimate was not particularly accurate when compared with the actual cost, and that “the initial estimate was essentially never right and often inaccurate”. An important distinction was that the scope of estimations conducted by the Insurance Companies was based on a per claim basis rather than on the overall loss. An overall loss estimation would occur later in the process, however this was not discussed in-depth in the interviews due to commercial sensitivity and because it tended to relate more to Insurance Company’s risk assessment rather than to loss estimation. Of note though is that all five companies utilized the actual, and therefore the replacement value of repairs, when finalizing their initial estimate assessment for every claim received, rather than the depreciated value .

4.2 Natural Disaster Loss Estimation and BAU

The selected six participants generally agreed that their methods for loss estimation following the Christchurch Earthquakes were essentially the same as BAU (business as usual) work as the end goal(s) remained the same . The notable differences though, was the necessary involvement of outside parties to assist in the process, and the fact that the companies’ loss estimation method(s) had to be simplified in order to respond to the scale of the damage being experienced, and the massive increase in the number and nature of claims received. From the findings it was difficult to compare the earthquake events with the companies BAU work. Despite the two Insurance Companies using the existing estimation method, all included some form of new process to deal with the earthquake events. However, one of the significant changes to BAU estimations by the Insurance Companies was to include a Project Manager on staff. The reason being that the insurers had never had to allow for earthquakes in Christchurch before, and therefore had no relevant /documented processes nor project management skills in-house. In the past, they (the insurers) had managed the process ‘from go to whoa’. The Project Managers’ most significant changes involved the incorporation of increased and specialised Information Technology (IT) Systems being introduced to manage the claims process, and the development of a new overall claims management process.

4.3 Consistency within the Industry

All participants believed there was a definite lack of consistency within the process of claims assessments and that the different parties were handling the earthquake related claims completely differently from each other. This was due in the main to the competitive market in which the insurance companies work, and the policy response of the insurer’s, where some are focused on the bottom line while others are customer focused. Insurers do not share information about their estimation methods, as that forms an essential part of their competitive edge in the market. This was not highlighted as an issue within the literature, but would be a prohibitive factor to introducing a loss estimation framework into New Zealand, which has one of the least regulated insurance markets in the world” (Insurance Council of New Zealand, 2008). This market is largely self-governed, and there is no framework for

compulsory reporting which would be a major factor in having a consistent method of estimation. To implement a standard method when there is a lack of control or a governing body that can implement a scheme, would be difficult. Furthermore, the current situation is complicated by the uniqueness of the (earthquakes) event, where entire pockets of land have been retired from use (meaning that they are unbuildable now). Insurance policies have never been written to take this into account before now. In addition, the New Zealand government has taken on some of the private insurer's risk where the property(s) were/are in the Red Zone, and offering packages to those red zone residents. The literature suggested the potential use of software in economic loss estimation such as HAZUS or Riskscape, but none of the companies interviewed have utilised software from New Zealand or overseas for loss estimation, as yet. This it seems was due to the perceived 'lack of need or benefit of new technology' in the residential insurance sector, as the companies have their own processes in place, and were confident regarding 'estimate accuracy'. The participants considered the current and new software on offer as more suited to risk assessment and hazard response rather than loss estimation on this (Christchurch earthquakes) scale.

4.4 Lessons Learned

A number of lessons have been learned by the Insurance companies and the Project Management companies as a resultant of the Christchurch Earthquake evens t(s). Three participants (from Company B,C &D) noted that the information technology and processes utilised have had to be changed to assist in processing the large numbers and scope of claims. Company B had to adjust cost estimates for repair of foundations to allow for a range of differing repair strategies, and associated (labour) rate ranges. Company D&E has had to upskill their contractors' abilities to prepare detailed post-natural disaster quotes, and what to include or exclude from those estimates. They also noted the need to find ways to ensure better consistency in pricing and communications in-house and with clients.

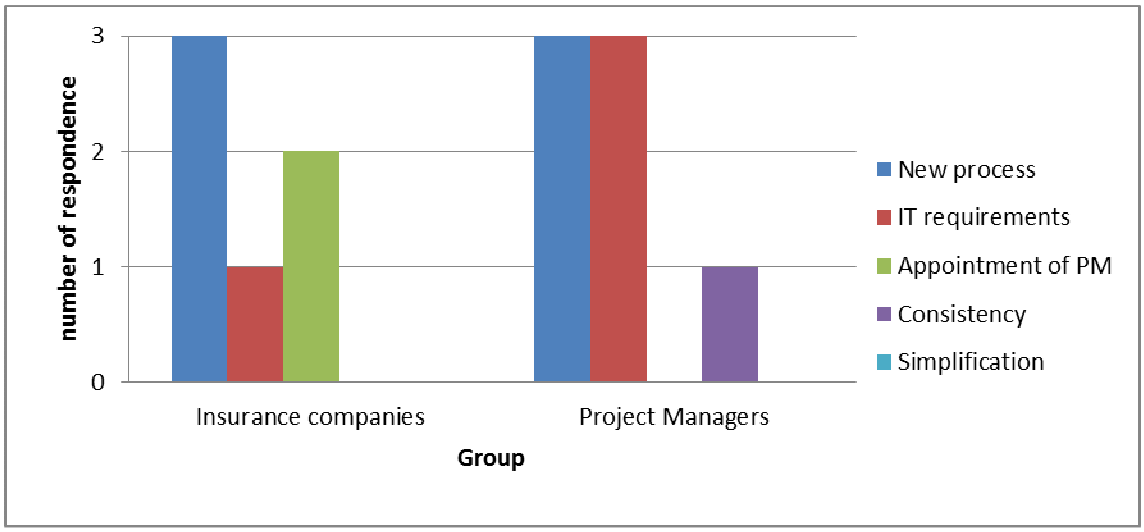

Figure 2: Number and Type of Response for Lessons Learned

4.5 Administration Costs

No literature was found in relation to how administration costs should be allowed for in an estimate or how it should be recorded. In the Christchurch earthquake event, a large amount of coordination and additional personnel was needed, adding to the administration cost, and this was shown by EQC paying out $138,000,000 in wage till September 2011 (Bennett 2011). This was an indirect cost which was a direct result of the event. The five companies sampled, identified significant administration costs relating to the Canterbury Earthquake, none had factored this cost on a claim by claim basis, instead it was treated separately.

5. Conclusion

The literature review established the current state of loss estimation and the limitations and problems associated with establishing a framework. The research findings identified that there was no consistent method of estimation loss, and this also agreed with the literature findings, as did the reasoning regarding why this occurred. To establish a consistent method between companies within the residential sector would be difficult, due to the competitive and sensitive nature of the private insurance market. In addition, the lack of regulation within the insurance industry does not aid the establishment of a consistent process. There would be value in having a consistent framework for natural disaster loss estimation in New Zealand to assist policy makers in the future, and aid in mitigation decisions by having comprehensive loss data stored and used in a consistent manner. Comparisons could then be made without fear of bias within the data. However, such a framework would be difficult to implement due to the issues identified and discussed as the research progressed. There is a possibility that in the future, and as the process evolves, uniformity may occur.

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Cooling the Planet by Urban Restructuring

Pekka Lahti[1]

Abstract

There is a wide scientific consensus about the current and seemingly invariably on-going climate change, the global warming. Moreover, it is becoming evident that even quite novel technological innovations (like CCS utilising biomimicry) and equivalent rapid measures cannot turn the trend until next ten or twenty years. The debate is now more and more turning to the mitigation of its probably serious consequences on the urban development and the whole human culture. The increased number and magnitude of heat waves, storms, flooding, sea level rise etc. are followed by loss of economic values as well as degradation of production power. All this might give reasons to new types of migratory movements, maybe even territorial fights for vital resources (like clean water and air, food and certain materials needed in the industrial processes). If this dystopia is going to happen, it calls for restructuring and reorganisation of the whole urban system. We should assess different roadmaps and scenarios. We need tools capable for assessing the urban eco-efficiency and especially the carbon footprint on local and global levels both linked with the systemic behaviour and dynamics of urban development. This could pave the way to global cooling.

Keywords: urban development, urban design, ecosystems, ecology, sustainability

1. Understanding urbanism and the role of nature

Sustainability of urban development is a popular topic among city planners and other practitioners (architects, engineers, designers, managers). Urban ecology is a rapidly growing field of science helping to understand some of the impacts. However, both in practical fields of different professions and in theoretical fields of different sciences most of the discussion is limited to the scale of a single urban unit like a neighbourhood, town or a city region (see for instance many readers on Urban Ecology: Douglas et al. (ed.) 2011, Gaston (ed.) 2010, Marzluff et al. (ed.) 2008, Mostafavi & Doherty (ed.) 2010, McDonnell et al. (ed.) 2009, Niemelä (ed.) 2011, Wheeler et al. 2004).

Typical question in urban ecology is: What are the impacts of city building on the living conditions of species or how do the different biological organisms survive in or adapt themselves to urban conditions? Most of the research on urban ecology uses concepts and tools of biology, meteorology, geology and other classical natural sciences. Urban

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economics deals with statistical analyses of prices, rents, income distribution, econometric modelling, price mechanism explaining urban change etc. Social and human sciences are interested in human behaviour, geographers are interested in anything which has a place and location, i.e. has geographical coordinates.

Ecologically oriented urban planners are interested in questions like: What is the most ecological urban form – city or countryside, village, small town, large city or metropolis, single city, linear or polynuclear city, or what is the most ecological urban density or optimum shape of blocks, streets, squares and parks, mesh size of networks or are urban sprawl and car dependence ecologically sustainable? *One* part of urban planners, designers and developers seem to support continuing and "classic" urban expansion pattern with the presumed economic advantages, i.e. assuming that growth itself and large scale production (economies of scale) guarantees the required supply, quality and variety of services, allows creating new cultural values, minimizes the resource use per capita, guides to the use of best available environmental technologies etc. The *second* part believes in small scale and local production, distributed small urban units, community approach, self-help etc. New urbanism seeks for a combination of small scale communities within large cities or polynuclear conurbations. The *third* part more or less ignores the question of sustainable urban form and relies on continuing technological (or maybe biotechnological) innovations: in sustainable future we can go on with all possible urban forms because carbon dioxide can be captured and stored in a way or another, possibly imitating biological processes (like those in seashells or corals) or using some other technology which we cannot see today. It is possible that all three approaches have an important role in an eco-efficient urban future.

The question of most sustainable urban form is perhaps not at all relevant in the global context. The problem is that there is hardly nobody to practice the science of "ecosystem of (all) cities" or "the global level of ecological urbanism" or "global urban ecosystem". Without knowledge, there is hardly any base for a credible ideal for eco-efficient urban form.

The global dimension, "the ecosystem of all urban units" is important because the whole (industrial) urbanism is basically global and the ecosystem itself is a global concept. The missing science is surprising because everybody knows that the world (the globe) is one – there is only one atmosphere, all oceans belong to the same sea and all cities are part of the same global economy utilizing the same global material and energy resources.

1.1 The role of nature in the classics of urban analysis

The review of more than 50 urban policy documents (Lahti et al. 2012a, Lahti 2012a) included both the most well-known classics (like Vitruvius, Howard, Wells, Unwin, Sitte, Benevolo, Saarinen, Le Corbusier, Mumford, Jacobs, Alexander, Lynch and Hall) and the very latest 21st century authors (altogether more than 1 000 individuals) of urban development, sustainability and ecology. The results of the review may surprise, because the awareness of the complex relationships between man, urban development and ecological consequences are still based on rather limited knowledge and understanding.

In the conventional understanding (in the classics) nature is regarded as a

1) bottomless reservoir of material and energy resources (even when there is no explicit reference to this fact – it is more or less written between the lines)
2) source of health, mental delight and refreshment (this is most self-evident and almost always quite clearly expressed)

A few examples from the classic literature of architecture and urban planning:

- Roman architect Marcus Vitruvius Pollio gave two thousand years ago detailed instructions how to take into account the sunlight, winds, water systems, local building materials, etc. on the construction site. The durability, healthiness and beauty were also very important to him. (The Ten Books on Architecture)
- More than hundred years ago English writer Ebenezer Howard described his garden cities as places with beauty of nature, bright homes and gardens, pure air and water and without slums and smoke. The areas outside garden cities were agricultural areas, fruit fields, forests, brickfields, water reservoirs and some other special areas – all for the well-being of city dwellers. (Garden Cities of To-Morrow)
- For the Swiss-French architect Le Corbusier in the 1920s the nature represented a place for pleasure and refreshment outside buildings and an aesthetic background for great architectural objects. “A City! It is the grip of man upon nature. It is a human operation directed against nature…” (The Radiant City)
- For the American architect and urban theorist Kevin Lynch in the 1960s and 1970s the nature provided an aesthetical element for the town scape, especially the “edge” between built and natural areas or between sea and land. (Image of the City)
- Peter Hall, the well-known British geographer and writer since 1960s, sees the urban development as a reflection of the social progress. The severe health and social problems (slums, diseases and poverty) in the 19th century industrial cities were reflected in the social utopias, first and foremost in the garden city movement promoted by Ebenezer Howard, Raymond Unwin etc. (Cities in Civilization)

Most of the classics try to figure out the role of built environment in the well-being of mankind, emphasizing beauty and social good, whether it is from nature or man-made origin. So far so good, but it is obvious that this has not been sufficient for a long time.

1.2 Modern understanding

During the last century the environmental awareness has grown so that the complex relationships between man and nature, the elements and functionalities within the “whole system”, the threats and conditions to human survival are subject to more systematic research. The amount of literature dealing with ecology, ecosystems, urban ecology, human impact on natural conditions, climate change etc. is growing fast.

After a short excursion to the newest literature on urban ecology or sustainability of urban development including 40 books with altogether 15 000 pages and written by more than 1 000 authors (Lahti et al. 2012a, Appendix 1) it seems quite clear that:

- The new themes and concepts like “urban ecology”, “green urbanism” and “sustainable urbanism” are getting very popular.

- The majority of the studies deal with highly industrialized countries (where most of the climatic problems have been created) and very few with developing countries (where the future challenges are the greatest); however in both parts the urbanization seems to continue on the “free growth” track
- There seems to be a large consensus that sprawling large cities waste resources, spoil the environment and create socially unfavourable living conditions; many authors seem to promote a kind of return to the compact and walkable city model, the European medieval city form perhaps.

We know that the built environment corresponds to at least half of the global carbon footprint (see for instance Baumert et al. 2005). What is missing is the systematic and hard fact investigation on the links and conflicts between world urbanization and global ecosystem. For the assessment we need a global and usable tool based on evidence and a systemic view built on credible causalities.

Ecosystem (ecological system) is any group of living (biotic) and non-living (abiotic) things interacting with each other. It can be local or global, but local ecosystems can be extremely difficult to separate from their surroundings. Cities and other urban communities are local ecosystems belonging to the global ecosystem.

There are two types of urban ecosystems:

1. Ecosystems in cities (air, water, soil, flora, fauna, ecosystem services, biodiversity, carbon cycles etc. within urban areas) – the narrow explanation
2. Ecosystems of cities (city as a complex cultural ecosystem, cities as one global ecosystem) – the broad explanation

Urban eco-efficiency is the quality of urban life at the cost of resource consumption and environmental harms caused by the urban development. The climate change and carbon cycles are among the key indicators of urban eco-efficiency – the hard core. The awareness and understanding of these key concepts are essential when enabling and promoting eco-efficient urban future.

1.3 Current and expected urban change

The three crucial indicators in the current development of urban ecosystems are global: urban growth, consumption of fossil fuels and (more or less as a consequence of the previous) level of greenhouse gases. The current trends in these crucial factors of urban ecosystems are maybe not surprising but they are clear (Figures 1–3). The correlation between the three is obvious.

The global urban ecosystem is a dynamic system which (temporally and historically) can be divided in three sequential subsystems (Figure 4). The relationships between the dynamics of urban development and dynamics of urban eco-efficiency deserve much more and deeper attention than is currently under way (Figure 5, Hradil et al. 2011). The path from Jay Forrester’s Urban and World Dynamics (1969 and 1971) to The Limits to Growth by the Club of Rome (1972) was interesting but too short, and today already rather overgrown.

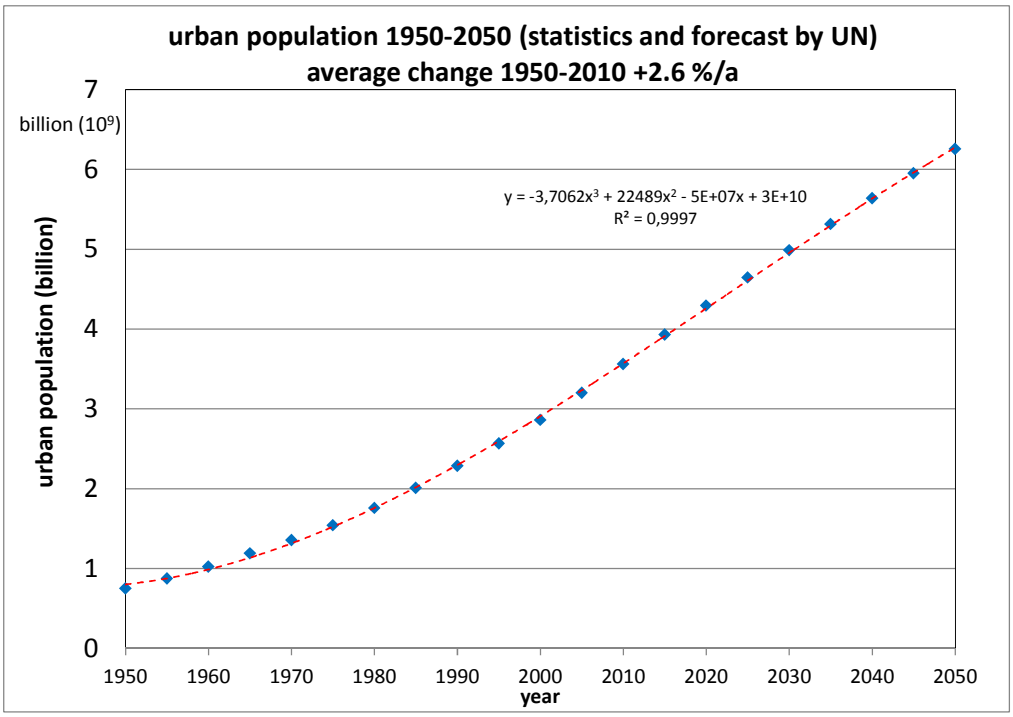


Figure 1: Urban growth during last 60 years and expected growth during next 40 years (blue dots: data from UN 2012) with the corresponding trend curve (red).

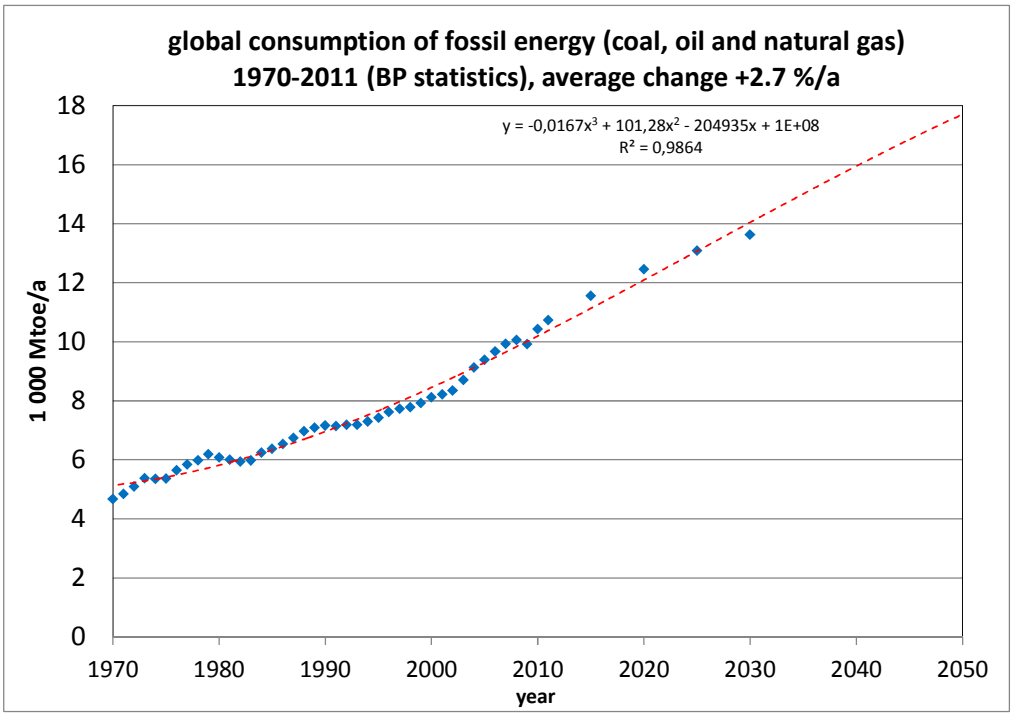


Figure 2: Fossil fuel consumption during last 40 years and expected growth during next 20 years (blue dots: data from BP 2012a and 2012b) with the corresponding and extrapolated trend curve (red) until 2050.

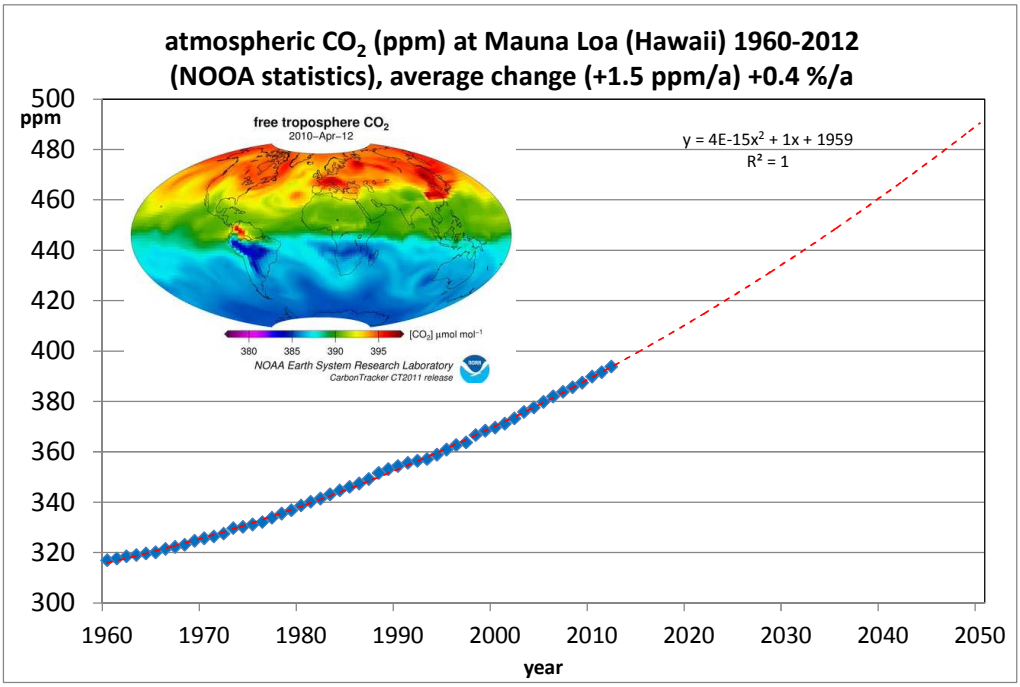


Figure 3: Atmospheric CO_2 at Mauna Loa (Hawaii) during last 53 years (blue dots: data from NOOA 2012) with the corresponding and extrapolated trend curve (red) until 2050. In northern hemisphere (see the image of the globe) the average values are around 2–10 ppms higher than in southern hemisphere (NOOA 2012, CarbonTracker CT2011) due to location of major industrial-urban centres and global air movements.

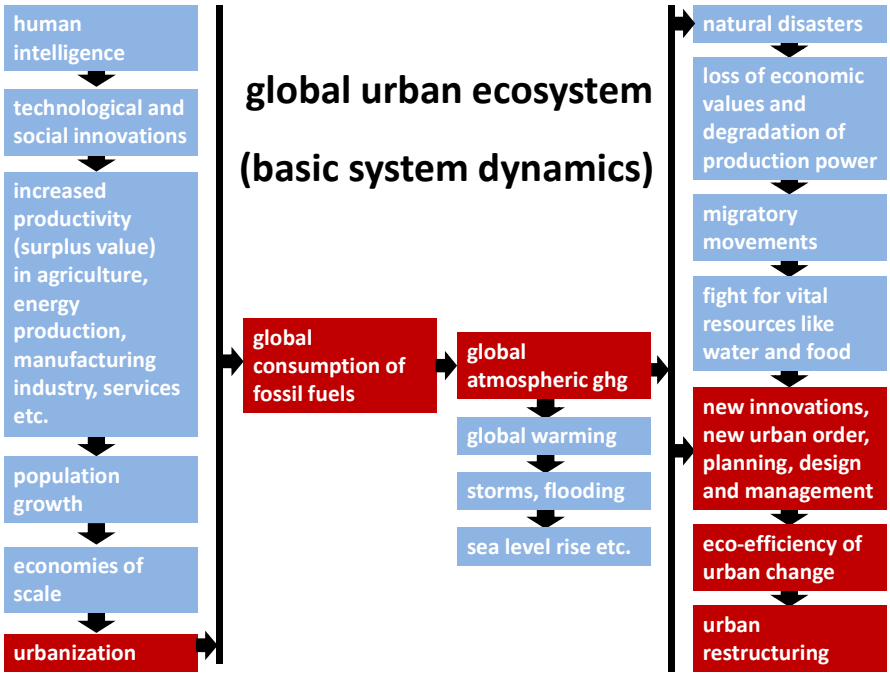


Figure 4: The global urban ecosystem described as three subsystems: 1. preindustrial and industrial phase (the left hand side), 2. counter-ecological phase (in the middle) and 3. preparation for ecological phase (the right hand side). The urban dimension (the chain of red boxes) is probably highly relevant, maybe even crucial part of the big picture, the expected success in the dynamics of the global urban ecosystem.

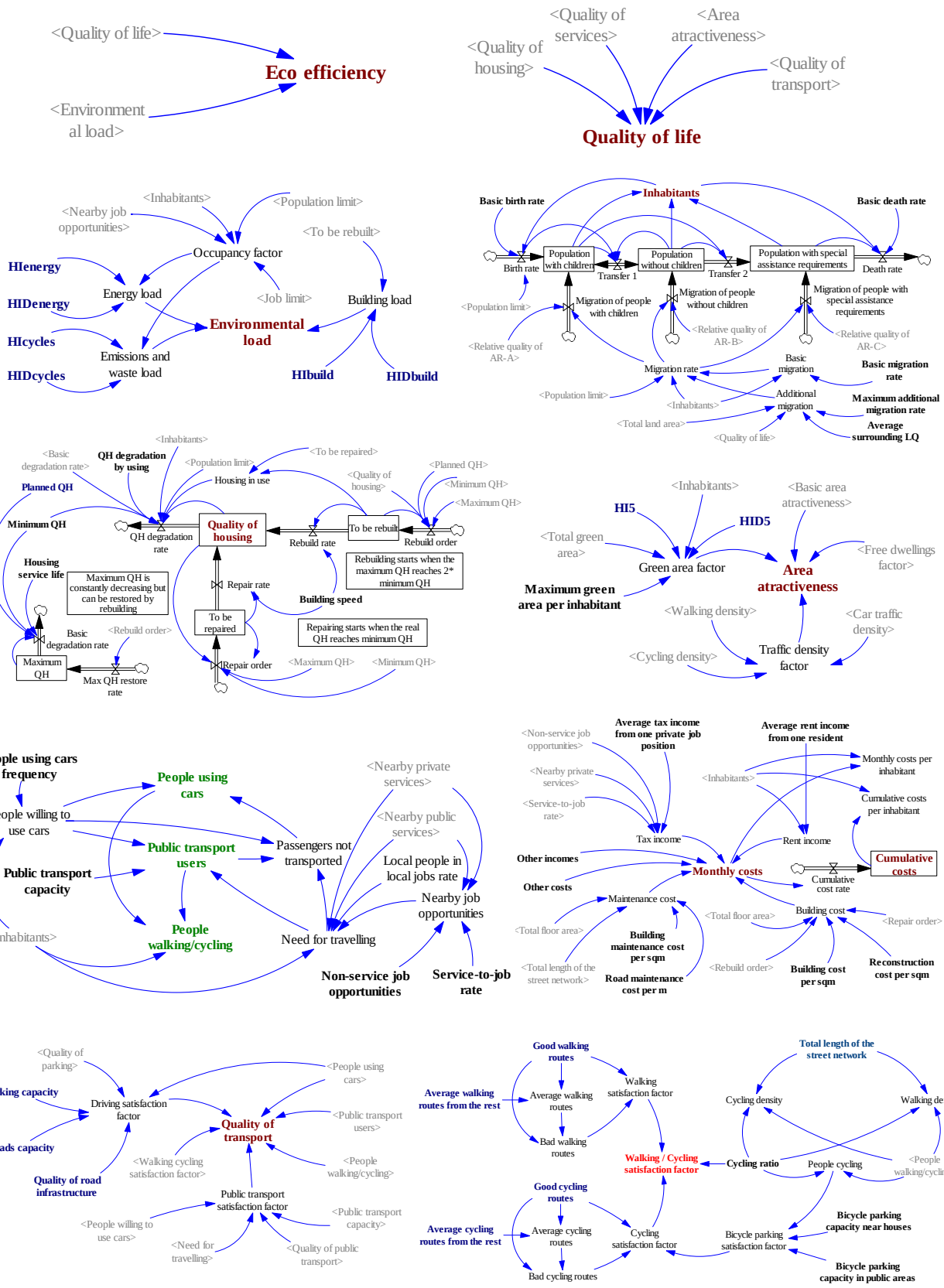


Figure 5: System dynamics of urban development and eco-efficiency, experiment on major sub-systems and impact relationships (Hradil et al. 2011)

The classical socio-economic development behind the urbanization process is normally understood as an extremely positive set of links creating welfare and material wealth – at least in the long run (and after each temporary recession periods). However, the direct consequence of the socio-economic progress has been counter-ecological, disturbing and shaking the balance and continuity of the global urban ecosystem by creating unexpected and harmful natural processes like global warming, storms, sea level rise etc.

The newest and currently emerging phase is a new type of socio-ecological development trying to mitigate and eliminate the negative impacts, return the development on the positive and ecologically sustainable track. The discussions on this kind of global fora (WBC conference) are part of this process. Much of the real and effective development is still hidden and veiled by many superficial processes. The real dynamics needs to be studied and modelled.

1.4 Urban “ecotools”, tools to assess eco-efficiency of urban development

There already exists tools for assessing ”urban eco-efficiency”, “urban sustainability”, ”green development” or alike. They are either in the market already or in the development or research phase. The ecotools cover the spectrum of urban dimensions and eco-efficiency indicators with a variety (see Table 1, the KEKO matrix of 40 different tools, Lahti et al. 2012b, Lahti 2012a) – each tool has its own strengths, weaknesses and market niche.

Methodologically, one of the most difficult tasks is to be able to combine numerous tangible and intangible aspects into one single eco-efficiency result – either a numerical or verbal expression (Figure 6). Difficult or not, this must be done in order to make a reasonable and feasible decision in each individual urban case: which one is the most eco-efficient alternative to promote the urban development towards the success (and finally the survival) of the global urban ecosystem. When using only one indicator, like carbon footprint (Figure 7), the task is much easier.

2. Conclusion

Looking back at the development of written urban policy documents of our civilization, i.e. social and architectural utopias, urban development visions and alike, shows that during the last twenty centuries the role of nature has been more or less the same: to provide human beings the material resources, mental delight and refreshment they need. Only during very last decades the understanding has widened to encompass also more systemic aspects: the interrelationship between man and nature, the environmental and ecological systems, their vulnerability and the global aspects. Both the global and dynamic dimensions of urban development need to be integrated with the (more or less static) assessment methods and tools for ecology and eco-efficiency of urbanism.

Table 1: A summary of the review of 40 different ecotools or "eco-efficiency calculators" (Lahti 2012a)

KEKO STUDY: SUMMARY OF INDICATORS IN 40 URBAN ECOTOOLS (© VTT Technical Research Centre of Finland, Aalto University & SYKE Finnish Environment Institute 30.11.2012)

+ included/ notified + partly ? N/A - excluded/ unnotified		area level					buildings		tech. infrastructure networks/systems					bluegreen infra		social infrastructure (services)						operating the built environment (technical infrastructure)										trans-port	indicators of eco-efficiency								
TOOL (provider)	locational choices, soil conditions	state level	regional level	city, municipality	district level	block level	residential buildings	occupational buildings, others	transport network and system	water supply, waste water and drainage systems	energy supply	information networks	green and other outdoor areas	water areas	commercial services	childrens' day care and school	health and other social services	sports and other recreational services	others (administration etc.)	heating	lighting	other use of electricity	hot water	cold water	waste water	cooling	solid waste management	repair and maintenance	demolition and recycling	utilization of existing structures	commuting, shopping and other trips, goods transport	consumption of materials	energy consumption	renewables	ghg emissions, carbon footprint	other emissions	wastes and recycling	ecosystems, ecosystem services	other assesment criteria (health, security etc.)
Aalto University Hybrid-LCA (Aalto)	-	+	+	+	+	-	+	+	+	+	+	+	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	+	-	-	-	-
Beyond Vuores (VTT)	+	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
BREEAM for Communities (BRE)	+	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
CASBEE-City (JSBC)	+	-	+	+	-	-	+	+	+	+	+	+	+	+	?	+	+	?	?	+	+	+	+	+	+	+	?	?	?	+	?	+	+	+	+	+	+	+
CASBEE-UD (JSBC)	+	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+	-	+	+	+	+	+	+	+	+	+
CitySim (EPFL, VTT)	+	-	-	-	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+	-	-	-	-	-	-	-	-	+	-	-	-	-	-	+
EcoBalance (VTT)	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+
ECOCITY (EU)	+	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Ecocity Evaluator (EP Ecocity Oy)	+	+	+	+	+	+	+	+	+	+	+	-	+	+	+	-	-	-	-	+	+	+	+	-	-	-	-	+	+	+	+	+	+	+	-	+	-	+
EcoProp (VTT)	+	-	+	+	+	+	+	+	-	-	-	-	+	-	-	-	-	-	-	+	+	+	+	+	-	-	+	-	+	-	+	+	+	+	-	+	-	+
ECOREG (SYKE)	+	+	+	+	-	-	+	+	+	-	-	-	+	-	-	-	-	-	-	+	-	+	-	-	-	-	-	-	-	-	+	+	+	-	+	+	+	+
EkoPassi (VTT)	+	-	-	-	-	+	+	-	-	-	+	+	-	-	+	+	+	+	+	+	+	+	+	+	-	-	+	-	-	-	+	+	+	+	-	+	-	+
Ecocommunity (VTT)	+	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+	+	+	+	-	-	+	+	-	-	+	+	-	+	+	+	+	-	+
ENVIMAT (SYKE)	-	+	+	-	-	-	+	+	+	+	+	+	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
EU ecolabel (EU)	-	-	-	-	-	-	+	+	-	-	-	-	+	-	-	-	-	+	-	+	+	-	+	+	+	+	+	+	+	+	-	+	+	+	-	+	-	+
EU GPP (EU)	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
FRES (SYKE)	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	-	-	-	-	-	+	+	+	-	+	+	+	+	-	-	+
Green Star Communities (GBCA)	+	?	?	?	+	+	+	+	+	+	+	+	?	?	+	+	+	+	+	+	+	+	+	+	+	+	?	?	+	+	+	+	+	+	+	+	+	+
HEKO (City of Helsinki)	+	-	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
KASVENER (SYKE)	-	+	+	+	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+	+	+	+	-	-	+	+	-	+	+	+	+	+	-	+
KUHILAS (SYKE)	-	-	-	+	-	-	+	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+	-	+	-	+
KULE (VTT)	+	-	-	+	+	+	+	+	-	-	+	-	-	-	+	+	+	+	+	+	+	+	+	-	-	-	+	-	-	-	-	+	-	-	-	-	-	+
KulMaKunta (VTT)	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+	+	+	+	-	+	+	+	+	+	-	+	-	+	+	+	+	+	+	+	+	+	-	-
Kuntaliitto ecological footprint (Kuntaliitto)	+	-	-	+	-	-	+	+	-	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+	+	+	-	+	+	+	-	+
KyläPassi (VTT)	+	-	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+	-	-	+	+	-	+	+	+	-	+	+	+
LEED-ND (USGBC)	+	-	-	-	+	+	+	+	+	+	+	-	+	-	+	+	+	+	+	+	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+
LIPASTO (VTT)	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	-	+	+	-	-	-
MenTouGou (VTT)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Metka (VTT)	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	-	-
NILIM tool (NILIM)	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	+	+	+	+	+	+	+	-	+
PIMVAG (Eco-Viikki) (City of Helsinki)	+	-	-	-	-	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	-	+	+	+	-	-	+	+	+	+	-	+	+	+
Nordic Swan label (Nordic countries)	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	+	+	+	+	-	-	+	+	-	-	-	+	+	+	-	-	+	-	+
PromisE (VTT)	+	-	-	-	-	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+	+	+	-	+	-	+	-	+	+	+	+	+
Constructor's ecocalculator (HKR)	+	-	-	-	-	-	+	-	+	+	+	-	+	+	+	+	-	+	-	+	+	+	+	+	+	+	+	-	+	-	+	+	+	-	-	+	+	-
Region-SD (SYKE)	+	-	+	+	-	-	+	+	+	-	-	-	+	+	+	+	+	+	+	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-	+	+
SYNERGIA (SYKE)	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	+	-	-	+	-	-	-	+
UZ (Urban Zone) (SYKE)	+	+	+	+	+	+	+	+	+	-	-	-	+	+	+	+	+	+	+	-	-	-	-	-	-	-	-	-	+	+	-	-	-	+	-	-	-	+
WinEtana (VTT)	+	-	-	-	-	+	+	+	-	-	-	-	-	-	+	+	+	+	+	+	+	+	+	-	-	-	+	-	-	-	-	+	-	-	-	-	-	+
YKEVAKA (VTT)	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+	-	+	+	+	-	-	-	+	-	-	-	+
YKR (SYKE)	+	+	+	+	+	+	+	+	+	-	-	-	+	+	+	+	+	+	+	-	-	-	-	-	-	-	-	-	+	+	-	-	-	+	-	-	-	+

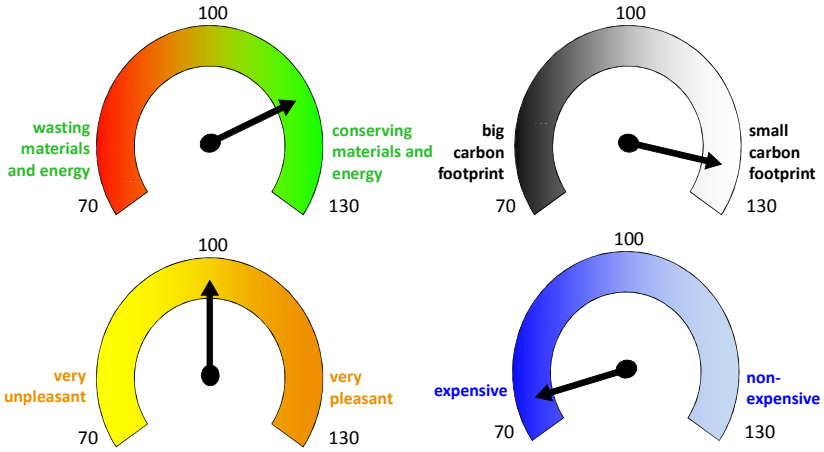
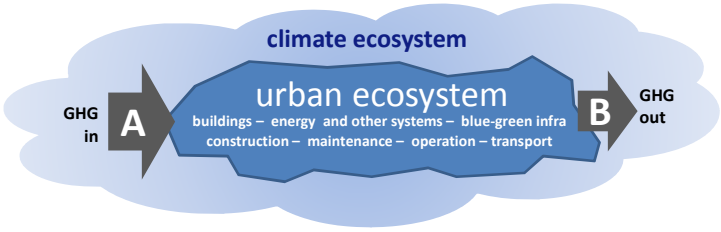


Figure 6: Eco-efficiency as a multidimensional entity, example of possible conflicts between different indicators. Considering any real case: is urban development eco-efficient if it is rather efficient in materials and energy consumption (upper left corner), has a small carbon footprint (upper right corner), is sufficiently (aesthetically, functionally etc.) pleasant (lower left corner) but in the same time extremely expensive (lower right corner) (Lahti 2012a)? How to take into account all dimensions of eco-efficiency simultaneously (including biodiversity, ecosystem services, accessibility and affordability of water, energy and other material resources, vulnerability and resilience of natural and man-made systems etc.)



if A > B, then urban ecosystem consumes more CO_2e gases than it produces, and
the net impact in the atmosphere is either slower increase or decrease of CO_2e level (ppm)

Figure 7: The crucial part of the global urban ecosystem is the linkage between urban ecosystem and atmospheric ecosystem (Lahti 2012a). The global carbon balance seems to be the necessary condition to all other eco-efficiency criteria.

The carbon balance (or net carbon footprint) of urban development can be measured rather objectively and with sufficiently exact numbers compared to many other elements of multidimensional eco-efficiency (Lahti et al. 2012b and Lahti 2012b)[2]:

$$\text{net carbon footprint of urban development} = \frac{\text{ghg captured from the atmosphere } (GtCO_2e) - \text{ghg released to the atmosphere } (GtCO_2e)}{\text{number of inhabitants and jobs (persons) } \textit{or} \text{ total floor area } (m^2)}$$

[2] The equation works globally without the denominator, but the relative figure (for instance per inhabitant) allows one the make comparisons between local urban development alternatives.

The data needed for the calculation include firstly the specific consumption (input) of carbon dioxide and other greenhouse gases (ghg) during the lifecycle of urban metabolism, the ghg captured during the urban processes and embedded in the physical environment. This should include all different materials used during the manufacturing, construction and operation of urban units. Secondly, the equivalent data is needed from the released ghg during the very same processes. To be able to compare urban solutions of different sizes, one needs also data on the volumes of alternatives (measured most often in number of inhabitants or total floor area). In principle we have enough knowledge and understanding for making the assessment, but we seem to lack the ability to construct globally effective feedback links in order to change the direction, to cool the planet (Figure 8).

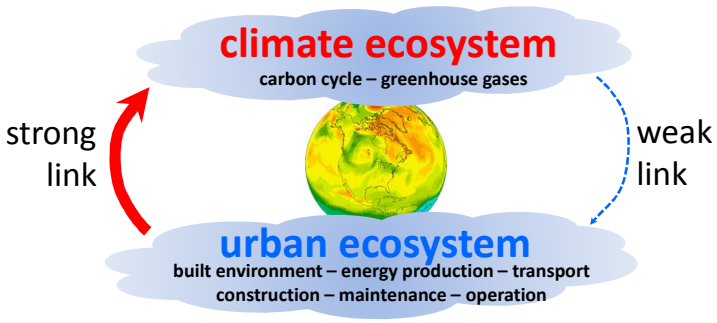


Figure 8: The interaction between the global urban ecosystem and the climate ecosystem where the strong link has so far been the man-made physical processes creating global warming whereas the weak link has been the human (re)action creating the required counter effect, the global cooling (Lahti 2012b). (the globe: NOOA 2012)

Without intentional and effective actions, we cannot say we have really understood the issue, can we? From now on, all potential urban development actions need to be evaluated: are they warming or cooling the planet? The data for constructing the tools that have the power to provide sufficient answers to the question is more or less already available.

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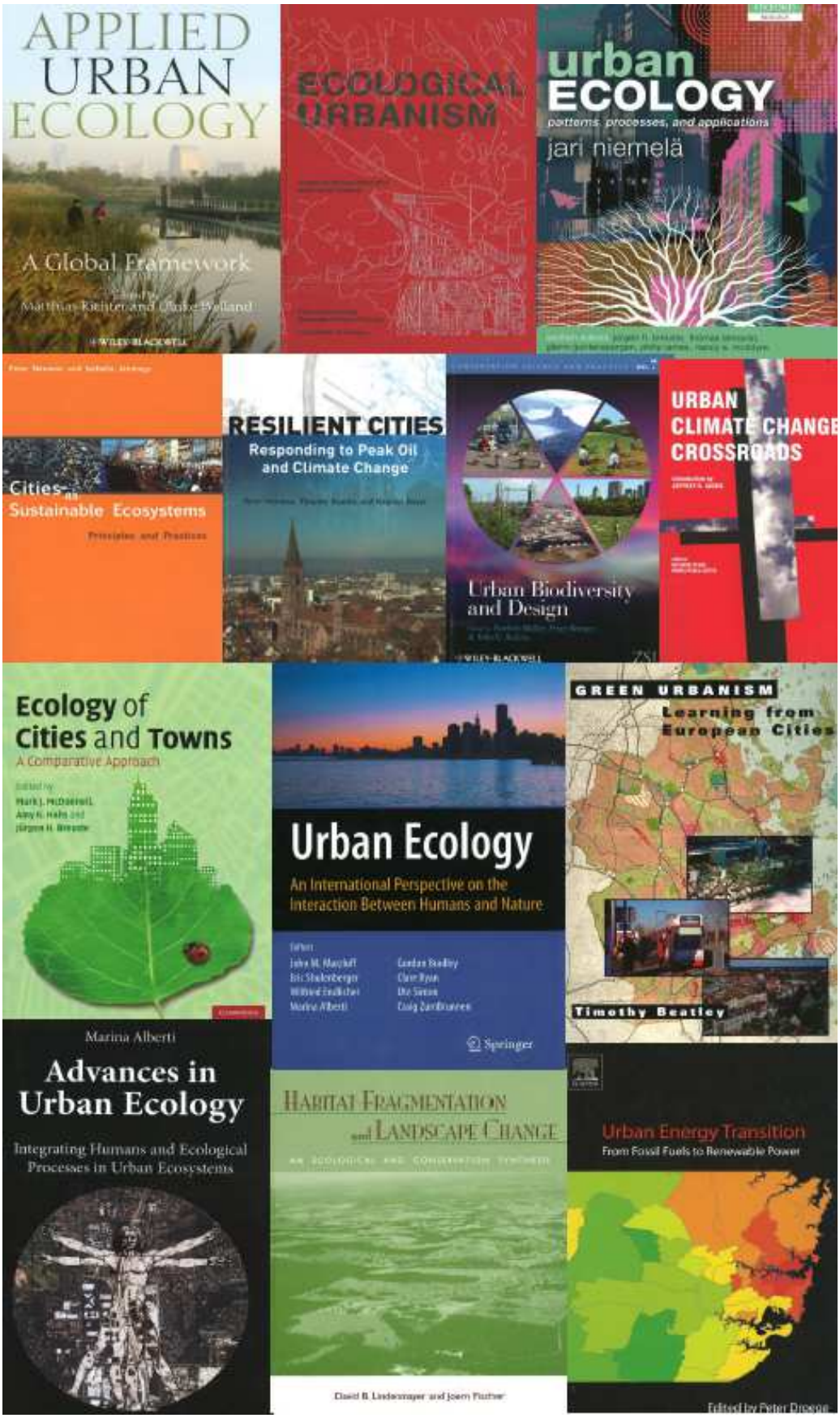
Appendix 1: Some of the reviewed 40 recent books on urbanism and ecology




APPLIED URBAN ECOLOGY
A Global Framework
ECOLOGICAL URBANISM
urban ECOLOGY
patterns, processes, and applications
jari niemelä
RESILIENT CITIES
Responding to Peak Oil and Climate Change
Cities as Sustainable Ecosystems
Principles and Practices
Urban Biodiversity and Design
URBAN CLIMATE CHANGE CROSSROADS
Ecology of Cities and Towns
A Comparative Approach
Urban Ecology
An International Perspective on the Interaction Between Humans and Nature
GREEN URBANISM
Learning from European Cities
Timothy Beatley
Marina Alberti
Advances in Urban Ecology
Integrating Humans and Ecological Processes in Urban Ecosystems
HABITAT FRAGMENTATION and LANDSCAPE CHANGE
Urban Energy Transition
From Fossil Fuels to Renewable Power

Towards a global construction database using a simplified systems approach

Stephen Gruneberg[1]

Towards a global construction database

The need for a global construction database is recognised but little activity has so far taken place to co-ordinate the national data that is already widely available on the internet. Construction data is gathered and made publicly available in almost all countries of the world. However, there are significant differences in definitions, means of gathering and methods of presentation. Two case studies are used to identify common approaches and characteristics and use is made of a recent CIB study of a systems approach to analysing construction industries internationally. National differences in approach to defining and collecting construction data as well as real economic differences may mean that a single universal approach may not be appropriate. It may therefore be necessary to cluster national construction data sets according to various economic, social and political criteria to facilitate useful measures of construction industries to be made accessible and internationally comparable and capable of aggregation on a global scale. This could then begin to meet the needs of policy makers in the absence of any other detailed worldwide construction industry data.

Keywords: Global construction data, construction sector system approach, cluster analysis, national construction industries, global construction yearbook

1. Introduction

Construction is a universal economic activity. The output of the global construction industry is achieved at a worldwide cost in terms of materials, plant and labour and in terms of pollution. Construction data on these and other economic aspects is gathered and made publicly available in almost all countries of the world. The website at the University of Westminster (University of Westminster, 2012) contains links to the majority of these sources.

However, according to the World Bank, (2011), the lack of international comparability especially in capital goods was a source of weakness in making international comparisons in the 2005 round of the International Comparison Program (ICP). A second round was implemented in 2011. However, since the 2005 round a number of issues have been identified involving construction. These included problems in making international construction price comparisons and assessing the basis and level of comparison appropriate

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for construction. The ICP ask how quality and level-of-service differences among countries might be incorporated in such comparisons.

The concept of a global construction industry implies that it is at least conceivable to aggregate the national construction industries of all countries. This is essential if the global impact of construction is to be measured. Only measuring the economic activity of one country in isolation gives no indication of what may be occurring internationally with international implications and consequences. Without an international perspective it is not possible to devise policies to counter damage to the natural environment, inequalities of wealth, or encourage the spread of good practice and sustainable development for humankind.

In order to aggregate the output of all construction industries, it is necessary to identify the relevant data and bring it to a common measure or yardstick. However, practical difficulties emerge in the data. Moreover, even accessing the data is problematic. To demonstrate the some of the issues and begin the process of integrating the construction data of different national statistical systems two small case studies have been conducted to critique the data available on the internet.

In the case of national income accounts a universal system has been established and this system is used by the United Nations to enable comparisons of national income to be made. The national accounts of every country are given in US dollars and national currencies in current and constant prices. It is conceivable that something similar could be devised for national construction industry data. Such a system would be the eventual aim of this research. The result would be improved data sets on which to base global and national construction policies, international comparisons and sustainable development.

This introduction is followed by two brief case studies, which are used to identify distinctive features that can be found in national construction data sets. The two construction datasets used are South Africa and the PR of China. These are discussed with a view to finding commonalities and differences as well as difficulties in accessing the statistics. The subsequent section returns to an earlier report of the CIB to discuss some of the theoretical issues that arise in identifying the scope of construction data and combining construction industry information internationally. Two examples of construction industries in Australia and Canada, discussed in the CIB report, are used to illustrate further the scope of the construction issues that could be developed. In the final section proposals and strategies are suggested to begin the process of developing construction economic data sets in a meaningful way.

2. Case studies

2.1 South Africa

Of all the data available on the African continent South Africa possibly produces the most comprehensive and easily accessible set of construction statistics. Entering the StatsOnline web page of Statistics South Africa, one click enables access to the latest publication available, which at the time of writing was the Construction Industry 2011 report. Downloading the main publication opens 15 tables describing various construction indicators.

The tables appear similar to information derived from the accounts of construction firms found in company annual reports. The breakdown of the construction industry is based on the income and expenditure of firms according to the types of service they provide, ranging from site preparation, the construction of buildings and construction by specialist trade contractors to renting of construction or demolition equipment with operators, a breakdown of work similar in scope to that of the Standard Industrial Classification (SIC) codes used in NACE, an acronym, which stands for the Nomenclature statistique des activités économiques dans la Communauté européenne, namely: the classification of economic activities as defined in the European Community. For each type of service, the opening and closing values of inventories are given as well as net profit or loss, the value of fixed assets, and capital expenditure on new assets.

Information is also given on the source of profits for each type of service or specialism. These sources include sales, services (construction work), rental and leasing activities, interest payments and profit from the sale or leasing of assets. A further breakdown of expenditure is also given in terms of purchases, payments to subcontractors, salaries and wages, depreciation, rental of plant and machinery, vehicle running costs, and repair and maintenance. Another table describes the value of fixed assets owned by each type of service firm from site preparation to demolition contractor. Details of current and non-current assets and liabilities are also given for each type of service firm.

The picture that emerges from the data on the South African construction industry is similar to what would be provided by individual firms from their own profit and loss accounts and balance sheets. The result is a vision of the performance of the industry in terms of its financial viability and productivity. This data set of the South African construction industry could be used as the basis for benchmarking data and estimating the aggregate performance of firms in a particular construction industry for international comparison purposes.

2.2 PR of China

Chinese data sets are available from the National Bureau of Statistics of China, (2013). Although more recent annual data up to and including 2011 appears to be available, the most recent year for which data is freely accessible, at the time of writing, is 2003. Chapter 14 of the China Statistical Yearbook is concerned with construction data, broken down into

32 subheadings, including 'main economic indicators' of construction enterprises, total construction output value by region, construction value added, pre- and post-tax profits of construction enterprises, labour productivity, number of construction enterprises by registration and status, number of staff and workers in construction enterprises, number and power of machinery and equipment owned, assets, liabilities and creditors of construction enterprises, total income of construction enterprises, construction quality of construction enterprises and state owned construction.

The emphasis on enterprises and state owned construction reflects the concerns of policy makers in the PR of China. In 1993 of the total of 20,998 construction enterprises only 505 (or 1.9 per cent) of construction enterprises were not state owned or owned by collectives. By 2002 the total number of enterprises had risen to 47,820 of which 27,107 (or 44 per cent) were foreign funded, or funded in Macao, Hong Kong or Taiwan. Thus not only had the number of enterprises more than doubled in the decade up to 2002 but the composition of those enterprises had shifted significantly away from direct public sector control. The figures for China also show that in the same period the average number of employees per enterprise was 405 people in 1993 and 470 in 2002.

These figures can be compared to the UK figures for the same year. In 2002 there were 166,181 contractors in the UK employing a total of 989,900 or only 6 employees per firm on average. In both countries, these figures may be read with caution, since UK firms tend to use a high proportion of casual labour not recorded as employees. Nevertheless, the contrast is striking. Also striking is the rapid increase in productivity in the PR of China between 1997 to 2002. According to Table 14.7 in the China Statistical Yearbook, in these six years productivity rose from 12,089 Yuan per person in 1997 to 19,316 Yuan in 2002, an increase of 37 per cent.

3. The Construction Sector System Approach

In 2004 the CIB published a report entitled, The Construction Sector System Approach: an international framework, edited by Carassus, (2004). This report contained a number of papers on the construction industries of Australia, Canada, Denmark, France, Germany, Lithuania, Portugal, Sweden and the UK on the theme of setting out an international framework to study the construction sector. Taking the report as a whole, several common themes emerge and it appears useful to use the report as the starting point of further study and research. The main theme was, of course, the sector system approach as it applied to the construction sector of each country considered.

Carassus (2004) argued that the construction industry had moved from large scale production to providing the services of the built environment. However, it can be argued that on a sector-wide basis the two concepts of production and services are intertwined and indistinguishable, even if firms may specialise in different aspects of the production of the built environment, including facilities management. Without physical buildings and infrastructure there would be no built environment and nothing to service and no built

services to provide. Production may be more circuitous and complex than in the past, due to increasing levels of specialisation caused by technological developments and layers of ownership and complex financial arrangements, such as the public private finance initiative, (PFI), and public and private partnerships, (PPP), which were prominent in the 1990s and early 2000s before the financial crisis of 2007. Nevertheless it is important to recognise that the physical built stock requires tending and new additions to the stock and demolition of redundant or obsolete buildings do take place.

With PFI and PPP there appeared to be greater emphasis on the life cycle of buildings and not just the production of the physical built assets. Carassus focused on a sector system approach, bringing the following issues together: the aim of construction activity, the shaping of its characteristics, grouping of construction activities, profit formation in the construction sector, fragmentation of the construction production process, the operational configurations of players and institutional regulations affecting the building process. (Carassus 2004, p8). According to Carassus, there is a distinction between construction industry analysis and construction sector systems analysis. Analysing the construction industry focuses on building buildings and infrastructures whereas a construction sector systems approach focuses on producing and managing the services provided by the built environment throughout the life of the built assets.

Although clearly an important distinction, the measurement of construction activity entails the former approach, restricted to those activities that build new or repair and maintain the existing stock of building. How that stock is managed, while clearly important, is beyond the scope of the study of global construction data at this stage. This may be contentious as Carassus (2004) rejects the principle that the main aim of construction is "to produce and manage necessary structures for people's living and working environment," (p10). Instead he says the main focus is "to produce and manage the services" of the built environment throughout their life.

Carassus (2004) defines the construction economic sector system as the organised complex of commercial and non-commercial relationships between productive and institutional actors producing and managing services of built structures throughout their life cycle. This definition includes the producers, consumers and regulators and the rules and regulations governing their activities. However, the focus of the following analysis of construction remains construction production activities and the materials and other resources used in the process.

Two country analyses, Australia and Canada, included in the CIB report, demonstrate the extent of construction activity that could be incorporated into discussions on global construction data. For example, de Valence (2004) points out that in Australia, the output data of the construction industry is divided into three distinct industry sectors, namely residential, non-residential and engineering construction. According to de Valence, in the 1990s, there was a shift in the housing market from separate houses to medium and high density developments especially in parts of Sydney and Melbourne. This indicated that shifts in the types of building may have had a significant impact on the interpretation of the data. The division of engineering construction data also reflects conditions in Australia, where a relatively small population inhabits a large area of land. In the Australian data set

the engineering construction sector is divided into six major components. These are road and bridge construction, electrical generation, transmission, water and sewerage, processing plants including oil and gas pipelines, and other types including railways, harbours and pipelines.

De Valence points out that there are no national built environment standards in Australia and planning is under the control of state governments. However, the majority of development decisions are made not at the state level but at the local level. Because each state has its own legislation regarding planning, development and environmental protection, construction market data needs to be considered on a state by state basis.

In Australian data size of firms by employment can be measured in size categories of less than 5, 5 to 19 and 20 and over. These size classifications are not compatible with the size classification used in the UK. The specialist trades are broken down into five broad categories, namely, site preparation, building structures, installation trades, building completion and other construction.

De Valence also discusses a broad definition of construction, which includes on-site services (trade services), client services (engineering, technical, etc.) building and construction project firms, materials and product suppliers, and machinery and equipment suppliers. By including materials and equipment suppliers, the size of the construction sector almost doubles in income, (from $58.6bn, to $110.4bn in the year 1996 to 1997) and employment, (from 484,100 to 682,000 employees in 1995 to 1996), according to de Valence (2004 p.31).

The value of repair and maintenance (R&M) is divided between residential and non-residential work on existing stock. In terms of residential R&M official statistics in Australia only record data on alterations and additions to houses for work valued at over AUD$10,000. According to de Valence, in 2002-2003 this work was valued at $4.6bn. To estimate spending on residential renovations, he suggests including a large proportion of the $8.3bn hardware sales to produce a total of more than $13bn per annum.

As the Australian Bureau of Statistics does not record R&M in the non-residential sector, de Valence suggests the equivalent can be estimated from a report produced by Arthur Anderson (1999) for the Facility Management Association of Australia. According to that report the total turnover of the Australian facility management industry was estimated to be more than $35bn, though de Valence points out that this could be a large underestimate. In any case, this estimate was not necessarily totally related to R&M. De Valence suggests that a final adjustment of both non-residential expenditure on facilities management and R&M would be approximately at least $15 billion.

Similarly, Manseau (2004) estimates the Canadian construction sector as measured by the output of contractors at between 10 and 12 per cent of GDP. The estimate is necessary because appropriate data for related sectors is not available. General and specialist contractors comprised 5.2% in 2002 (Statistics Canada, 2003). Manseau acknowledged that the size of services in construction, including design, engineering and technical services was very difficult to assess.

Data for construction in Canada include building permits, housing starts, completions and vacancy rates, flows and stocks of fixed non-residential capital, wage rates and various price indices. It also includes construction capital expenditure giving a breakdown of as many as 56 building types. However, many of the building types are distinct from those in use in the UK official construction statistics, those some terms overlap with the UK typology. For example, under commercial building construction the Canadian data includes laboratories, freight terminals, grain elevators, automotive dealerships, motels, convention centres, fast food outlets, plazas, bunkhouses, dormitories, camps and broadcasting and communication buildings.

Manseau points out that the share of each major type of construction output was relatively stable in the 1990s. For example, the residential building sector was around 33% of total construction, the non-residential building was 20% and the engineering sector accounted for the rest at 47%. In describing the size distribution of firms in Canada, Manseau reports that in 2000, the sector comprised approximately 215,000 contractors employing 896,000 people, with a third of firms being sole person firms and with 95.6 % of all firms receiving a revenue of less than US$1.4M in 2003. According to Manseau, the turnover of only 0.3% of contractors exceeded US$14m but the combined output of these largest firms represented over 23 per cent of total construction output in Canada.

From the data it would appear that repair and maintenance is a lower percentage of construction output in Canada than it is in Europe, according to Manseau (2004), who argues that as much as CAN$50bn is spent each year on replacement rather than repairs to existing stock.

4. Discussion

Whatever assessment of the size of the Canadian construction industry is made from existing data, Carassus (2004) draws the conclusion that using a systems approach to assessing the size of the construction sector in any country increases its size significantly and hence gives more weight to its importance to the economy. This also takes into account the shift in economies towards the tertiary sector, emphasising the service aspects of construction as well as the physical production of buildings and structures.

Carassus refers to four existing classifications used by Boyer (1996) to identify the main institutional contexts of markets and goes on to add a fifth. The first type of market environment is an ‘anglo-saxon’ model that relies on liberal market values, relatively little regulation, private finance and relatively poor conditions of employment. These characteristics were typified by the UK, Canada and Australia. The second model, he termed the ‘social-democrat’ model which can be described in terms of tripartite agreements between the state, employers and the unions. Examples of social democratic construction systems included Denmark and Sweden.

Similar to the social democratic system, the third model called 'corporatist' also relies on a system in which the state, employers and unions, called "social partners" negotiate to protect shared social values, including worker protection. This described the system in Germany. The fourth system is defined as 'public'. In this system the role of government is emphasised, as it is seen as the co-ordinator of the economy and finance. Examples of public systems include France and Portugal. Carassus' fifth model, which he refers to as 'transitional' applied to those countries, whose construction sectors were shifting from a soviet style planned economy to a market driven system. Typical of this category of construction industry was Lithuania.

Describing a number of types of business environment, Carassus' approach of classifying the countries in his report used cluster analysis, a method of grouping countries by similar economic characteristics. Jackson and Deeg (2008) view clusters as similar combinations or institutional configurations of economic variables in different countries. In the case of construction this could include the stage of development, the technology and materials used and the output mix of buildings and structures.

Amable (2003) carried out a cluster analysis of a greater number of countries than those in the Carassus study, using various indicators outside construction, including competition, labour markets, corporate governance, social policies and education systems. This produced more general types of capitalism, namely: market-based, social-democratic, continental European, Mediterranean, and Asian. Though still Euro-centric, these descriptions may well be appropriate for an approach to global analysis of construction industries. However, while clusters may emerge in terms of Amable's geo-economic, geo-social and geo-political analysis, they may be too general to apply to data on the construction industry. The focus on aspects of the construction industry and measures of construction output remain the ultimate focus of this research.

5. Concluding remarks

Cross border differences in construction industries may well imply that no one universal measure or system of measuring can be adopted to make all construction industries meaningfully comparable or capable of being aggregated. It may well be necessary to divide national construction industries into sub-groups in a manner first suggested by Turin (1973). Elkhalifa and Shaddad, (2010), describe Turin's classification of national construction industries in terms of international modern, national modern, national conventional, and traditional. Each classification has a distinct and predominant use of materials, ranging from modern methods using technological developments to using locally sourced materials applying simple techniques, depending on building types and civil engineering requirements.

Of course many countries have been omitted from this brief survey. The purpose of which is to show the possibilities of undertaking far more international comparisons and investigations to begin the process of aggregating and comparing data sets, a process begun by the 2004 CIB report edited by Carassus (2004). It therefore follows that a yearbook

based on a development of an annual update of the approach used by Carassus (or if not annual, then bi-annual) would be an extremely useful document, if carried out on an global scale. Such a project could be the output of the CIB Global Construction Data Task Group.

The issues identified include the distribution of building and civil engineering between residential, non-residential and civil engineering, the distribution of orders between corporate, non-corporate and public sector, construction as a share in value added, construction employment as a proportion of total employment, the distribution of new build and work on exiting stock in both building and civil engineering, the value of the net addition to the built stock in both absolute output terms and as a proportion of the value of the built environment stock, and the value of the built environment stock as a percentage of GDP, the distribution of firms in the construction sector by numbers employed by firm and by specialism and region. Other aspects of the construction production process include materials, international trade, and construction professionals.

Taken together these indicators form one definition of a construction sector system approach. Carassus (2004) sees these as enabling analysis of four aspects of construction: namely, statistical analysis, strategic planning of firms, sustainable development and construction innovation. On a global scale, this work would also be useful for national government construction policies, international organisations such as the United Nations, the World Bank, regional development banks and many other users. Its importance cannot be over-stated.

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The performance of early contractor involvement contracts

Branko Koncarevic[1]

Abstract

Recent developments in the construction market have highlighted the need for alternative procurement models that offer substantial benefits over traditional models, when considering overall project outcomes. Accordingly, there is a need for an improved project delivery method. Early contractor involvement (ECI) is one such model that holds promise for resolving project management challenges in the infrastructure sector. The literature indicates that ECI adopts greater relational contracting principles and more equitable risk allocation than traditional contract types. However, the performance of ECI contracts has not been comprehensively reviewed in the literature, due to the emergent nature of this contract form. An extensive literature review was undertaken to assess the extent of current knowledge in this area, to synthesise such knowledge and to develop the conceptual framework to guide the fieldwork phase of this research, which is planned in the future. That phase will examine the association between relationship quality on the project team and project outcomes. This paper reports on the results of the literature review, which is the first phase of the larger PhD study.

Keywords: procurement, partnerships, collaboration, outcomes, success

1. Introduction

The historically poor performance of traditional contracts has attracted criticism from many scholars (Belout and Gauvreau 2004; Eriksson and Westerberg 2011; Rahman and Kumaraswamy 2004). Moreover, the construction industry is often heavily criticised because of poor project outcomes in terms of time, cost and quality. Traditionally, literature on project performance has focused on this 'iron triangle' (Swan and Khalfan 2007) and client's imperative for immediate project success (Eriksson and Westerberg 2011).

Recent developments in the construction market have highlighted the need for alternative procurement models that offer substantial benefits over traditional models in terms of overall project outcomes (Leiringer, Green and Raja 2009). Eriksson and Westerberg (2011) stated,

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“for a new procurement procedure to be implemented, key change lies in understanding how novel procurement models actually work and effect project performance”.

In Australia, early contractor involvement (ECI) contracts have recently emerged as a more promising procurement approach (Swainston 2006). Resolving the poor performance of traditional contracts is highly important for project success; however, research on this topic is limited. Only a few limited studies exist, due to the emergent nature of ECI contracts (Mosey 2009b; Song, Mohamed and AbouRizk 2009; Van Valkenburg et al. 2008).

Prior research has identified ECI as “a radical change from the traditional business practice” (Song, Mohamed and AbouRizk 2009), resulting in many challenges because contractors are involved in early design stages. Their study singled out contracting practice, culture change and teamwork as the biggest challenges in ECI. Nichols (2007) confirmed this observation, citing difference in culture as one of the major factors causing the poor performance of the ECI model. According to his report, Nichols (2007) suggested the causal factor in these areas is due to lack of understanding of the ECI concept. As there is limited research on ECI and the benefits it can provide, Song et al. (2009) have recommended that people who have been involved on successful ECI model can provide knowledge and experience that can provide a better understanding of ECI. This literature review draws on this practical experience as well as theoretical contributions to understand the positive and negative impacts of ECI.

The idea of involving contractors in early design stages is not new; however, ECI is novel as a contract delivery model (Swainston 2006). The UK pioneered the development of ECI when the Highways Agency (HA) first adopted the model in 2001, and since then, the HA has used this relationship contract as its preferred procurement route. In Australia, the Queensland’s Department of Transport and Main Roads (TMR) introduced ECI in November 2005 with a pilot project, the Maroochy River Bridge Duplication.

In Australia, there are three contract delivery ECI models (Wilson and Abson 2010). The first is ECI contracting, which is like a negotiated D&C contract. ECI is a process in which a contractor and designer work together in a contractual relationship with the client; first to scope and price a project (Stage 1) and then to design and construct a project (Stage 2). Secondly, dECI (double ECI) is a D&C procurement approach that involves selecting two competing groups. Each group consists of a contractor and its designer. These groups simultaneously develop concept designs and undertake pricing. One of these groups is then selected to undertake detailed design and construction. Thirdly, early tender involvement (ETI) is a procurement approach that involves the choice of two or three competing contractors to participate in value engineering and the refinement of a client’s preliminary design (Wilson and Abson 2010). This process amends the design and contributes to the finalization of tender documentation. Generally, the competing contractors will then offer a schedule of rates or a lump sum price based on the refined tender documentation made into a traditional contract (Wilson and Abson 2010).

2. ECI Characteristics

ECI has several distinct advantages over traditional contract types and is emerging as a preferred model for many government client agencies across the globe, notably in Australia, the Netherlands, New Zealand, the United Kingdom and the United States of America (Scheepbouwer and Humphries 2011). ECI can be seen as a hybrid model of relational and traditional contracts (Mosey 2009a; Van Valkenburg et al. 2008), aiming to obtain the benefits of both models. When compared to traditional contract models, ECI will allow greater partnership, as the contractor will work closely with the client in the early design stage, unlike the construct-only model. Furthermore, when compared to traditional contracts such as D&C, risks in ECI are shared equally throughout the project, and until all risks are assessed, the price won't be agreed upon (Wilson and Abson 2010).

The Australian ECI model starts like an alliance project. Depending on the complexity of the project and assessed risks, the project may continue in one of two ways; (1) if design allows less complicated execution and risks are minimal, the contractor will take over execution of the project. In this case, project continues as D&C model. However, (2) the project will continue as an alliance if the risks are too high due to complexity of the project and the nature of these risks. Furthermore, when the client is not satisfied with contractor's performance, the contract will be re-tendered. This scenario does not allow the original contractor to re-enter the project. Since risks are managed as early as possible, ECI are expected to achieve substantial value for money for the client.

As a relational contracting model, ECI requires a close working relationship between client, contractor and designer. The three parties involved benefit from this arrangement as they are able to identify and align goals and objectives building cooperative relationships (Mosey 2009a; Ng et al. 2002). Moreover, closer relationships in ECI models increase trust among these parties benefiting from the open communication while providing solid ground for innovation (Eriksson 2008; Mosey 2009a; Song, Mohamed and AbouRizk 2009; Van Valkenburg et al. 2008) and improving design and construction processes (Eriksson 2008).

However, in order for ECI to be successful, client, contractor and designer need to be jointly committed to best-for-project outcomes (Chan, Chan and Ho 2003). This means that trust needs to exist between the parties. Lack of trust can sometimes exist for the client, when the contractor and designer have no experience in ECI models (Eriksson 2008; Jergeas and Van der Put 2001). As a solution, Eriksson (2008) recommend implementation of soft criteria, (e.g. collaborative ability, shared values) to resolve these issues while the client is selecting their contractor and designers. This approach can be a starting point for building open communication between client, contractor and designer attitude ensuring trust (Ng et al. 2002).

One of ECI core principles is improved risk management, by engaging contractors in early project phases. This approach puts the client in a position to identify and allocate risks more effectively (Mosey 2009a; Rahman and Kumaraswamy 2004). Due to this approach, the ECI model requires client, contractor and designer to work in a more collaborative manner.

In ECI, contractors are recognized as having invaluable input to design; therefore, contribution of their knowledge and expertise in early design is expected to improve design and buildability (Mosey 2009a; Song, Mohamed and AbouRizk 2009). Furthermore, contractor's themselves also benefit from ECI since their input has a direct impact on their own performance in terms cost, time and quality. (Gil et al. 2002; Jergeas and Van der Put 2001; Song, Mohamed and AbouRizk 2009). This contribution of knowledge and expertise guaranties contractor's profit through better cost control along with reduced cost for contract administration (Song, Mohamed and AbouRizk 2009).

In summary, previous studies showed ECI can lead to improved project delivery (Chan, Scott and Chan 2004; Jergeas and Van der Put 2001; Mosey 2009a; Song, Mohamed and AbouRizk 2009; Van Valkenburg et al. 2008). This positive impact is possible because ECI can reduce cost due to contractor's early input (Jergeas and Van der Put 2001; Mosey 2009a; Song, Mohamed and AbouRizk 2009; Van Valkenburg et al. 2008). Unlike the traditional contracts, ECI performance arises from the potential for improved relationships as a consequence of improved trust (Chan, Scott and Chan 2004; Jergeas and Van der Put 2001; Mosey 2009a; Song, Mohamed and AbouRizk 2009; Van Valkenburg et al. 2008). As a result, closer relationships on ECI projects can be expected, leading to openness in communication. As client, contractor and designer jointly scope project, ECI projects can benefit from shared and efficient use of resources resulting in delivering projects with improved quality (Song, Mohamed and AbouRizk 2009; Van Valkenburg et al. 2008). Since contractors give their input early in design, ECI models benefit from improved schedule performance as decisions are made in the early phase of the project (Song, Mohamed and AbouRizk 2009).

The main challenge for ECI in the existing literature revolves around the unwillingness of the client and contractor to share vital information (Eadie et al. 2012; Song, Mohamed and AbouRizk 2009). Song et al. (2009) also identified cultural barriers as a major obstacle for successful performance of ECI contracts. Furthermore, existing studies underline the need for better understanding of ECI among client, contractor and designer to enable it to be fully embraced by the practitioners (Mosey 2009a; Song, Mohamed and AbouRizk 2009).

The literature emphasizes that one factor in particular effects project performance - the quality of the relationships between the client, contractor and designer (Eadie et al. 2012; Mosey 2009a; Song, Mohamed and AbouRizk 2009; Van Valkenburg et al. 2008). The reason is that at the early stage of a project, little is known about the project activities and project execution. This means that project uncertainty is at its highest during this stage of the project, especially for projects with a high degree of novelty such as ECI.

As the client, contractor and designer have different interests and ambitions in a project, they will influence the project according to what role they play in relation to the project. This potential influence of the client, contractor and designer is highest in the early phase, before a detailed agenda is set and the cost involved for making changes is low. This implies that the early phase of a project development is the most important time for innovative activities and for planning a project execution that will optimise project outcomes.

3.Conceptual Framework

The impact of project delivery methods on project performance is a well-established topic in the literature (Al Khalil 2002). However, recent studies raise the need to verify links between relationships and outcomes in ECI projects. The majority of ECI studies had found that projects delivered under the ECI method have a better chance of achieving goals when compared to the traditional procurement models (Mosey 2009b; Scheepbouwer and Humphries 2011; Song, Mohamed and AbouRizk 2009; Van Valkenburg et al. 2008). The next phase of this research will examine the features of ECI projects that give them the best chance of achieving goals, by examing the research question: “does relationship quality have a significant impact on ECI project outcomes?”

To answer this question, a conceptual framework that derives from this review and its conclusions is proposed (Figure 1). This framework can be used in any ECI project context and scholars can fine-tune the variables used. This framework can guide researchers with the development of appropriate scales for future studies.

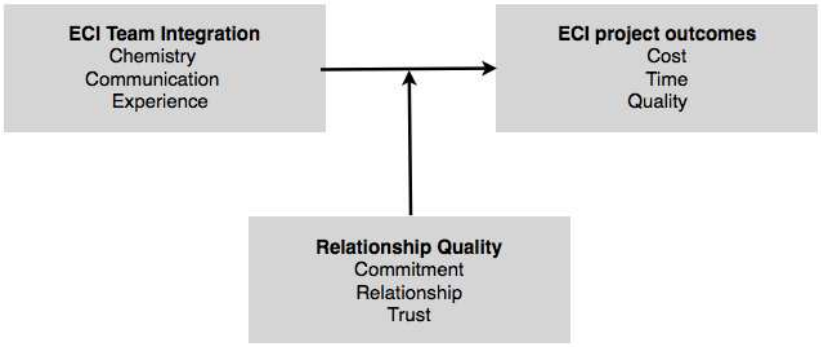

Figure 1: Conceptual Framework

The main challenges in implementing ECI arise from relationships, trust and commitment. These challenges identified in this literature review are the main constructs of the relationship quality concept (Athanasopoulou 2009) that is a starting point of larger PhD study. Future research will address the importance of the early phase of projects as one of the fundamental issues associated with ECI, and the high degree of uncertainty due to their novelty. In spite of the fact that past research shows that how the early phase of a project is executed may dramatically influence the project's outcomes, it is surprising to observe that this has almost been neglected in the Australian construction industry. Another observation is that the current understanding in this industry is limited as to which aspect of ECI has the greatest effect on total project performance. Improved insight into the ECI model will allow stronger involvement of client, contractor and designer in the early phase, and enhanced project outcomes.

In their seminal study, Dwyer, Schurr and Oh (1987) have established relationship quality as a concept made of several constructs. Athanasopoulou (2009) reviewed this and other

literature on relationship quality and found that only three major dimensions - commitment, satisfaction and trust have been validated in different contexts. This is in line with findings of Naudé and Buttle (2000) who also acknowledged that commitment, trust and satisfaction are main dimensions of relationship quality comprehensively studied in the literature. Guided by the extensive relationship quality literature review, the future study will focus on commitment, satisfaction and trust as the key relationship quality drivers impacting relationship quality on ECI projects.

The relationship quality literature emphasises that the participants in a relationship must benefit for it to continue for the long term (Hennig-Thurau, Gwinner and Gremler 2002; Hennig-Thurau and Hansen 2000). In the ECI context, for the client, these benefits can be focused on either the project outcomes or on the relationship itself. The latter types of relationship quality outcomes are referred to as relational benefits. Furthermore, in the context of this study, these benefits are those that client is likely to receive as a result of having cultivated a relationship with a contractor and/or designer in terms of project outcomes.

The impact of relationship quality on operational performance has been extensively researched in the relationship marketing literature (Fynes, De Burca and Mangan 2008; Fynes, de Búrca and Marshall 2004; Fynes, Voss and de Búrca 2005; Su et al. 2008; Van der Vaart and Van Donk 2008). All these studies have introduced numerous performance measures and methodologies emphasising that relationship quality leads to superior operational performance in terms of cost, time and quality, among others. Another common theme to these studies is the role of management in improving performance (Fynes, De Burca and Mangan 2008). However, the relationship quality drivers identified in this study have received little or no attention in the current literature. While relationship quality drivers have been extensively tested in the marketing literature in terms of their impact on relationship performance (Fynes, De Burca and Mangan 2008; Fynes, de Búrca and Marshall 2004; Fynes, Voss and de Búrca 2005; Heide and John 1990; Morgan and Hunt 1994), their impact on ECI performance has received no attention in the project management literature. Accordingly, the future study will examine how relationship quality effects ECI performance in terms of cost, time and quality.

The concept of the study points to the role of relationship quality in building strong relationships between client, contractor and designer in ECI resulting in enhanced relationship quality. The project participants can improve project outcomes by developing relationships based on commitment, satisfaction and trust (Athanasopoulou 2009; Naudé and Buttle 2000). In summary, enhancement of the understanding of the key relationship quality drivers in ECI is critical to the effective management of relationships between the client, contractor and designer.

4.Conclusion

This paper has developed a framework that will help organize the fieldwork being planned for a larger PhD study. The fieldwork will aim to focus on one factor in particular that effects project performance - the relationship quality of the project participants. The rationale for this

research is that, at the early stages of a project, there is a limited research about the relationships in ECI and their impact on project performance. For projects with a high degree of novelty, such as ECI, the uncertainty is the highest in the early stages of the projects. Although the influence of client, contractor and designer is highest in this early stage, there is a dearth of research about how their relationships impact on planning and project execution. These issues are poorly addressed in the literature and will be addressed in the upcoming PhD study.

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Sea Level Rise and Smart Historic Coastal Communities: Lessons from Savannah, GA and St Augustine, FL

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Abstract

Experience and lessons learned suggest that the most effective strategies will require designing a number of responses at both the regional and local levels. Many efforts have underemphasized community-based research and have subsequently resulted in outcomes of climate models and scenarios that are too broad for effective planning and adaptation at local scales. There is a need for a 360 degree assessment of the critical issues based on a case study approach. The research presented in this paper investigates impact of projected Sea Level Rise (SLR) on representative historic buildings in coastal communities in the South East focusing specifically on St Augustine Florida and Savannah Georgia. Several lessons can be drawn from the natural and man-made artefacts in such historic cities. The paper discusses specific ways through which such cities exemplify practical responses to the climate. This notwithstanding it is important to bear in mind that they have not been exposed to environmental conditions that are drastically being altered through climate change. There is a need for a 360 degree assessment of the critical issues. The discussion in this position paper culminates into a description of an emerging collaboration framework that is directed at enabling stakeholders to perform such an assessment.

Keywords: Sustainability, Historic Communities, Sea Level Rise, Adaptation Planning

1. Introduction

2011 and 2012 may well be remembered as the point at which the "average American" developed a good understanding of climatic scale impacts in the form of extreme weather events (Institute for Sustainable Communities, 2012). The summer of 2011 became the second hottest on record with most States experiencing summer highs in excess of 100˚F (NOAA, 2011). July 2012 set the record as the hottest July and the hottest month ever observed since records began in 1895. The summer of 2011 and the summer of 2012 are

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second and third behind the summer of 1936. Drought conditions that gripped a record number of counties by mid-summer were reported as being the worst experienced since the Dust Bowl years of the 1930s. National Oceanic and Atmospheric Administration (NOAA) pointed out that heat wave and drought events affected 90 million and 80 million people across the U.S. in 2011 and 2012 respectively. The impact on human settlement has been catastrophic. For example, in 2011, U.S. experienced 14 extreme weather events that exceeded $1B in total damage (NOAA, 2011). The impacts of the more recently tropical storm Sandy included over two million households in the state of New Jersey, 72,000 homes and businesses were destroyed, and loss of human life. Storm surge and flooding affected a large swath of the state.

As a direct result of the growing frequency of these extreme weather events, climate change adaptation has rapidly moved up the policy agenda for many local governments which is a shift from the previous years when the focus was on mitigation. Climate change adaptation in this context refers to “adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities.” Climate change “mitigation” as used here means an action designed “to reduce the sources or enhance the sinks of greenhouse gases” associated with global climate change (Institute for Sustainable Communities, 2012). There has been a growing interest in understanding Sea Level Rise (SLR) and the associated risks of elevated tidal inundation, increased flood frequency, accelerated erosion, rising water tables, increased saltwater intrusion, and a suite of ecological changes.

This notwithstanding, many of the efforts have underemphasized community-based research (Riedlinger and Berkes, 2001). Such approaches result in outcomes of climate models and scenarios that are too broad for effective planning and adaptation at local scales (Jones, 2001). The authors’ research focusses specifically on assessing the local responses using natural and man-made artefacts in historic cities, which exemplify practical responses to the climate. Climatic changes are expected to affect coastal communities around the world, many of which are already considered vulnerable to on-going climatic variability (IPCC, 2001; Monrul and Mizra, 2003). As Klein and Nicholls (1999) point out, these biophysical changes result in socio-economic impacts such as loss of land infrastructure and coastal resources as well as declines in associated economic, ecological, cultural and subsistence values.

There are some efforts underway in industry and at every level of government to incorporate adaptive responses into existing climate change initiatives. As pointed out by the Institute for Sustainable Communities (2012), the US generally lags behind in international efforts on climate adaptation. The discussion in this paper is directed at specifically investigating the internal mechanisms, skill sets, and performance incentives within US communities that can enable them to transition towards a climate-change adaptive culture. The research presented in this paper investigates impact of projected SLR on representative historic buildings in coastal communities in the South East focusing specifically on St Augustine Florida and Savannah Georgia.

The discussion in this position paper is based on an on-going research project directed at assessing specific ways through which environmental conservation, green building and historical preservation professionals can collaborate to develop strategies for adapting to impacts of climate change and mitigating the associated threats through sustaining the built and natural environments.

2. Research Approach

Experience and lessons learned suggest that the most effective strategies will require designing a number of responses at both the regional and local levels. Many efforts have underemphasized community-based research and have subsequently resulted in outcomes of climate models and scenarios that are too broad for effective planning and adaptation at local scales. There is, therefore, a need for a 360 degree assessment of the critical issues based on a case study approach. As previously indicated this on-going research is directed at investigating the impact of projected climate change, focussing specifically on SLR, on representative historic buildings in coastal communities in the South East. Part of the work involves assessing case study buildings in St Augustine, Florida and Savannah Georgia. The context is culturally very significant. In 2015, the United States will celebrate the 450th birthday of its first successful colonial settlement – St. Augustine, Florida. Many of the original settlers' buildings still exist in St. Augustine as a testament to the long and storied history of this oldest continuously occupied American city. Savannah is unique among American cities. Not only does it retain Oglethorpe's original town plan of 1733, but much of its celebrated 18th, 19th and early 20th century architecture is extant as well. The Hostess City features a 2.2 square mile National Historic Landmark District—reputedly the largest of its kind in the United States—and that Landmark District includes thousands of historic buildings. Several lessons can be drawn from the cities' natural and man-made artefacts.

The authors are currently conducting a case study of historical buildings in the selected regions. The study will provide insights of current best practices, lessons baseline case of SLR impacts on historical buildings. Many of the efforts focusing on SLR (along with the associated risks of elevated tidal inundation, increased flood frequency, accelerated erosion, rising water tables, increased saltwater intrusion, and a suite of ecological changes) have underemphasized community-based research (Riedlinger and Berkes, 2001). Such approaches result in outcomes of climate models and scenarios that are too broad for effective planning and adaptation at local scales (Jones, 2001). Consequently, the longer term goal of the research is to tie any existing efforts into a broad framework of resilient, sustainable and smart coast community development. The authors will engage with different stakeholders to identify and prioritize the immediate threats specifically related to SLR; create a preliminary strategic plan for adapting using a SWOT analysis; and set up timeline for continuous improvements. This approach is expected to result in the development of a knowledge base and professional network for strategic planning for the adaptation of historic coastal communities to the threats associated with SLR.

3. Projected Climate Change for the Case Study Context

Research on global systems suggests that coastal communities and regions are becoming increasingly vulnerable to sea level rise (SLR) and climate change. As a result, researchers and practitioners are developing processes, tools and strategies for adapting to future impacts and the challenges to public safety, local economy and native ecosystems. The historic coastal communities selected for the study are among the oldest civilizations in the United States, which makes cultural and historic preservation an essential part of the national, regional and local initiatives on developing adapting strategies and best management practices (BMPs). Given that buildings are best representatives of the social, economic and environmental profile of a local community, it is of great interest to stakeholders at all levels to understand the potential threats SLR has imposed on buildings, the severity, and the efforts needed to mitigate such hazards. Unfortunately, there is very little literature in place addressing this issue, or there is no consistent records showing that a systematic and validated approach has been taken to assess the impacts of SLR on historical buildings in coastal communities.

Existing and projected changes to climate patterns around the world are expected to begin altering the behavior of hydro-meteorological phenomena within our lifetimes. Climate change is considered by many as the most far reaching and wide-ranging problem of our time. As it is expected to affect every sector of human life for years to come, there is a need for a holistic assessment of the critical issues. Rising sea levels and the risks triggered by changing weather patterns pose a substantial problem to the large portion of the world's population residing along the coasts and in cities built along major rivers including historic cities in Florida and Georgia. Table 1 gives specific examples of some of these changes (Ammon et al, 2009, Alvarez et al, 2001, Wilbanks et al, 2010 and Nearing et al, 2004).

4. Stakeholder Engagement and Participatory Capacity Building

Climate change is likely to have dramatic impacts on sea change communities through diminished potable water supplies, rising sea levels, storm surges, and increased intensity of flood events – with indirect impacts on health, financial sectors, and biodiversity. A comprehensive review of the existing body of knowledge has revealed that minimal work has been to develop adaptation strategies for climate change-buildings at the regional and community level, which entails the complexity of various building types across a spectrum of life spans, the embedded historical and cultural legacies, and the socioeconomic ties with the local context. Given the inherent diversity within sea change communities with regard to age, culture, and socio-economic status there are likely to be differences in ways of adapting (Smith et al, 2011). Early approaches to adaptation took a ''top-down'' perspective, moving from global climate model scenarios to sectoral impact studies and then to assessments of adaptation options (Van Aalast et al, 2008).

Buildings provide an interface between the outdoor environment, which is subject to climate change, and the indoor environment, which needs to be maintained within a range that keeps the occupants safe and comfortable, and which is suitable for any key processes that are executed within the enclosed space (De Wilde and Coley, 2012). Given that the

performance of buildings with respect to this parameter heavily depends on exposure to weather elements, their design, construction and maintenance should factor in both the current and future climatic conditions. The current practices must be re-evaluated based on the possible climate change scenarios (Morton et al, 2011). Some researchers have tried to address this through focusing on the adaptation and resilience of buildings to a changing climate. Most of such efforts assess use relatively straightforward performance indicators such as energy use for heating, energy use for cooling, and building overheating (De Wilde and Coley, 2012).

Table 1: Summary of Projected Climate Changes

Climatic Condition	Florida	Georgia
Temperature	Florida may experience increases in average temperature of between 4 and 10°F over the next 100 years. This change will also be associated with warmer summer highs and cooler winters. The summer heat index, which reflects both temperature and humidity, will increase by 8 to 15°F by the year 2100.	Existing climate models have been predicted that the temperature could be increased by 4.5 to 9°F on average by 2080s.
Precipitation	Rainfall amounts in Florida are projected to either increase or decrease by as much as 20%. This could result in longer stretches of wet and dry periods with droughts more likely to occur.	Precipitation could increase or decrease by 20% in the next century
Soil moisture	The rainfall amount and intensities are the major factors controlling erosion under climate change. The results of simulation study suggest that erosion will increase approximately 1.7% of each 1% change in annual rainfall.	Rainfall is the major factor controlling erosion under climate change. The results of simulation study suggest that erosion will increase approximately 1.7% of each 1% change in annual rainfall.
Sea level	Sea level is expected to rise roughly 8 to 16 inches without taking into account on-going land subsidence (which varies by location). Taking subsidence into account, actual sea level rise of 16 inches is likely and as much as 30 inches may be possible in significant areas of Florida.	The average sea level rise estimated to be somewhere between 8 and 24 inches by 2010.

Climate impact assessment studies require a definition of the future conditions that will be considered in the analysis (i.e. the climate change scenario and the control settings), a definition of the object under investigation (a building and its subsystems), and a focus for observation and quantification (definition of appropriate performance metrics). The emerging

body of knowledge, as summarized by De Wilde and Coley (2012), covers the following areas:

- Climate data for building performance studies (e.g. Guan, 2009, Gaterell and McEvoy 2005, Nik et al, 2012);

- Climate change impact studies for the built environment (e.g. Hacker et al, 2005, Wan et al, 2011, Jentsch et al, 2008);

- Performance metrics for climate change impact studies (e.g. De Wilde et al, 2011, Williams et al, 2011).

The contents of these studies captured the spectrum of individual buildings, building systems as well as the urban realm, and investigated issues across the life cycle of buildings from planning, design (Pyke et al, 2012, Robert and Kummert, 2012), construction, to facility management (De Wilde and Tian 2012). There is consensus across such studies that the existing policy and regulatory framework is based on historic climate. The review of such efforts supports the authors' original assumptions concerning the e absence of strong external pressure to incorporate climate change issues into decision-making (regulation or taxation in this case). Coupled with the existence of forces that directly work against this (that is, the cost of climate-related measures combined with limited liability for future buildings), in combinations with the inherent uncertainty of climate change, there is no incentive for the stakeholders to shift their mode of operation from the prevalent "wait and see" approach to a more pro-active one that requires taking action now (Morton et al 2011, Steemers, 2003).

Hertin et al. (2003) highlighted that the currently loose incentive structure is likely to lead to questions of climate change adaptation being driving by principles of "satisficing rather than optimizing". That is, climate relevant decisions are likely to be made in response to specific events and governed by the practical constraints that surround these (i.e., time, money, and regulation) rather than by more long-term goals and ideals (e.g., to design and construct buildings that will remain resilient and function given a changing future climate).

In addition to conducting a comprehensive review of existing literature, the authors have also interviewed different stakeholder to establish the baseline cases of SLR impacts on local historical buildings. The initial findings have revealed that knowledge gaps remain a key barrier to designing and implementing strategies for adequately responding to the threats associated with sea level rise. The targeted stakeholders have expressed a strong interest in working within a multi-disciplinary setting to develop a comprehensive understanding of the threats from projected sea level rise. As a direct response to this request, the authors are convening a workshop in the city of Savannah that will be hosted by Georgia Southern University. Confirmed participants include city planners, building officials, owners, designers, contractors, and community representatives. The focus of the workshop will be building consensus on defining the problem and seeking for adapting strategies. SWOT analysis and other strategic planning models will be utilized to fully understand the impacts, risks, resources and opportunities associated. The deliverables will be a consensus report on

identified major impacts of SLR on historical buildings, the social, economic and environmental risks of such threats, critical financial and personnel resources needed to mitigate such risks and the opportunities in developing effective action plans through broad collaboration among stakeholders.

5. Conclusions and Further Work

Although climate change is a global threat, action implementation is local. In order to effectively prepare for and adapt to the impacts of climate change, local action at the state, city, or even neighbourhood level must be coordinated efforts on a wider scale. The success or failure of such depends on community perception. As Rebetez (1996) points out, "perceptions play a crucial role in the ability of a community to adapt to climate change as misguided views can impede a group's response or ability to cope with external stresses, leaving them vulnerable." Community vulnerability is exacerbated when community perceptions about their environment are adversely affected by the introduction of new technologies that alter the way in which they access (indigenous) traditional resources Alessa (2007). While it is clear that new technologies and local knowledge impose conflicting tensions on community vulnerability, it remains uncertain how these two processes interact with each other to influence individuals' perceptions of their local climate, and how this leads to the emergence of an overall community perception that drives local decision-making. In order to gain perspective on the tension between new technologies and local knowledge, the authors will in subsequent efforts also investigate how community perceptions evolve over time when subject to changes in technology and local knowledge, and how these dynamic perceptions influence the vulnerability of a community to climate change.

As previously indicated, there is a great need for collaboratively developing and distribution knowledge among different stakeholders. In subsequent efforts the authors will contribute to dissemination and awareness creation activities through the use of existing collaborative partnerships. Within the University of Florida this will be achieved through partnerships with i) the Shimberg Center headed by Bill O'Dell has extensive experience in undertaking community-based projects with different stakeholders in Florida including but not limited to State Officials and champions of the needs of Low Income Families; ii) the Urban Planning/ Landscape Architecture driven Sea Level Rise project in Levy County and St John Florida initiative headed by Kathryn Frank (Dr Obonyo is a senior personnel in this project); iii) Morris Hylton who has extensive Historic Preservation spanning several regions including New Orleans and Nantucket.

In Savannah, Georgia this goal will be achieve through collaborative efforts with i) the USGBC Georgia Chapter, Savannah Branch led by Jean Uhl. Jean is actively collaborating with building officials and green building professionals in the Savannah area; ii) Jackie Jackson Teel, Director of Comprehensive Planning at Chatham County – Savannah Metropolitan Planning Commission. Jackie has extensive experience in environmental planning and policy-making process as an expert in stakeholder involvement in Chatham County – Savannah area; iii) the Sea Grant Community Climate Adaptation Initiative funded by NOAA and led by Jason Evans from the University of Georgia Carl Vinson Institute of Government. Dr. Evans is an environmental sustainability analyst in the Institute's

Environmental Policy Program and an expert in developing policy recommendations that take into account the wide range of possible environmental implications.

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Impact of the French innovation and research policy on construction firms

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Abstract

For many years France has been characterised as a country where state intervention was needed to guarantee the wealth and the strength of the economy. Most of the funds dedicated to R&D focused on large programmes limited to specific sectors such as nuclear, space, aeronautics, telecommunications, and defence, and were mainly monopolised by large companies. Therefore SMEs were often ignored. However, this scheme has been challenged by the growing role of the European Union and French regions in national programmes. Under the new institutional framework public expenditures are not only devoted to R&D but also to innovation.

The construction industry is characterised by a high proportion of very small firms who do not have any internal R&D department. R&D in construction is also not organised as formally as in manufacturing companies. The level of R&D expenditures appears to be lower in construction than in any other industry. As a consequence the industry is not able to benefit from most public R&D programmes. However R&D is just one source of innovation and construction firms tend to use less formal way to innovate. The business activity has also a strong influence on the propensity to carry out R&D.

To illustrate how the construction industry has benefited from the French innovation and research policy, the paper will first characterise the evolution of the French national policy in the domain of research and innovation. Then, it will examine the role of Research, Development and Innovation (RDI) for construction companies and describe two public schemes aiming at supporting innovation within construction firms and the diffusion of low energy buildings. Finally, the analysis will present the role of RDI in the innovation strategy of a small sample of construction companies located in the Aquitaine region (South-West of France).

Keywords: Innovation, construction, R&D policy, RDI, SME.

1. Introduction

In 2008, France spent 41.7 billion Euros on R&D. When expressed in terms of GDP, it represented 2.14% (OST, 2010). It accounted for about 3.8% of world R&D expenditure. For many years France has been characterised as a Colbertist state. Most of the funds

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dedicated to R&D focused on large programmes limited to specific sectors such as nuclear, space, aeronautics, telecommunications, and defence (Mustar and Larédo, 2002). This public support was mainly monopolised by large companies. Firms employing less than 250 employees were frequently ignored. However this scheme has been challenged by the growing role of the European Union and French regions in national programmes. Under the new institutional framework public expenditures are not only devoted to R&D but also to innovation. Moreover SMEs are at the core of the innovation policy.

The French construction industry (building construction, installation and finishing and civil engineering) is characterised by a large number of SMEs employing less than 10 employees. Conversely firms employing more than 250 people are limited. They represent less than 0.1% of the firms of the industry whereas their contribution to the production reaches about 20%. These firms are usually not at the core of the national policy supporting R&D and innovation.

The construction industry has never been considered as strategic for French national independence. Thus it has not been able to benefit from the large programmes. However policies supporting the innovation capacities of SMEs do not target any sector and are more adapted to the specificities of the sector. Moreover public procurement can be a source of innovation and R&D in construction. For example large and complex buildings involving a network of actors are frequently leading participants to launch R&D to circumvent technical bottlenecks encountered during the course of the project.

The paper will first characterise the evolution of the French national policy in the domain of research and innovation. Then it will examine the role of R&D for construction companies and the importance of public funding. Finally the analysis will focus on the role of R&D in the innovation strategy of a small sample of construction companies located in the Aquitaine region.

2. Characteristics of innovation and research policy in France

According to Ergas terminology (1987), France technology policy was for a long time considered as « mission-oriented ». As in the United-States and the United-Kingdom, technology policy was linked to objectives of national sovereignty. The focus is on radical innovation (“big science is deployed to solve big problems”) and most public R&D is dedicated to the defence sector and key sector for international strategic leadership such as nuclear energy and telecommunications.

Mustar and Laredo (2002) confirmed this view and propose four traits to describe the French research system:

1. Most public research budget is directed towards a limited number of sectors which contribute to the objectives of national independence (nuclear, space, aeronautics, defence, telecommunications…);

2. Basic research is mainly done by CNRS (National Centre of Scientific Research). Universities mainly focus on teaching and are competing with French higher education institutions which train the “elites”;

3. Several public research institutes carry out research for the needs of several governmental departments;

4. A limited number of large companies monopolise most public support for research. However SMEs do not belong to this network and do not benefit from public funding.

These policies faced several limitations at the end of the eighties. It appeared that they yielded few direct benefits and crowded out a large share of commercial R&D. Only a small number of high-technology firms were the recipients of public subsidies. The spin-offs were limited. Traditional sectors such as construction did not benefit from the high level of public expenditures on R&D.

Ergas opposes “mission-oriented policies” to “diffusion-oriented policies” which aim at diffusing “*technological capabilities throughout the industrial structure, thus facilitating the ongoing and mainly incremental adaptation to change*” (p.192). Countries such as Germany, Switzerland, and Sweden tend to adopt “diffusion-oriented policies”.

During the 1990s several changes have affected French national policy. Large programmes have received less support. Partnerships between CNRS and universities have been reinforced and the research potential of universities has grown. Around 2000, there were about 14 000 researchers and research engineers at CNRS versus 45 000 teacher researchers at the universities (Mustar and Larédo, 2002). However, it was mainly the development of support for innovation and tax credits that modified the French innovation and research policy:

- The National Agency for the Valorisation of Research (ANVAR – now OSEO) was created to support innovative SMEs. It was organised on a regional basis. The agencies located everywhere in France, aid small firms not only through financial assistance, but also through technological advice. The main tool was a zero-rate loan that could cover up to 50% of the costs of the innovation project. The firms refunded the agency only in case of success and without paying any interest. Large firm were usually excluded from this procedure.

Research tax credits were introduced and contributed to the development of R&D activities in SMEs. In 1987, 3 500 applied to the scheme. In 2000, applicants exceeded 6 000. Several successive changes in the way to take into account R&D expenditures increased the number of beneficiaries by 147% between 2000 and 2007 (table 1 – OST, 2010). In 2008, the scheme was simplified and in 2010 about 18 000 firms asked for research tax credits (Froger, 2012).

Table 1: Research tax credits

	Research tax credits							
	2000	*2001*	*2002*	*2003*	*2004*	*2005*	*2007*	*Evolution 2007/2002 (%)*
Declarations	*6344*	*6253*	*5907*	*5833*	*6369*	*7400*	*9658*	*+64*
R&D expenditures declared	*10248*	*10712*	*11668*	*11300*	*11600*	*13500*	*15300*	*+31*
Beneficiaries	*3060*	*2810*	*2760*	*2757*	*4250*	*5430*	*6822*	*+147*
Volume in million €	*529*	*519*	*479*	*428*	*890*	*982*	*1687*	*+252*

OST (2010)

Moreover two new key players appeared in the French research landscape: the regions and Europe. With the Decentralisation Act (1982), the regions brought complementary resources which supplemented the investments of the State. Europe also provides supports for research and innovation through its successive Research Framework Programmes. The European budget has grown very fast from 678 million Euros (2.4% of its budget) in 1985 under the First Framework Programme (1984 – 1987) to 6.5 billion Euros (5% of its budget) in 2008 under the Seventh Framework Programme (2007 – 2013).

3. Construction, R&D and public financing

3.1 R&D and the construction sector

The economic literature shows a positive relationship between firm size and the likelihood of performing R&D. Several advantages are put forward to explain this relationship: "*the greater willingness of larger firms to incur risks associated with R&D, the greater access to finance by larger firms, the greater ability of larger firms to internalise R&D spillovers due to greater diversification, and the greater likelihood that larger firms will possess the complementary capabilities (e.g. marketing) necessary to exploit innovations*" (Cohen and Klepper, 1996, p. 936).

The construction industry is characterised by a high number of very small firms. In France in 2007, among the 369 100 firms of the industry, 339 900 (92.1%) employed less than 10 employees and contributed to 33.44% of the production (Commissariat Général au Développement Durable, 2010)[2]. Conversely the number of firms employing more than 250 people is limited. They were about 300 in 2007 representing less than 0.1% of the firms of the industry. Their contribution to the production reached 20.2%. This specificity and the nature of the innovation process within the industry explain why R&D expenditures are much lower than in other manufacturing sectors (table 2). Most innovations developed by contractors are made at the job site in the course of a construction project and they do not require a high amount of financial resources. Innovations are mainly project specific and they barely require R&D. Innovations are "*ad hoc responses to problems encountered in the*

[2] The Commissariat Général au Développement Durable distinguishes three categories in its classification: building construction, installation and finishing and civil engineering.

course of a construction project that an innovating builder was engaged in. They were emphatically not "R&D projects" in any formal sense" (Slaughter 1993: 87). When they do some R&D, contractors collaborate usually with materials and/or equipment suppliers on specific projects. The resources dedicated to this activity are much smaller than those of their suppliers.

Table 2: Internal R&D expenditures of the private sector

	Internal R&D expenditures of the private sector					
	2002 (Billion €)	*2007 (Billion €)*	*Evolution 2007/2002 (%)*	*2002 (Billion €)*	*2007 (Billion €)*	*Evolution 2007/2002 (%)*
Manufacturing sector	***18.0***	***20.2***	***+ 12***	***82.3***	***81.5***	***- 1***
Aeronautics and space construction	*2.3*	*2.7*	*+15*	*10.7*	*10.8*	*+ 1*
Electric equipment	*4.6*	*4.3*	*- 6*	*21.0*	*17.4*	*- 18*
Pharmaceutical industry	*2.8*	*3.5*	*+ 27*	*12.8*	*14.3*	*+ 12*
Equipment goods	*1.7*	*2.2*	*+ 27*	*8.0*	*9.0*	*+ 12*
Transport	*3.2*	*3.7*	*+ 15*	*14.9*	*15.1*	*+ 1*
Chemistry	*2.2*	*2.4*	*+ 10*	*10.0*	*9.7*	*- 3*
Natural resources intensive industry	*0.6*	*0.7*	*+ 11*	*2.7*	*2.7*	*- 2*
Labour intensive industry	*0.5*	*0.6*	*+ 29*	*2.3*	*2.6*	*+ 14*
Non-manufacturing sector	***3.9***	***4.5***	***+ 18***	***17.7***	***18.3***	***+ 4***
Primary sector and energy	*0.9*	*0.9*	*+ 9*	*3.9*	*3.8*	*- 4*
Agro-food industry	*0.5*	*0.5*	*+ 5*	*2.3*	*2.1*	*- 7*
Construction	*0.1*	*0.1*	*+ 9*	*0.4*	*0.4*	*- 4*
Services in transport and telecommunication	*2.4*	*3.0*	*+ 24*	*11.1*	*12.1*	*+ 9*
Total	***21.8***	***24.8***	***+ 13***	***100***	***100***	***-***

OST (2010)

This situation was also typified by Pavitt (1984, p.356) who was the first to put ahead the existence of sectoral patterns of technical change. He categorised general contractors as "*suppliers dominated firms"*. Firms from this category devote few resources to R&D. They focus their innovative activities on processes. "*Most innovations come from suppliers of equipment and materials, although in some cases large customers and government-financed research and extension services also make a contribution*".

These elements are confirmed by the fourth Community Innovation Survey (SESSI 2006) which integrated for the first time firms from the French construction industry. One of the aims of this large study was to characterise innovation within the industry. 39.4% of the French construction firms, who were surveyed, declared that they were innovative between 2002 and 2004. These figures are lower than for manufacturing and service industries (46.2%).

The survey (table 3) also indicated that internal R&D is the main input for firms employing more than 250 people while smaller firms follow a different path. They rely either on training or on the acquisition of equipment. Thus focusing too much on R&D could be misleading since very small firms which are dominant in the industry innovate through different paths. Patel and Pavitt (1994, 543) drew similar conclusion: "*We have shown that when we treat technical change as synonymous with R&D activities in science-based industries, we are in danger of neglecting up to nearly 40% of what is going on in technical change, especially in non-electrical machinery and in small firms."*

Table 3: Input for innovation between 2002 and 2004 within innovative contractors (%)

	Internal R&D	*External R&D*	*Acquisition of equipment*	*Acquisition of external knowledge*	*Training*
10 - 49	*45,4*	*16,9*	*53,8*	*11,7*	*48.4*
50 - 249	*48,3*	*16,8*	*57,3*	*23,8*	*68.9*
250 and more	*69,1*	*31,0*	*47,3*	*22,6*	*53.6*
Total	*46,6*	*17,4*	*54,0*	*13,6*	*51.2*

Source : SESSI (2006) - http://www.insee.fr/sessi/enquetes/innov/cis4/EH.html

However this lack of R&D is also problematic since R&D raises the "absorptive capacity" of the firms (Cohen and Levinthal, 1990). This "*absorptive capacity*" is defined as the ability of a firm to recognize the value of new, external information, assimilate it, and apply it to commercial ends is critical to its innovative capabilities. It is a function of firm's prior knowledge. Thus R&D is also a way to take advantages of external knowledge and to use existing networks.

3.2 Public funding for R&D in construction

R&D expenditures of the construction industry are very limited compare with other sectors. In volume it is even the sector with the smallest budget dedicated to R&D. About 90 per cent of these expenditures are financed by internal resources (OST, 2010). This is confirmed by Tessier (2008) who indicated that only 16 per cent of firms from the construction industry have access to public funding (versus 36 per cent for manufacturing companies). Only large civil engineering companies operating at the international level were able to receive some public support.

Public funding to the sector mainly comes from OSEO, the public finance company supporting innovation. However all financial products and services developed and proposed by OSEO are not dedicated to the construction sector. This is not the case of "PREBAT" ("Programme de Recherche et d'Expérimentation sur l'énergie dans le BATiment" - "Research and experimental programme on energy in building") which aims at reducing energy consumptions in buildings.

3.2.1 The innovation aid schemed proposed by OSEO

Since its creation OSEO has developed a whole range of products and services in order to cover the needs of innovative SMEs. OSEO's activities are complementary with those developed by banks or venture funds. OSEO covers three lines of activities

- Supporting innovation and technology transfer (*OSEO innovation*)
- Financing investments and operation cycle, in partnership with banks and finance institutions (*OSEO financement*)
- Guaranteeing bank financing and equity investments (*OSEO garantie*)

The financial support brought by *OSEO Innovation* covers part of the expenditures dedicated to R&DI (Research and Development, Innovation). Innovation activities include the acquisition of technology, industrial design, trial production, feasibility studies and market tests and launch (OECD, 2005).

In 2009, 176 construction projects represented 4.08 per cent of all projects financed by OSEO through the "innovation aid" scheme (OSEO, 2010a). This aid contributed to the development of 131 innovative projects in the building sector (10.9 M€), 23 projects in civil engineering (2.4 M€) and 22 projects proposed by material suppliers (1.35 M€). However the borderline between construction and other industrial sectors is frequently very thin. For example, in the energy sector among the 156 projects financed in 2009 (16.6 M€), 38 (3.9M€) were dedicated to the building market (optimization of heating systems, software to monitor energy consumption – OSEO, 2010b).

Moreover OSEO focuses mainly on the smallest and youngest enterprises that experience greater difficulty in gaining ready access to financing. 33 projects (20%) were developed by SMEs with less than 3 years old. They received 2.68 M€. Firms with less than 20 employees (the majority in the construction industry) received 6.19 M€ for 88 projects.

Several of these projects are linked to sustainable construction which is a source of business opportunity. To reduce greenhouse gas emissions and energy consumption, new products and process are created. It concerns photovoltaic cells which are integrated to the envelop of the buildings, new construction systems based on products offering a smaller environmental impact, industrialisation of the construction process, development of Building Information Modelling. But the innovation aid scheme is not adapted to project-based activities and innovation developed during the course of a construction project.

3.2.2 The programme PREBAT

In 2007 "PREBAT" was launched by the government at the national level to spur sustainable construction. It was one of the measures taken to address climate change, to restore biodiversity and to limit environmental and health risks. The aim was threefold:

1. To anticipate the change of thermal regulation which would become very ambitious both for new and existing buildings;

2. To find solutions to technical and economical bottlenecks;

3. To develop experimental projects.

To reach these targets, several priorities were defined for the period 2007 – 2012. One of them was to lead the construction value-chain toward low energy buildings before the implementation of a new regulation in 2013, requiring that all new buildings (residential and offices) have to consume 50kwh/m²/year. Public and private clients who accepted either to construct low energy building or to renovate buildings to reduce drastically energy consumptions received financial supports. This was a stimulus to diffuse new technologies, new systems and new construction processes associated with low energy buildings.

The programme was financed by ADEME (the French Environment and Energy Management Agency) and French regional authorities. Public subsidies rose from 7.2 M€ in 2007 to 42.8 M€ in 2010. 11 Regions took part to the programme in 2007 and 20 in 2010. 1 025 projects were supported during this period. 65% of the projects concerned new buildings and 35% renovation projects.

The subsidies delivered by ADEME and the French regions covered on average about 10% of the construction costs. It represents approximately the additional investment costs linked to better energy performance**.**

The impact of the programme was considered as positive. 80% of the 241 clients surveyed (Eurêval, 2012) had never built a low energy building before. About 75% (mainly households) considered that without financial subsidy the financial equilibrium of the project would have never been reached.

However the learning process appeared to be limited since most clients were in charge of just one project. According to the experts who evaluated the programme, clients would have needed three consecutive projects to learn about the process of constructing / renovating low energy buildings: at the first time, the client discovers the process and identifies the technical problems. During the second project, he starts to solve them. The third time he monitors most technical issues. However public authorities who were the main beneficiaries (they represent 36 per cent of the clients) considered that they learnt a lot and they developed new practices. The programme was a way to raise their competencies and to make them aware on the specificities of the future regulation and on some specific technical items (e.g.: blower-door tests, implementation of new material and equipment).

Similarly the learning impact was quite important within the design team. Moreover the programme raised the competencies of the contractors and installation and finishing companies. For example, to guaranty the energy performance of buildings, electricity and plumbing companies have to make box-out at the design stage and they are not allowed to drill on site.

4. Role and impact of R&D in construction: a regional survey

4.1 The context of the survey

In 2011, CSTB and a consultant company were commissioned by CREAHD (a regional institution promoting innovation in the construction industry and gathering firms, public and private research organisations and universities) to examine the innovation strategy of firms from the construction industry located in the Aquitaine Region. Firms were questioned about the organisation of their innovation process, the funding, the results of the innovation and the role and importance of R&D within the context of sustainable construction. Telephone interviews with general managers or executives (R&D, financial…) were carried out between June and September 2011.

Four groups of firms were targeted: 1/Designers and architects; 2/ Suppliers of material; 3/ Building companies; 4/ Civil engineering companies;

An electronic survey was first sent to 3280 firms representing the four aforementioned groups. 139 answered. Then in-depth interviews were carried out with nineteen companies representing each group. All the firms firstly answered to the electronic survey. CSTB was in charge of ten interviews. The following section will present the main results of these interviews. “A” and “B” represent the architect and the design office; “C” and “D” are the suppliers; “E”, “F” and “G” are the building companies. “H”, “I” and “J” are the civil engineering companies.

4.2 The role of R&D in the innovation strategy of construction companies

“A” and “B” were innovative but they did not really conduct R&D. According to both actors, innovation is pulled by the evolution of the regulatory environment (for example the thermal regulation is becoming more stringent) and the introduction of new equipment and products by suppliers. Innovations are usually developed with the partners of the building site. The suppliers are often the leaders but either the architect or the design office frequently coordinates the innovation process. The client who finances the project has also a key role to play. Indeed projects which are less financially constraint open more opportunities for innovation.

The two suppliers of material (“C” and “D”) belong to large international companies with R&D facilities. “C” employs 120 people and has three regional laboratory gathering 11 R&D engineers. These researchers have to identify the constraints of the building site, to develop solutions in order to strengthen the competitive advantage of the firm and to answer to the expectations of the client and to follow-up the construction project. When projects are very complex, the firm receives the support of the R&D unit of the group. “D” has no permanent budget for R&D. It develops research when its financial margins are better. Thus the research activity is not continuous. However the firm is still able to benefit from the exchange of best practices among the affiliates of the mother company.

The three building companies are typical example of the diversity of situations within the sector. “E” has less than 10 employees, “F” 53 and “G” is the subsidiary of one of the three major companies in France. “E” has no R&D department but the manager has developed a R&D project with both public and private research laboratory. This collaboration led to the creation a new product. The SME has also received the financial support of several local agencies promoting innovation since the product is closed to the market. However due to its limited financial and research capacities the innovation process is very long and the SME still lacks a commercial network to sell its innovation. “F” has three employees who work part time for the internal R&D department. The rest of the time they are involved in marketing activities which are complementary to their research work. It is a way to get feedbacks from the market. Thanks to this research activity, this contractor was able in the past to diversify its activity. It has developed several products and has become a supplier of the industry (in 2010, the turnover was 7.6 million and about 3 million was connected to the commercialisation of new products – the other part was linked to its traditional building activity). This SME regularly cooperates with a local engineering school for most of its research projects. Due to a bad experience with OSEO (the firm had to refund the public agency when its business activity was affected by the crisis), it prefers to innovate by using its internal resources. “G” has no internal R&D competencies. However it can benefit from the support of the central lab located around Paris and a regional design office. However the main source of innovation is the internal database gathering information on the internal innovation awards’ scheme. These awards are open to all affiliates (and employees) of this large company and concern all types of innovation. The aim is to prevent employees to re-invent the wheel and to promote the exchange of best practices between affiliates located in remote places. “G” has already been involved in several experimental projects launched at the national level to promote innovative processes in construction.

Among the three civil engineering companies, two are affiliates of large companies. Both have a R&D laboratory. For “H”, the aim is to keep the link between its research activity and the needs of the market. One of the key issues of this lab is to watch the evolution of the regulation and to anticipate market changes. This strategy allows “H” to sell new products before its competitors. “H” frequently cooperates with local engineering schools and suppliers. In the past it also received the financial support of OSEO for some products dedicated to the construction site. Head of units (e.g. marketing, finance) are frequently the main barrier to R&D. Indeed when the construction market has to face a crisis and when prices go down, they try to reduce R&D budgets. But since the company has developed a culture of innovation, most budgets are not diminished on the long run.

“I” has no permanent R&D lab but several engineers are mobilized for complex projects such as the high-speed train. Only internal resources are used to finance research projects. Most innovations come from suppliers of products and equipment. “H” and “I” consider that the public R&D funding is not adapted to the research activity connected to the construction site. Indeed the life cycle of a construction project is very short while most public supports are dedicated to new products with longer life cycle.

“J” is a SME with less than 20 employees. It has no R&D activity. The innovations developed by the manager concern the organization of the company.

5. Conclusion

The construction industry is frequently criticized for its limited capacity to invest in R&D. A basic statistical comparison between construction and all manufacturing industries turns at the disadvantage of the construction industry. However R&D in construction (e.g. contractors, architects) is not organised as formally as in manufacturing companies. Only large company can support a dedicated R&D department. Most development activity occurs on the building site. Moreover several activities which are at the core of the construction business are not classified as R&D by the Frascati Manual. For example, *"investigations of proposed engineering projects, using existing techniques to provide additional information before deciding on implementation, is not R&D…* » (Frascati Manual, 2002, p.30). Similarly "*the vast bulk of design work in an industrial area is geared towards production processes and as such is not classified as R&D, There are, however, some elements of design work which should be considered as R&D, These include plans and drawings aimed at defining procedures, technical specifications and operational features necessary to the conception, development and fabrication of new products and processes*." (Frascati Manual, 2002, p.44). Thus the project-based nature of the industry does not fit well with the official classifications.

R&D does not have to be considered as an end. It has just to be considered as a way to reach a better performance or to develop new product / process. The innovation model is not linear and can be considered as a chain-linked model (Kline and Rosenberg, 1986). Several innovations are due to feedbacks from the market. Moreover the flexibility of the construction process allows for adaptation and development of existing products.

Further research has to be developed to examine the complementary role of R&D in construction (the "absorptive capacity") and analyse the impact of training on innovation. Indeed training is considered by the smallest enterprises as the main input to innovation.

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Whole moves Technology for Historic Building Preservation and the Decision Making Process

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Abstract

The main purpose of this study is to discuss the techniques and decision-making processes of integral moving of historic buildings in Taiwan. The study mainly analyzes the details of integral moving of mixed-structure and brick-structure historic buildings; furthermore, to provide an alternative for those which either could not preserved at the original locations or to be demolished with a much applicable techniques to preserve them.

The major research methods include literature review, case studies, and field researches. Selected cases are those which were successfully moved. There were mixed-structure buildings such as Taipei Workshop, Kaohsiung Railway Station (Vision of Kaohsiung), and the brick-structure building such as the old hall of the Department of Pharmacy, National Taiwan University.

The study discovers that decision-making processes of historic building preservation project in Taiwan are usually influenced and buildings could not be preserved at the original locations due to urban renewal projects. Also, after moving, these buildings serve as exhibition halls. Once the structure of historic building itself is assessed, and it is strong enough to withstand the vibration during the moving, then the technique of CUT-OFF is applicable; on the other hand, if the building structure is weak, then the techniques of UP-DOWN or OPEN-CUT are applied and adjustable due to the conditions on site.

Keywords: Whole moves, Techniques of Up-Down, Open-Cut, and Cut-Off.

1. Foreword

While facing rapid urban development and rising of land price, conflicts between old buildings and new constructions have been emerged. Most historic buildings are under demolition due to the damage and inappropriateness of location and space. For those buildings which are with economical or cultural value, Re-locating these old buildings serves as an alternative solution for heritage preservation, which keeps these historic buildings preserved or reused, instead of being abandoned at the original location, or being demolished. The article is going to generalize and analyze the techniques and strategies of relocating historic buildings with different structures. Through focusing on the concept of integral relocating technology and the ways of construction, a clear information of the process regarding decision-making and key points regarding management will be obtained. This study would like to confirm the completeness and safety of building relocating by applying appropriate techniques; moreover, to create a revolution regarding the

co-existence balance between the contemporary urban development and the historic buildings.

2. The Definition of Integral Re-locating Technology

The definition of integral re-locating technology is to move the building from where it locates originally to a new location. There are various situations which require buildings to be moved away from the original location. The most essential point of this technology is to remain the entirety and functionality of buildings. There is a high demand of professional techniques in building re-locating, and also it is risky. The main body of the building is not allowed to be damaged and the structure needs to be reinforced and firmed within a certain range. There are two ways of building re-locating based on main body re-locating, one is “integral re-locating of main structure” and the other is “integral demolition and re-locating”.

3. Case Study

Generally, there are three ways of re-locating historic buildings based on different techniques and ways of preservation in Taiwan:

(1)Integral Demolition and Re-locating: Construction materials are numbered and reorganized at the new location; however, this will not be discussed in this study..

(2)Integral Re-locating of Main Body: The whole building is moved to the new location for permanent positioning and reuse.

(3)Integral Re-locating of Main Body: The building is temporary moved to where is closed to the original location. After the renovation of construction has been done, the building will be moved back to the original site.

The study mainly focuses on discussing “integral re-locating of main body”; merely, there is still a brief introduction of “integral demolition and re-locating”.

3.1 Integral Re-locating of Main Body: The whole building is moved to the new location for permanent positioning and reuse. (The old hall of the Department of Pharmacy of National Taiwan University)

National Taiwan Hospital was planning to build an 11-story building and 3-story underground as their new conference center and medical research building at where the old pharmacy building located. Due to the lack of space in the eastern hospital area, and also the plots of land are scattered, it is not possible to have another two complete and big enough clearings for the building permit.Therefore, the hospital decided to tear down the pharmacology and pharmacy hall of the medical school at XuZhou Road. However, with the petition of professors and students, and also the investigation of historic building held by the department of civil affairs of Taipei City, the result shows that there is historical significance in these two buildings which should be preserved, and the pharmacy hall is especially valuable. Therefore, the school decided to preserve these buildings and move them 22

meters forward that more closed to the side of XuZhou Road for better coexistence of new and old buildings..



Pic 1--Before and after re-locating of the old hall of the Department of Pharmacy of National Taiwan University

3.1.1 Strategies at Different Stages

The pharmacy halls were built during the period of Japanese domination. Although there are no related literature reviews regarding these buildings, the buildings are investigated and confirmed being built around the age; the labs at first and second floor built later were not the preservation targets. Based on the construction concerns, the floor was tore down and rebuilt. After confirming the preservation parts, the excavating on the edge of the foundation was executed. After re-locating the sewer system, the buildings were discovered as entire brick masonry constructions without ground beams; therefore, new ground beams were going to be built with section steel to withstand the fragile structures; furthermore, to reinforce the structural members and the cracks around doors and windows with concrete, superstrength healant, and putty. The construction applies up-down technique which mainly works by adding new ground beams. The buildings were moved horizontally 4 meters a day with hydraulic synchronous jacks, adding numerous round steel pipes and making pressure-bearing boards to cooperate with the power hoist. During the re-locating process, it is necessary to observe the uneven load problems or cracks of the buildings with naked eyes. Also, the inclinometer was used for measuring brick walls and columns, ground or building subsidence, and the tilt variation. The buildings were moved 22.7 meters north from the original location. After finishing building the new construction, the old and new buildings will coexist harmoniously.

3.1.2 Following Steps of Construction Preservation and Applications

The old hall of department of pharmacy in National Taiwan University was recognized as a historic building in March, 1999. The whole building was built during the period of Japanese domination and it was the first department of pharmacy in Taiwan established by National Taiwan Medical School. Lee Chen Yuan, the academician of Academia Sinica, also established his poisonous serum research center here. The spirit beyond the building itself is much more meaningful and essential. The school intended to turn it into a pharmacology museum in the future. The interior of the old building is currently unused, and the exterior space is shared with the new building

3.2 Integral Re-locating of Main Body: The body of construction is temporary moved to where near the original location. After finishing the renovating construction, the construction will be moved back to the original site. (Taipei Workshop)

Taipei Workshop, located at the intersection of Tacheng Street and Shimin Boulevard, is recognized as the grade three civil historic building which overlapped 4.8 meters with Beimen Station of Taipei MRT Songshan Line and conflicted with its entrance. Additionally, the project of Taiwan Taoyuan International Airport Access MRT System between Sanchong and Taipei was designed to pass through Taipei Workshop underground. The construction process might cause historic building subsidence and cracking. At the same time, Taipei Workshop also located on the planned road of Tacheng Street which conflicted with the road expansion project. To strike a balance between historic preservation and major transportation development, Department of Rapid Transit System planned to move Taipei Workshop 30 meters east south along with Tacheng Street under the preservation and safety of the historic building. Taipei Workshop was temporarily located at the west side of the wartime command center of Taiwan Governor-General Office, and it would be moved back to the original location after finishing the underground construction



Pic 2—Before & after re-locating of Taipei Workshop

3.2.1 Strategies at Different Stages

Taipei Workshop was established in 1909. Its architectural style is Japanese brick masonry with steel structure. There are not reference describing about the basic structure of its body and depth. However, the design, basic structure, and the depth would all influence the excavating, soil retaining, dewatering, and drainage, so the excavating of the foundation is necessary. Also, considering the fact of the history, exploratory trench was undertaken especially. However, due to its nature of Archaeology, there is no further discussion in this study. Before re-locating, there are still several steps needs to be operated first, such as demolishing the additional parts of the construction, reinforcing the structure, designing re-locating techniques, preparing for the measurement of the construction, temporary protection, and repair works. To confirm the related construction materials for sustaining the weight while raising and re-locating, the test of the strength of the rebar-planting and the raising strength of fixture and ground beam were done on other brick buildings which was scheduled to be demolished in the same area after getting the approval of Taiwan Railway. The re-locating applies OPEN-CUT which excavates the basic structure entirely along with the re-locating route, and paves rigid pavement and tracks for dragging the newly-built rigid

tray under the existing foundation to withhold the structure of main body; and then re-locating engineering is executing later.

To ensure the safety of the process, the whole process is under computational syncing Hydraulic jack system, which is moving slowly with concrete ground beam, section steel tracks, and round steel sticks to the new location. The building was moved 30 meters horizontally and rose for 1.5 meters. At the same time, there are professionals investigating the re-locating construction record and make reports regarding this process.

3.2.2 Following Steps of Construction Conservation and Applications

The architectural style of Taipei Workshop is the combination of Qing Dynasty and Japanese-rule style, which stands out its historic significance. In the near future, the interior of the workshop will be renovated as a gallery of historical photos, audio and video archive. The city government is also planning to move the first German-made steam locomotive “Teng Yun” which was introduced by Liu Ming Chuan, the first Taiwan governor during Qing Dynasty, from its original exhibition hall, National Taiwan Museum to Taipei Workshop. There will be an integral design of the Workshop and the future MRT stations. Now, since the tunnel construction has been finished, Taipei Workshop could be moved back to the original site. Currently, the preservation project is still ongoing with wrapping the exterior with iron sheet, reinforcing the repair, and restoring the old as old; furthermore, investigating and studying the historical document for better restoration.

3.3 Integral Re-locating of Main Body: The building is temporarily moved to where near the original location. While the renovating construction is finished, the building is moved back to the original site. (Kaohsiung Railway Station)

According to the transportation project designed by Kaohsiung City Government, the area was going to be a three-rail union station (Kaohsiung Rapid Transit, High Speed Railway, and Railway). The original project was to demolish Kaohsiung Railway Station, but it happened to be included in the competition of 100 historic buildings at that time; therefore, the demolition project drew people’s attention. Finally, because of the opposition of scholars and public opinion, the city government gave up the idea of demolishing the train station. Later, Railway Reconstruction Bureau of Ministry of Transportation and Communication decided to move away main structure of the train station away for the underground construction. After the construction finished, the station was moved back to the original site. It now temporarily serves as a gallery

3.3.1 Strategies at Different Stages

The train station was built in 1940. Before re-locating, there are five investigations need to be done: development process, construction analysis, structure analysis, currently situation, preservation research, and cultural and historical significance estimation. Finally the main body of construction which is full of memorial significance was left and the additional parts built on demand function would be demolished. Basically, the preservation was about re-locating the main crown structure of the construction. The front of the construction was

preserved and the exterior wall was cut into 4 pieces on the left and five pieces on the right. While preserving and reinforcing the original construction materials and techniques it was built with, the repair was carrying out based on the principle of “restore the old as old” and reuse. Afterwards, to excavate the foundation around the station and reinforce the ground beams. The technique, Open-cut and oblique re-locating are applied on the re-locating. To make sure the good connection and completeness between the old station and the new station, the prime directive is to maintain the front entrance, and some walls of two wings of the station were preserved for exhibition. There were many cutting positions. Cutting, demolishing, and re-locating should be executed without damaging the main body. These would be reorganized after re-locating back to the original sites. Roof tiles were demolished first for specific preservation, and would be restored later. The weight of cutting walls were about 50 to 60 tons (includes steel structure), which needs 25 tons, 160 tons, 200 tons cooperating with the 35-ton trailer and move to the eastern location for permanent positioning




Pic 3—The positions before (left) and after (right) re-locating Kaohsiung Railway Station

3.3.2 Following Steps of Construction Preservation and Applications

Now the train station has been moved to the temporary site and become “Vision for Kaohsiung”. Based on the historical significance of the building itself, citizens could understand better the current situation of their city and future city planning. The purpose of “Vision for Kaohsiung” is to present the past, present, and future of Kaohsiung; moreover, to get citizens understand more about urban development and the blueprint. Except for the exhibition space, some spaces will be outsourced. Industries are responsible for the cleaning of exterior spaces, environment beautification, and also the maintenance fee and utilities.

4. The Preservation Standard of Integral Re-locating of Historic Building and Strategies

Usually, in Taiwan, the preservation of historic building is based on integral demolition and re-locating of brick and wood structure, and the integral re-locating applies to concrete structure. The construction process could be divided into three stages: preliminary assessment, design, and post-construction. In the primary stage, the integral movability is judged upon field investigation, data collection, structure examination, and structure analysis. In order to get a better understanding of the original structure of the construction, original location, and new location, it is necessary to excavate and investigate the geological conditions and evaluate the safety and reliability of the structure before executing the re-

locating. The reinforcement is undertaken according to the precise calculation, especially to historic buildings, the safety of structure and deformation amount are way much important than ordinary houses. In Taiwan, historic buildings are usually built with concrete, brick and wood. Most of them are courtyards, temples, town halls, stations, and so on. Without reinforcing the structure and fixing it integrally first, the fragile structures and construction materials will often get cracked or even damaged.

4.1 Integral Demolition and Re-locating and Integral Re-locating of Main Body

There is no distance limit in demolition and re-locating. Because it numbers the construction materials and then demolishes them and reorganizes in somewhere else. The key point of this technique is on the preliminary assessment which requires a profound investigation and understanding of the history and architectural style of the building. There are two concerns of the re-locating, one is the completeness of the construction after reorganizing, the other is while the re-locating distance is longer, it might change the environment too much. Therefore, after the re-locating, historic buildings usually won't be used for other purposes but become exhibition halls for cultural relics which needs to be maintained and protected by experts of heritage preservation in a long term and with a great amount of maintenance fee. Also, there is a high demand of professional skills for the demolition of historic buildings. Without dealing it properly, it would cause other damages, even the irreparable results. Disputes would come along as well. Therefore, while executing internal demolition, carefulness and exhaustiveness are needed..

Integral re-locating of main body is the combination of architecture and civil engineering. The basic principle is similar to using hoist to move goods horizontally, which works by turning and raising. The influences it might cause to the surroundings during the re-locating process is a big concern. The re-locating distance is limited. But while the new location is nearer to the original location, the influence it brings to the environment is not that much. Basically, this technique requires cut-off at the ground beams of the construction which separates the construction and the foundation. Install mobile joists at the cut-off, and set new foundation at the new location. Between new and old foundation, there is a re-locating track. After installing the power system, move the construction from the original location to the new location without causing too much vibration. Later, remove the joists and tracks, and connect the construction structure with the new foundation.

Integral demolition and re-locating belongs to the field of heritage preservation which is very complicated on demolition and reorganization. The relevant knowledge and practical experiences of repairing or re-locating traditional, Japanese, and contemporary architecture are required for personnel. The consumption of human power, time, budget are higher, and even the controversy is greater than integral re-locating of main body. Also due to different construction methods, different techniques are applied. If the circumstances is acceptable, it would be better to move historic buildings with integral re-locating of main body which is safer and more complete.

4.2 The Technique of Integral Re-locating of Main Body

There are three techniques of Integral Re-locating of Main Body, such as techniques of OPEN-CUT, CUT-OFF, and UP-DOWN. According to the construction structures, it is necessary to assess basic structure, the weight of re-locating, the subsidence, tilt, cracking of buildings; also, construction materials, decoration situation, and blocks on the route, for a better executing way. While dividing works because of construction process, there are five steps which includes excavating and examining the structure on site, reinforcing the main body, setting up mobile system, re-locating structure, and connecting structure

(1)OPEN-CUT

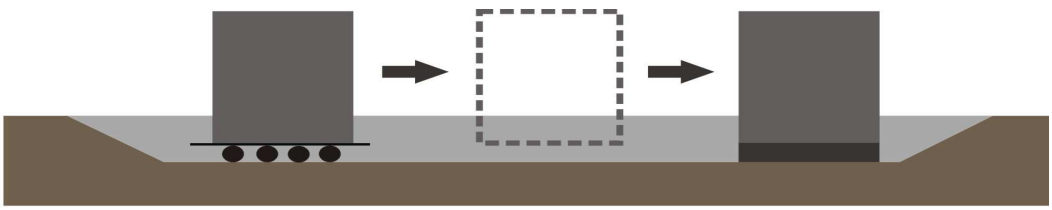
Based on its literal meaning, OPEN-CUT is to excavate at the bottom of construction, to move along with the route, to re-locate at new locations, and then to install supports and tracks. After re-locating the construction at the new location, the repairment and will be done.
Advantages: ·

- Simple and easy work
- Shorter construction period
- Less construction expense
- There is neither raising nor lowering in this technique, so the risk is less.

Disadvantages:

- There are earthwork needs to be excavated, dumped, and backfilled for recovery.
- If there are roads on the re-locating route, it would disturb the traffic and the influence it brings might take a long time.

Pic 5—The Schematic diagram of OPEN-CUT



(2)CUT-OFF

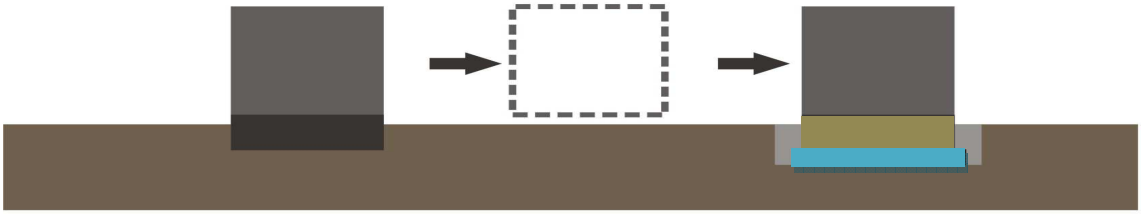
Excavate the ground around the building and cut off the foundation; then replace the supports and move the construction to the new location. Later, connect the original construction with the new foundation, and then repair it.

Advantages: ·

- The re-locating route is on the ground surface, no excavation, dumping, backfill needed.
- There is neither raising nor lowering in this technique, so the rick is less.

Disadvantages:

- Tough work
- Longer construction period
- Higher construction expense
- Need to cut off the foundation and it is easy to get the original construction



Pic 6—The technique of CUT-OFF

(3)UP-DOWN

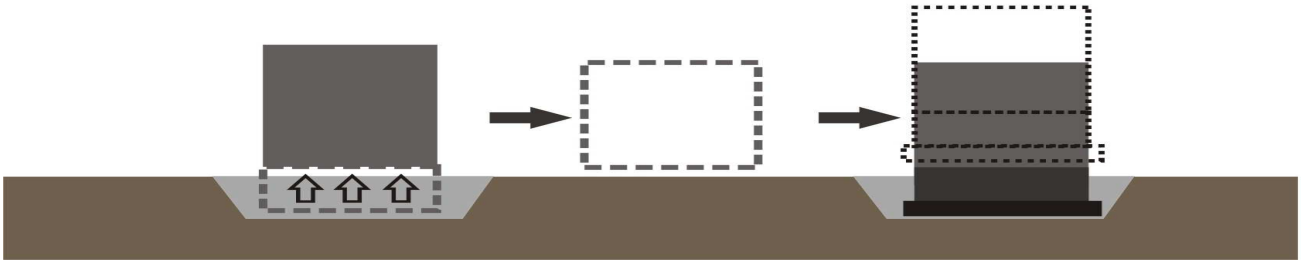
To excavate around the construction and then raise the entire building completely. After re-locating the construction at the new location, the construction should be lower down for connecting with the new foundation.

Advantages:

- The re-locating route is on the ground surface, no excavation, dumping, backfill needed.

Disadvantages:

- The most difficult technique among these three techniques
- The longest construction period
- The most expensive ·
- With higher construction risk due to the raising and lowering



Pic 7—The technique of UP-DOWN

4.3 Considerations s and Key Points of Integral Re-locating of Historic Buildings

Generally, there are three essential points of integral re-locating of historic building.

(1) The protection and preservation of surroundings of the construction are included. The planning of the whole area is supposed to scheme out before the re-locating project. Environment protection comes first. If the environment could be recovered and renovated, then recovery comes first. Unless it is impossible for recovery, then building re-locating is the least option.

(2) Constructions preserved following its history, functions, outcome, and decoration are supposed to be conserved especially; such as Kaohsiung Railway Station, Taipei Workshop, and so on.

(3) Some constructions which only have additional parts which worth of preserving could be partially demolished and then undertake the re-locating. After re-locating, it could also connected with the design of new constructions.

Many historic buildings are lack of maintenance for years; therefore, the structures are greatly damaged. Due to the lack of original designs and documents, the assessment is done with the investigation on site. If the risk of re-locating is way too high, then demolition re-locating could be considered. The key points of re-locating are: reinforcing the structure, replacing, setting tracks, and connecting and fixing.

(1) Structure Reinforcement: Usually, the structure of historic buildings are seriously damaged due to its age. Therefore, before re-locating, the structure assessment and reinforcement are required to be done, which could avoid the damages during the re-locating. Take Taiwan as an example, the common historic buildings could be classified into three kinds: traditional wood structure, brick-wooden structure of Ming and Qing Dynasty, and the masonry and concrete buildings of the period of Japanese dominant.

Wooden structure: The structure components are brick tiles, wood frame, stone drum, square tiles, brick-stone foundation, stairs, and foundation with a mixture of lime, clay, and sand. Roof and wood frame are supposed to be reinforced.

Brick-wood structure: After Ming and Qing Dynasty, most brick-wood structures of wood frame, brick walls, wood stairs, wood floor, and tile roof. Need to pay attention to wood frame, floor and stairs.

Others: During the period of Japanese Rule, masonry and concrete buildings are now still functional. The structures are complete and able to use normally. There is no further reinforcement needs to be done usually. If the reinforcement is needed, the premise is the outcome.

(2) Replacement: Most historic buildings in Taiwan are low-rise, the weigh is light, and the bearing of replacement is little; but the wholeness of structure is bad. Therefore, the strength of foundation needs to be increased.

(3) Railway technique: Most historic buildings needed to be relocated are small. The total weight is light but the entire structure is bad. Thus, it is very sensitive to the vibration. Therefore, the foundation of tracks needs to be strong enough. While excavating the foundation, the influences happened between the upper part of the construction and the original foundation are essential. The excavation of large area should be avoided.

(4) Connection and fix: The most direct way to preserve the original construction.

The wholeness of integral re-locating could not be decreased. While constructing the re-locating speed could not be too fast. Also, the supervision needs to be improved. Except for consulting with the construction design department, it is necessary to negotiate with relevant people of heritage preservation.

5. Conclusion

There are two factors influenceing decisions regarding integral re-locating, which are social and economic factors. On the perspective of economic factor, if the construction is still functional, and there is no safety or space concerns, the re-locating expense is one sixth of the total of demolition and new construction. On the perspective of social factor, except for the historic sites being protected by law, it is very expensive to move and repair other buildings which also have memorial or historic significance. Most owners choose to demolish the buildings, but that causes unpredictable cultural loss. Based on most people's opinions of the society, it is much easier to demolish and rebuild those buildings than to move them. Unless there are strong opponents from the public or the construction itself incidentally arouses most people's vibrations, the re-locating could be possible. After re-locating, most historic buildings serve as exhibition halls, and based on the investigation, the operation of exhibition hall could not really afford the maintenance fee actually. Some buildings even become absent or damaged without repair eventually. Therefore, while making the decision of building re-locating, the following plan of how to use and maintain the building is necessary and essential; otherwise, it would fail the goodwill from the beginning.

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Crane Safety: Lessons from the Nuclear Industry

Bryan Hubbard[1], and David Zukley[2]

Abstract

Fatalities and injuries involving crane operations on U.S. construction sites have not appreciably changed over the last 20 years. Incidents causing injuries and fatalities occur due to events such as crane boom contact with overhead power lines, workers struck by a crane load, and cranes collapses. Recently, a study was completed on construction crane operations on or near U.S. nuclear power plants. Safe and effective crane operation is critical for operational use and construction processes in and around active nuclear power plants. Construction activities near active nuclear sites require that crane operations are well planned in advance, monitored to consider all potential adverse impacts to nuclear operation, and reviewed with all key personnel. The U.S. Nuclear Regulatory Commission (NRC) has documented numerous crane related incidents and conducted exhaustive studies on the root cause of the incidents. The NRC has also made numerous regulations and inspection procedures, and provided guidance to reduce the risk of a crane incident. Many of the concepts and procedures developed for both operational crane use and construction use would benefit crane operations on a general construction site. To determine if some of the unique requirements for nuclear crane operation would benefit the general construction industry, a review of procedures and requirements in the nuclear industry was completed. A series of case studies where then examined to determine if additional safety features may have assisted in preventing the incidents. For the particular case studies shown there was evidence that increased requirements may have prevented an incident, however, following proper protocol for general crane operations would also have assisted in preventing the incident. The nuclear crane requirements would be considered excessive in the general construction industry, however, general concepts such as redundancy, thorough planning of lift operations, load monitoring, and specially designed lifting mechanism and lift points could be implemented or already are implemented in the general construction industry. To improve safety of crane use, it may be appropriate to turn to crane requirements that have very low probability of failure, such as in the nuclear industry.

Keywords: Crane, Safety, Nuclear, Redundancy

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1. Introduction

The operation of cranes on the construction site has long been a source of injuries and fatalities in the workplace. In order to reduce the number of crane incidents on construction sites, construction firms have developed more advanced planning procedures and training materials to ensure the safe and effective operation of cranes. Crane manufacturers have also improved safety by providing improved and easy to understand crane operation information and developing new systems to detect when cranes are beyond their operational capability. Despite all of these efforts, incidents involving cranes are still common on the construction site. The focus of this study was to review the very stringent operational requirements for crane operation on a U.S. nuclear power plant site and to determine if there are operational requirements in this industry that may help improve crane safety in the general construction industry.

In nuclear power plant operation there are numerous activities in which heavy loads need to be moved and hoisted. If these loads were to impact critical nuclear systems because of a failure of the equipment or human error, a serious nuclear incident could result which would endanger the lives of many people. In order to prevent such incidents, the U.S. Nuclear Regulatory Commission (NRC) provides regulations for safe crane operation in and around active nuclear power plants. These regulations exceed typical safe crane construction operational requirements and focus on the critical nature of load and what may impact the load versus the safety of the worker. While these regulations may be excessive for the general construction industry and only utilized on facilities with hazardous material or expensive industrial equipment, they provide insight into potential areas where further crane operational safety measures could be improved.

This paper provides an overview of crane operations on U.S. nuclear power plants through a review of regulations and pertinent literature. The operational requirements for the NRC are then compared with a typical crane lift procedure on a construction site that is well planned and documented. For the purpose of this study, a general construction industry “critical lift” plan is used for the comparison. The stringent NRC requirements are then used to evaluate documented cases of crane operational failures to determine if the additional NRC requirements would have reduced the probability of the injury or fatality.

2. Background

2.1 U.S. Crane Injuries and Fatalities

The operation of cranes on construction sites in the U.S. is a source of numerous injuries and fatalities. In 2011, there were 680 non-fatal injuries involving cranes where workers spent a day or more away from work (BLS 2010). Additional information about crane fatalities is shown in Table 1. Based on this data, there are a significant numbers of workers injured or killed in crane related incidents. The majority of incidents are caused by being struck by an object, which includes a falling object. Being caught in the equipment and being electrocuted by power lines are also common causes of injuries involving cranes.

Table 1. United States Fatal Occupational Injuries where a Crane was the Primary Incident Source (BLS 2010)

Year	Total Fatalities	Struck By Object	Caught in or Compressed by Equipment	Contact With Electrical Current	Transportation Incidents	Non-Categorized
2010	17	5 29%	6 35%	3 18%	0 0%	3
2009	23	16 30%	6 26%	3 13%	3 13%	4
2008	45	16 36%	9 20%	9 20%	0 0%	11
2007	30	11 37%	9 30%	5 17%	5 17%	0
2006	28	10 36%	6 21%	6 21%	6 21%	0
2005	43	10 23%	12 28%	13 30%	8 19%	0
2004	39	20 51%	5 13%	10 26%	0 0%	4
Total	225	88 39%	53 24%	49 22%	22 10%	22

2.2 Crane Operation in the Nuclear Industry

For nuclear reactor safety, it is important that heavy loads hoisted by a crane are done properly to ensure plant safety and security. The focus of crane regulations are the protection of equipment and critical systems, however, inherently the regulations also protect the workers. One of the main regulations for crane use inside the facility is the NRC regulation, NUREG 0612, "Control of Heavy Loads at Nuclear Power Plants" (George 1980). This report provides guidelines for managing heavy loads and the additional redundancies that are required in order to prevent a load drop or other damage that may release radioactive material. The main strategy employed by the NRC is entitled "Defense-in-Depth". The NRC provides the following definition:

> *"Defense-in-Depth: An approach to designing and operating nuclear facilities that prevents and mitigates accidents that release radiation or hazardous materials. The key is creating multiple independent and redundant layers of defense to compensate for potential human and mechanical failures so that no single layer, no matter how robust, is exclusively relied upon. Defense-in-depth includes the use of access controls, physical barriers, redundant and diverse key safety functions, and emergency response measures". (NRC 2012)*

The NRC and the Department of Energy (DOE) also provide guidelines for construction operations on or near nuclear power plants. During the construction of nuclear power plants in the United States there were significant crane related incidences that prompted the NRC to do an in-depth look at construction cranes. Reports that provide additional information on safe use of cranes include: 1) NUREG -1774, "A Survey of Crane Operating Experience at U.S. Nuclear Power Plants from 1968 through 2002" (Lloyd 2003); 2) NRC Inspection Manual 2515 Appendix F, "Reactor Construction Activities Near Operating Units" (NRC 2008); 3) Department of Energy Report, "Independent Oversight Special Study of Hoisting and Rigging Incidents within the Department of Energy" (Neubauer 1992).

2.3 General Construction Crane Operation

Information on crane operations in the commercial sector was gathered in order to allow a comparison between crane operations on nuclear sites and general construction project sites. For operational and safety issues involving cranes on a typical construction site the American Society of Civil Engineers (ASCE), "Crane Safety Training for Engineers and Supervisors" (ASCE 2009) provides extensive crane safety information. A more condensed set of guidelines for critical lifts is provided by The Hartford Loss Control Department report, "Crane Critical Lifts" (The Hartford 2008). Figure 1 shows an example of a crane critical lift plan. These references provide detailed information on planning and executing a critical lift.

3. Results

Based on a comparison of guidelines for nuclear crane operation and general industry crane operation, a number of operational variances were found. As expected, the crane operation for the nuclear industry contains more detailed requirements and more specialized equipment. A select few of the requirements are discussed along with case studies on how these requirements may assist in reducing the number of crane incidents.

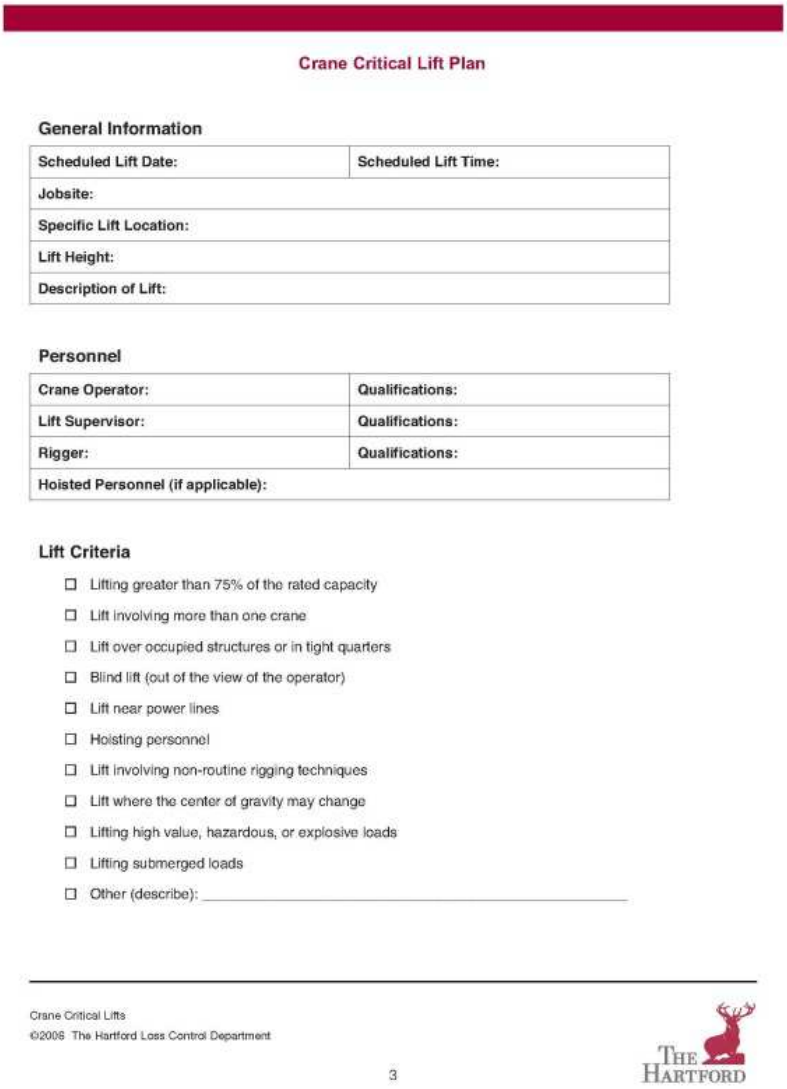
3.1 Comparison of Nuclear Crane Operation and General Industry Crane Operation

3.1.1 Single-Failure-Proof

A notable equipment requirement for the nuclear industry is that certain cranes be required to be "Single-Failure-Proof". The cranes that handle nuclear material must be equipped such that a single failure will not result in a crane dropping a load or cause a system failure during a critical lift (Porse 1979). The concept of single-failure proof requires significant redundancy in the crane lifting system and additional control requirements. Single-failure-proof crane features may include (Whiting 2012):

- Creep speeds on one or more motions
- Area or zone restrictive limit switches
- Redundant mechanical drives
- Cameras mounted at various locations

- Motion and position indicating lights or readout
- Remote operation



Crane Critical Lift Plan

General Information

Scheduled Lift Date:	Scheduled Lift Time:
Jobsite:	
Specific Lift Location:	
Lift Height:	
Description of Lift:	

Personnel

Crane Operator:	Qualifications:
Lift Supervisor:	Qualifications:
Rigger:	Qualifications:
Hoisted Personnel (if applicable):	

Lift Criteria

- ☐ Lifting greater than 75% of the rated capacity
- ☐ Lift involving more than one crane
- ☐ Lift over occupied structures or in tight quarters
- ☐ Blind lift (out of the view of the operator)
- ☐ Lift near power lines
- ☐ Hoisting personnel
- ☐ Lift involving non-routine rigging techniques
- ☐ Lift where the center of gravity may change
- ☐ Lifting high value, hazardous, or explosive loads
- ☐ Lifting submerged loads
- ☐ Other (describe): _____

Crane Critical Lifts
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THE HARTFORD

Figure 1. Example Page of a Critical Lift Plan from Hartford (The Hartford 2008)

In the general construction industry, rarely are there requirements to have a redundant mechanical lift system or rigging to prevent a dropped load. The single-failure-proof concept also requires additional systems to monitor load location, confirm location visibly, and have very low speed (creep) capability. Some of these features may be found on newer cranes in the general construction industry. With the advancement of load sensors and position detection equipment, many of these systems are becoming more affordable options for all types of cranes, not just those servicing the nuclear industry.

3.1.2 Safe Load Path with Mechanical or Electrical Interlocks

Another difference between nuclear crane operations and general crane operations is the extent to which a safe load path is designed and implemented (George 1980). In the general construction industry, it is recommended that a diagram of the intended load path be identified and that other hazards be noted, such as proximity to power lines and other workers. However, in the nuclear industry, the load path is clearly prescribed for each lift and the crane may be incapable of going near any potential hazards because of mechanical and/or electrical interlocks; this load path requirement for the nuclear operation exceed requirements for a typical lift in the general construction industry.

Advanced cranes in the general industry have the capability to limit crane movement areas. For example, collision monitoring is important when working with multiple tower cranes. Large construction sites may have multiple cranes, with moving booms and varying loads throughout the day. The cranes may be equipped with an internal system to prevent movement in certain areas or collision monitoring systems. Figure 2 shows two cranes on a job site in China outfitted with a collision monitoring system.



Figure 2. Tower Cranes in China with Collision Monitoring

3.1.3 Special Lifting Devices

In the nuclear industry special lifting devices are required for heavy loads (greater than 10,000 pounds or 5 tons) containing nuclear material (George 1980). These lifting devices interface with specific designated lifting points on the load. Specific lifting points and special lifting devices are becoming more prevalent in the general construction industry. These devices tend to be more common when repetitive lifts are required of a specialized nature. Figure 3 shows a specially designed lifting rig for a wind turbine blade. The lifting device positions the turbine blades and hub on the generator and reduces the need for a second crane. The construction industry is also starting to use more prefabricated units. The prefabricated units often come with specific lifting points and special lifting instruction.



Figure 3. Customized Crane Attachment for Hoisting Main Hub into Place

3.2 Case Study Review

In this section, case studies are presented to explore whether the additional crane requirements in the nuclear industry would reduce the probability of an incident occurring. The case studies were chosen as an example of how nuclear crane operation concepts such as redundancy, thorough planning of lift operations, load monitoring, and specially designed lifting mechanism and lift points may have assisted in preventing an incident.

3.2.1 Crane Load Dropped

In 2000, a construction worker died after the rigging carrying a steel beam failed. A lifting procedure had been developed and implemented. Multiple lifts had been performed without incident. The construction workers deviated from the original plan and lifted a much heavier load. The nylon slings failed, dropping the load on a construction worker. In addition to the overloaded slings, no devices were provided to protect the nylon slings from the sharp edges of the steel beams (FACE 2000).

An analysis by the National Institute for Occupational Safety and Health (NIOSH) Fatality Assessment and Control Evaluation (FACE) provided the following review of the incident:

- “Ensure that nylon slings are not overloaded.
- Ensure chafing material is used to protect nylon slings from sharp edges.
- Ensure that all elevated loads are controlled with tag lines.
- Ensure crane operators making lifts are aware of the rating capacity of the rigging devices used to lift the load. “(FACE 2000)

The review of the incident indicates that many of the general construction guidelines for crane operation were not followed and the incident could possibly be prevented following standard crane operational procedures. For example, careful attention to the load rating of the slings would have to be accounted for in the lifting plan. If this crane operation was being performed on a nuclear construction facility near hazardous material, additional requirements may have prevented the incident. The single-failure-proof crane would have redundant systems that may have prevented the rigging failure when one of the straps failed. In this case, the redundant system could have been additional straps to support the load.

3.2.2 Crane in Contact with Electrical Current

In 2004, two heavy equipment mechanics were electrocuted by overhead power lines while operating a truck mounted crane. The two men had been sent out to work on a piece of road construction equipment that was parked under 12kv lines. The mechanics used a truck-mounted crane to replace a component on the equipment. The crane was controlled with a portable unit that was connected to the truck by an electrical cable. Once the component was replaced, one of the mechanics remotely operated the controls to move the boom out of the way. The boom hit the overhead power lines, causing the fatalities. (FACE 2004)

The NIOSH FACE report provided the following review of the incident:

- “Ensure heavy equipment mechanics know the safety and health hazards specific to their job assignments.”
- “Ensure all employees perform safety and health inspections prior to starting their job assignments in order to find, eliminate, or control safety and health hazards as well as unsafe working conditions and practices, and to comply fully with the safety and health standards.”
- “Ensure all employees are provided with mechanical and physical safeguards to the maximum extent possible in order to perform their job assignments safely.”
- “Ensure heavy equipment mechanics are properly trained on machine operation and safety and their achievement of skills is verified through a testing program. “(FACE 2004)

Cranes coming in contact with electrical power lines is one of the main causes of fatalities in the construction industry. Based on the fatality data in table one, over the last seven years, 22% of crane fatalities were due to crane contact with electrical current. Many crane safety guidelines for the general construction industry crane operation were not followed based on the FACE assessment. If the workers had followed these guidelines, this incident may have

been avoided. If some of the more stringent nuclear guidelines had been implemented, the probability of the incident would have been significantly reduced. For example, the path a crane is allowed to take during an operation is clearly defined to avoid potential hazards. If there is a significant hazard, the crane may be unable to operate in this sector. The crane used for the operation would probably not be advanced enough to have this capability, but as technology advances, this may be something that can be implemented on even simple pieces of equipment. In addition to the safe path nuclear criteria, guidelines for working around active nuclear power plants require an assessment of potential damage to electrical lines entering into the power plant. These electrical systems may support vital systems on the power plant site.

3.2.3 Crane Load Lifting Point Failure

In 1994, a construction worker died when a 10,000 pound (5 ton) concrete slab being hoisted by a crane was dropped. The concrete slab was being used to cap a 10,000 gallon commercial septic tank. The worker was killed when two steel re-bar eyelets, embedded in the concrete slab that supported the crane rigging failed. (FACE 1994)

The NIOSH FACE report provided the following review of the incident:

The manufacturers of pre-cast concrete products should:

- "Install lifting inserts in their products that are suitable for use at the time of installation.
- Ensure that load lifting anchor points and rigging accessories are capable of carrying the intended load.
- Design, develop and implement a comprehensive safety program for all employees that includes, but is not limited to, safety training and hazard recognition for septic tank construction and, particularly, rigging operations" (FACE 1994)

In the lifting of nuclear material over 10,000 pounds special lifting points are required along with a special lifting device. Based on information from the nuclear industry, lifting points have to be specially designed and redundant to avoid a load drop. As noted in the regulations:

"Provide redundancy or duality such that a single lift point failure will not result in uncontrolled lowering of the load; lift points should have a design safety factor with respect to ultimate strength of five (5) times the maximum combined concurrent static and dynamic load after taking the single lift point failure." (George 1980)

4. Conclusions

This paper provides an overview of crane operations in the nuclear industry and examples of requirements that may useful in preventing crane incidents in the general construction industry. These requirements are compared to three crane fatality case studies to see how more stringent crane requirements may have affected the outcome of crane incidents in the

U.S. For the particular case studies shown there was evidence that increased requirements may have prevented an incident, however, following proper protocol for general crane operations would also have assisted in preventing the incident. Many of the nuclear crane requirements would be considered excessive in the general construction industry, however, general concepts such as redundancy, thorough planning of lift operations, load monitoring, and specially designed lifting mechanism and lift points could be implemented or already are implemented in the general construction industry. To improve safety of crane use, it may be appropriate to turn to crane requirements that have very low probability of failure, such as in the nuclear industry.

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Employee involvement and empowerment in health and safety: A perception of small and medium contractors in South Africa

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Abstract

Purpose: It is well known that managing H&S helps ensure that construction organizations are achieving their H&S objectives and targets. As such, the H&S management practices constitute a vehicle to improve H&S performance outcome. However, the challenge is to determine what needs to be measured and practiced by SMEs at project level. The objectives of this paper are therefore to determine the H&S elements indicative of SMEs, employee involvement and empowerment H&S practices and the influence of employee involvement and empowerment on H&S performance at project level.

Research methodology: A survey was conducted using a structured questionnaire consisting of 31 items categorized in five independent variables (IV). This was developed from extensive literature and four rounds of Delphi survey. A total of 216 valid questionnaires were analysed using statistical package for social sciences (SPSS) version 20. Inferential statistics were used to determine the perception of SMEs employee involvement and empowerment practices. Finally, standard multiple linear regression analysis was undertaken to establish the influence employee involvement and empowerment had on H&S performance.

Findings: Five IVs were retained as valid and reliable factors of H&S practice within SMEs at project level. However the study established that employee involvement and empowerment is not greatly practiced and does not influence H&S performance.

Limitations: Self-administered questionnaire for SMEs and the majority of the respondents conducting business in Gauteng province in South Africa are limitations in this study.

Value: The findings indicate the need to fully involve and empower employees in H&S activities of SMEs at project level.

Practical implication: This study provides the basis of informing the H&S policy that employee involvement and empowerment is not greatly practiced within construction SMEs in South Africa at project level. Hence, the need to encourage this practice within South African SMEs is highly recommended.

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Keywords: authority, insight, participation, workers

1. Introduction

In South Africa the construction industry accounted for a total of 74 deaths recorded on site in 2003 and was ranked third after mining and transport. Records of the Compensation Commissioner and Federated Employers Mutual Assurance Company Ltd (FEMA) reported approximately 25,500 accidents per annum (Construction Industry Development Board (CIDB, 2004). The current construction H&S statistics available provided by the Department of Labour (DoL) covering the period 2004/05 to 2007/08, reveal a sharp rise in fatalities and non-fatal accidents as indicated in Table 1.

Table 1: Construction health and safety statistics

Accident/Year	2004/04	2005/06	2006/07	2007/08
Fatal	54	81	79	162
Non-fatal	159	250	245	396
Total	213	331	324	558

Source: Adapted from CIDB 2008 report

Furthermore, as per the year 2007 the direct cost of claims finalized according to FEMA amounted to about ZAR116million, implying indirect cost of around ZAR1.65 billion. Similarly figures from the compensation commission can be estimated to about ZAR3.5 billion per year or around 2% of the construction spent, to cater for direct and indirect cost of accidents (CIDB, 2008). It is worth noting that the aforementioned statistics are inclusive of large, medium and small contractors. Aside from the direct compensation and medical costs associated with accidents the costs to the economy are immense and include rework, lost time, damage to plant and equipment, disruption, productivity loss, legal fees and loss of skills to the industry.

1.1 Current challenges encountered by SMEs in managing H&S in the South Africa construction industry

South African SMEs in construction have been described as being largely underdeveloped (Department of Public Works (DPW), 1999), and face several challenges that include the lack of H&S training and competence (CIDB, 2008). They generally lack knowledge of pricing procedures, contractual rights and obligations, law, management techniques and principles as well as technology (Martin, 2010). Furthermore, given their limited resources and capacity, they would typically have poorer H&S practices and culture. They are also less likely to have an established H&S management system, furthermore, the management of H&S is mostly less structured and based on prior contract experience of the owners (CIDB, 2008). It is likely that these contractors would not be aware of the demands and requirements of the South African generic and construction H&S legislative framework and requirements. Furthermore, employee involvement and empowerment in H&S would be minimal.

1.2 Health and safety performance measures

The establishment of a good H&S culture within SMEs can undoubtedly help organizations to control and reduce their construction costs and increase the efficiency of their operations in the long term (Ferreira et al., 2011). Since poor H&S culture can lead to risks to human lives, much attention has been paid over the past few years, to organizational H&S culture, especially to its characteristics that is definitions, core elements or leading indicators and its leading indicator metrics. This is because there is no consensus of the definition of H&S culture, as different authors define H&S culture to suit their situation (Choudhry et al., 2007). Furthermore, there is no consensus of the measures or indicators to effectively monitor H&S culture (Fernandez-Muniz et al., 2007).

Unfortunately, several measures for H&S performance measurement are used. The most common of these measures is accident rates and fatal injuries (Hinze, 2005). These are lagging indicators or downstream indicators, which are inherently flawed (Trethewy, 2003) and unsuccessful in providing meaningful measures of H&S performance (Hinze 2005), they are not concerned of how to improve H&S performance, but rather they are concerned with negative H&S performances or failure of the H&S system (Cohen, 2002). Furthermore, the possibility of under-reporting of accidents (Dindsdag et al., 2008) especially in countries where the reporting system is poor is high (CIDB, 2008) hence not reflecting a true outcome of H&S performance. Mohammed (2003) further indicated that using accident statistics can encourage under-reporting as workers may fear being reprimanded for compromising the safety performance of the workplace. Despite the limitations of using outcome H&S metrics, they can provide valuable information, especially when used in combination with well selected current leading indicators (Blair et al., 2010).

To overcome the limitations of using lagging indicators, Trethewy (2003) suggest that features of upstream, leading indicators or proactive indicators of H&S culture that have the greatest downstream consequences namely reduction of accidents, absenteeism, but to name a few need to be identified. This was further supported by Hinze (2005). Graborwski et al., (2010), further states that using leading indicators of H&S culture gives early warning before the incident or accident takes place.

Dingsdag et al., (2008) maintains that there are still no standard national and international leading indicators for measuring H&S culture or H&S performance that are accepted by the construction industry or any other industry. Hinze (2005) indicated the need to develop a range of leading indicators that are relevant to the construction organizations requirements. This statement is supported by, Blair et al., (2010), who assert that what works for one industry or size of organization may not work for another industry or size of organization.

2. Literature review

Ng et al., (2005) developed a framework to evaluate H&S performance at project level and organization level. Their study identified 13 sub-factors for organization level and 18 for

project level. The main project related elements were; project management commitment, hazard management, information, training and promotion of H&S, implementation of H&S system of work, H&S inspection, recording, reporting and investigation of accidents, emergency procedures of H&S and H&S review. The organization related elements were; administrative and management commitment, H&S training, selection and control of subcontractors, H&S review, accidents records and compliance with legislation, codes and standards. This model did not reflect whether the factors or sub-factors had an influence to improve H&S performance, but rather there importance to improve H&S performance. This is a limitation of this framework and further research is required to validate this model.

Teo and Ling (2006) developed a model to measure the effectiveness of construction site H&S management. The model was based on 3P + I, where "3P" represented policy factors, process factors, and personnel factors and "I" represented incentive factors. These core factors were measured in terms of 17 sub-factors. The model comprised of a hierarchical framework with different levels of measurement where level 1 represented the main factors, level 2 represented the attributes required to measure level 1.

Chinda and Mohamed (2008) developed H&S culture model adapted from the European Foundation Quality Model (EFQM), they identified several enablers, namely; leadership, policy and strategy, partnerships and resources, processes, and H&S outcomes such as goals. The study examined the interrelationships of the elements and their impact on the H&S outcomes. The enablers were measured using 34 indicators. The "best fit" model that was attained included a final set of 24 indicators with leadership commitment as the key driver of H&S culture. This enabled performance improvement in the form of reduced numbers of accidents, improved industrial image, improved workforce morale and reduced accidents cost.

Fernandez-Muniz et al., (2007) developed a positive H&S culture model that included management commitment, employee involvement and safety management system (SMS). The SMS was composed of; H&S policy, incentives, training, communication, planning and control. The study found that H&S improved when managers and employees were involved in H&S activities and the effective implementation of SMS. The conceptual model constituted of 57 items including four outcome measures or lagging indicators. The model finally consisted of 29 items that could arguably reduce the number of personal injuries and damage of materials. Motivate employees to work and reduce absenteeism which would lead to reduced lost time at work. This model was developed to fit different industries and different sizes of organization. The challenge is that different industries and different sizes of organizations differ in their working environment and characteristics, and no measure will work effectively for all industries or even all sites within the same location (Blair *et al.,* 2010), whose sentiment was supported by Maloney, (2011).

3. Problem statement

Based on the aforementioned gaps and developments in measuring H&S performance coupled with SMEs H&S challenges and their importance to the economy. This research proposes to answer the following specific research questions.

- What are the H&S elements that are indicative of SMEs at project level?

- What is the perception of SMEs on employee involvement and empowerment practices? and

- Do employee involvement and empowerment in H&S influence H&S performance at project level of SMEs?

4. Research methodology

A mixed method design was used for this study. The questionnaire was developed from relevant literature and four rounds of Delphi survey with 20 H&S experts of, which 16 H&S experts completed all the four rounds of Delphi. The developed SME questionnaire was administered to upper management personnel to establish their H&S practice at their project level. The survey consisted of 31 statements/items/leading indicator metrics addressing five H&S elements rated using five point Likert-scales indicating their level of agreement.

Other parts of the questionnaire were designed to profile the participants in terms of their; gender, position in the company, level of experience in the construction industry and the number of years in the current organization. Following the questionnaire pre-testing with eight upper management personnel or those who were knowledgeable of H&S practices in their organizations, the final refined version of the SMEs questionnaire was presented to 1450 conveniently sampled SMEs using email and drop and collect methods. 228 questionnaires were returned and 216 were deemed eligible for analysis. The statistical package for social sciences (SPSS) version 20 was used to analyze the factor structure of the H&S practices, extracted using maximum likelihood and PROMAX rotation. The perception of the respondents was reported using inferential statistics i.e. means and standard deviation. Finally, the influence of employee involvement and empowerment in H&S on H&S performance was determined using standard multiple linear regression analysis.

5. Results and discussions

5.1 The health and safety elements indicative for SMEs

The reliability and the validity of the proposed elements obtained from literature review and Delphi survey are analysed and the results of each H&S element are tabulated below:

Upper Management Involvement and Commitment in H&S

The result in Table 2 indicates that the corrected item-total correlation were greater than the suggested cut-off value of 0.30 (Nanually et al., 1994) suggesting that the items are good measures of the element and the Cronbach alpha is greater than 0.70 (Nanually et al., 1994) indicating internal reliability. The Kaiser-Meyer-Olkin (KMO) of 0.890 with Bartlett's Test of Sphericity of $p<0.000$ were also obtained. Indicating consistency with the recommended

KMO cut-off value of 0.60 and Bartlett's Test of Sphericity of p<0.05 suggested by Hair et al., (2010). This result suggests that factor analysis can be conducted with the data.

All nine items expected to measure upper management commitment and involvement loaded together on this factor. An Eigenvalue of 5.107 and factor loadings greater than 0.452 for all of the items were established and are reported in Table 2. The factor loadings were greater than the cut-off value of 0.40 recommended by Hair et al., (2006). The factor upper management commitment and involvement explains 46.427% of the variance in the data. Therefore, sufficient evidence of discriminant validity is provided for this construct. This result concurs with Fernandez-Muniz et al., (2007). The item that loaded highly on this element was "I/We communicate regularly with workers about H&S".

Table 2: Upper management commitment and involvement in H&S

Eigen value 5.107 % of variance 46.427		Cronbach-alpha 0.868 KMO 0.890 p<0.000		
Item	Question	Factor loading	Corrected Item total correlation	Cronbach level after deletion
UMC 3	I/We communicate regularly with workers about H&S	0.786	0.718	0.847
UMC 4	I/We actively monitor the H&S performance of the projects and workers.	0.778	0.737	0.844
UMC 8	I/We encourage discussions on H&S with employees	0.728	0.689	0.849
UMC 7	I/We regularly visit workplaces to check work conditions or communicate with workers about H&S	0.717	0.663	0.850
UMC 6	I/We actively and visibly lead in H&S matters by e.g. walk through the site etc.	0.672	0.600	0.855
UMC 5	I/We take responsibility for H&S by e.g. stopping dangerous work on site etc.	0.667	0.598	0.854
UMC 10	I/We ensure that the H&S equipment is bought e.g. hardhats, overall etc.	0.618	0.566	0.857
UMC 9	I/We conduct toolbox talks with the workers regularly	0.604	0.555	0.857
UMC 2	I/We accord workers H&S training when there is less work in the project.	0.491	0.476	0.865
UMC 11	I/We reward workers who make extra effort to do work in a safe manner.	0.465	0.432	0.873
UMC 1	I/We encourage and support worker participation, commitment and involvement in H&S activities.	0.452	0.415	0.867

Worker involvement and empowerment in H&S

The result in Table 3 indicates that the corrected item-total correlation were greater than the suggested cut-off value of 0.30 (Nanually et al., 1994) suggesting that the items are good measures of the element and the Cronbach alpha is greater than 0.70 (Nanually et al., 1994) indicating internal reliability. The Kaiser-Meyer-Olkin (KMO) of 0.819 with Bartlett's Test of Sphericity of p<0.000 were also obtained. Indicating consistency with the recommended KMO cut off-value of 0.60 and Bartlett's Test of Sphericity of p<0.05 suggested by Hair et al., (2010). This result suggests that factor analysis can be conducted with the data.

All five items in Table 3 expected to measure the factor employee involvement and empowerment loaded together on this factor. An Eigenvalue of 3.079 and factor loadings attained were greater than 0.458 for all the items and concurs with the cut-off value of 0.40 recommended by Hair et al., (2006). The employee involvement and empowerment explains 61.557% of the variance in the data. Therefore, sufficient evidence of discriminant validity is provided for this construct. This result concurs with Fernandez-Muniz et al., (2007). The item that loaded highly on this element was "Our workers are involved in the production of H&S policy".

Table 3: Worker involvement and empowerment in H&S

Eigen value 3.079 % of variance 61.577		Cronbach-alpha 0.842 KMO 0.819 p<0.000		
Item	Question	Factor loading	Corrected item total correlation	Cronbach level after deletion
WIS 4	Our workers are involved in the production of H&S policy	0.863	0.757	0.778
WIS 2	Our workers help in developing of H&S rules and safe work procedures	0.839	0.770	0.776
WIS 5	Our workers are consulted when the H&S plan is compiled	0.814	0.714	0.791
WIS 1	Our workers are involved in H&S inspections.	0.598	0.563	0.832
WIS 3	Our workers can refuse to work in potentially unsafe, unhealthy conditions	0.458	0.444	0.857

Occupational Health and Safety Management System

Three factors of occupational health and safety management system were validated, namely; project H&S planning and communication, project supervision and H&S resources and training. The results are reported below;

Project H&S planning & communication

The result in Table 4 indicates that the corrected item-total correlation were greater than the suggested cut-off value of 0.30 (Nanually et al., 1994) suggesting that the items are good measures of the element and the Cronbach alpha is greater than 0.70 (Nanually et al., 1994) indicating internal reliability. The Kaiser-Meyer-Olkin (KMO) of 0.764 with Bartlett's Test of Sphericity of $p<0.000$ were also obtained. Indicating consistency with the recommended KMO cut off value of 0.60 and Bartlett's Test of Sphericity of $p<0.05$ suggested by Hair et al., (2010). This result suggests that factor analysis can be conducted with the data.

All four items in Table 4 expected to measure the factor project H&S planning and communication loaded together on this factor. An Eigenvalue of 2.786 and the factor loadings attained were greater than 0.665 for all the items and concurs with the cut-off value of 0.40 recommended by Hair et al., (2006). The project H&S planning and communication explains' 69.644% of the variance in the data. Therefore, sufficient evidence of discriminant validity is provided for this construct. This result concurs with Fernandez-Muniz et al., (2007).

The item that loaded highly on this element was “Our firm uses procedures to identify possible H&S dangers on site”.

Table 4: Factor project H&S planning and communication

Eigen value 2.786 % of variance 69.644		Cronbach-alpha 0.852 KMO 0.764 p<0.000		
Item	Question	Factor loading	Corrected item total correlation	Cronbach level after deletion
PPC 2	Our firm uses procedures to identify possible H&S dangers on site	0.833	0.749	0.788
PPC 3	I/We include H&S in our projects program	0.822	0.763	0.784
PPC 1	I/We consider H&S when layout of site is done	0.769	0.671	0.823
PPC 4	I/We organize regular meetings to verbally inform workers about the risks and preventive measures of their work.	0.665	0.598	0.850

Project supervision

The result in Table 5 indicates that the corrected item-total correlation for each item were greater than the suggested cut-off value of 0.30 (Nanually et al., 1994) suggesting that the items are good measures of the element, whereas Cronbach alpha is greater than 0.70 (Nanually et al., 1994) indicating internal reliability of the element. The Kaiser-Meyer-Olkin (KMO) of 0.868 with Bartlett’s Test of Sphericity of p<0.000 were also obtained. Indicating consistency with the recommended KMO cut off value of 0.60 and Bartlett's Test of Sphericity of p<0.05 suggested by Hair, et al., (2010). This result suggests that factor analysis can be conducted with the data.

Table 5: Factor project supervision

Eigen value 3.640 % of variance 60.662		Cronbach-alpha 0.868 KMO 0.868 p<0.000		
Item	Question	Factor loading	Corrected item total correlation	Cronbach level after deletion
PSP 1	I/we allow supervision of work by staff trained in H&S.	0.786	0.722	0.837
PSP 5	I/we undertake informal H&S inspection of the work place daily.	0.781	0.719	0.837
PSP 2	One of our employees trained in H&S identifies dangerous activities.	0.718	0.658	0.848
PSP 3	I/we undertake formal H&S inspection of the work place daily.	0.714	0.644	0.850
PSP 4	I/We allow local authorities and H&S enforcement agencies to visit sites for inspection.	0.693	0.645	0.850
PSP 6	I/we regularly undertake H&S audits of projects	0.666	0.620	0.854

Table 5 results further indicate that all six items expected to measure the factor project supervision loaded together on this factor. An Eigenvalue of 3.640 and the factor loadings

attained were greater than 0.666 for all the items and concurs with the cut-off value of 0.40 recommended by Hair et al., (2006). The project supervision explains 60.662% of the variance in the data. Therefore, sufficient evidence of discriminant validity is provided for this construct. This result concurs with Fernandez-Muniz et al., (2007). The item that loaded highly on this element was “I/we allow supervision of work by staff trained in H&S”.

Health and safety resources and training

The result in Table 6 indicates that each corrected item-total correlation were greater than the suggested cut-off value of 0.30 (Nanually et al., 1994) indicating that the items correlate well in the element and the Cronbach alpha is greater than 0.70 (Nanually et al., 1994) indicating internal reliability. The Kaiser-Meyer-Olkin (KMO) of 0.801 with Bartlett’s Test of Sphericity of p<0.000 were also obtained. Indicating consistency with the recommended KMO cut-off value of 0.60 and Bartlett's Test of Sphericity of p<0.05 suggested by Hair, et al., (2010). This result suggests that factor analysis can be conducted with the data.

Table 6: Factor H&S resources and training

Eigen value 3.281 % of variance 65.628		Cronbach-alpha 0.864 KMO 0.801 p<0.000		
Item	Question	Factor loading	Corrected item total correlation	Cronbach level after deletion
HSR 2	I/we provide correct tools, equipment to execute construction work.	0.783	0.724	0.832
HSR 5	I/we ensure that workers are trained to do the work safely	0.771	0.706	0.830
HSR 4	I/We ensure our workers are properly trained to take care and use personal protective equipment	0.763	0.691	0.834
HSR 3	I/we conduct induction of all workers on H&S before commencing work on a particular site	0.751	0.698	0.835
HSR 1	I/We buy hardhats, gloves, overall etc. for workers	0.708	0.639	0.847

All five items in Table 6 expected to measure H&S resources and training loaded together on this factor. An Eigenvalue of 3.281 and the factor loadings attained were greater than 0.708 for all the items and concurs with the cut-off value of 0.40 recommended by Hair et al., (2006). The factor H&S resources and training explains 65.628% of the variance in the data. Therefore, sufficient evidence of discriminant validity is provided for this construct. This result concurs with Choudhry et al., (2007). The item that loaded highly on this element was “I/we provide correct tools, equipment to execute construction work”.

5.2 Perception of SMEs on employee involvement and empowerment H&S practices

Furthermore, the result in Table 7 indicates that two of the five practices were considered to be highly practiced by the SMEs. These highly ranked practices were; “workers can refuse to work in potentially unsafe, unhealthy conditions” and “workers are involved in H&S

inspections" with mean values of 4.26 and 4.02 respectively. They were also reliable measures of employee involvement and empowerment in H&S. The reliability values were above the recommended value of 0.70 recommended by Hair et al., (2006). However, the least H&S practice was "workers are involved in the production of H&S policy" with a mean value of 3.64.

Table 7: Employee involvement and empowerment in H&S

Item	Action	Mean	Standard deviation	Cronbach level after deletion	Rank
WIS 3	Our workers can refuse to work in potentially unsafe, unhealthy conditions.	4.26	0.788	0.857	1
WIS 1	Our workers are involved in H&S inspections.	4.04	0.884	0.832	2
WIS 2	Our workers help in developing of H&S rules and safe work procedures.	3.87	0.931	0.776	3
WIS 5	Our workers are consulted when the H&S plan is compiled	3.68	1.047	0.791	4
WIS 4	Our workers are involved in the production of H&S policy	3.64	1.006	0.778	5

5.3 Influence of employee involvement and empowerment on H&S performance

The result in Table 8 indicates that employee involvement and empowerment was the least practiced of the five H&S practices with a mean value of 3.90. Furthermore, employee and empowerment in H&S does not influence H&S performance as the t-value was less than ±1.96 at 1.28 and was non-significant at 0.20, which was greater than 0.05. This is contrary to the findings of Fernandez-Muniz et al., (2007). However, H&S resources and training, upper management commitment & involvement in H&S and project supervision influenced H&S performance. Hence, they were significant.

Table 8: H&S practices influence on H&S performance

H&S practice	Mean	Std. Deviation	N	t-value	Sign. (*p*)	Rank
H&S resources and training	4.51	0.56	212	3.03	0.00	1
Upper management commitment & involvement in H&S	4.33	0.48	193	3.06	0.00	2
Project H&S planning and communication	4.19	0.66	207	-0.22	0.83	3
Project supervision	4.14	0.64	204	3.06	0.00	4
Employee involvement & empowerment in H&S	3.90	0.73	208	1.28	0.20	5

6. Conclusions and recommendations

The results of this study are encouraging and suggest that the H&S elements are valid and reliable practices within construction SMEs. The results therefore concur with the study of Fernandez-Muniz et al., (2007) and it can be indicated that H&S culture within SMEs in South Africa comprises of, upper management commitment and involvement in H&S, employee involvement and empowerment in H&S, project H&S planning and communication, project supervision and H&S resources and training. The five H&S practices

measuring employee involvement and empowerment were practiced with different intensity. SMEs agreed that their workers can refuse to work in potentially unsafe, unhealthy conditions and their workers are involved in H&S inspections. However, the SMEs indicated that their workers involvement in the production of H&S policy was not comprehensively practiced. The perception of SMEs on employee involvement and empowerment in H&S was the least practiced of the five elements of H&S. Furthermore, it did not influence H&S performance.

Further research is advocated. This is to determine the reason why employee involvement and empowerment did not influence H&S performance. Furthermore, the use of structural equation modelling in developing H&S performance improvement model for SMEs at project level is suggested for further study. This will enable to compare the multiple linear regression analysis and structural equation modelling results.

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How Architecture promote Right to Health in Hospital

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Abstract

In the last decades both care and hospital have faced intense transformations. Hospital is not only called to assure quality of care in order to remove or reduce a condition of disease, but it has to answer to new social needs to provide citizens' health rights. Hospital have also become a complex structure, connected to the city and territory, where the traditional health functions are developed to promote values that underlie the community, such as solidarity, equity, participation. These values come true through social interactions that occur in hospital spaces and they are the condition of the effective enjoyments of rights. The aim of this paper is to highlight as architecture contributes to promote effective enjoyment of social rights in hospital care.

In order to face this study public spaces in hospital represent the most interesting sphere because they are the primary welcoming spaces for patients, visitors, citizens and at the same time they are the primary space to address the users towards the hospital activities of care.

The relationship among social right, social relations and space can be study only with the contribution of different disciplines: architecture, law and social science. Thus the interdisciplinary approach is a fundamental requirement and represents the added value of the research.

Since the focus of the research on the 'relation-based approach' as new paradigm of right to health, we decided to investigate how space affects the experience of patient in public spaces. Research methodology consists of a survey-based approach to collect information on aspects of the 'relations', analysing case studies of hospital buildings. We combined spatial analysis of hospital layout with observations of user behaviour. The direct comparison between use pattern and spatial characteristics led up to identify two results: a set of interdisciplinary meaningful topic for interrelation between space and rights; a set of spatial indicators for each meaningful topic.

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The explanation work of data produced with case studies analysis leaded to collect them in a summary tool which includes the key topic in enjoyment of right to health.

The most important innovative contribution which improves on knowledge consist of making evident that environment contributes to enjoyment of rights and showing how architecture can support right to health.

Keywords: Hospital assets, Social needs, Health rights, Spatial Layout, Hospital public spaces

1. Introduction

The aim of this paper is to highlight as architecture contributes to promote effective enjoyment of social rights in health field and especially in hospital care.

We approach this theme with a new interdisciplinary point of view aimed at addressing how hospital building can meet social needs of people, with specific emphasis on right to health in public spaces. From a legal standpoint, the right to health is a highly social and relational right whose one of the most important variables is represented by the spatial-organizational aspect. How space supports or prevents the enjoyment of right to health? We suggest that configurational factors of spatial layout play a key role together with the consolidated environmental elements (Evans, 2003; Ulrich et al., 2008). Configuration factors have to do with the set of geometrical interrelated relations in a spatial layout.

The relationship among social rights, social relations and space can be study only with the contribution of different disciplines: architecture, law and social science. Thus the interdisciplinary approach is a requirement to face this theme and represents the added value of the research since it can provide decision-making processes with a more comprehensive vision of the existing problems and possible prospects.

As a result of a number of factors we are facing profound changes in care, which therefore lead us to also re-consider architecture and its value.

In the last decades hospital too has faced intense transformations. From one hand hospital is not only called to assure quality of care in order to remove or reduce a condition of disease, but it has to answer to new social needs to provide citizens' health rights. These needs are seen within an integrated concept of health as a "state of optimal physical, mental and social well-being"[4]. Some new social needs are related to easy access to care, promotion of the social respect culture, attention to doctors-patients relation, relations involving caregivers-doctors-patients.

[4] In some way this definition of health rights involves the Vision of World Health Organization (WHO):"Health is a state of optimal physical, mental and social well-being, and not only the absence of disease".

On the other hand hospital have become a complex structure, connected to the city and territory, where the traditional health functions are developed searching levels of excellence to promote values that underlie the community, such as solidarity, equity, participation. These values come true through social interactions that occur in hospital spaces and they are the condition of the effective enjoyments of rights.

Therefore we can talk about the way in which space is lived, and the needs of those who live in it. The physical environment is a key factor. In particular space is a significant element behind success for the quality of life of both patients and staff, because it concerns social relations. Therefore, architectural decisions behind space dynamics play a critical role.

The hospital spaces that we define ‘public’ -such as spaces of interface, welcoming, waiting, where people meet, and not directly involved by care activities - have assumed a particular meaning because they are the places where new social needs occur and they are the connection between health performance and city.

This paper is structured in three part: a first description of background around which we are moving that deal with the role of public spaces in hospital transformation process and the review of State of the Art; a second part that shows the methodology used and the analysis conducted on case studies with a paragraph concerning the relevance of this method in relation to the purpose; a third part with a short description of the results with an in depth analysis of a requisite and the final discussion.

1.1 The idea of public spaces in hospital

The theme of public spaces is strongly connected to the role of the hospital within cities and local areas, to the hospital as service for the community and humanisation of care. Urbanity and Socialisation. The first concept underlines the importance for a new hospital to be integrated to the urban weave in a multi-level built environment. The focus is on the role of the hospital as a catalyst of re-qualification, of re-generation and development of cities, abandoning a concept of hospital as a separated place from the city-life: hospital as ‘civic architecture’ (Curtis et al., 2009).

Socialisation entails, in a complementary way to Urbanity, the concept of solidarity and belonging to the community, thus an open hospital that holds areas dedicated to social and cultural activities that can be used, for example, by voluntary services. The modern/ hospital tends to open itself to and include new kind of public spaces.

Previously the term ‘public spaces’ overall referred to the connectives of entrance of the hospital, the area of distribution that precedes the hospital functions. Currently this term gains a much wider meaning. The hospital entrance becomes an articulated and complex space, the conformation of the hospital layout gets set to receive big halls, proper streets, parks, capacious loggias and covered squares. These areas modify not just the hospital physiognomy but represent spaces that are functionally new so that they can be called spaces of interface or hybrid spaces (Torricelli et al., 2010).

They embed, indeed, a mixed of activities from information and communication of the reception to waiting areas and rest stop zones. These hybrid spaces are the primary welcoming spaces for patients, visitors, citizens and at the same time they are the primary space to address the users towards the hospital activities of care.

The introduction of public spaces within the hospital is one of the major factors that have been shaping the contemporary hospital (Fiset, 2006).The growth of public spaces in hospitals began in the late 80's with the establishment of big atrium hotel-like or mall-like that incorporates nature (Verderber and Fine, 2000). To these followed the development of proper distribution streets within the spatial layout.

Actually, due to this function of transition areas, public spaces aim at progressively accompanying the user within his/her health journey guiding him/her in the status transition from a public sphere to a private one. Thus public spaces can negatively or positively affect users, visitors and staff in their expectations.

1.2 The idea of space and social rights

From Europe Whitepaper (2007) we read that "Community health policy must take citizens' and patients' rights as a key starting point". The powerful effect of this policy can be analysed if we consider linkages between the right to health and the space of care. There is strong evidence that places of care for weak people need to promote participation.

Therefore the creation of places and spaces of care must consider participation as an essential requirement for social rights satisfaction. In fact, social rights are based not on a person claim, but on a process of participation in life expressed in a place (Von Benda-Beckmann and Griffiths, 2009). Therefore legal rules that embody such rights must consider the particular connection of the human's life with those places or, specifically, with the spaces where life takes place.

The working hypothesis is that the full satisfaction of social rights does not depend solely on the distribution of single state benefits, but on social life as it happens in places such as the built environment and buildings. Therefore social rights require the existence of social links - as family, school, working environment, social and personal life environment - in which and through which everybody becomes a person and is able to express him/herself as such. Space is essential for the meaning of social rights: it is more properly the place where these rights are exercised, and not the practical result of politics.

We assume that there is a close relationship between social rights and space. The research is going to develop this assumption relating to the kind of relation and the way in which space affects the dynamics of the rights protection in hospital facilities.

The social dimension of space is the pivot to discover a new dimension of social rights and at the same time it represents a connection between Architecture Discipline and Law Discipline. In fact, the relationship between space and society is like a dogma in defining the nature of architecture, from the functionalism of the Modern Movement to the works by C.

Alexander. For this reason now we frequently hear of discussions about 'social space' and 'social power of architecture'. So we use architecture as a tool for social expectation, but also as an aid to promote social politics and social rights.

1.3 Originality vision of the research

The new vision identified by this research is the social dimension of space as dimension of social rights. The most important innovative contribution which improve on knowledge consist of making evident that architecture contributes to enjoyment of rights.

The space makes possible the enjoyment of right to health, both because it fosters efficient supply of performance/service and because it creates condition for psycho-physical comfort and because it fosters accessibility and integration in the community. Some dimensions of these health rights are: privacy, control, proximity, access to information, relations-based approach[5].

The points of originality of this project are mainly two.

The first is the approach to the theme of public spaces within hospitals not as a canonical approach. The first innovation, in fact, resides in the consideration of ‘space of care as relationship’, between patient and staff (medical and administrative), between patient and visitor (caregiver and relative), and between patient and patient. In the scenario of socio-spatial study on hospital architecture, the Evidence-based studies on humanisation (Zimring, 2009; Ulrich et al., 2008) and on the supportive psychosocial environment (Dilani, 2006), was focused on relations between environmental quality and users satisfaction. In this study the focus is moved in exploring the role of the environment in facilitating social relationships. This study indeed aimed at isolating those aspects that move the attention from a patient-centred approach to a relation-based approach (Beach et a., 2006). Within the relationship between the built environment and the care, an emerging element is that many studies investigated the hospital rooms and just few regarded the public spaces.

The complexity of the issue acts also a changing in methodology, because the idea is not to deliver guideline for good practices in design of these spaces, but to understand deeper the relationships and the relatives influences that work on architecture field. Particularly the relation between protection of health rights and places is taken in account.

The other originality point of the project is about taking an advancing in research method for design articulated on analysis, monitoring and decisions support methods taking into account new users’ needs related to right to health. This progress in research methods is very useful for architects and for those who are decision makers in health politics (delivers and managers).

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[5] These new dimensions of health rights emerged from the on-going interdisciplinary research of SPACES Interdisciplinary research on health care spaces (www.rightspaces.eu). This study has been funded by the Region of Tuscany and is the project currently involving the research fellow. The team includes scholars of lawyers, sociologists and architects.

2. Methodology

Since the focus of the research on the 'relation-based approach' as new paradigm of right to health, we decided to investigate how space affect the experience of patient in public spaces, exploring the relation between space and pattern of users' behaviour to know how space protects social rights. So we adopted a survey-based approach to collecting information on aspects of the 'relations', analysing case studies of hospital buildings using a GIS technology.

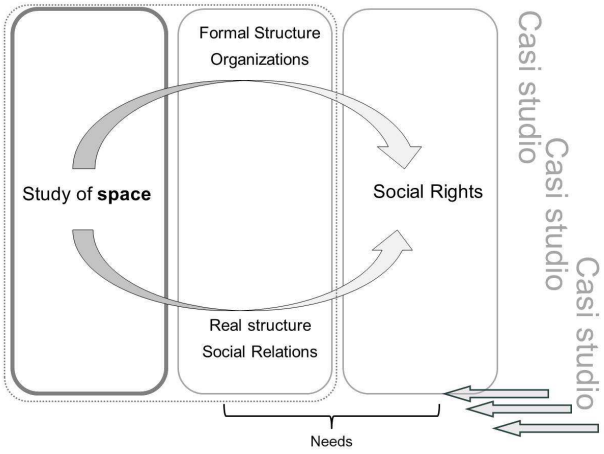

Figure 1: Diagram of relation between space and social rights. The relation consist of a 'formal structure' and 'real structure'. The first is the set of procedures and regulations and, in SPACES research, it is studied by the legal scholars. The second is the set of spontaneous and adapting social relations studied by the sociologists and by architects.

We combined spatial analysis of hospital layout with observations of user behaviour. The spatial analysis was led by configurational analysis methodology integrated with traditional architectural methodology such as functional and typological analysis and the observation was carried out by snapshot technique. Both the methodologies were applied at the same kind of spaces.

We choose these methods because it needs to observe the 'real structure' of society - that is behaviours and adaptation of procedures that happen in space (Fig. 1) -, in order to understand new needs related to right to health. Then because it needs to study those elements of space which have to do with pattern of users' behaviour. We choose to focus on configurational aspects as they affect the social relations in space: meeting, communicating, taking and giving information, getting closer (Hillier, 2007).

2.1 Syntactical description of spatial layout

The configurational analysis methodology used is Space Syntax (SSx), a method developed at Bartlett School of London. We adopted such methodology as suitable for study the

relationship between space and society, between configuration of space and patterns of users' behaviour.

The method moves from the idea that buildings are 'social object' (Hillier, 2007). They significantly perform in fulfilling and sustaining human society. SSx analyses mathematically the complex relationships of space to achieve a description of its quantitative and qualitative syntax proprieties and how they affect how people exploits space, thereby favour or undermine relationships among users.

SSx method and technique infers, through social observations and spatial layout analysis, the existing correlation between social and physic sphere investigating how much architecture impress social relations. Spatial configuration is space through which people move, and in which they are brought into face-to-face contact with one another. Contact is a prerequisite for interaction, communication and the transactions of social and economic life (Penn, 2008). Therefore configurational approach seems to be the most appropriate method to fit with the purpose.

The SSx method is based on the idea of *configuration* which is defined as a set of interdependent relations in which every relation is determined by its relation with all the others. Relation can be studied among different spatial elements: rooms, streets or networks. The spatial elements selected, their representation (lines or convex spaces), their relations constitute the spatial model. Line represents the visual straight line passing through a space, whereas convex space represents the space in which every point in its perimeter can be seen from each other point of its perimeter.

Relations among spatial elements are analysed by software generating parameters. The most important parameter is the *Integration*. It refers to accessibility as geometric property of space and express how much every space in the system is accessible from every other space of the system.

The integration value is described by maps showing the spatial accessibility degree in the spatial model concerned, using a value scale (to which a greyscale colour corresponds) going gradually from spaces more integrated, i.e. those more easy accessible (conventionally black), to spaces less integrated, i.e. more difficulty accessible (conventionally light grey).

The degree of accessibility is a property of space calculated considering geometrical and topological variables of a spatial layout as: changes of directions, length, distance, deep, connections and angular degree of intersections among spatial elements. Studies (Hillier, 2007; Hillier and Hanson, 1984; Penn, 2008; Penn et al, 2007; Turner, 2000; Penn and Turner, 2002) have shown that the degree of accessibility is a good predictor of people movement.

2.2 Description of social data

The observation technique selected to investigate the patterns of users' behaviour is that of snapshot. It consist of a sequence of snapshot of the activity occurring at a precise moment in the space. Every category of people, position, activity and interactions are graphically recorded on a GSI plan. We choose this kind of technique because, according to a socio-spatial approach, space is lived by people. Moreover because snapshot technique allows us clearly to determine the type of relation, which has a fundamental role in our research (see Introduction).

Our concern here focuses on understanding pattern of users behaviour, so we excluded studies about specific events which were faced by the sociology group.

Particularly the observations served to locate where and how people move inside hospital taken as case studies, and to locate where a certain type of relations happen and among which categories of people.

We observed Patients, Old Patients, Foreign Patients, Medical Staff (doctors and nurses), Administratives , Porters. We noted different kind of relations: Health, actions and interactions regarding to health and care; Social, generic actions and interactions; Wayfinding, actions and interactions regarding information on wayfinding.

2.3 The analysis

We conducted analyses matching spatial models of every case study with social pattern noted during the observations. As first step we created a public spatial model considering all spaces free accessible by public (corridors and rooms where outpatients and visitors can arrive by themselves). The public model represents correctly the public spaces system of the hospital, that is those spaces which we suggest are meaningful for the enjoyment of right to health.

In the spatial model we divided space by convex spaces adopting the following criteria: the geometry of space (spaces where every point in the perimeter are visible from every point), the visual field of observer (spaces completely visible by the visual field of observer walking on it), the function belonging to space (deskpoint, waiting area).

Looking at the configurational analysis we read a description of the complexity of the spatial system. This complexity is measured by a geometrical (number of lines, number of convex spaces, surface, metric distances) and a configurational point of view (*Integration*).

The comparison between pattern of users' behaviour and configurational characteristics of space bring to light two intermediate results. The first consist of a series of meaningful topics describing the relationship between space and rights. The second result, referring to architectural discipline, consist of a series of spatial indicators for every meaningful topic.

3. Results

3.1 The framework

Interpretation of data produced by case studies analysis leaded up to collect them in a summary tool defined 'framework' which includes the key topic in enjoyment of right to health (Table 1).

The framework is structured in three sections. In the first section there are the two dimensions of right to health: *Relation* and *Proximity*.

Table 1: The interdisciplinary framework

New dimension of rights to health		Meaningful Topics	Maps
Relations	Proximity	Accessibility	
		Physical accessibility (Complexity of spatial system, Geometric compactness, Accessibily of public vertical link from main entrance) Intelligibility	
		Access	
		Visibility Location of access respect to integration accessibility core Walkability Permeability (from public to private sphere) Location of welcome and reception	
		Waiting	
		Organization of emergency and outpatient flow Quality of waiting: Light, Furniture, View Access to waiting area Morphology and visibility of doors	
		Access to information	
		Accessibility of information points Wayfinding Intelligibility	
		Relationability	
		Social contact (person-institution; person-medical staff) Taking charge of the patient	
		Identity	
		Image Hospital mission Social role	

Relation is a dimension concerning the relation between person and hospital institution (formal and informal), person and person, person and public power and it could be

cooperative, conflicting or competitive. *Proximity* is a dimension structured in spatial (distance, urban context, transportation, orientation), cognitive (right to information, right to know roles and functions, informed consent, living will), political (active citizenship - not a mere target of regulations and policy).

In central section there are all topics of interdisciplinary interest. Within each topic there are the elements emerged from case studies analysis which could become indicators for enjoyments of right to health. For instance looking at *Waiting* topic we find especially three architectonical aspect which have to do with the waiting inside the hospital: 1) the location of waiting area in relation to circulation flow which affects accessibility for the patient; 2) the morphology and visibility of the entrance doors of the health service in waiting area which is related with the patients need of 'take in charge'; 3) elements as light, furniture arrangement, view outwards that directly affect users comfort and indirectly affect trend to social interactions.

In last column the visual maps (Fig. 2 and 3) which highlight the importance of related indicators find place.

3.2 The Access

We want provide here in a detailed way an example considering the topic *Access* and looking how accessibility and visibility characteristics of spatial layout can facilitate access to information and access to health service.

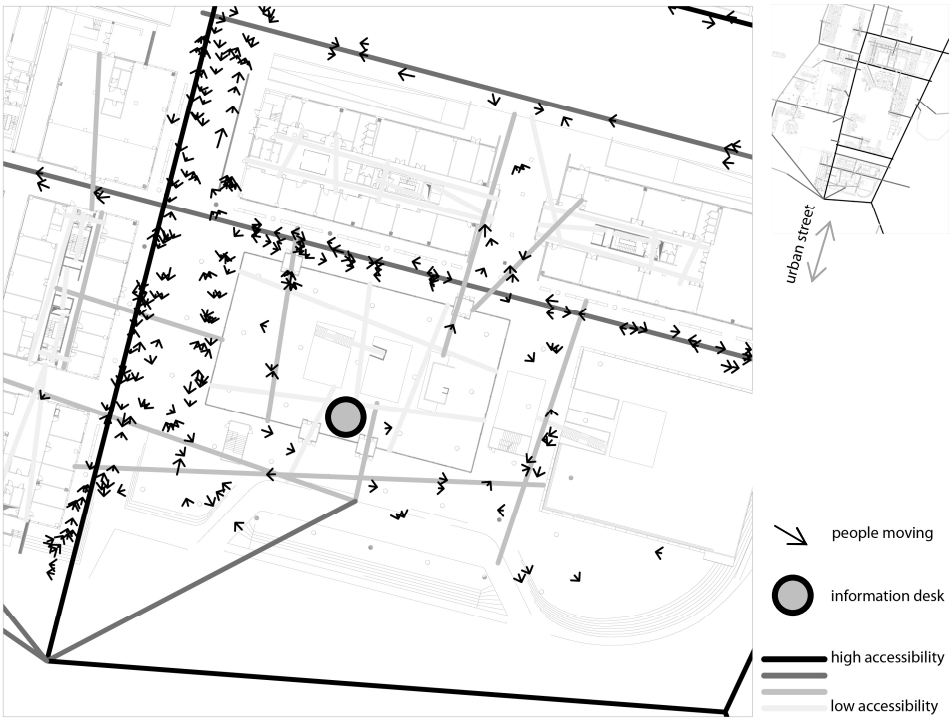

Figure 2: Careggi Hospital: on the right top the accessibility map of the hole hospital, on the left a zoom on the access to the hospital from the urban street.

We propose here a comparison among hospital entrance of Santa Maria Nuova and Careggi which allow us to observe the critical point in access to hospital for a patient. We can note in the maps: the layout analysis (axial lines in greyscale), the location of information point (circles), the concentration of meaningful groups of social relations, the users desire line (arrows) (Fig 2 and 3).

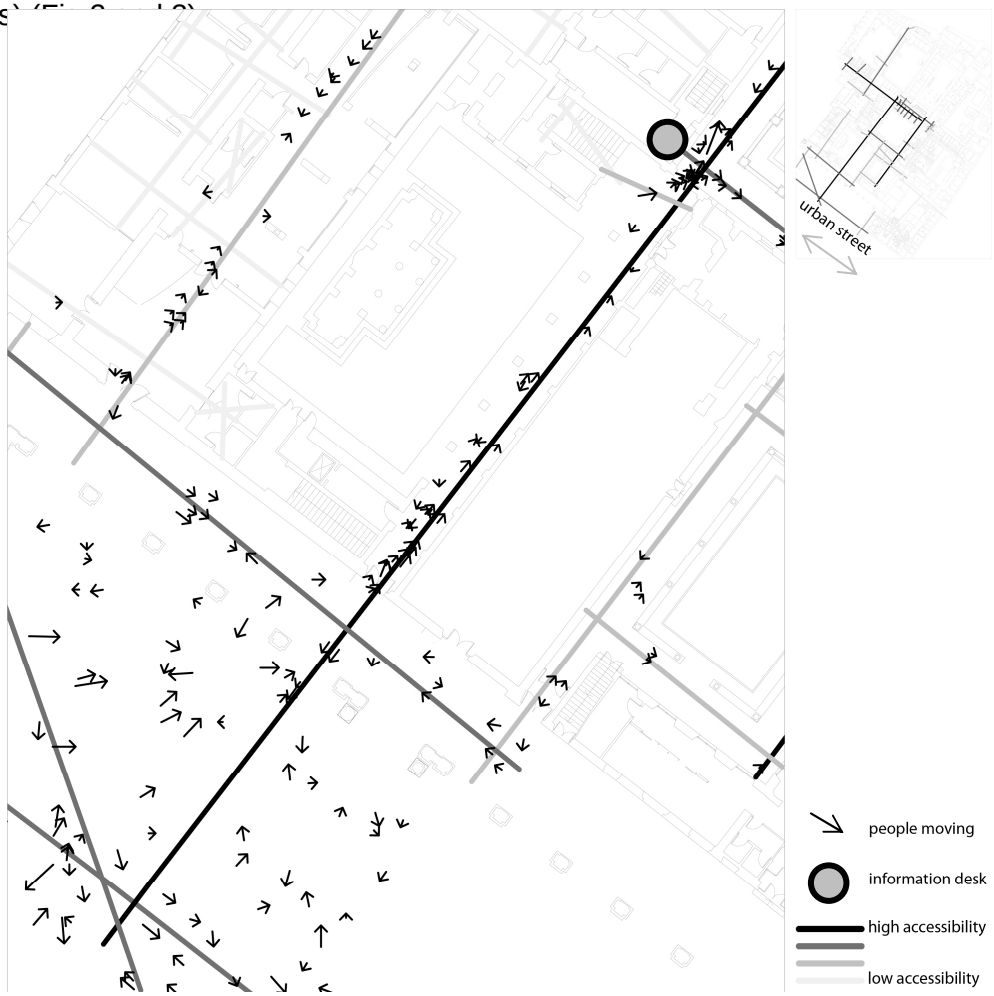

Figure: 3 Santa Maria Nuova Hospital: on the right top the accessibility map of the hole hospital, on the left a zoom on the access to the hospital from the urban street

The layout analysis is represented by the accessibility map of hospital (Fig 2 and 3 on the top right) obtained with the configurational analysis: each line that represents a circulation path assumes a grey scale color which indicates his accessibility degree in relation to all other lines of the hospital system. The black arrows represent people moving from the city to the inside the building meanwhile they are entering to the hospital. We can see in the maps the location of welcoming desk: in the Careggi hospital the desk is neither visible nor accessible as it is out of the desire line of the patient and in a space with low accessibility (lines light grey), although with glass walls. In the Santa Maria Nuova Hospital the desk is not directly visible from the entrance, but it is more accessible as it is on the central axis of access to the hospital, represented by a line with high configurational accessibility.

This has to do with access to information and with equity to the access, two important topic for right to health. A particular meaningful result which gets a central aspect of relationship

between protection of rights and physical space is represented by identification of critical point of patient journey, both spatial and organizational, and useful parameters in order to intervene in a managing and transformation phases.

4. Conclusion

Interdisciplinary approach has been important to understand how configurational properties of space, in particular accessibility and visibility, can affect on social and behavioural dynamics in order to fulfil right to health. Through the interdisciplinary work social and legal problems have arisen and how they are related to the spatial. The framework in Table 1 represents the integrated results. In this paper the indicators under the topics are related to architectural field and are adaptable to every context of transformation and monitoring in hospital. They can be a useful tool for the management of hospitals and for the architects as it improve the awareness in designing or refurbishing new hospitals.

The GIS use has been a tool particularly convenient for this interdisciplinary research in which space plays a significant role. The GIS has allowed spatializing social and spatial phenomena and showing them in thematic maps for a comparison. This tool applied to the building scale can have great potentiality in the healthcare sector to monitoring organizational, managerial and spatial transformations.

Future developments of the research are from one hand creating an evaluation tool for politics, healthcare management teams and healthcare designers, that it will be generated from the indicators found. On the other hand translating to the healthcare network in the territory the study among social rights, social phenomena and space.

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A tentative comparison of the performance of Strategic Alliance and Design/Bid/Build project delivery methods

Jelle Koolwijk[1]

Abstract

Project delivery methods that are based on the concept of supply chain integration are believed by many to lead towards a more effective and more efficient way of working than other, more traditional ways of project delivery like the design-bid-build (DBB) method. This tentative study compares the cost performance of strategic alliance (SA) with that of a DBB. based on cost estimates at the Pre-construction stage. The cost estimates of three SA's have been compared to three DBB cost estimates, which have been made by three external cost consultants, to see if there are indication of one project delivery method is superior.

Three large scale housing renovation projects which are delivered by a similar form of SA have been selected for this study. The three alliances exist of different clients, contractors and subcontractors which are working in different regions. The target cost estimates made by the SA's for the three projects have been compared with external cost estimates. These external cost estimates have been made by three different external cost consultants. The external cost estimates were made based on the assumption that the project would be delivered based on a traditional DBB method. The external cost consultants weren't informed about the SA that was set up to deliver the project.
Project costs per element were compared. Upon completion of the analysis, the hypothesis that SA projects are superior to DBB projects in regards to costs was researched.

Keywords: Strategic alliance, Design/Bid/Build, project delivery methods

1. Introduction

As budgets of social housing associations (SHA's) in the Netherlands continue to come under pressure, SHA's are seeking for ways to increase efficiency (De Wildt and Luijkx, 2011). To increase efficiency in comparison to the traditional design-bid-build (DBB) method, SHA's have adopted several different project delivery methods. One of these methods, strategic alliancing (SA), has been gaining the interest of a group of SHA's the last few years which resulted in a set of pilot projects. The following definitions for DBB and SA are used in this paper.

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Design/bid/build (DBB) is a project delivery method in which the owner enters into a contract with an architect/engineer (A/E) firm that provides design services based on the requirements provided by the owner. The A/E deliverables includes plans and specifications for the construction of the project. These documents are subsequently used by the owner as the basis to make a separate contract with a construction company. Although many methods are used for awarding this contract, the most common approach is to solicit bids from different construction companies. The company providing the lowest bid will then build the project based on the documents produced by the A/E. Therefore, two separate contracts, with two separate entities, are utilized by owners to complete one construction project, including two solicitations and procurement steps.

Strategic alliancing, in this paper, is a (project) delivery method in which the owner enters into a long-term collaborative multi-party agreement with a main contractor, multiple specialized (trade) contractors and an A/E firm. All alliance partners work together if they are one (virtual) company.

At the start the alliance partners are selected based on their capabilities shown in similar projects, reliability in previous projects, transparency in cost structures and communication, and aligned interests. When the alliance is in place, the owner sets high level targets for the alliance. Together they work on an integrated design using a process that resembles a target value design process as described by Ballard (2011). This process results in full plans, specifications and budget which incorporated the know-how of the alliance partners. When the plan fits within all the pre-set targets, the construction of the works is awarded to the alliance. The alliance is awarded a follow-up project when their performance keeps increasing in regard of pre-set Key Performance Indicators (KPI's). Other characteristics of this strategic alliance are:

- unanimous decision-making by a board containing all alliance partners;
- open book accounting, using a form of activity based costing with set margins;
- risk/reward schedule which looks like the Australian project alliance methods;
- performance measurement (costs, time, quality, customer satisfaction);
- target value design process;
- open communications (all information is shared within the alliance through a web portal);
- lean planning (traditional and location based);
- joint sessions to develop and enhance the joint processes (value stream mapping sessions, lean planning workshops, et cetera).

The modus operandi of this strategic alliance has a close resemblance with the project alliance delivery method known from Australia (Ross, 2003; Koolwijk, 2006; Lahdenpera,

2011). However, it is called a strategic alliance and not a project alliance because the alliance is set up for multiple (similar) projects. The intended relationship is long-term beyond a discrete project. Paragraph 2 will elaborate further on the different forms of strategic alliances.

As stated before, a group of SHA's have adopted the use of strategic alliances the last few years. Unfortunately many of them have difficulties assessing the impact of the use of this method because the information is spread over different SHA's. Fortunately a group of consultants which guide the pilot projects, one of them being the author of this paper, are in contact with each other, thus giving the opportunity for bringing together the project data for further analysis as being done in this first tentative study into this group of strategic alliances.

2. Strategic alliances

This paragraph will first describe strategic alliances in general. Then it is explained why strategic alliances are rare in the construction industry in regard of other industries like manufacturing. Finally the strategic alliances which are part of this paper, are described.

2.1 Strategic alliances in general

Strategic alliances are inter-firm cooperative arrangements aimed at achieving the strategic objectives of the partners (Das and Teng, 2001). Strategic alliances are voluntary organizational relationships that involve meaningful and durable exchange, sharing, or co-development of new knowledge, products, services or technologies (de Rond, 2003). Inkpen and Ross (2001) show us that strategic alliance provide organizations a way to bring together their resources to create value, value that each partner could not achieve if they acted alone. According to Nooteboom (1999), strategic alliance come in many forms, including horizontal alliances between competitors, vertical alliances between buyers and suppliers, and diagonal alliances between firms in different industries.

Alliance structures have been categorised in a large number of different types of alliance forms. The categories used most frequently, which have been made by Das and Teng (2001a), are the equity versus non-equity strategic alliance.

As stated by Doz and Hamel (1998), an equity alliance operates as either a distinct operating entity (e.g. joint venture) with its own authority structure, or involves an equity investment by one of one partner in the other. Joint ventures involve the creation of a separate entity by two or more partners, so that control of the alliance resides with the partners and also with the joint venture company.

A non-equity alliance (or contractual alliance) is formed among independent partners, based on written agreements and verbal understandings (Doz and Hamel, 1998). These alliances are medium or long-term relationships. An important source of control is the written agreement or contract. It typically lacks an ultimate standalone decision-making authority.

Non-equity alliances can take a unilateral or bilateral form (Das and Teng, 2001b; Colombo, 2003). Unilateral contractual alliances involve well-defined transfers of property rights. Examples include licensing agreements, distribution agreements and some research and development contracts. What makes it unilateral is that each partner undertakes their obligations independently, so contracts tend to be complete and very specific as to the expectations of each party. Limited coordination and cooperation is needed, and partners have limited engagement with each other.

Bilateral contractual alliances involve cooperation and coordination as both parties work together to achieve the alliance outcomes. Examples include joint research and development, joint marketing, joint product development, and some forms of supplier partnerships and outsourcing arrangements. The activities of partners are sometimes integrated and linked tightly.

2.2 Why strategic alliances are rare in construction

Strategic alliances are very rare in the construction industry in contrast, for example, to the manufacturing industry. One of the main reasons for this lay in the difference in production environment and the lack of a focal company.
The construction industry, as mainly a Engineer-to-Order (ETO) industry, is characterised by a high degree of uncertainty (Bertrand & Muntslag, 1993). Demand tends to be "lumpy", with each unit of demand representing a large proportion of capacity. Markets are difficult to forecast due to unknown sales volumes and unknown product specifications for future orders. Forecasting the demand, even at the product type level, is extremely difficult due to the customised nature of the products (Muntslag, 1994).
Also, Brown et al. (2001) express the prevailing conditions in the construction industry to be that ‘‘the majority of construction projects are one-off, which often means that no long-term business relationships can be established’’. A buyer is thus likely to switch suppliers from one episode (project) to the next, which makes expectations concerning future business featured by uncertainty (Gadde and Dubois, 2010). As a result, it is not likely for suppliers (and buyers) to undertake “asset-specific” (i.e., relationship-specific) investments, thus it is impossible for the buyer nor the supplier to get the benefits of such an investment.
Therefore, in construction most long term arrangements with suppliers are aimed at the management of building materials (Vrijhoef, 2011). A comprehensive approach which includes clients, developers, main contractor(s), sub-contractors and suppliers, like a strategic alliance, is generally lacking (Briscoe & Dainty, 2005). Another problem that is critical for the integration of the supply chain in the construction, is the absence of a generally accepted focal company initiating the integration of the supply chain, as is the case in manufacturing (Vrijhoef, 2011). Often the client organisation has been regarded as the likely proponent for integrating the supply chain (Briscoe et al., 2004). This because the client organisation is at the start as well as the end of the entire construction process, and gives the initiative to start this process as well as being the end customer of the product. This places the client in a dominant role. Many clients have limited in-house expertise in construction management and are heavily reliant on bought-in expertise, i.e. consultants. Consultants are less positive about partnering than clients and contractors; they perceive a loss of control (Black et al. 2000).

2.3 The strategic alliances in this study

A Dutch social housing association (SHA) called ComWonen and a large main contractor called Dura Vermeer started a program called chain collaboration in 2008. ComWonen and Dura Vermeer formed a SA for the development and construction of social rental houses. ComWonen and Dura Vermeer claim that their first project was delivered 12% cheaper, with a higher quality and 6 weeks earlier than business as usual. Because of this program, strategic alliances gained the interest of more SHA's in the Netherlands. At this moment, as far as the author can see, around eight different SHA's in the Netherlands are having pilot projects with SA's. Three of these SHA's have participated in this explorative study.
These SHA's are relatively skilled construction clients who own a large amount of relatively homogenous assets (houses). The smallest SHA in this study owns approximately 6.000 houses, while the largest SHA owns around 20.000 houses. These assets form the basis for a relatively stable production environment: the renovation projects are combined in such a way that they (potentially) form a more or less constant stream of production for the alliance. This makes it interesting for the alliance partners to make relationship-specific investments in order to improve their joint performance. The so-called 'shadow of the future' (Axelrod, 1984; Dal Bo, 2005) stimulates the alliance partners to keep improving project after project because performance targets are increased by the SHA after every project.
The strategic alliances can all be considered as non-equity bilateral contractual alliances (see paragraph 2.1). All alliance partners work closely together to achieve the alliance outcomes. A written agreement is the basis for control. As stated before in paragraph 1, the modus operandi resembles the project alliance delivery method as used in the Australian practice.

3. Research method

Because the amount of projects in this study is very small, the data sample is also limited. To perform a statistical analysis, like for instance Hale et al. (2009) did for American Design and Build projects, it's simply too early. Instead, a more straight forward method was chosen to gain some first insights in the performance of these SA's in comparison to the DBB method. This method is explained in paragraph 3.1. Potential limitations to this method are reviewed in paragraph 3.2.

3.1 Research method

There are three pilot projects part of this study. Each project is delivered by a different strategic alliance. Two of these alliances are setup for the renovation of relatively standard houses from the 1970's. One alliance is formed for the renovation of small monumental houses from the late 19th century.

The three pilot projects are being guided by the same group of consultants. One of them is the author of this paper. These consultants implemented a process that makes it possible to compare the outcomes of the pilots with traditional DBB delivery method. This process ensured that for every pilot project an external cost estimate was made by an experienced

cost consultant. For every project a different cost consultant was involved. In the following figure the office location of the three SHA's and the CC's has been marked per project.

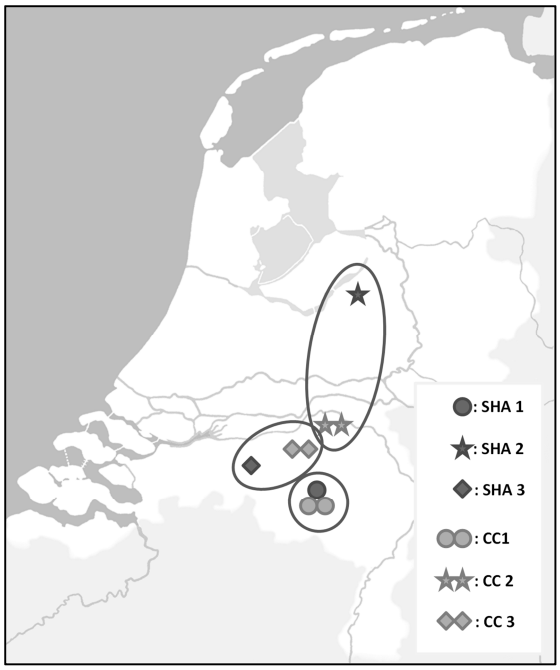

Figure 1. The office location of the three SHA's and three CC's which were part of this study.

To make a clean comparison of the cost estimate of the CC and the cost estimate of the SA the following steps where followed (also see figure 2):

- The SA's developed all project documents. When these where finished, at the pre-construction stage, all specifications, drawings, amounts and types of materials, and activities the SA has planned were shared with the CC's. This way a relatively high amount of cost related information was shared with the CC's.

- The planning data from the SA was not shared with the CC. The SA spent a relatively large amount of time on the efficiency of the production process. More than they are used to in a traditional process. This effect would be given away to the CC when the planning would be shared.

- The cost data of machinery, materials and man-hours was also not shared with the CC. The SA is transparent in their real costs through the use of the activity based costing method. Also, results from purchasing materials flows back to the project budget. This is different from traditional working methods and therefore not shared with the CC to make a clean comparison.

- The CC's did not know about the SA's. They estimated the works if they were tendered as a DBB project.

- The CC and the SA did not have any direct contact. All information, questions and changes were communicated through the project manager of the SHA.

- The project manager checked the final estimates of both the SA and the CC to make sure all information (amounts, specs, et cetera) in the documents is the same.

- The author of this paper did a second check on the data to see if there are differences that could influence the outcomes of both estimates.

- After this check, the information was further analysed for this study.

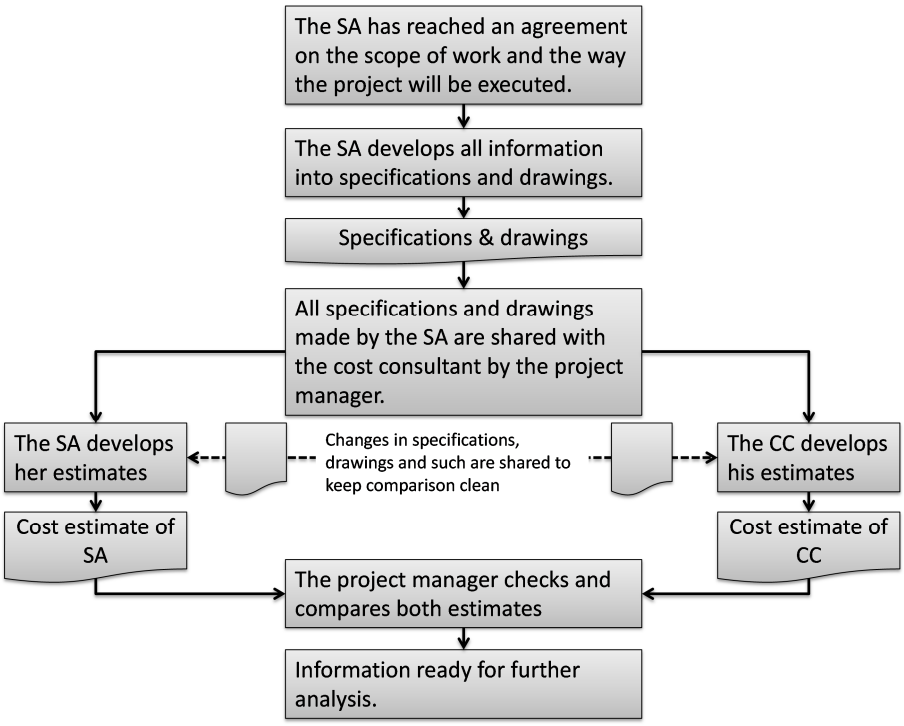

Figure 2. Method followed to get comparable estimates from the SA and CC

After the cost estimates of the SA and the CC where received and checked by the project manager, the cost data was further analysed. The analysis consisted of three steps:

- A check on differences in activities, types and/or amounts of materials, to see if both estimates are really comparable

- High level comparison: Making a comparison of the total estimated turnover between the CC-cost estimate and the SA-cost estimate.

- Low(er) level comparison: A comparison of the prices per element.

3.2 The use of (external) cost estimates to measure cost performance

The research method used for this study relies heavily on the accuracy of cost estimates by the SA as well as the CC. Therefore, it is necessary to place the findings of this research project in to the perspective of other studies done in this field.

Liu and Zhu (2004 and 2007), who summarized the findings on the cost estimation accuracy for construction projects dating back to the 70's, showed that estimation accuracy level for construction projects hardly changed the past four decades and remained around 10%. They also found that at the preconstruction stage, when the project scope clearly defined, the expected accuracy level is typically around 5%.

Liu and Zhu (2004 and 2007) also summarized the wide range of factors influencing cost estimation that has been identified by extant literature including government regulation, plan changes, quality of the contractor management team, priority on construction deadlines, completeness and timelines of project information, bidding situations, project characteristics, experience on similar type of project, the estimating process, and the experience of the estimators.

On the accuracy of cost estimates executed by external cost consultants in comparison to actual construction costs, regrettably no findings were found.

4. Checking the estimates before making the comparison

When the cost estimates where received, they have been checked to see if there are differences in activities, types and/or amounts of materials. A difference in the base of the estimates will have its influence on the comparability.
The first check was on the use of materials; if the materials specified are the same in both cost estimates. Things like brand, type and dimensions of tiles or plasterboard have been compared. It was found that most of the materials specified where the same.
The second check has been done on the activities. In this check, minor differences were found. Some activities done by the SA were not part of the cost estimate by the CC. Most of these activities have to do with extra quality that was put in the project by the SA at the last moment. Because these activities have been put in by the SA, these activities should have an negative effect on the SA-estimate in comparison with the CC-estimate. The SA simply delivers more than estimated by the CC.
The final check has been done on the amounts (m1, m2, units, et cetera) that have been calculated. In the next figure a comparison from one of the projects (#3) is shown. The other projects showed similar patterns, which are not further reviewed for this paper.

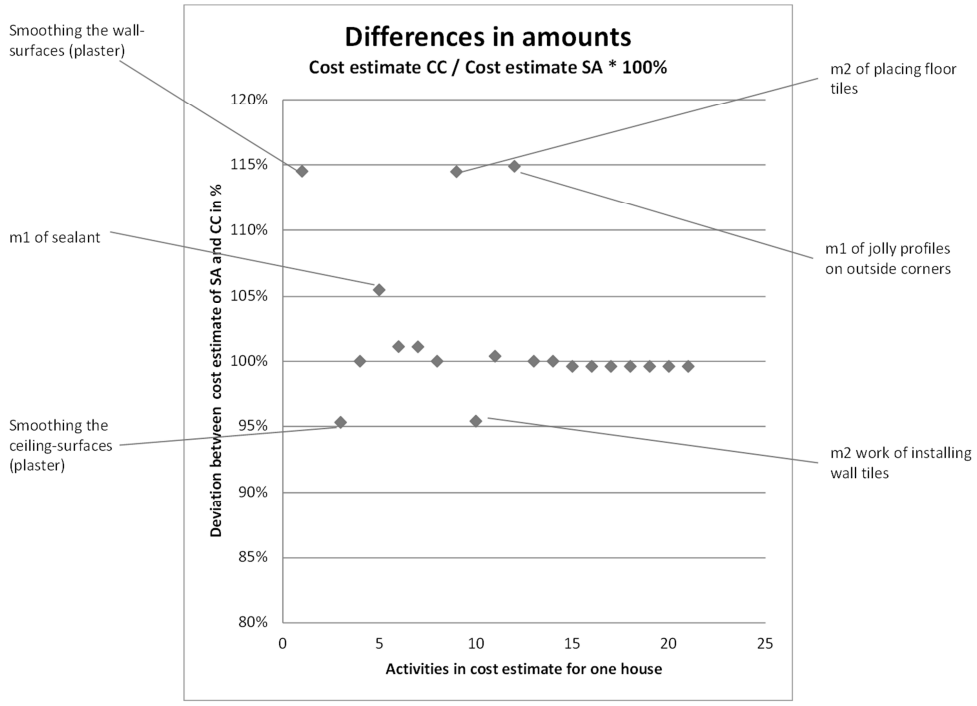

Figure 3. The differences in amounts between the estimate of the CC and SA

In figure 3 you can see that not all amounts in both estimates where the same. In the next table the activities with a difference more than 1% are further explained.

Table 1. Activities in one of the projects that had a large difference (>1%)

Activity	Difference in amount per house	Unit price SA (euro's)	Unit price CC (euro's)	Subtotals (euro's)
Smoothing ceiling surfaces	-1,2 m2	5,-	7,76	-3,31
Smoothing of wall surfaces	+2,1 m2	24,-	14,45	+20,01
Placing of jolly profiles on outer corners	+1,34 m1	3,6	2,65	+1,27
Sealant in bathroom	+2 m2	10,-	5,59	+8,82
Installing wall tiles	-0,6 m2	34,88	41,59	-4,03
Placing floor tiles	+0,15 m2	59,43	63,03	+3,6
			Total	+26,36 / house

In table 1 the difference in amounts between the two estimates is given. A '+' means the CC has estimated a larger amount than the SA. A'-' means the opposite. Also the price per element is given for both estimates. Here you can see larger differences. In this price per element, purchasing results and labour hours per element are reflected. Figure 4 (see next paragraph) will show the rather big differences found in prices per element.
The subtotal in table 1 shows the effect of the difference in amounts multiplied with the difference in price. The sum of all subtotals results in a total difference of 26,- per house. Project number 3 contains 100 houses, which means only a difference of approximately 2600,- in total can be explained by differences in amounts. A very small difference in regard of the total costs of this project.

5. Results

In table 2 the first comparison is made on the estimated turnover for each project.

Table 2. Direct and total costs estimates of the SA's and CC's compared

Project #	Costs	Estimate SA	Estimate CC	% difference
1	Direct costs	2.505.915,-	2.848.242,-	13,6%
	Total costs (excl. vat)	3.620.778,-	2.784.202,-	30,1%
2	Direct costs	738.082,-	771.889,-	-4.4%
	Total costs (excl. vat)	1.084.094,-	1.013.952,-	6,9%
3	Direct costs	2.188.279,-	2.663.796,-	21,7%
	Total costs (excl. vat)	2.980.272,-	2.352.553,-	26,7%

In table 2 it is shown that all three SA's perform better in comparison to the CC's when looking at the total costs. Looking at the direct costs, this difference gets smaller. Project 2 shows a negative result when looking at the direct costs.
Because the check on the activities, and types and/or amounts of materials can only explain a differences from around 1% (see paragraph 4), a comparison has been made between the prices per element to see if this could explain these differences. The following image emerges.

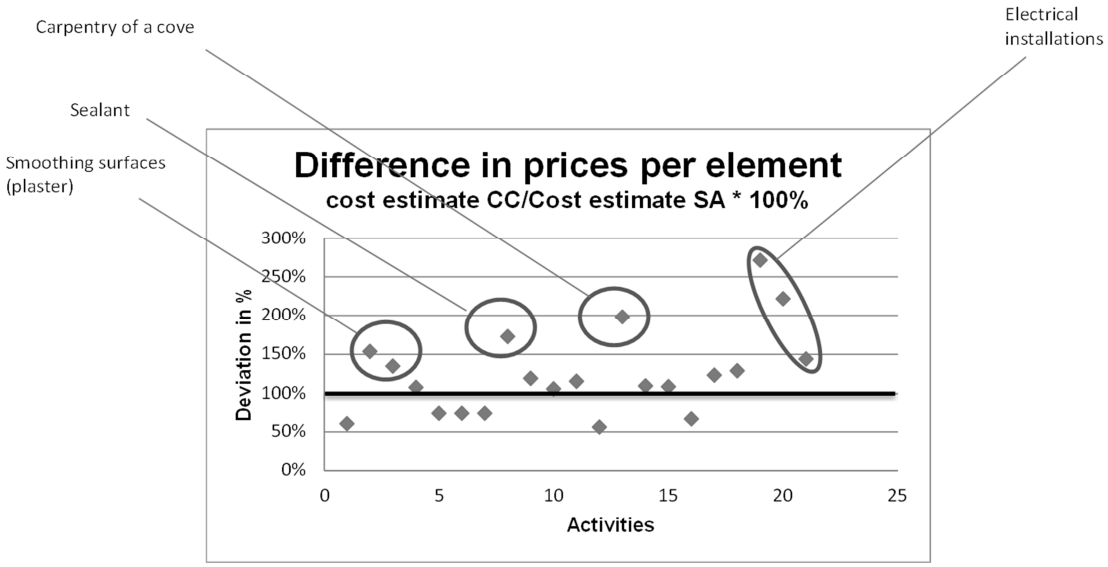

Figure 4. Comparison of prices per element between the estimate of the CC and SA

Figure 4 shows us that most of the prices per element are estimated higher by the CC than the SA (100% means the prices per element are the same). Some of these prices per element differ quite extremely (almost 300%), which looks like a fundamental different viewpoint of 'what needs to be done' between the CC and the SA. However, the information between the SA and the CC was shared almost one-on-one. Also questions could be asked about what needed to be done if there were doubts by the CC.

6. Conclusions and discussion

As noted in the first paragraph of this paper, this paper contains the first results from a tentative study. It compared cost data of an experienced CC, which calculated the same project if it was delivered by a DBB, with the cost data of a strategic alliance (SA) to see if there are indications of one project delivery method is superior in regards of costs. Because of the small data sample, only three projects where part of this study, this somewhat straight forward method was chosen to see if there are any differences in performance between the two delivery methods.

The first results are tentative; no firm conclusions can be drawn. However, the first results could indicate that a SA outperforms the DBB method in regard of costs. When we look at the price per element it looks like a SA can deliver the same product for a lower price. This could be the result of many things like a higher efficiency or lower profit margins per element among the alliance partners.

When looking at the total costs in comparison to the direct costs, the difference in the estimates gets bigger. This could be an effect of the activity based costing method applied by the SA's. The general expenses in the SA project are lower because only the costs that can be directly related to the project are paid by the client. Other costs, like acquisition costs, are not covered.

What could also be the case is that the three different cost consultants, which all have experience in estimating these type of projects based on full specifications, were wrong. In this case all three CC's were given the full specs of the project and all information from the alliance partners in regard of activities, and types and amounts of materials was shared.

They also had the opportunity to ask questions about the project through the project manager to gain more information. As stated by Liu and Zhu (2007), accurate prediction of construction costs is heavily dependent upon the availability of quality historical cost data and the level of professional expertise among other things. Both elements seem to be in place in this study. However, Liu and Zhu (2004), after reviewing studies on cost estimation accuracy, also concluded that the estimation accuracy level for construction projects is around 5% at the Pre-construction stage. This could also explain the difference, but one would expect that one or two SA's would score worse in regard of DBB.
What remains is to finish this first tentative study by looking at the post-calculations of all three projects. One of these post-calculations have already been received. It shows that the alliance returned 4% of its budget back to the SHA whereas this SHA is used paying between 6 and 8% extra for change orders in DBB projects. Also a comparison will be made with project that is similar to one of SA projects, but is delivered with de DBB method. The author hopes to carry out this study later this year. Finally, interviews with all participants can be held to gain an expert opinion about the effects (not only costs) of working with an SA.

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5D BIM: Creating Cost Certainty and Better Buildings

David Mitchell[1]

Abstract

This paper looks critically at where BIM implementation is on the pathway and sets out the opportunities that arise when 5D (the linking of cost information to a 3D model) is considered to be more than just a quantity take-off exercise. It proposes a methodology, from a practitioner's perspective, for applying 5D BIM to the design and construction of projects with the goal of delivering better buildings with cost certainty. A fundamental of the methodology is to use existing, proven technologies to overcome the problems that exist when the onus is on the BIM author to code model objects in a fashion that estimators can understand. The purpose and intention of this paper is simply to provide context and to start the discussion on what 5D BIM is with a view to developing a mainstream methodology that can be included within a BIM execution plan for a project.

Keywords: 5D BIM, Collaboration, Cost Strategy, Living Cost Planning, Lean Practices.

1. INTRODUCTION

To date, a lot of the focus on Building Information Modeling (BIM) implementation has simply been about design firms learning how parametric 3D modeling software works.

Design firms have been learning about the capabilities of their chosen BIM authoring tool, gauging the benefits to the firm, achieving a level of confidence in an isolated way and exploring collaborative work flows where information is exchanged in two directions.

Working against an even more collaborative approach is a belief that BIM can only add value to large projects and when Integrated Project Delivery (IPD) is the preferred delivery system. Whilst integration is the long term outcome, industry is currently grappling with the issues surrounding collaboration and is now starting to solve the stumbling blocks of liability, ownership and protection of data and intellectual property. The development of BIM guides and execution plans have made it possible to define expectations and clearly specify design deliverables at the various design stages.

While these developments have been extremely encouraging in the area of 3D design very little development has happened in the fields of 4D - linking time and scheduling data; and

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5D - linking cost data to the 3D model. For instance the Veteran's Affairs (VA) BIM guide simply refers to a "4D BIM - phasing plan" and the "discretionary additional use" of "5D - Material take-offs and cost estimating".

For BIM to be truly successful in providing better buildings then all of the D's need to be embraced. This paper will concentrate on 5D and what it can do, so that open discussion can occur and as an industry we can shift to practicing 5D and shaping it as a standard practice for the future.

Change and reform in the construction industry is long overdue, the catalysts for change are here and these will be the accelerators that drive the BIM process to become the industry norm rather than the exception.

2. CATALYST FOR CHANGE

The Global Financial Crisis and world events have made development and construction uncertain. World thinking has changed our behaviours. For the first time in decades people are saving, credit cards are being avoided and there is a growing sense of frugality.

When a consumer decides to spend, it seems that a "saved" dollar is more valuable than a "borrowed" dollar and that a "saved" dollar won't be wasted. Today's consumers are extremely well researched and won't be rushed because there is no compelling reason to buy. There is no fear that prices will rise because competition is rife, in fact delaying the purchase may mean that the product gets cheaper.

So it makes sense to take the time, to be certain that the product is reasonably priced, is of the highest quality and is supported with a strong level of service.

Previously this delay or slowness to purchase was seen as a lack of confidence in the future – something that will pass but now there is a growing realisation that structural change is occurring and that these conditions are here to stay. There is a new paradigm in play.

For the development and construction industry it is particularly difficult to meet this paradigm because past experience tells us that construction is expensive and it is uncertain. Often a customer does not really visualise what is being built until it is built and there is an expectation that there will be delays and cost increases.

Successful building is about creating certainty - in design, buildability and cost. Wisdom, intelligence and technology can create certainty by getting back to basics and making grounded decisions based on facts.

3. BIM PATHWAY

At present projects can confidently be managed using a staged and independent process of inputting data into independent models with the parties collaborating but not integrating to use the software in a beneficial way. For example, architects can set their design, engineers

can create the structural framework and air-conditioning contractors can submit their components all independent of each other using different authoring tools. Software, like Navisworks and Solibri, are then used to bring each model together to deliver a coordinated design.

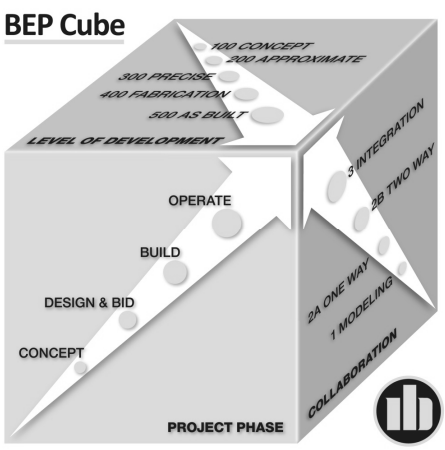
Andrew Gutteridge worked with the Australian Institute of Architects to champion the BIM pathway to provide a logical learning curve for the industry to move from working in isolation to collaboration. The culmination of their work was production of a diagram “Towards Integration” which was later included within the CRC Construction Innovation publication - National Guidelines for Digital Modelling.

Using this diagram as a reference and applying it to the Australian industry, it was found that the mainstream uses 3D modeling in an isolated way (1B) and the cutting edge design teams are acting in a collaborative way (2A one-way and 2B two-way collaboration). Rather than spending time judging whether what is being done now is BIM or not BIM, it is far more important to acknowledge that industry is practicing and improving and that this is just part of the BIM pathway.

Industry design professionals are mostly engaged in the use of parametric modeling in one form or another but sceptics have a lack of trust in the software’s intelligent design to fully integrate the model for each element.

Construction professionals also perceive a lack of protection of the input of information and data, if and when it is changed, by who and how it is tracked. What is important to remember is that even at 2A and B the duties and working practices for two dimensional work remain the same for three dimensional work.

At this point on the pathway it doesn’t matter how you relate to parties throughout design, but rather that you do and that the obligations and design outcomes are clear.



Development of the BIM Execution Plan (BEP) has provided this clarity. The BEP defines the scope of design work, the Level of Development (LOD) and the two-way exchange of information for all parties to the project including the quantity surveyor (QS), cost engineer or estimator and can be clearly depicted on three scales – refer figure 1.

Figure 1: BIM Execution Plan Cube

4. CREATING COST CERTAINTY IN 5D

Developing certainty in cost, design and buildability reduces risk and creates better projects with sustainable profits. We know that 3D modeling and strong design coordination creates certainty in what is being built and that the 5th Dimension, or 5D, is all about cost. While there is considerable discussion and collaboration between different design partners often 5D is reduced to just the simple one liner of “Quantity Take Off” and attention is placed on coding by the designer with an expectation that later the costing process will be made easier.

This approach means that several opportunities are missed:

1. The costs are not known until the model reaches LOD 300 or greater.

2. The design itself is not tested at an early stage for functional efficiency or benchmarked against known elemental costs.

3. There is no integrated cost plan and the design team is not provided with real-time cost feedback as the design progresses.

4. The costing process is still a separate exercise which is not transparent.

An alternative and better approach is for the cost planner to push accurate cost codes into the model information and then to extract all of the information that is needed to complete a thorough cost estimate via a 5D BIM authoring tool. Part of this approach includes making allowances for work that has not yet or will not be modeled.

This approach means that all of the “missed opportunities” will be delivered and the result is a better building because the available money can be targeted at the most important features of the building design in a transparent way that builds trust amongst all project partners.

5. 5D QS AND COST PLANNER

The modern QS is taking the traditional QS role to the next level, utilising models to provide detailed and accurate 5D estimates and living cost plans. This assistance is provided to projects at any phase from concept design through to construction and completion.

The ability to complete a series of estimates for various designs at the early phase of a project is paramount because this is when the dye is set, planning evolves and cost overruns are avoided. If the scope of a project matches the budget at the outset then constant redesign is avoided and the priority features of the project are included.

It is well established that early decisions have the highest level of influence on project outcomes at the least cost. This is because redesign, construction delay and disruption, change order and rework costs are avoided.

The technique is simple, basically an estimate is done, then its elemental costs are benchmarked and the functional performance of the design is analysed and tested against competing projects. The QS then provides feedback to the concept designers, a new scheme is produced and the process is completed again.

Once the project design passes this budget test and proving up phase then the Cost Plan is established for the project and this recipe becomes the basis for managing and monitoring the fluctuating construction costs during design.

A 5D QS can do this extremely quickly, an endless number of times and in a complexity of combinations. For a 2D QS this is not possible because project schedules do not allow enough time for endless manual take-offs and even if there was, then the re-measurement process is too labour intensive to be viable, the combinations that need to be considered are too complex and there are too many variables for a QS to complete the required “what if” style calculations manually.

The traditional process is to complete the design to a particular stage i.e. schematic design, developed design, etc.; then freeze further design until an estimate is completed and permission is granted to proceed to the next design stage.

Today there are modern techniques for the 5D QS to use within the traditional frameworks to set cost strategies and a 5D Cost Plan (or Living Cost Plan). These techniques can be blended within the traditional design and construction phases as follows:

6. CONCEPT DESIGN

At the feasibility and concept design phase, a cost strategy is set that considers all aspects of the project, the client’s brief, the designer’s vision and the site constraints. The strategy is developed after first completing a concept estimate and then testing its elemental costs by benchmarking and the design efficiency by analysing its functional performance.

6.1 Initial Concept Estimate – LOD 100

The initial concept estimate is a fast and effective way to determine the cost of a project and allow decisions to be made quickly and with certainty.

Working with the overall massing model (AIA LOD 100) in Sketchup, Revit or an IFC format, the 5D QS prepares a concept estimate that is presented in an elemental format and sets out each elemental unit rate and quantity. It is understood that not everything is modeled and the 5D QS uses experience to ensure that the total project is included within the estimate. This is done by supplementing the model information with 2D on screen measurement where necessary.

This concept estimate becomes the basis for recompiling the estimate to consider alternative designs during the proving phase of the concept design.

6.2 Elemental Cost Benchmarking

The 5D QS uses cost intelligence from past experience and actual project cost data to critique, review and compare the elemental costs contained in the initial concept estimate to other similar or competing projects. This exercise identifies inefficiencies and highlights opportunities that will benefit the project bottom line. Cost benchmarking is done on an elemental basis because this provides the most consistent results; examples of building elements include substructure, columns, upper floors, staircases, roof, external walls, etc and are fairly consistent around the globe. Some of the different elemental formats include UniFormat II (USA), UniClass (UK) or ACMM (AUS).

By way of example a concept estimate containing a rate of $354.90 per m2 for columns and upper floors would exceed the actual average costs of $279.09 per m2. If the design is made more efficient a cost saving of 3.6% against the estimated total building rate of $2,078.57 per m2 is achieved.

6.3 Analysis of Functional Performance

In a similar fashion the functional performance and efficiency of a building is analysed against actual project performance data to further identify inefficiencies and highlight opportunities to create further savings.

In Table 1, the example concept design for a planned apartment building contains 36 apartments with an average area of 168.9 m2. This exceeds the completed project average of 101.9 m2. It is also apparent that much of the inefficiency is occurring within the common spaces and car park areas which are not income producing. Correction of these inefficiencies would improve the building cost performance by 20% without effecting the saleable area and income.

Table 1: Functional Performance Analysis

	Planned Project Concept Design	Actual Completed Projects (Average)
Residential Area / Unit	98.5m2	65.3m2
Common Area / Unit	30.9m2	11.6m2
Carpark Area / Unit	39.5m2	25.0m2
Building Area / Unit	**168.9m2**	**101.9m2**
Residential Area / Unit	98.5m2	65.3m2
Balcony Area / Unit	33.5m2	12.9m2
Saleable Area / Unit	**132.0m2**	**78.2m2**

7. DETAILED DESIGN

At detailed design, the goal of the 5D QS is to produce a schematic design estimate with dynamic links to the model information that will form the foundation for the living cost plan that is used for developed design and bidding. The living cost plan becomes the basis for providing updated estimates every time the model information is changed that can be used for forecast final cost, budget variances, value management, finance, funding and final investment decisions or in negotiations with a contractor.

7.1 Schematic Design – LOD 200

Working with the schematic design model (AIA LOD 200) in Revit or IFC format, the 5D QS prepares a sketch design cost plan that is presented in an elemental format stating the generic construction materials, finishes and services specifications.

The 5D QS maps the model and adds an elemental pricing code to the model information. It is helpful if the author has included UniFormat II (USA), UniClass (UK) or ACMM (AUS) codes in the model information but often it is much quicker and more accurate if the 5D QS adds the preferred codes for the task.

Dynamic links are then created between the generic architectural and structural model elements, the 5D QS elemental rate library and the selected project template that is contained within the 5D BIM authoring tool such as CostX.

It is understood that not everything is modeled and the 5D QS ensures that all of the work is estimated by supplementing with 2D on screen measurement where necessary. Trust and transparency is supported by providing a fully functioning and executable CostX reader version of the sketch design cost plan that is easily interrogated because of the dynamic links between the models, elemental areas and rate library. This executable file becomes the basis for the living cost plan which can be recompiled to consider alternative designs, different construction methods, materials and generic engineering systems during development of the schematic design and any time the model information is revised.

7.2 Developed Design – LOD 300

Working with the developed design model (AIA LOD 300) in Revit or IFC format, the 5D QS prepares developed design cost plans that are presented on a sub-elemental and trade basis, stating the specific construction materials, finishes and services specifications. The final estimate states each sub-elemental unit rate and quantity.

At this stage an extra level of costing detail is added to the model information. This can be done via an instance parameter and then the model is re-mapped where necessary to create further dynamic links between the specific model assemblies (including architectural, structural, civil and MEP), the detailed rate library and the selected project template that is contained within the 5D BIM authoring tool. Again the model information is supplemented with 2D on screen measurement and the executable file continues to be the living cost plan

This detailed information can factor into the different stages of the design and construction process and helps to consider in detail the labour, materials, equipment, and subcontractor costs for each building element.

7.3 Coding

In circulation today there are a number of different coding systems but there is not a published industry code that is suitable for becoming a price code which will automatically link a rate to a specific system or assembly. UniFormat II is one example and while it is close to achieving this goal it has insufficient levels to specifically identify the material and fixing condition. For these reasons the 5D QS uses its own specific code for the material and fixing conditions which is pushed into a model as an instance parameter.

8. QUANTITY TAKE-OFF AND BIDDING

For design, bid, build procurement the rate library is removed from the executable file so that what remains is a bill of quantities that is easily interrogated by contractors and subcontractors because the dynamic links allow each quantity to be viewed in the model. The file is also recompiled in a trade format so that the quantities reflect the scope for each subcontract. Often the building information comprises individual models and the 5D QS uses tools like Navisworks and Solibri to coordinate visually. MEP forms approximately 30% of the total project cost so special care is needed during this phase to ensure that quantities for mechanical, electrical, hydraulic, fire and transportation services are actively coordinated with the building trades.

9. CONSTRUCTION

9.1 Contractors Priced Bill of Quantities – LOD 300

Working with the construction model (AIA LOD 300) in Revit or IFC format, at the commencement of construction, the 5D QS attaches the contractor's offered rates and prices to the executable file. The contractors priced bill of quantities is presented on a trade and zone basis and states the description for each item (including the specific construction materials, finishes and services specifications), the quantity and the offered rate. In some instances re-mapping of the model is necessary to create further dynamic links between the model zones and specific assemblies.

9.2 Change Orders, Variations and Payments

The dynamic links mean that variations and change orders can be calculated reliably, easily and quickly every time a change occurs in the model information. Progress payments are also calculated from the executable file by isolating the completed zones by trade and recompiling the quantities to produce a progress payment calculation that is transparent and easily interrogated. During construction the model will evolve from LOD 300 to LOD 400 as changes occur on site and shop drawings are developed. The 5D QS continually coordinates

the construction model with the contractors priced bill of quantities and provides cost updates, budget performance and variances through each stage of construction.

9.3 Cost Integrated Construction Model – LOD 400

As construction progresses the model information is changed to produce the revised documents that are necessary for the construction process – this information is stored in the Model software. The 5D QS also changes the cost information to reflect the actual contract sum and any cost adjustments and payments that occur during construction – this information is stored in the 5D BIM authoring tool.

9.4 As-Built Cost Data & Facilities Management – LOD 500

Once validation and synchronization is completed between the as-built (AIA LOD 400 or 500) Model and the FM system, The 5D QS pushes the project as-built cost data into the Model instance parameters. The as-built cost data packet usually comprises several different pieces of information including the replacement cost at the base date, manufacturers expected life for replacement, effective life for depreciation and estimated running cost for operating budgets. Care is taken to omit construction costs that will not be incurred again such as demolition of pre-existing buildings.

This as-built cost information is then ready to be integrated into the Facility Maintenance System and FM database for use throughout the life cycle of the project.

10. CONCLUSION

The 5D QS has developed specialist technology skills which compliment traditional cost planning techniques that set strategies from preliminary designs when plans evolve and cost overruns are prevented. 5D BIM provides the ability generate savings and efficiencies and to drive costs for buildings, infrastructure, heavy engineering or land development in the direction that is wanted. When negotiating with contractors and subcontractors the ability to visualise quantities creates trust and is relied upon.

5D BIM is here and finally there is traction to make 5D an integral part of the QS tool kit and every project to create cost certainty. It is one thing to use the technology but on its own it will not generate the certainty that customer's desire.

This requires the wisdom and intelligence of a 5D QS and cost planner. So while it's the way of the future and a must for all projects going forward, it is critical to work with people who know what they are doing and know how to leverage it to get the best results for the building from initial concept through to procurement and on-going management of post construction.

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Energy Saving Behaviour (ESB) Level of Practice- Comparison case study between green and conventional office building

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Abstract

Findings from previous studies show that many cases of green buildings have not achieved their desired performance. Often the actual energy consumption is different from that predicted at design stage. In some cases, actual energy usage consumed more energy than a similar conventional building. The difference between actual and predicted energy usage can be explained by the differences between assumed and actual behaviour of occupants, the use of building energy controls, and building operation management. While implementation of green buildings is not entirely successful in achieving energy saving targets, adoption of energy saving behaviour should result in better energy efficiency performance. Currently energy saving behaviour has been given less focus in improving green building performance. This study uses a comparison case study between green buildings and conventional buildings to better understand Energy Saving Behaviour (ESB). The objective of this paper is to investigate the level of energy saving behaviour practiced in between green and conventional office buildings. Findings from case studies show respondents in green buildings practice more ESB than respondents in conventional building. This paper also identified ESB with high and low scores in both green and conventional building. Categorisation of these ESB may aid building managers to target which behaviours that requires increase in its adoption rate. In addition, the timing of some of the ESBs performed was identified to capture better understanding of occupant's preference to save energy. Findings from the survey show that most respondents answered with ESB "turned off at the end of the day" and "when away for an hour". The study concluded that although some ESBs are recognized in green building users, energy waste is still evident due to the high non-performance of other ESBs. .

Keywords: ***Energy Saving Behaviour (ESB), Energy Efficiency, Green Buildings, Energy Performance***

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1. Introduction

In many cases green buildings did not achieve optimum energy efficiency performance. Often the actual energy consumption is different from what was predicted at design stage and consumed more energy in comparison to conventional buildings of the same size and function(Bordass, Cohen et al. 2001, Office 2002, Cohen, Bordass et al. 2007, Sawyer, De Wilde et al. 2008, Wedding 2008, Scofield 2009, Ashuri 2010, Howe and Gerrad 2010). Howe and Gerrad (2010) and Wener and Carmalt (2006) pointed out that the reality is majority of green buildings are not energy efficient and these buildings will continue to be used for many years to come. Hes, D.(2005) , Armitage (2010)and Bond(2011) reported that many 4 star certified buildings do not perform even at a 2 star level. This "mismatch" primarily results from the differences between assumed and actual patterns of occupants, the use of controls, and building operation management (Cole and Steigner 1999, Bordass 2001, Reiss 2005, Kubba 2010). In an on-going research by Andrews et al.(2010) it was stated that buildings may fail to perform as planned, because operators do not- or cannot operate the buildings as intended, and because occupants sometimes behave differently than expected. Documented studies showing poor performance such as that indicated above could possibly impede the rate of implementation of green buildings in a country. Therefore, it is necessary that energy performance in green buildings should be improved to achieve optimum energy efficiency performance. A successful performance of green building can be achieved by further reducing energy consumption through changes in human behaviour. Study by Cole (1999) and Steinberg (2010) have shown that integration of Energy Saving Behaviours (ESB) has not been given sufficient focus in green buildings. ESB can be divided into two categories: efficiency and curtailment behaviours (Gardner and Stern 2002). Efficiency behaviours include actions like purchasing energy efficient equipment such as insulation, and energy efficient light bulbs. Curtailment behaviours involve repetitive efforts to reduce energy use, such as lowering thermostat settings. The focus in this paper is on curtailment behaviours since green buildings which already have energy efficient technologies have shown that efficiency behaviour alone did not achieve optimum performance in saving energy. In addition, Energy Efficiency Conservation Authority (EECA), New Zealand (EECA 2011) highly encourages curtailment behaviour as a way to reduce energy consumption in office buildings. This paper investigates the level of practice rate in Energy Saving Behaviour (ESB) between green and conventional office buildings. The aim of this paper is to acquire better understanding of the occupant's behaviour in the building in order to develop an effective intervention strategy to increase ESB adoption rate.

2. Literature Review

Energy Saving Behaviour (ESB) is defined as a specific action to reduce energy consumption (Gardner and Stern 2002). A total of 18 Energy Saving Behaviours (ESB) was compiled from previous studies in a residential, office, and university context as shown in Table 1. These ESB are common behaviours that are encouraged for occupants in buildings to help save energy. The aim of this study is to investigate the current level of practice in ESB between green and conventional office building

Table 1 Energy Saving Behaviour (ESB) List

CODE	Item Description	Reference
ESB1	Use dishwasher only when there is full load	(Barr and Gilg 2006, Wood and Newborough 2007)
ESB2	Boil less water instead of filling up the whole kettle	(Wood and Newborough 2007)
ESB3	Read documents on computer screen rather than printing	(Steinberg 2009)
ESB4	Use double sided printing	(Steinberg 2009)
ESB5	Reduce multiple computer monitors to one (if you are using multiple computer screen)	(Heerwagen 2010)
ESB6	Work on a laptop instead of a computer	(EECA 2011)
ESB7	Turn down computer screen brightness	(Steinberg 2009, Ryu 2010)
ESB8	Put screen to sleep instead of using screen saver	(Kolata 1986, Ulrich 2008).
ESB9	Print in booklet format or double sided rather than one sided	(Steinberg and Landis 2010)
ESB10	Shut down my computer	(Kolata 1986, Stern 1986)
ESB11	Shut down colleagues computer if seen left turned on	(Kolata 1986, Stern 1986)
ESB12	Turn off my computer monitor if seen left turned on	(Kolata 1986, Ulrich 2008, Steinberg 2009).
ESB13	Use task lighting whenever appropriate, and switch off main lights	(Kolata 1986, Ulrich 2008, Steinberg 2009).
ESB14	Switch off lights in unused space	(Energy 2011, Lab 2011) (Carriere and Rea 1988, Barr and Gilg 2006, 2011)
ESB15	Use natural daylight whenever appropriate, and switch off lights	(Heerwagen and Diamond 1992)
ESB16	Close windows and exterior doors when heating/ cooling systems are used	(Heerwagen and Diamond 1992, Heerwagen 2010)
ESB17	Close curtain/ window blind at night to prevent heat loss	(Heerwagen and Diamond 1992, Barr and Gilg 2006, Andrews, Yi et al. 2011)
ESB 18	Ensure electronic appliances are turned off	(EECA 2011)

3. Research Methodology

Four case studies were selected to compare energy efficiency practices among occupants in green and conventional buildings. Two of each category of buildings was chosen. Thomas Building (TB) and Owen G Glenn Building (OGGB) were identified as green building because the designintent was to be energy efficient. Faculty of Engineering (FoE) and Old Choral Hall (OCH) building was selected as suitable for conventional building as it does not incorporate energy efficient design.

Case study 1- Thomas Building – Green Building (TB)*.* The extension Thomas Building, a 4 storey building was built in 2011 with the design intention for the building to be green building certified by GreenStar New Zealand. The area of the building is 4,958m2 with an estimated population of 160 occupants. The design intended a rating NZGreenStar between 4 star to 5 star. Energy efficient features in the building incorporated a double glazed tinted low E with double skin facade. The outer glazing with fritted dot pattern provides 30 % shading. Access for natural ventilation is provided through inoperable window louvers. Most areas in the building have occupancy sensors. The building also adopts the variable air volume (VAV) system which is energy efficient compared to a typical air-conditioning system.

Case study 2- Owen Glenn Building – Green Building(OGGB). The Owen G. Glenn Building, a 7 storey building was completed in 2007. The area of the building is 74,000m2 with an estimated population of 400 occupants.The main energy efficient features incorporated in the building were highly glazed window to optimise natural daylight, with layered facades to provide solar shading. Occupancy sensors and automatic building control systems were connected with the Energy Management System.

Case study 3- Old Choral Hall– Conventional Building (OCH). Old Choral Hall building, a 4 storey building completed in 1872. Total estimated population in the building is 100 occupants. This building was identified as one of the historical buildings in New Zealand. No energy efficient design was incorporated at the time it was built. Hence this building was selected suitable as a conventional building.

Case Study 4- Faculty of Engineering- Conventional Building (FoE).Faculty of engineering building, is a 12 storey building with an estimation of 300 occupants. The building was reported to have no energy efficient features in the building.

A survey was conducted to evaluate the extent of energy saving behaviour practice, and identify potential strategies to encourage energy saving behaviour. The questionnaire was structured into four parts. Part 1 consisted 17 items on ESB asking respondents to rate their actions using a likert type scale of 5 – Always to 1- Never. Part 2 in the questionnaire was on ESB performance in different time events for 3 items using a categorical scale of three. Part 3 required respondents to select which of the electronic appliances they have and consequently select their actions after usage on the electronic appliances they have using a categorical type scale of three which are “I leave it ON”, “I turn off appliance” and “I turn off main switch”.

4. Results and Discussion

The questionnaire was sent out to an estimated total of 1100 people in the building in from May 2012 to September 2012. A total of 270 replies were received for a response rate of 25%. Table 2 shows the breakdown percentage response rate in each building. A total of 113 respondents received in conventional building with a percentage of 28 percent. 157 respondents were received in green buildings constituting a percentage of 22 percent.

Table 2 Response Rate

Type	**Total Population**	**Total Respondents Received**	**Response rate**	**Name of Building**	**Population**	**Respondents received**	**Response rate**
Conventional Buildings	400	13	28%	**FoE**	300	80	27%
				OCH	100	33	33%
Green Buildings	700	157	22%	**TB**	300	68	23%
				OGGB	400	89	22%
TOTAL	**1100**	**270**	**25%**	TOTAL	1100	270	25%

4.1 Part 1: Energy Saving Behaviour (ESB) Actions

Respondents were asked to rate their actions for 17 items on Energy Saving Behaviour (ESB) using Likert scale of 5=Always to 1=Never. The total score of ESB actions for each respondent is aggregated to represent the overall performance in practicing ESB as shown in Figure 1.Total scores of the ESB actions are categorised into five levels with minimum score at 17 and maximum score at 85. A comparison in the ESB scores between green and conventional building is shown in Figure 1. Respondents who rated “I always do” for most ESBs, is seen highest in green building (26%) as compared to conventional building (11%). While respondents who never practice ESBs is seen highest in conventional building (27%) as compared to in green building (14%). Findings from these results are similar with study by Tajabadi (Tajabadi 2010) where green building practices more ESB than respondents in conventional building.

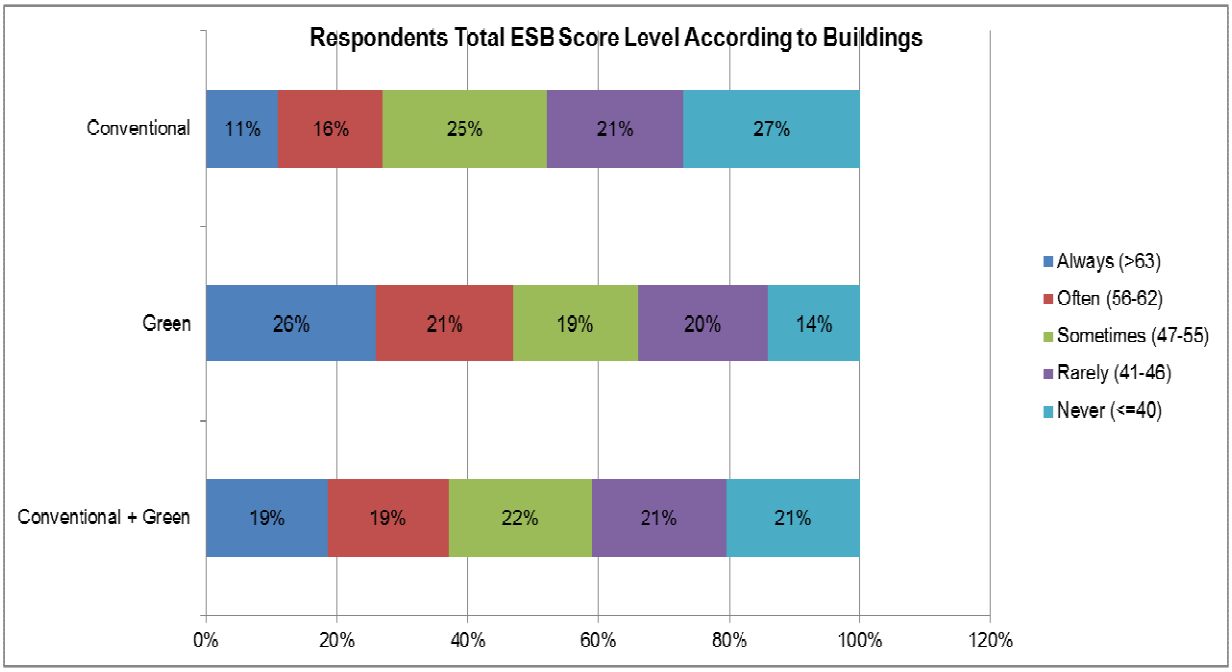

Figure 1 Respondents ESB Total Scores Level

Mann-Whitney U test was conducted to compare the energy saving behaviour scores on each of the ESB actions by respondents from green and conventional building. A significance value of p less than 0.05 indicates that there is a significant difference between the two groups. Table 6 shows that there is significant difference for five ESBs which are ESB 1Use dishwasher only when there is full load, ESB 2 Boil less water instead of filling up the whole kettle, ESB 5Reduce multiple computer monitors to one (if you are using multiple computer screen);ESB 6 Work on a laptop instead of a computer; and ESB 13Use task lighting whenever appropriate, and switch off main lights. The highest mean ranks in all five behaviours were respondents from green building. These results show that respondents in green building perform better for these behaviours as compared to respondents in conventional building.

Table 3 Mann-U Whitney U test on ESB between Green and Conventional Building

CODE	Item Description	Sig. Difference (p)	Existence of Difference	Mean Rank		Higher Mean Rank
				Conventional	Green	
ESB1	Use dishwasher only when there is full load	.000	Significant	79.23	**121.78**	Green
ESB2	Boil less water instead of filling up the whole kettle	.000	Significant	81.71	**119.30**	Green
ESB3	Read documents on computer screen rather than printing	.691	Not Significant	98.95	102.05	-
ESB4	Use double sided printing	.359	Not Significant	104.09	96.92	-
ESB5	Reduce multiple computer monitors to one (if you are using multiple computer screen)	.026	Significant	92.81	**108.19**	Green
ESB6	Work on a laptop instead of a computer	.009	Significant	90.29	**110.71**	Green
ESB7	Turn down computer screen brightness	.153	Not Significant	94.91	106.09	-
ESB8	Put screen to sleep instead of using screen saver	.185	Not Significant	95.22	105.78	-
ESB9	Print in booklet format or double sided rather than one sided	.212	Not Significant	105.45	95.56	-
ESB10	Shut down my computer	.222	Not Significant	95.69	105.31	-
ESB11	Shut down colleagues computer if seen left turned on	.159	Not Significant	95.84	105.17	-
ESB12	Turn off my computer if seen left turned on	.988	Not Significant	100.56	100.44	-
ESB13	Use task lighting whenever appropriate, and switch off main lights	.011	Significant	87.63	**113.38**	Green
ESB14	Switch off lights in unused space	.194	Not Significant	90.53	110.47	-
ESB15	Use natural daylight whenever appropriate, and switch off lights	.418	Not Significant	95.32	105.68	-
ESB16	Close windows and exterior doors when heating/ cooling systems are used	.460	Not Significant	97.27	103.74	-
ESB17	Close curtain/ window blind at night to prevent heat loss	.119	Not Significant	103.41	97.60	-

ESB that are significantly different are shown in the red circles in Figure 2. The largest gap between the trend line for green and conventional is on ESB 1 (use dishwasher only when there is full load). Respondents in green building claimed to often practice ESB 1 with mean value of 3.04, while respondents in conventional building rarely practices it with a mean value of 1.57. Respondents also claimed to often practice ESB 2 (Boil less water instead of filling up the whole kettle) with a mean value of 3.22 in green building, while respondents in conventional building claimed to rarely practice this behaviour with a mean value of 1.99. ESB 5 (Reduce multiple computer monitors to one) is sometimes practiced by respondents in green building with a mean value of 2.10, while in conventional building it is rarely practiced with a mean value of 1.70. ESB 6 (work on a laptop instead of a computer) is sometimes practiced by respondents in both green and conventional building with a mean value of 2.72 and 2.19 respectively. ESB 13 (use task lighting whenever appropriate, and switch off main lights) is sometimes practiced in both green and conventional building with a mean value of 2.77 and 2.23 respectively

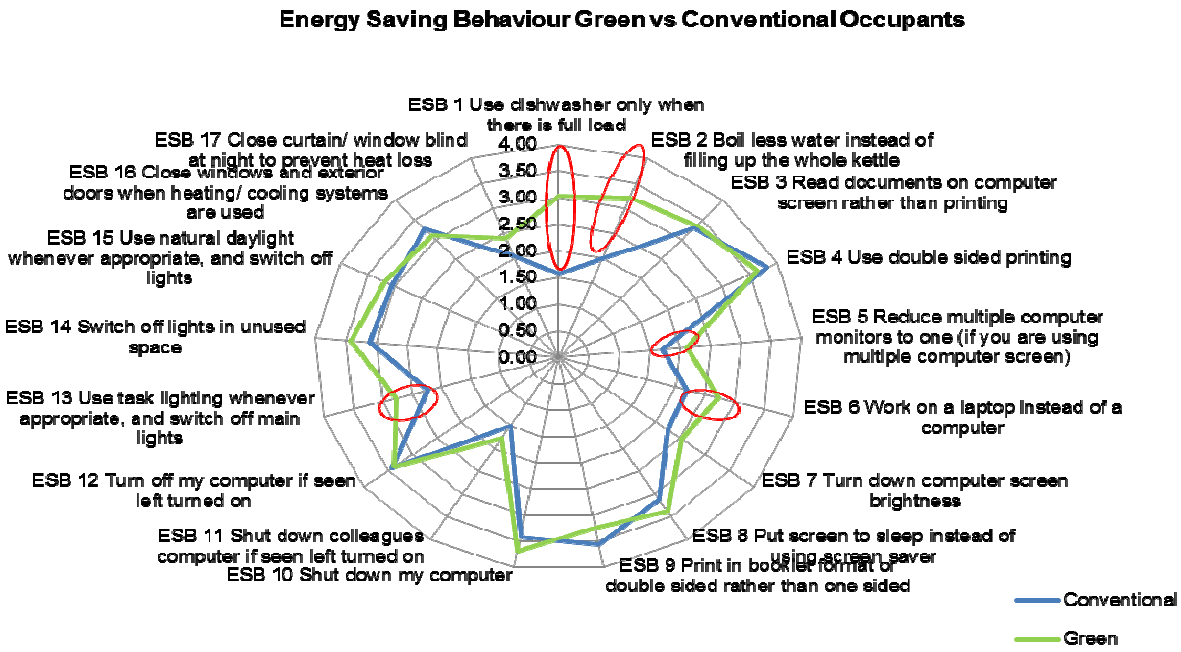

Figure 2 Energy Saving Behaviour Green vs Conventional Occupants

The remaining ESB list (3, 4, 7, 8, 9, 10, 11, 12, 14, 15, 16, and 17) are determined not statistically significant different between green and conventional building through Man-U Whitney test as shown in Table 5. This shows that the rest of the ESBs are practiced somewhat at a same level. An illustration of the overall performance in both green and conventional building can be seen in Figure 2 where a trend line of higher mean scores of the ESBs are from green building. There are a total of eleven ESBs with mean score value between 3.00 to 4.00 rated as often practiced in green building, and a total of nine ESBs often practiced in conventional building. Out from the eleven ESBs that are often practiced, a total of nine ESBs often practiced were identified common in conventional and green building as listed in Table 7. The remaining two ESBs (ESB 1 and ESB 2) found in green building is not seen in conventional building. In conventional building, the only ESBs with higher mean score are for ESB 4, 12, 9, and 16, while mean score for the rest of the ESBs are seen higher in green building

Table 4 Mean Score ESBs (HIGH and LOW SCORES)

CODE	***ESB***	***Mean Score***	
		Green	***Conventional***
ESB 10	Shut down my computer	3.69	3.42
ESB 4	Use double sided printing	3.65	3.81
ESB 14	Switch off lights in unused space	3.42	3.11
ESB 12	Turn off my computer if seen left turned on	3.39	3.42
ESB 8	Put screen to sleep instead of using screen saver	3.38	3.12
ESB 3	Read documents on computer screen rather than printing	3.34	3.29
ESB 9	Print in booklet format or double sided rather than one sided	3.24	3.57
ESB 15	Use natural daylight whenever appropriate, and switch off lights	3.19	3.05

ESB 16	Close windows and exterior doors when heating/ cooling systems are used	3.09	3.25
ESB 1	Use dishwasher only when there is full load	3.04	1.57
ESB 2	Boil less water instead of filling up the whole kettle	3.22	1.99
ESB 13	Use task lighting whenever appropriate, and switch off main lights	2.77	2.23
ESB 6	Work on a laptop instead of a computer	2.72	2.19
ESB 7	Turn down computer screen brightness	2.53	2.24
ESB 17	Close curtain/ window blind at night to prevent heat loss	2.40	2.05
ESB 5	Reduce multiple computer monitors to one (if you are using multiple computer screen)	2.10	1.70
ESB 11	Shut down colleagues computer if seen left turned on	1.77	1.50

*Note: Boxes highlighted indicates LOW scores

A total of six ESBs have mean score below 3.00 in both green and conventional building as shown in Table 7 highlighted in red. These results indicate that improvement in adoption rate of the ESBs is necessary in both buildings. Nevertheless, improvement of behaviour in conventional building is required more since there is an additional two ESBs (ESB 1 and ESB 2) that are identified as low score.

4.2 Part 3: ESB 18 Ensure electronic appliances are turned off

Table 9 shows that respondents in green building perform better than in conventional building due to the higher number of personal electronic appliances turned off at main switch (24% in green building, and 16% in conventional building). As for office electronic appliances; are very few turned off at main switch in both buildings. An improvement in this behaviour may potentially save more energy. Respondents in green building show less occurrence of personal electronic appliances turned on, while in conventional building showed less occurrence of office electronic appliances left turned on. Reasons for these behaviours are unknown and a further investigation is required to gain better understanding of the situation. Nevertheless, a comparison between personal and office electronic appliances shows that there is a larger percentage of office electronic appliances left turned on. It is suspected that the reason for the behaviour is because of the sense of ownership on personal belongings of the electronic appliances. This creates a higher sense of responsibility for their actions after using the electronic appliances(Lopes, Antunes et al. 2012). However, a higher percentage of items switched off at the appliance itself is seen in conventional building 56% personal electronic appliances in conventional building turn off appliance after usage while only 51% total items in green building turn off appliance after usage.

Table 5 Actions on Electronic Appliances

		Personal Electronic Appliances		***Office*** Electronic Appliances	
		Conventional	*Green*	Conventional	Green
Actions	I leave it ON	29%	26%	71%	78%
	I turn off appliance	56%	51%	24%	19%
	I turn off MAIN switch	16%	24%	5%	2%
TOTAL		100	100%	*100%*	100%

5. Conclusion

Findings from case studies show respondents from green building significantly practices more ESB than respondents in conventional building for five ESBs which are ESB 1 (Use dishwasher only when there is full load), ESB 2 (Boil less water instead of filling up the whole kettle), ESB 3 (Reduce multiple computer monitors to one (if you are using multiple computer screen), ESB6 (Work on a laptop instead of a computer), and ESB 13 (Use task lighting whenever appropriate, and switch off main lights). Respondents from green building performed ESB 18 better for personal electronic appliances. This is due to the higher number of appliances turned off at main switch and lesser appliances left turned on. However, respondents in conventional building have higher number of appliances turned off at the appliance itself for both personal and office electronic appliances. Respondents in conventional building also performed better for higher office appliances turned off main switch and leaving lesser office appliances turned on. This paper also identified high and low scores in ESB for both green and conventional building. Categorisation of these ESB may aid building managers to target which behaviours that requires increase in its adoption rate. ESB with high scores are ESB 10, 4, 14, 12, 8, 3, 9, 15, and 16. ESB with low scores are ESB 13, 6, 7, 17, 5, and 11. It is only ESB 1 and 2 that has high scores in green building but low scores in conventional building.In addition, the timing of some of the ESBs performed was identified to capture better understanding of occupant's preference to save energy. ESB 12 and ESB 14 were more likely to be turned off at the end of the day and when away for an hour. An improvement in ESB 12 and 14 is to have them implemented at every 10 minutes. Respondents perform ESB 10 at the end of the day the most in green and conventional building. It is suggested that energy can be further reduced if performed at every one hour. This information may contribute in developing a strategy to increase ESB adoption rate. Results also showed ESB 12(turn off computer) and ESB 14(switch off lights) are claimed to be practiced more.It is expected that occurrence of energy waste for these two events(EW 4 and 5)are seen lesser. However, observations on energy waste for these two events were reported to be seen more. Other observations on energy waste were seen for EW 1 and EW 6 which indicates necessary for improvement. The findings showed that behaviours to reduce energy consumption in these scenarios is necessary for improvement. EW 3 showed low score and its ESB showed high score which indicates good performance. As for EW2 scored too low demonstrating that occurrence of energy waste in this event is rarely seen. Thus, EW 3 and EW 2 is not necessary for improvement. Gaining better understanding of people at work, can ensure that interventions are successful. Future research is required to understand the underlying motivational and barrier factors of these ESB are necessary. The following are questions to be addressed How come respondents in GB practices more ESB than in CB? What makes the respondents scored high on ESB? Why do some respondents score low on ESB? How can we increase the rate for respondents with low score on ESB? A qualitative evaluation tool is suggested as the appropriate research methodology to gain in depth answers from the questions.

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Understanding Energy Use in New Zealand's Non-Residential Buildings.

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Energy and Water demand in New Zealand's Non-Residential Buildings.

Understanding how energy and water resources are used in non-residential buildings is key to improving the energy and water efficiency of New Zealand's building stock. More efficient buildings will help to reduce greenhouse gas emissions and enhance business competitiveness. The Building Energy End-use Study (BEES) is establishing how energy and water resources are used in non-residential buildings and what factors drive this use.

Capturing the building, social and economic dynamics of energy and water consumption across the non-residential stock is by no means a trivial task. BEES has developed a sample frame and data collection methods to establish a representative sample of non-residential buildings and a multi-method approach that allows data from different sources to be triangulated.. Data on building structure, business activities and energy and water use have been collected. This has been achieved by compiling complementary data sets from broad surveying of buildings and businesses through to specific data collection and intensive detailed monitoring of individual premises. This paper provides an overview of the research methodology and key energy results from the project to date. It includes an understanding of the profile of the non-residential building stock, energy use baselines, determinants of resource use and an insight into the possible intervention points to improve resource use efficiency.

Keywords: Non-residential buildings; Energy efficiency; Energy end-use; Building characteristics.

1. Introduction

In New Zealand a significant amount of research on improving energy efficiency and the services it provides for housing has been completed, (Isaacs et al, 2010a), but information and research on non-residential buildings was minimal Once this was recognised, and funding and support made available from both government and the building industry, a

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research project was initiated. The project, the Building Energy End-use Study (BEES) aims to provide new knowledge on how energy and water resources are used in non-residential buildings in New Zealand and develop and understanding the factors that drive this use.

Through collection of measured data using surveys and monitoring the project objectives are to quantify and characterise the energy and water use in non-residential buildings and understand how energy is used in today's non-residential buildings. This will improve models of non-residential building energy use; provide design and operation guidance, and guidance to create more productive work environments. The research aims to provide a base for development of the New Zealand Building Code (NZBC), Standards and rating tools, along with Government policy development and implementation. It will also support the reduction of GHG emissions and adaptation to climate change.

To conduct this research, a range of skills and disciplines are necessary and a multi-disciplinary as well as cross-organisational, best-fit team of researchers has been assembled. This includes physical and social scientists, building energy and modelling experts and a statistician. This paper provides an overview of the BEES research and key results to date. It includes an understanding of the profile of the non-residential building stock, energy use baselines, determinants of resource use and an insight into the possible intervention points to improve resource use efficiency in these buildings.

There are several different definitions of non-residential buildings both internationally and within New Zealand so an early step of the research methodology was to develop a BEES definition of non-residential buildings. After investigating overseas approaches and definitions available within New Zealand it was decided the New Zeland Building Code definitions were the most appropriate. Therefore, buildings defined as Commercial and Communal Non-residential Assembly Care fell within the scope of the project (Isaacs et al, 2010b). This meant the key focus of the study would be on buildings where office and retail activities were conducted. This ensured that industrial and other buildings in sectors in which energy and water consumption was primarily attributable to the industrial processes housed in the building were excluded.

2. BEES Sample Frame

In New Zealand there is no database or regular census of non-residential buildings. Therefore to collect data from non-residential buildings other means of providing a sample frame was necessary. As a proxy the best available information available was the property valuation records. Selected valuation records were purchased from PropertyIQ and Auckland City Council (who had their own valuation department). These were in two key groups; valuation records that had category codes that were consistent with the BEES non-residential buildings definition; commercial buildings and two industrial categories (IW-warehouse and IS-service). The industrial categories were included because they had the potential to contain businesses that provided office or retail activity. This subset, defined as building records, provided the sample frame for the study (Isaacs et al, 2010b). It consists of over 50,000 building records.

The sample frame was stratified into 50 strata; a combination of floor, use and region groups. The floor area groups that divided the sample into quintiles based on estimated total floor area has been the dominant strata group used for data collection (see Table 1).

Table 1: Sample Frame Count by Floor Area.

Floor Area Group	**1**	**2**	**3**	**4**	**5**	**Total**
Minimum Floor Area	5m²	650m²	1,500m²	3,500m²	9,000m²	
Maximum Floor Area	649m²	1,499m²	3,499m²	8,999m²	111,000m²	
No of Building Records	33,781	10,081	4,288	1,825	564	**50,539**
% of Building Records	67%	20%	8%	4%	1%	**100%**
QV Total Floor Area (million m^2)	9.9	9.6	9.5	9.6	9.8	**48.3**
% floor area	20%	20%	20%	20%	20%	**100%**

From this framework a stratified sample of 3000 building records was randomly selected as the sample for analysis and data collection. The remaining building records in the sample frame were intended as replacements.

2.1 Survey and Data Collection

A range of data was required at several different levels to allow analysis to meet the project objectives. This included data and information on both the selected buildings and the businesses within the buildings. This was important because energy and water used within buildings is dependent on both the fabric and services (e.g. central heating) of the building but also the activities of the businesses within the building. Also, typically it is the businesses working within a building that pay for the energy and water use (whether directly or indirectly).

A business may work across multiple locations so the unit that links a business to a location is defined as a premise. This may be a single building or part of one building, i.e. where the business and building intersect.

The BEES programme has gathered data from via a range of methods:

- Web search using web-based search engines and the addresses provided from the building records provided a range of data including: building size and shape, estimated number of floors, number of buildings per building record, where possible business names and estimated floor plate areas.
- Data collection of business names, addresses and phone numbers within the BEES buildings were gathered from a range of other sources including: businesses directory data, street searching, internet based options (e.g. Google Street View) and organisations who supply business contact information.
- BEES Phone survey of premises was completed for the first 2000 building records from the sample. The survey provides information on the occupation of the premise

including the number of employees, hours of use, tenancy and ownership, appliance counts, operation of heating and cooling.

- Meter and water billing records for premises that provided consent. For every phone survey a request to access their billing data records for a two year period was requested. This required a formal signoff form the businesses to enable access to the data from the energy or water company.
- Detailed monitoring of a small group of premises. This provided physical data, typically over a two week period, on the energy use and end-uses within a premise, including lighting, plug loads and heating. Daylighting, temperatures and CO_2 measurements were also recorded.
- Detailed interviews for case studies. Detailed interviews or surveys were completed to better understand the complex relationship between, owners, property managers and tenants. Also a small set of building case studies to understand the user perceptions have been completed using the BUS method (Usable Buildings Trust, 2006).

The initial concept for the data collection was to have a cascading model so each level of greater detail would be a subset of the larger sample, starting with the web search of the randomly selected 3000 building records (Figure 1).

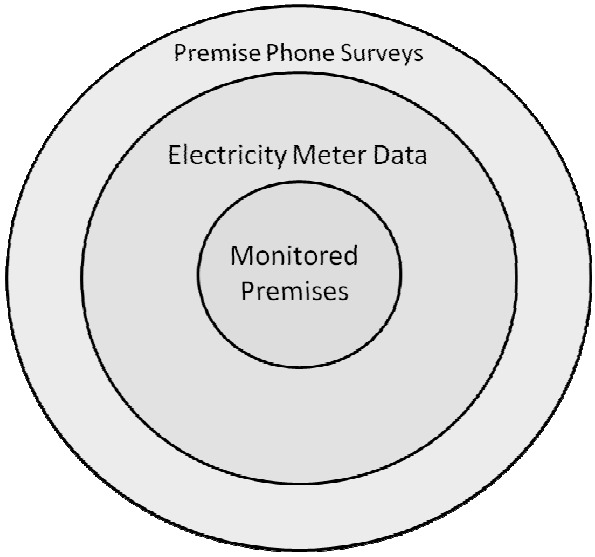

Figure 1: Data collection cascading model.

In reality the data collected has been more disparate. The diagram below shows the relationship of the data sets at a premise level. The result shows rather than a cascading sample there are areas that intersect. The reason for this has been twofold:

- Very few premises were prepared to carry out all three components, especially where the level of ‘sign off’ increased. In particular, the two step process required from completing the phone survey to signing a consent form for the meter data.
- Having two parallel research streams (surveying and detailed monitoring) meant that a few of the detailed monitored premises when requested at a later date to complete a phone survey opted not to proceed.

Premise Data	Total
Phone Survey	840
Meter Data	402
Monitored	101

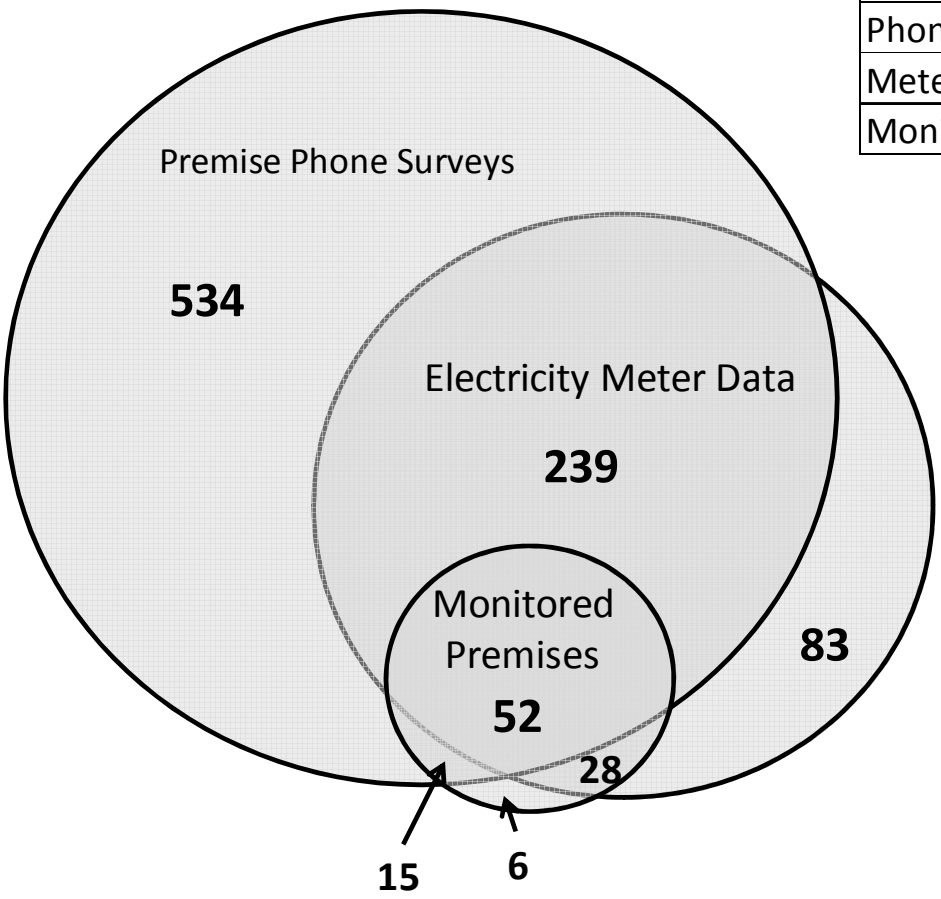

Figure 2: Data collection numbers from Premises (n=957).

However, the multiple option approach to data collection has provided rich datasets that can be interrogated and cross linked in numerous ways. These allow analysis of relationships between the physical buildings and their characteristics, the building activities, building owners and its users, and the services provided. All of these have an impact on the energy and/or water use and the potential to improve efficiency of use.

3. Results

The BEES data allows analysis to better understand the physical nature of the building stock and through modelling the identification of opportunities to improve both energy and water use at a broad level and energy end-use at a detailed level. Through the survey and interviews the energy efficiency opportunities can also be identified for the different groups of people involved in managing and using non-residential buildings. For each of these a significant amount of analysis is being undertaken to meet the programmes objectives. The following provides some of the key results and knowledge to date.

3.1 Building Characteristics

An unexpected outcome of the research has been the ability and necessity to use the data to develop a good understanding of the overall non-residential building stock.

Table 2 provides an estimate of the number of non-residential buildings in NZ. It suggests there are approximately 33,000 non-residential buildings in New Zealand, a combination of office, retail and mixed use. The reduction in from the sample frame is because when assessed in detail, approximately 20,000 did not fit the BEES non-residential building criteria. Non-residential buildings have a total floor area of about 31,000 million square metres. There are estimated to be about 400 buildings in the largest floor area strata (over 9,000m²) when assuming one building per building record. However at the other end of the scale there are approximately 23,000 buildings with a floor area less than 650m^2 (Isaacs, 2011).

Table 2: Non-residential buildings by size

	Building Floor Area					**Total**
Minimum Floor Area	5m²	650m²	1,500m²	3,500m²	9,000m²	
Maximum Floor Area	649m²	1,499m²	3,499m²	8,999m²	111,000m²	
Approx. No. of 'Buildings'	22,915	5963	2617	1072	398	32,965
% of Buildings	70%	18%	8%	4%	1%	**100%**
Total Floor Area (million m²)	6.9	5.8	5.8	5.7	7.0	31.0
% floor	22%	19%	19%	18%	22%	**100%**
Average floor area (m²)	300	967	2200	5270	17,530	**940**

The data can also be analysed to provide estimates of the number of storeys per building and hence explore the relative importance of low rise versus high rise buildings. Table 3 provides a breakdown of the web search sample by number of storeys per building for BEES eligible with floor area data. It shows 50% of this representative sample is single storey, although this group is only 32% of the floor area. Approximately 10% are 6 storeys or more although percentage of the floor area is double that at 20% of the sample.

Table 3: Web-search Analysis by Number of Storeys per Building

Number of Storeys	No of Buildings	% of Buildings	Total Floor Area	% of Floor Area
1	1071	50.5%	2955	32.4%
2	578	27.2%	1944	21.3%
3	115	5.4%	577	6.3%
4	95	4.5%	644	7.1%
5	44	2.1%	267	2.9%
6	37	1.7%	284	3.1%
7	34	1.6%	245	2.7%
8	21	1.0%	195	2.1%
9	20	0.9%	156	1.7%
10+	107	5.0%	1841	20.2%
Total	**2122**	**100%**	**9108**	**100%**

Both Table 2 and Table 3 show the skewed nature of this building stock, with the majority of the buildings being small single storey buildings and very few large multi-storey buildings, with the average floor area across this building stock is only 940m^2.

While the web search provides data on the current use of most of the buildings, comparison of the original building use (as reported in the valuation) and the current use proves to be interesting. For example a building coded as “Industrial Warehouse” in the original valuation record, may have moved to “Retail” use. Table 4 shows that by count 11% of the industrial service categorised building records and 5% of the industrial warehouse building records have changed their use and now used predominantly for either retail or office activities. Future analysis will be completed to determine and code the current use of the buildings in the IS and IW buildings.

Table 4: Building Record count by size and use category –

Use Group	Building Record (Count) Floor Area Size					Total	%
Minimum Floor Area	5m²	650m²	1,500m²	3,500m²	9,000m²		
Maximum Floor Area	649m²	1,499m²	3,499m²	8,999m²	111,000m²		
Office Total	3709	997	547	314	131	5698	17%
Retail Total	12,806	2365	716	224	113	16,224	49%
Mixed Total	3446	1318	646	338	98	5846	18%
IS Total	2444	839	328	84	14	3709	11%
IW Total	510	444	379	113	42	1488	5%
Grand Total	22,915	5963	2616	1073	398	32,965	100%
%	70%	18%	8%	3%	1%	100%	

Operational characteristics can be added to the physical information in the web search and valuation data through the use of phone survey data, which is currently available for of 791 premises. For example, the phone survey asked about the use of mechanical ventilation, air-conditioning and passive options (Saville-Smith & Fraser, 2012). Results from the premise

survey showed a strong, and possibly not surprising trend, that the larger the building the more likely it will be air-conditioned, as shown in Table 5. Based on the total building stock and using these percentages Table 5 also provides a national estimate of the number of air-conditioned buildings by floor area strata.

Table 5: Estimate on number of air-conditioned buildings in New Zealand based on premise survey.

Premise survey (n=791)	**Building Size (total floor area m^2)**				
Minimum Floor Area	5m²	650m²	1,500m²	3,500m²	9,000m²
Maximum Floor Area	649m²	1,499m²	3,499m²	8,999m²	111,000m²
Percentage air-conditioned (% of premises)	34.4%	48%	55%	70.7%	76.6%
Estimated number of buildings air-conditioned	7883	2862	1439	758	305
Estimated total number of buildings in this building size	22,915	5963	2617	1072	398

The ability to open windows shows the opposite pattern and can be assumed to represent the passively ventilated non-residential building stock. Only about one-fifth (21.6 percent) of premises in very large buildings have windows that open, compared to 72.1 percent of premises in buildings less than 650m^2.

Overall, approximately 40% of the BEES building stock is estimated to have air-conditioning. This was reported from the premise surveys, so it is possible that some of these buildings use a split system single unit heat pump for individual room or premise air-conditioning and heating (using similar plant as would be found in a residential house), rather than a central HVAC (heating ventilating and air conditioning) system. The detailed monitoring found this to be the case, where in the first 77 buildings monitored from Strata 1-4, the most common type of heating/cooling system was by heat pumps (Camilleri & Babylon, 2011).

Future analysis of the building envelope data will provide new understanding of passive design opportunities, but the premise survey has already revealed that double glazing has a low penetration rate with similar proportions of premises (about 12% irrespective of floor area) reporting the presence of double glazing.

Collectively, the BEES analysis is developing a picture of New Zealand's non-residential building stock. It shows the diversity of the physical nature and activities within the buildings. The most dominant collective group is small retail shops (less than 650m^2) with an estimated 12,806 buildings, or approximately 39% of the total stock. The next largest group is small office buildings (under 650 m^2) at 11%. These results are suggesting that there will need to be tailored energy efficiency strategies to meet the different building types and uses. Perhaps most importantly it is suggesting that while the largest opportunities by building count may be in the very large buildings, there is a sizeable amount of floor area in the small buildings, albeit in a very much larger number of these buildings.

3.2 Who Managers the Buildings?

The energy and water efficiency of any building not only depends on the physical nature (building envelope and services) and the activities carried out within, but also on how the building is operated and managed. The management/owner/tenant relationships have an impact on the energy efficiency opportunities, so understanding these relationships are an important aspect to the characteristics of this non-residential building stock.

The analysis of phone survey premise data highlights smaller buildings are managed and used differently from larger buildings. This is shown in Figure 3. The recipients were asked who managed the building they occupied. For buildings less than 650m2, less than 20% response reported a building manager but most concerning was that approximately 40% said there was no one managing the building. At the other end of the scale for those premises in buildings over 9000m2 approximately 50% had appointed building managers.

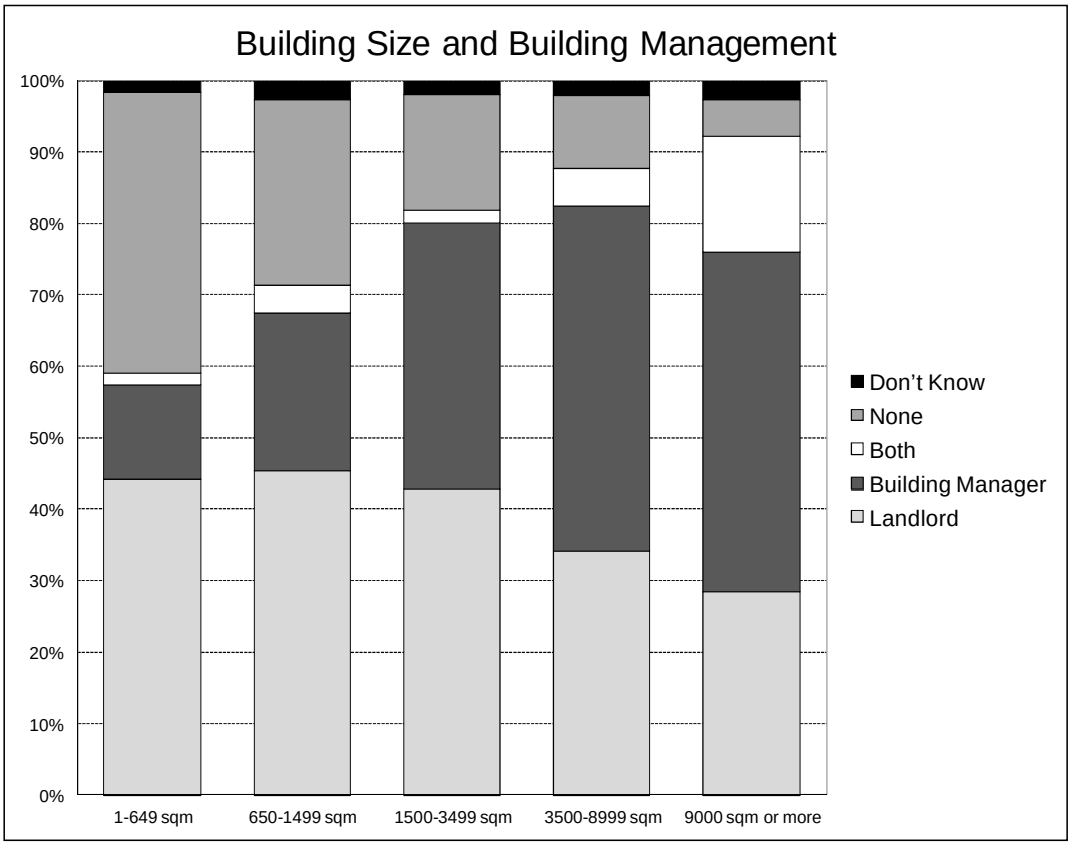

Figure 3: Reported building management in BEES surveyed premises.

Analysis revealed that building size when cross referenced with building ownership, use and occupancy generated different market segments.

The combined building characteristics presented above gives an indication of huge variation in this building stock, in not only the physical nature, but also resource uses and management. Therefore it is important not to develop broad brush initiatives to improve either energy or water efficiency that attempt to cover the all non-residential buildings.

Instead targeted initiatives that are carefully matched to segments defined by particular combinations of owner, occupant and building type are likely to be more successful.

3.3 Understanding End-uses

Detailed monitoring of premises provides an in-depth understanding of energy end-use which can be related to the services provided by energy use and the activities within the building. The BEES project has monitored premises in over 126 buildings to provide time of use energy and environmental data. Where possible, metered revenue data for at least a 12 month period was also obtained. Analysis of the meter data to date has shown that these randomly-selected buildings within the BEES sample have a much wider distribution of energy use intensity (energy use per square metre, EUI), with some much lower and some much higher, than previously measured. What is interesting to note is the very low and very high EUI are all from buildings occupied by retail business (Bishop and Isaacs, 2012).

Through interrogating the monitored data it is possible to understand what is driving the energy use within a premise. An example is shown below of a premise with a very high EUI.

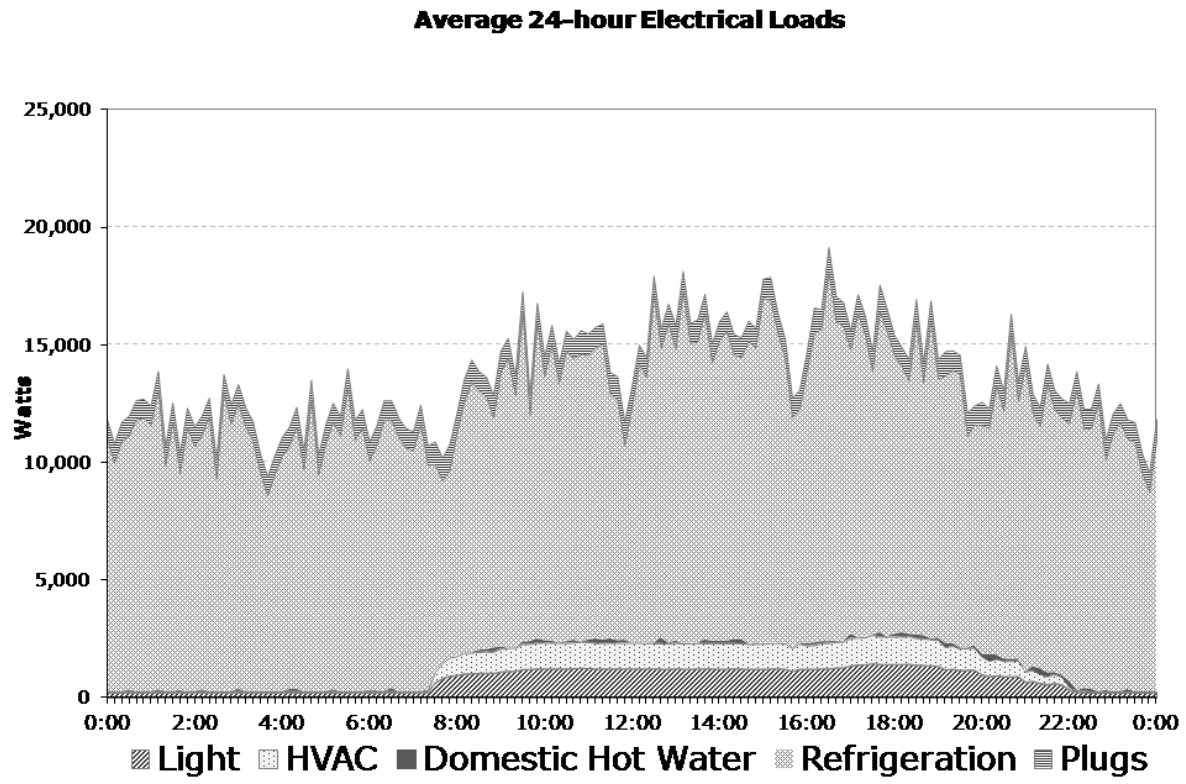

Figure 4: 24hr electrical profile from detailed monitoring – Liquor store

Figure 4 shows the average weekday electrical load for a small (298m^2) retail liquor store. The EUI for this premise was high at 401 kWh/m^2 which is outside the historical typical range of 100 - 300 kWh/m^2. From the detailed monitoring it was possible to determine the reason for the high load was the refrigeration, which not only is very high but also not cycling and running on full 24hours a day. Both the lighting and HVAC indicate hours of use from just before 8:00 in the morning to 8:00 at night. Observation from the revenue data shows the

energy use is not temperature dependant which implies the refrigeration systems are unlikely to be operating efficiently.

Analysis and observations of a further five premises with anomalously high EUIs, of which all were retail buildings, found high EUI were invariably associated with food handling (cooking and/or refrigeration), so it was their high process loads which caused the high energy use. Several of them had refrigeration systems that were operating for long hours with poor control and poorly insulated storage areas.

It is only through the end-use monitoring that nuances of energy use within non-residential buildings can be fully understood, especially given the heterogeneous nature of this stock. The detailed monitoring also provides base data to improve building energy modelling inputs and scenarios explicit to New Zealand.

4. Insights and Learnings to date

This paper provides an overview of the BEES research and an insight into the analysis to date. An understanding of the size of the non-residential building stock in terms of size, construction and form has been developed along with a breakdown of retail and office activities. Further analysis into mixed use buildings, which is those that have both retail and office or other uses, and changes over time, will be completed as part of the project.

An understanding of the variation in EUI's much greater than previously recognised has been observed through monitoring and revenue data with a six-fold increase from the very low EUI's to the high EUI's. These outliers all have retail activities whilst office buildings have a smaller range, typically within the expected 100 – 300 kWh/m2. Already the monitored data has improved our knowledge of the energy end-uses, and in particular identified refrigeration in food processing and retail outlets as offering opportunities for significant cost (and energy) savings. The research will continue to investigate and explain large variations and the key energy uses for the different types of buildings.

The importance of the management and ownership structure of New Zealand's non-residential buildings has been identified in relation to building size and the survey data suggests opportunities for improved energy efficiency need to be shaped accordingly. Large buildings are more likely to be managed by professional property, building or facility managers; and small buildings are either unmanaged or managed by owner-occupiers, tenants or landlords with little awareness or interest in resource efficiency.

Analysis of the finalised data sets, along with building energy modelling will enable benchmarks and indices developed for energy tools and policy development, leading to more efficient non-residential buildings in New Zealand.

5. Acknowledgements

The authors would like to thank the BEES research team members for their contribution to the research. BEES is a joint project involving BRANZ Ltd; the Centre for Research, Evaluation and Social Assessment (CRESA); Energy Solutions Ltd; Centre for Building Performance Research (CBPR) at Victoria University of Wellington; and John Jowett, consulting technician.

Thanks to the funders and supporters of the research. BEES is funded by BRANZ Ltd. through the Building Research Levy and the Ministry of Business, Innovation and Employment through its Building and Housing group and its Science and Innovation group, and the Energy Efficiency and Conservation Authority (EECA).

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A METHOD TO ENSURE AIRTIGHTNESS OF THE BUILDING ENVELOPE

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ABSTRACT

Several research projects have shown the importance of airtightness of buildings in order to ensure efficient energy use, good indoor environments, protection against moisture and general durability. The building industry in Sweden has shown interest in becoming a general method to support different actors to reach airtight building envelopes.

The purpose of this project has been to identify and develop a method to follow in order to design and construct airtight building envelopes. The method can be used by the building developer, designer and/or construction company and is a means of applying knowledge and experience from research and development projects to practical use.

Based on experience from several building projects and earlier research in the area of airtightness, this project presents a general method for the design and construction of airtight buildings, covering all aspects from initial formulation of requirements, through general and detailed design, to production and monitoring. The method is based on quality assurance through constant documentation, communication, inspection and verification, with the help of routines and associated checklists.

Experience from building projects where good airtightness has been achieved shows the importance of information and education. Appropriate and suitable information must be provided to a number of parties, such as designers, carpenters, electrical contractors and HVAC contractors. Another important factor is ensuring that requirements in respect of airtightness are clearly expressed and followed-up. Early measurement during the construction stage is one example of positive action to ensure good airtightness.

The routines, checklists, training materials, and tips for further reading or investigation that have been developed by the project are available on a website in order to make the material as available as possible to actors in the Swedish building sector.

Keywords: Airtightness, building envelope, method, requirements, monitoring, quality management.

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INTRODUCTION

There is a need for a method that can be implemented in the building process to achieve airtight buildings. There are experiences from the building process where airtight building envelopes have been reached, and there are also knowledge from research projects that can be communicated to the building industry to assist in the process to ensure airtight building envelopes. Example of airtight buildings where experiences has been collected are the buildings in Lindås, see Figure 1.

1. OBJECTIVE

The objective of the work of the project is to develop a general method for the construction of airtight buildings, covering formulation/expression of requirements, planning, design and construction. The method is based on quality management/assurance through ongoing documentation, communication, inspection and verification, using quality management procedures and associated checklists. The checklists provide a means of disseminating the results obtained and knowledge acquired for practical application.

The intention is that the method should assist those involved in the building sector, and particularly contractors, to ensure that a building meets the function requirements that have been specified. Properly drawn-up function requirements and quality management of the construction process provide favourable conditions for producing an airtight building.

2. IMPLEMENTATION

The work has been carried out in two stages. Stage 1 developed the quality assurance method, while Stage 2 tested it in a pilot project, with the results being thereafter evaluated. The associated training materials have also been tested in connection with starting a building project. Improvements have been made, based on experience from the pilot projects.

3. METHOD FOR PRODUCING AIRTIGHT BUILDINGS

3.1 Airtightness during early planning stage



Figure 1. Clear formulation of requirements provides the basis for successfully achieving an airtight building. The Lindås houses are an example of such a project, in which requirements were formulated and monitored.

The following procedures are intended to assist developers in their own work of deciding on requirements and monitoring their application in order to arrive at good airtightness:

The developer's procedure/checklist (can also be used by the developer's representative):

a) Decide on the required ambition level for the developer's own work.

b) For conversion/rebuilding projects, perform a survey/inventory.

c) Formulate requirements for an airtight building. This must include both technical requirements and those governing work/activities. See chapter 4.

d) Check/review procurement procedures and contract details in order to be sure that requirements are being correctly understood.

e) Appoint a person to be responsible for monitoring application of requirements and deciding the forms of monitoring.

f) If necessary: arrange information/training for those involved prior to starting work.

3.2 Airtightness during design stage



Figure 2. Penetrations through the sealing membrane can be avoided if the membrane is applied in such a way as to leave a gap for installation of the building's services systems.

The following is a procedure description/checklist to assist the designer's work of achieving airtight buildings, bearing in mind that it is not only this work that is important, but also communication of the necessary information to developers and contractors.

The designer's procedure/checklist for the design stage:

a) Appoint a person to be responsible for matters relating to airtightness during the design stage, with his/her work including this procedure/checklist.

b) Go through the requirements and intentions with the developer, ensuring that all are properly understood and accepted.

c) Provide necessary information/training.

d) Perform the design work and prepare documentation in accordance with checklists.

e) Perform internal checking of design documents in respect of airtightness.

f) Identify, plan and document critical production stages in conjunction with contractors. See Figure 2 as an example where the penetrations could have been planned for in a better wa.

g) Handing over to contractors: prepare a plan for airtightness during the production stage in conjunction with contractors.

h) Collect and put together all necessary documentation.

The following is a description of the procedure for the developer's monitoring of the work during the design stage. The developer's involvement is important and helps to maintain quality.

The developer's procedure for monitoring during the design stage:

a) Contact with the person responsible for airtightness aspects, and checking his/her internal communication of requirements, dissemination of information and provision of training.

b) Checking of documentation of materials to be used for air sealing purposes and of proposed designs.

c) Obtain confirmation that the contractor has carefully gone through the design documents.

d) Obtain confirmation, in conjunction with the contractor, that the contractor has identified critical tasks, and that an inspection plan for production/construction has been prepared.

3.3 Airtightness during production stage



Figure 3. An airtightness test (Blower-Door), looking for air leaks, provides indication of whether the requirements have been fulfilled.

The following is a description of the contractor's procedures/checklists for the work of delivering an airtight building, for which the contractor's quality of workmanship is important, as is communication with the designers and the developer.

The contractor's procedure/checklist for the production/construction stage:

a) Appoint a person to be responsible for airtightness-related work aspects at the site.

b) Go through the airtightness requirements.

c) Go through the design documents together with the designers, to discuss critical stages / details of production.

d) If changes are made, show that airtightness requirements will be met after the changes.

e) Draw up an inspection plan in conjunction with the designers.

f) Arrange internal information/training that also includes sub-contractors.

g) Work planning (before each new stage).

h) Preliminary airtightness testing and leak tracing. In Figure 3 a blower-door equipment is shown. Leak tracing can often be carried througt by a thermography in cold climates. Alternatives that are decribed and used in Sweden are measuring air velocity or using smoke to detect air leakages.

i) Final airtightness testing.

j) Feed back information/experience to the designers.

The developer's procedure for monitoring during the construction stage:

a) Contact with the person responsible for matters relating to airtightness and ensuring that he/she is providing all necessary internal communication of requirements, information and training.

b) Ensure that documentation from internal inspections is being prepared in accordance with the overall inspection plans.

c) Check documentation from early airtightness tests/leak tracing and from any resulting improvements/corrections.

d) Obtain confirmation/documentation from final airtightness testing that all requirements have been fulfilled. (This may possibly be done before expiry of the warranty period.)

3.4 Airtightness during operation stage

During the life of the building, the airtight layer is often inaccessible for inspection and maintenance, yet there are joints and structural components that may need maintenance or attention. If the building is extended or converted, or if new penetrations are needed, it will be necessary to ensure that the work is carefully performed, and based on careful design, in order not to destroy the airtightness of the building through unsuitable designs.

Procedure for maintenance of airtightness:

a) Check airtightness around penetrations (e.g. ducts into the roof space).

b) Check airtightness around window casements and frames and doors.

c) Note and investigate complaints concerning draughts or cold floors. These are often due to a non-airtight building envelope, and can generally be put right.

4. EXAMPLES FROM THE METHOD – REQUIREMENTS

The following are a number of suggestions as to how the developer might formulate requirements, who is responsible for fulfilling the requirements, and how the parties concerned should confirm that the requirements have been fulfilled. The developer can choose those suggestions that best match his ambition levels. Alternatively, the suggestions can be seen as starting points for formulation of other requirements. Just how the requirements for a project should be formulated depends on many factors, such as the choice of contract form.

The planning and design stage

Requirement no. 1: Appoint a person within the design organisation to be responsible for matters relating to airtightness.

Requirement no. 2: The aim of the design, in respect of airtightness, is to deliver the necessary conditions (supported by good quality of workmanship during construction) for ensuring that the building meets the airtightness requirement at a pressure difference of ±50 Pa. (Select one of the alternatives below.)

Alternative 1: Maximum air leakage as specified in the energy balance calculations for the building *.

Alternative 2: Air leakage through the building envelope not to exceed xx l/m²s *

* Requirement 10 specifies how airtightness is to be tested, and must be stated together with the requirement governing maximum permissible air leakage. It can be important in some cases also to include a requirement that specifies the required airtightness between different parts of the building (e.g. between fire cells or apartments). See also Requirement 10.

Airtightness requirements for windows and doors can be specified separately. They might be required to meet, for example, Class 4 airtightness requirement in accordance with EN 14351-1. Class 4 permits a maximum air leakage of 3 m³/hm²

at 100 Pa pressure difference. (This information is given by the window/door supplier.)

Requirement no. 3: The aim of design is also to ensure the necessary conditions for continued airtightness during the life of the building, through appropriate choices of design details, materials and combinations of materials. It must be known or demonstrated, and documented, that materials such as tapes, mastics etc. are durable when applied to the materials to which they are intended to be applied. It is also important that their adhesion is good under the conditions to which they will be exposed (e.g. temperature).

Requirement no. 4: Designs for airtight buildings must clearly include, show and describe detailing (in the form of drawings and descriptions), such as:

- How penetrations, leaks and holes in the airtight material can be avoided.
- How penetrations through the sealing layer should be made, where they cannot be avoided.
- In lightweight structures: how joints in the sealing layer are to be made.
- Connections around windows, doors and access hatches to roof spaces.
- Connections between joists etc. to the building envelope.
- Connections between outer walls / roof structure.
- Connections between tie beams / sloping roofs / braced walls.
- Connections between lightweight structures and concrete structures.
- Connections between steel structures, pillars, glulam beams etc.
- Connections of prefabricated elements.
- Structures in contact with the ground.
- Particular jobs and feasibility / method of construction to be agreed with the contractor.

The construction stage

Requirement no. 5: The contractor must appoint a person responsible for the building's airtightness. He/she will manage the work needed to ensure compliance

with the requirements, be responsible for the contractor's testing, and prepare and submit documented verification to the developer.

Requirement no. 6: Startup / **work planning** must be performed where specific tasks for airtight buildings are being planned in conjunction with the designers. An **own inspection plan (airtightness testing)** of technical features and workmanship must be prepared.

Requirement no. 7: Training of personnel at the site (construction, electrical, ventilation, HVAC personnel etc.) to be carried out in connection with start of work.

Requirement no. 8: Results from own inspections of technical solutions and jobs to be documented. The documentation must also describe how problems, defects, etc. have been dealt with. In the case of general defects, all persons concerned on the site must be informed.

Requirement no. 9: Performance measurements and leak tracing must be carried out at an early stage, as soon as the airtight layer or membrane has been applied and fixed, and when no further holes will be made in it. The need for repairs or improvements must be decided. The results are intended to document that no local leaks can cause future problems as a result of the positions and size of leaks. (Depending on just where leaks are, they can cause problems such as draughts, inward leakage of ground radon or local moisture problems in roof spaces.) For large buildings, parts of the building can be completed and airtight-tested at an early stage. Airtightness must be better than the requirement as set out below. Measurements must be made in several areas, as specified by the developer.

Requirement no. 10: Verification measurements must be made when the building envelop has been completed, and must fulfil the airtightness requirement at ±50 Pa pressure difference.

Alternative 1: Maximum air leakage as specified in the energy balance calculations for the building .

Alternative 2: Air leakage through the building envelope not to exceed xx l/m²s

Verification in small and large buildings: Test airtightness in accordance with EN 13829:2000, and report the results at least x days before the date of final inspection of the building.

Requirement no. 11: Repeat the confirmatory airtightness measurement as specified in Requirement 10 when the building's guarantee period expires, in order to confirm that the airtightness performance has not declined. The developer may also wish to consider including a requirement or conditions for monitoring the performance after a certain number of years.

Requirement no. 12: In the event of any changed methods, the contractor must show that airtightness requirements are being fulfilled, and that no other requirements have been overlooked.

CONCLUSIONS

If function and performance requirements have been properly formulated, and the physical production process is quality-assured, conditions are favourable for achieving an airtight building. The routines and checklists provide a means of applying the knowledge and experience from research and development projects to practical use.

ACKNOWLEDGEMENTS

The project has been financed by SBUF and FoU-Väst.

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Integrating Building Information Modelling and Augmented Reality for Construction Projects in Oil and Gas Industry

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Abstract

Construction site is the place where the process of building or assembling infrastructure happens. As one of the most complicated type of projects, large scale construction projects involve large human multitasking activities across different geographical locations and a wide range of disciplines as well as high frequency exchange of information. The most commonly recognized way of executing a project includes preparing the construction drawings, planning out the contract, allocating the workload, scheduling, and administering the progress. This paper introduces many innovative techniques including Augmented Reality (AR), barcode reading and indoor way-finding technologies, and integrates them as alternative means of executing certain activities of construction project. Using a Liquefied Natural Gas (LNG) scenario, this paper presents: (i) a study of how AR can be effectively used to improve the way the information is accessed; (ii) sensing and tracking technology such as barcoding as a technological feasibility of locating a specific component of complex LNG plants based on computer-based information; and (iii) indoor way-finding technology integrated with AR, with which the construction worker can easily find out where the exact component is located in a warehouse or actual construction site.

Keywords: Augmented reality, barcode reading, indoor way-finding, liquefied natural gas

1. Introduction

In construction, 3D modelling is often seen as an unnecessary complication by practitioners (Arayici et al., 2011). Very often it suffices to develop a 2D design for single details or specific building locations, and the same principle is applied on many locations inside the building. At the same time, a more unrefined model is needed from the total building perspective. However, when the focus is on a detailed workpiece, then more detailed

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information context concerning the ambient components will be shown. Defined as the combination of real and virtual scenes, AR is able to combine the 3D object into the normal viewing perspective without losing any of the advantages of object movement and individual movement in real-world environments (Toro et al., 2007, Doil et al., 2003). Therefore, AR can be used to facilitate the monitoring and control of a construction project's progress, and to visualize a facility in the context of the real workspace to enable the 'as built' progress against 'as planned'.

Construction process requires a high level of automation and integration of information and physical resources (Čuš Babič, 2010). Yet, the effective locating of information developed in data repository during the actual construction process challenges the designers, planners, workers, and managers throughout the entire construction lifecycle. Typically, they interact with a project through various information mediums and models mainly based on 2D planer isometric drawings or elevations (Gao et al., 2006). Integrating the barcode reading technology with navigating software packages such as navisworks can ease the information location process and support various work tasks, i.e., error checking, component finding, property browsing and so on (Turner et al., 2003; Gressel and Ehrlich, 2002). This facilitates site work, requiring individuals to both, to manage information and transform physical resources to a constructed facility.

In order to allow accurate indoor overlays and enable you to create indoor assistance of way-finding, information or games, we prototyped an indoor way-finding system which applies the Latitude Longitude Altitude - Markers (LLA Markers) (Jörg, 2002). On mobile devices such as iPhone and Android, the LLA way-finding works seamlessly. If a valid marker is found, the location of the smartphone will be adjusted according to the encoded latitude and longitude coordinates of the marker while the GPS sensors of the smartphone are ignored. This fixed location will be shown by an AR arrow, which points to the correct and cost-effective path to the components that are needed.

2. Assisting technologies for on-site construction work

2.1 Augmented reality walk-through

Traditionally, design is realized through the production of 2D shop drawings from a 3D object model. The traditional method of having an index sheet and a mass of drawings in the site offices that are 'thumbed through' to look at a specific detail is a time-consuming and tedious process. This AR Walk-through functionality can facilitate design and constructability review process (Vainio, 2002). Specifically, this AR functionality can provide a full 3D interactive solid model of the design, giving the workers a visual understanding of specific details (Abowd, 1997).

As depicted in Figure 1, the camera can recognize a set of tracking markers and bring up the 3D models accordingly. If in the office, the table-top AR can overlay the 3D model right on the area where it is located in the paper drawing plan (see Figure 1). The results look like all the 2D plans are extruded to have 3D effects. Users can split the 3D model in cubes, for example, to have a closer look at each floor level, to examine each specialty trade, or to

examine each selected cross section. If onsite, by picking up the marker and hold it vertically, users can even walk into and through the module named 14108, which is an actual LNG plant provided by Woodside Energy Ltd. and feel what it is like on real construction site (see Figure 2). Users can rotate, zoom, and show problems such as missed insulation and valves.

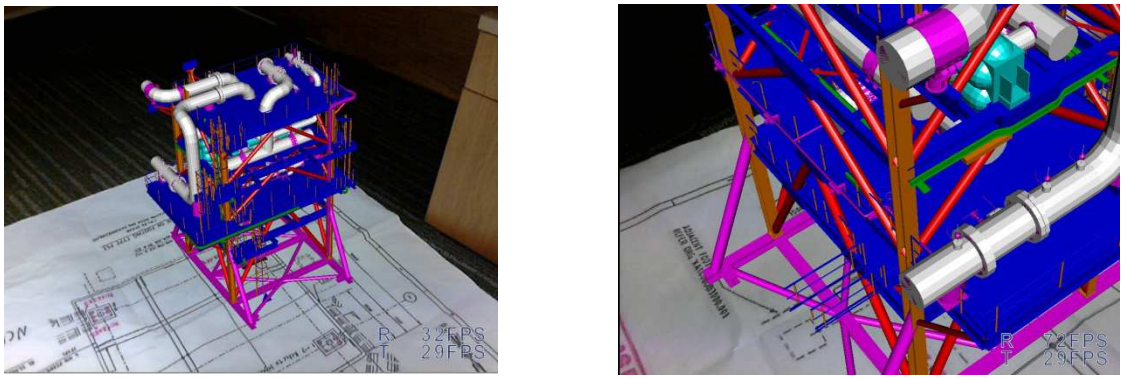


Figure 1. Table-top Augmented Reality for design and constructability reviews

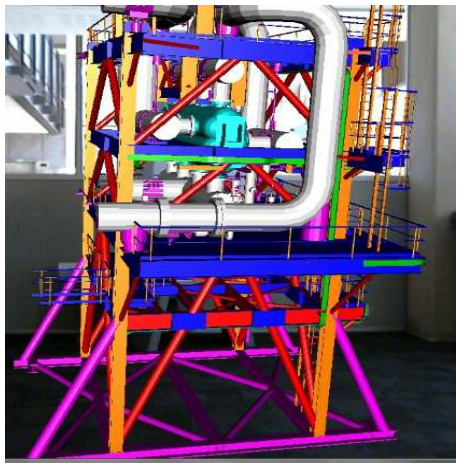


Figure 2. Augmented Reality visualization of 4D CAD models in the context of real environment

In this study, AR has been identified as a solution. This is where AR technology comes into the picture since from a cognitive psychology standpoint, it has the potential to merge the informational activity to the direct work activity to make information access more efficient and therefore completely change the way we think about and use instructions. As an emerging technology, AR can integrate the information context such as the assembly path and fixation forms of parts/components into the real workspace.

A summary of the AR for assembly is as follows:

1. We are now on the fabrication and assembly site
2. The pipe needs to be installed, but workers do not know what, where and how
3. Workers are trying to look for information in stacks of drawing, which takes time and there involved many simple mistakes.
4. Using AR-based animation, we can simulate the installation sequence visually in the real scale and right in the real context as well.

Construction workers can then see the location, angle, orientation, dimension, shape, geometry, materials, texture, assembly sequence, assembly path, assembly safety instructions and therefore streamline the assembly– knowing what to do.

Models are real-time loaded during the assembly task, so the workers are able to control the animation process by left-clicking (loading model and playing animation) or right-clicking the mouse (unloading model and reversing animation).

2.2 4D-based model locating triggered by Barcode

As shown in the Figure 2, the 3D model of an LNG plant is massive in file size and it has to be more user-friendly if the AR and Virtual Reality (VR) technologies are to be adopted and widely used in LNG. A tracking and automatic positioning prototype is developed, including the barcode of each component of the construction. Therefore, all of the specific components could be searched and located by their unique ID.

With an independent or integrated barcode reader in 4D CAD, the user can scan the barcode on a piece of pipe and the model of the pipe will be highlighted (see Figure 3 and 4). Alternatively, we type in any tag number or barcode of the associate component. Users can then view and modify the properties of the pipe in 4D CAD. Relevant manuals, specifications and certificates associated with this pipe could also be viewed.

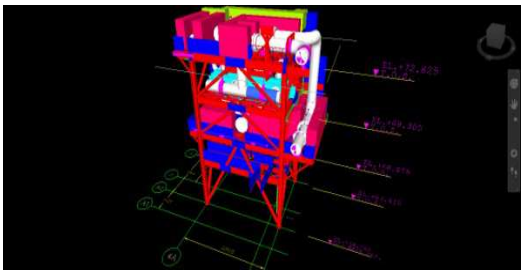


Figure 3. Highlighted item in 4D CAD

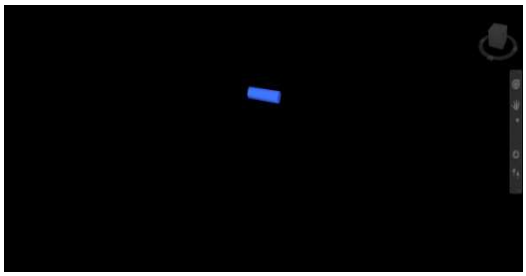


Figure 4. Component locating in 4D CAD

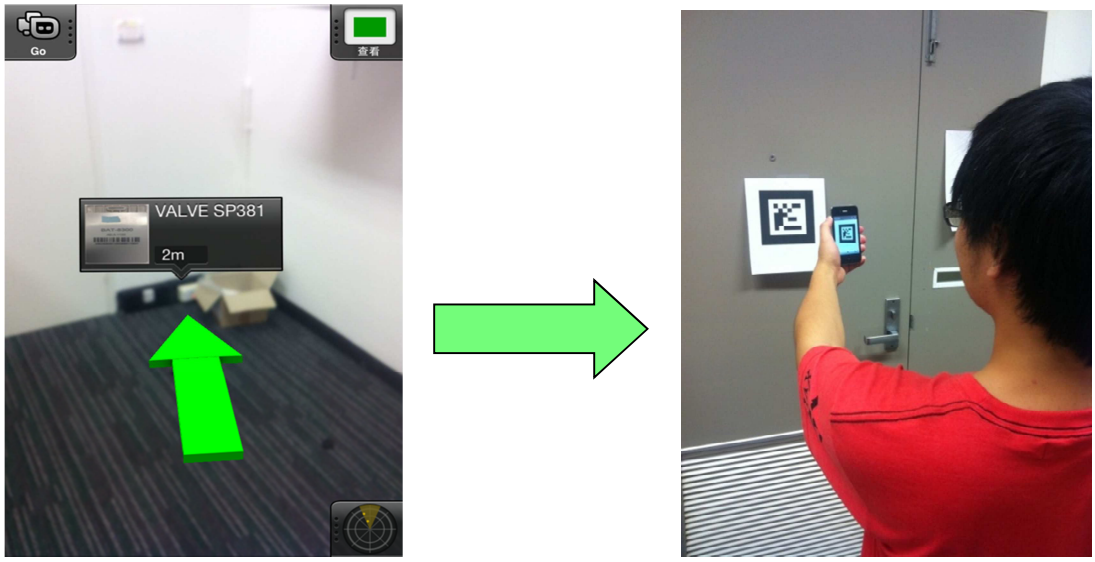
2.3 AR-based Way-finding

A geographic coordinate system enables every location on Earth to be specified by a set of numbers. A common method of coordinates is latitude, longitude and altitude (LLA). Latitude and longitude are the two numbers representing horizontal position and altitude represents the vertical position. The latitude (abbreviation: Lat., φ, or phi) of a point on the surface of Earth is the angle between the equatorial plane and a line that passes through that point. It

is normal to the surface of a reference ellipsoid which approximates the shape of the Earth. Latitude is used together with longitude to specify the precise location of features on the surface of the Earth. Latitude and longitude together with some specification of height constitute a geographic coordinate system as defined in the specification of the ISO 19111:2007 standard. The difficulty is the amount of time needed to get accurate latitude and longitude positions of a particular location. The easiest way is using Google Maps to overlay indoor blue print and retrieving locations from there. The implemented application scenario can be described through the following example:

1. A box containing a valve with an Radio Frequency Identification (RFID) tag on has arrived at warehouse, however, the material coordinator does not know where it is because the warehouse has thousands of similar-looking boxes
2. The material coordinator is now looking for the valve on the 1st floor in the warehouse
3. He inputs a valve number into the iPad interface
4. He then scans the reference marker at the entrance of the warehouse (see Figure 5a)
5. There is a green arrow (see Figure 5b) showing on the iPad screen with valve ID and the estimate distance from where the entrance is to the arriving box
6. He follows the arrow indicator and walk towards the box

As the valve has an attached RFID, the RFID readers in the warehouse can pick up its accurate location in a real time manner and within a short period of intervals of updating. As the location of the box is changed, the directional indicator from where he is standing to the new destination of the box will be updated as well. Because the RFID readers can write back into tag its current location, way finding becomes much easier than before.



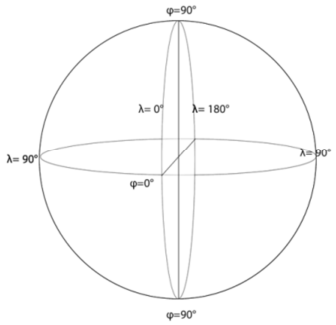
(a) (b)

Figure 5. Augmented Reality-based way-finding: (a) scan a quick reference marker to know where he is; (b) a virtual arrow indicator shows where and how far to go

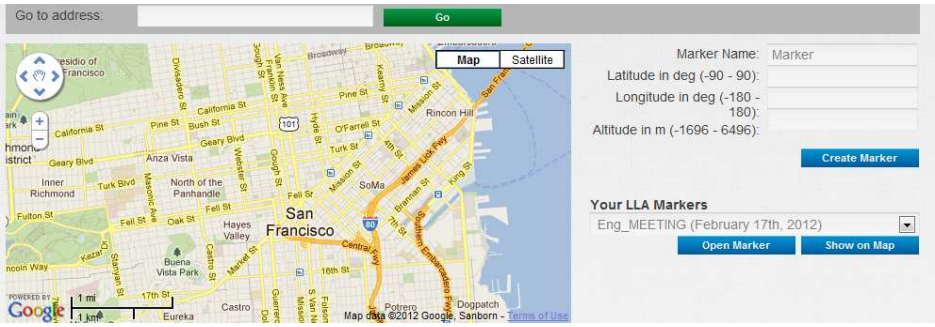
On iPhone and Android devices, the LLA Marker detection works seamlessly. If a valid marker is found, the location of the smartphone will be adjusted according to the encoded latitude and longitude coordinates of the marker while the GPS sensors of the smartphone are ignored. This fixed location will stay until a different marker is found or the developer returns a different trackingXML on an event. Accuracy with LLA Markers is approx. 20cm (40cm in Altitude).

The difficulty is the amount of time needed to get accurate latitude and longitude positions of a particular location. The easiest way is using Google Maps to overlay indoor blue print and retrieving locations from there.

Users can use the interface as shown in Figure 6b to either click on the map or type in latitude/longitude/altitude to create an LLA Marker. You are able to resize the marker according to your needs. In general a size of about 2-4 inches (5cm - 10cm) is good for most use cases. It should be noted that the Altitude value is currently not being considered.



(a)



(b)

Figure 6. (a) Geographic coordinate system of longitude and latitude; (b) Interface of longitude, latitude, and altitude converter

3. Conclusions and future work

This paper presents three innovative technologies in facilitating the execution of construction project. The combination of these is based on the processing of digital information context, which provides a more intelligent alternative against the conventional means of handling a construction project. Contractors still tend to stay within their comfort zone, where they unreflectively adopt tried and tested technologies rather than evaluating and adopting new technological solutions such as AR.

Our future work aims to address a serious issue regarding the development and uptake of AR tools relating to the social phenomenon associated with this, as technologies are inseparable from the cultural and social settings. Therefore, the development process of designing AR tools should be cognizant of this relationship by working with (and through) designers' cognitive and behavioral drivers and constraints by explicitly 'building-in' and embracing the knowledge creation, application, storage and retrieval cycles. Contractors should therefore be actively encouraged to embrace the AR technologies' 'intentions' and 'capabilities', or they could find themselves entrenched in their 'comfort zone' of familiarity.

Another issue is the lack of standardization of information and communication technology (ICT) tools. The issue is that workers use different ICT tools and maybe different datasets. There needs a unified approach, just like onsite BIM has becoming a standard approach of the upstream data integration before construction starts, which is envisaged to be our next endeavor.

Acknowledgement

The research work presented in this paper was initiated by Mr. Martijn Truijens, the Lean Construction Technology Advisor, Woodside Energy Limited (WEL). Acknowledgement also goes to Woodside Energy Limited, which initialized and co-funded the research work presented in this paper and the contributed time of their staff members and experts to the research and developmental work that has been described and presented in this paper.

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A Synthesis of Fast-Track Highway Construction Delivery in the U.S.

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Abstract

Fast-tracked construction projects are nothing new. The use, however, of some types of fast-track contracts in certain sectors of the construction industry is new. One example of this is the use of Construction-Manager-at-Risk (CMR) within the highway construction industry in the U.S. Even newer is the similar concept of Construction-Manager-as-General-Contractor (CMGC). The traditional system of design-bid-build (DBB) has been employed by all Departments of Transportation (DOTs) in the U.S. for almost a century. The shift toward design-build (DB) as a time-saving method has been successful in many ways, but use of the system during the past decade has revealed some disadvantages. CMR is a delivery system often employed in vertical construction, and transportation agencies have recently begun to use it for horizontal construction. The fact, though, that fewer than 15 states have used CMR or CMGC to date points to challenges in its use. The biggest challenges are in the areas of construction, design and statutory standing and this paper discusses all three. CMGC cannot legally be used for public transportation construction projects in most U.S. states, but once an agency has decided to pursue the implementation of CMGC, there are certain broad concepts that must be understood. In many cases, this requires a significant and aggressive change in the culture and philosophies of the constructors and designers from traditional DBB design projects. For instance, the standard design methods, schedules, and plan review stages that are frequently used in designing DBB projects, may prove to be inadequate to realize the advantages of CMGC. Designers are required to take a much more active role in working with the owner and constructor during the entire design process, for such things as early and continuous value engineering, right-of-way phasing, real-time pricing, increased coordination meetings, accelerated designs, etc., during the early stages as well as throughout the entire design process. Designers may therefore need to be educated in the process of receiving real-time input

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from the constructor, as well as being flexible in modifying standard items such as traffic control plans, to best fit the chosen approach to construction.

Keywords: Fast-track, Project Delivery, Design-Build (DB), Construction-Manager-General-Contractor (CMGC), Accelerated Construction.

1. Introduction

Highway construction projects in the past were procured by way of qualifications-based submissions design and competitive low-bidding construction. This procurement method, commonly known as Design-Bid-Build (DBB), involves the division of the design and construction processes: designers selected on their credentials, construction contractors chosen by lowest bid. With this divided structure and implementation of separate contracts, DBB provides a checks and balances system for both parties involved. Unfortunately, this division limits innovations, results in increased cost and time growth, and promotes hostility between owner, design and construction personnel.

Growing concern with deteriorating infrastructure and population growth have underscored the necessity of highway agencies to expedite key projects from planning, through design, and on to construction in a shorter period of time without the requisite increase in available funding. In an effort to encourage improved quality and efficiency, and as a means to accelerate project delivery, some states have legislated alternative project delivery systems including Design-Build (DB) and Construction-Manager-as-General Contractor (CMGC). DB presents a single point of responsibility and both DB and CMGC underscore innovation, teamwork, and early involvement by the constructor during both design and planning phases.

The successful execution of a DB or CMGC program entails a considerable and aggressive change from the traditional philosophies and cultures associated with DBB project designers. The researchers will examine the varying approaches for managing design decisions and assess the comparative advantages of alternate methods of overseeing key aspects of the design process that influence project cost, quality, and scope.

2. Literature Review

The groundwork of the DBB project delivery system is the practice of choosing designers in accordance with pre-established qualifications (Brooks Act – Public Law 92-582), and choosing contractors from sealed bids, where the lowest responsive and responsible bidder is awarded the contract, typically based on 100% Plans, Specifications and Estimates (PS&E) (Scott 2006). This system has offered taxpayers, over the last few decades, safe, adequate, and efficient transportation facilities while simultaneously preventing partisanship in public contracting. DBB, however, did not always offer the owner the best value for all project types and circumstances.

Growing pressure to accelerate projects and a mounting burden to maintain quality prompted highway agencies to evaluate the use of alternative contracting procedures and

procurement methods. DBB had been the conventional project delivery method for transportation projects in the U.S. from the 1930s until the Intermodal Surface Transportation Efficiency Act of 1991 introduced DB. The Federal Acquisition Reform Act (1996) had sanctioned the use of DB for federal highway projects, and the Transportation Equity Act for the 21st Century (1998) permitted federal funding for state Departments of Transportation (DOTs) to award DB contracts if enabling state legislation was in existence. Consequently, some states passed new codes and legislation to permit the use of alternative project delivery methods.

One obvious drawback to the DB project delivery system is less agency control over design. Because the design-builder often contracts out design services, design management was significantly different from what agencies were previously familiar with under DBB. Further, communication between the agency and the design professional goes through the same design-builder entity, which frequently was a single contractor or a joint venture of contractors.

Transportation agencies are motivated by these concerns to seek alternatives to DBB and DB. Construction-Manager-at-Risk (CMR) and the comparable Construction-Manager-General-Contractor (CMGC) offers accelerated project delivery while permitting the agency to maintain design control. Earlier studies discovered that adding CMGC to the delivery toolbox of a state DOT offered several benefits (NCHRP 2009, 2010). For DOTs, when DBB and DB cannot meet contrasting project objectives, CMGC provides a conservative option. Illustrated by the Utah Department of Transportation (UDOT) in their use of CMGC projects, Figure 1 recommends a project delivery method selection process (Alder 2007, Alder 2010). CMGC was also recognized as "a less radical shift in procurement culture than design-build" (NCHRP 2010, p. 3), and was utilized in prompting change from transportation agencies that had not embraced DB.

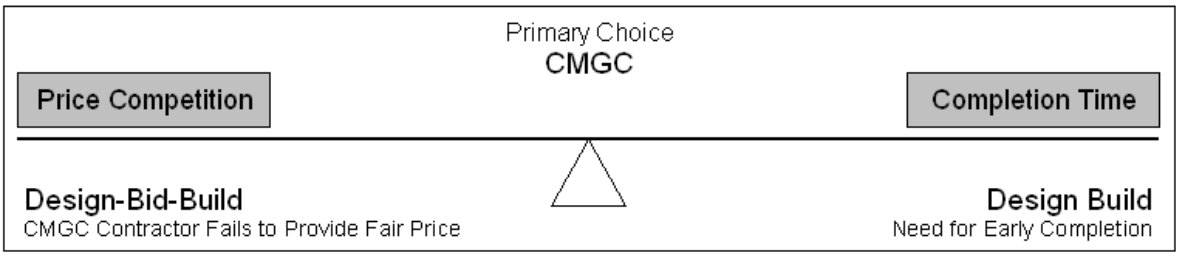

Figure 1: UDOT Balanced Delivery Approach

CMGC employs an integrated team approach, incorporating professional management into the planning, design, and construction phases of a project. Similar to DBB, the owner contracts design and construction separately; however, it is best to retain the construction manager (CM) and design consultant at, or nearly at, the same time by way of a qualifications-based or best-value selection process.

During the pre-construction phase of a project the CM behaves as a consultant. With a pre-construction services contract, the CM aids the owner with constructability reviews, design reviews, estimating, scheduling, and budgeting. The CM may also provide non-standard services including the securing of financing or selection of the design professionals. During

the construction phase of a project, the CM is “at risk” and behaves as a general contactor (GC) would on a DBB project.

Under CMGC, subcontracts may be cost reimbursable, fixed-price, or guaranteed maximum price (GMP). The relationship between the CMGC and owner changes when bound by a GMP, as they now have to manage construction costs below that amount. Further advantages to using CMGC instead of DBB include the following:

- Recommendations for constructability and early use of innovation
- Agency has considerable control over the design
- Construction components are fast-tracked prior to complete design, resulting in potential time savings
- More accurate and earlier cost estimating by the designer
- Budget constraints and construction needs dictate priority order of design

In order to sensibly select between the implementation of a DB or CMGC program, an understanding of general concepts is required. Successful implementation of a DB or CMGC program calls for a change in the design philosophies from the traditional DBB project. To facilitate the education of the design community – while at the same time generating and maintaining collaboration among the participants – the design management practices of the agency must be adjusted. Additional education may be needed in the fields of accelerated design, continuous value engineering, real-time pricing, and right-of-way (ROW) phasing. Shifts in responsibility may also be needed for budget management and full project schedule. Requiring that a project be divided into multiple phases is also key to successful implementation as it allows for the early start of a project, early product or material procurement, permitting, utility relocation, and ROW challenges.

3. Research Methods

Data for the research project were obtained from those within and external to state transportation agencies. The primary sample population consisted of select DOT officials who were familiar with the design management process of their agency. Additional individuals were obtained from local government agencies, including city, county, airport, toll, and transit authorities. Also included in the study population were select design consultants and contractors (CMs).

The primary task for the research team was defining the state of practice in the use of DB and CMGC delivery systems for highway construction projects. State DOT offices were contacted by telephone, and individuals having explicit knowledge regarding the state’s design process were identified. Fifty two state transportation agencies (including the District of Columbia and Puerto Rico) and 13 non-DOT public transportation agencies were contacted, 65 in all.

3.1 Level 1 interviews

A primary set of interview questions was developed as a means to assess each state agency's recent experience with DB and CMGC project delivery methods. The initial set of questions were identified as the Level 1 Interview Instrument and it was separated into a telephone component and an email supplement. Dividing the questions was a means to improve the data acquisition process. Interviewees were able to answer brief, principle questions almost immediately, and they were permitted ample time to gather job-specific details for the more complex queries. Further, the division of questions allowed for a continued level of contact between the interviewers and the state agencies.

The telephone portion of the Level 1 Interview consisted of a series of "Yes/No" questions that related to the agency's familiarity with DB and CMGC project delivery systems. The questions inquired if either system had been implemented within their agency, and if so, what year the first project was executed and how many total projects have since been completed. The research team also inquired into the use of "other" alternative/innovative project delivery systems (besides DB and CMGC).

The email supplement was distributed to state agencies that had prior experience with DB and/or CMGC projects (as determined from the initial telephone portion of the interview). These questions were submitted as a separate correspondence and inquired about the types of projects executed, their locations, final costs, and notable details concerning project execution.

Investigation of the Level 1 Interview responses helped in identifying state agencies as potential candidates for the Level 2 Interview. The data from this primary investigation also provided the researchers a set of criteria to determine if an agency displayed satisfactory experience with DB or CMGC delivery systems:

- Recent application of the project delivery system (i.e., within the past five years)
- Consistent application of the project delivery system (i.e., having completed more than five projects)
- Prospective as a case study example (as determined from their supplementary information or through direct knowledge by a research team member)

In order to accurately represent the construction activities of local government agencies, 13 non-DOT transportation agencies contacts were included in the Level 1 Interviews. These agencies were identified as entities outside the realm of the state DOTs that have either implemented or plan to implement a DB or CMGC project. The research team conducted Level 1 and Level 2 interviews on these non-DOT agencies using the same process as for the DOTs.

3.2 Level 2 interviews

A series of in-depth interview questions were developed by the research team as a means to evaluate key aspects of project scope, implementation, cost, and quality. The questions also investigated strategic issues that related to responsibility and liability within the design process. They were compiled according to their general relevance and appropriateness of delivery (e.g., as a telephone interview, emailed supplement, or case study interview). Also, the questions were geared specifically towards their practical application to post-award design management.

The initial telephone portion of the interviews consisted of “Yes/No”, multiple choice, and open-ended questions that related to specific design management problems including cost and scheduling, risk management, and phasing. The questions compared the agency’s experience with DB/CMGC as they related to typical design-bid-build projects. Email supplements were provided to agencies whose telephone answers warranted further investigation.

3.3 Case studies

A detailed evaluation of the Level 2 interviews produced a list of noteworthy projects or programs that could be investigated with the goal of developing a collection of descriptive case studies that could provide a good cross-section of the current practice on fast-track highway projects in the U.S. Key personnel for these projects or programs were contacted and site visits were scheduled. During the site visits, the authors were able to conduct interviews with project managers, DB/CM firm agents, designers, agency employees, and CMs and to collect project documents and other archival material. This well-rounded approach to data collection provided the authors with a large and redundant amount of information according to guidelines on case study research (Yin 2009).

According to Yin (2009),

these case studies were conducted by through a review of contractual documentation, agency documentation, and archival material; and, interviews with key project participants. On-site iinterviews investigated issues such as designer selection process, value engineering, the nature of the pre-construction services, subcontractor involvement, change order management, payment procedures, and other issues that could potentially influence successful implementation of the project delivery system.

The two Principal Investigators (PIs) for this project conducted the case studies interviews. One of the two PIs conducted the interviews to key personnel on DB projects and the other PI was in charge of interviews to personnel on CMGC programs. The PIs spent from 2-4 days on each location conducting the face-to-face interviews. In rare cases, these site interviews were anticipated or followed by over-the-phone interviews or email communications.

4. Results

4.1 Level 1 interviews

The Level 1 Interview data were compiled into a comprehensive spreadsheet that allowed for a thorough review of the information: familiarity and use of DB, CMGC and "other" (non-DB or CMGC) innovative delivery systems; frequency of use; and year of first execution. Preliminary numbers from the Level 1 Interview, as shown in Table 1, reveal that the DB delivery system is recognized by all state DOT agencies and 85% of non-DOT transportation agencies. The data also show that it is used by most DOTs (81%) and non-DOT transportation agencies (69%), and only 8% of states claimed to have no enabling legislation.

Table 1: Knowledge and Use of Design-Build Project Delivery Systems by Agency

	DOT Agency of 52 (%)	**Non-DOT Agency of 13 (%)**
Knowledge:	52 (100%)	11 (85%)
Use:	42 (81%)	9 (69%)
No Enabling Legislation:	4 (8%)	

Of the DOTs that have employed DB, the earliest use dates back to 1983 (Kentucky). The most recent initial use shows that six states first implemented DB in 2010. Several states introduced the system in the 1990s (11 states) and 2000s (24 states). Looking at non-DOT agencies, the earliest implementation of DB projects was in 2002 and the latest was in 2011. Table 2 shows the progression of DB implementation for both types of transportation agencies.

Table 2: Dates of Implementation of Design-Build Project Delivery Systems by Agency

	DOT Agency total (% of 52, % of 42 using DB)	**Non-DOT Agency total (% of 13, % of 9 using DB)**
1980-1989:	1 (2%, 3%)	
1990-1999:	11 (21%, 26%)	1 (8%, 11%)
2000-2009:	24 (46%, 57%)	6 (36%, 67%)
2010-present:	6 (12%, 14%)	2 (15%, 22%)

For DOT state agencies that have implemented DB, the number of projects each state has completed (or have begun) varies from the single digits to several hundred. At the time the interviews were completed, the following have been documented: three states have completed only one DB project; 22 states have completed between two and 10 projects; eight states have completed between 11 and 20 projects; two states have completed between 21 and 50 projects; two states have completed between 51 and 100 projects; and

four states have completed over 100 DB projects. Looking at non-DOT agencies, the number of projects per agency varies between one and 10. Table 3 shows the number of DB projects executed by both types of transportation agency. The discrepancy in total number of reported DOT agencies using DB projects (42 documented in Table 2 versus 41 reported in Table 3) is due to one agency failing to provide this information by the time of publication.

Table 3: Number of Design-Build Projects Implemented by Agency

	DOT Agency total (% of 52, % of 42 using DB)	**Non-DOT Agency** total (% of 13, % of 9 using DB)
One Project:	3 (6%, 7%)	2 (15%, 22%)
2-10 Projects:	22 (42%, 52%)	7 (54%, 78%)
11-20 Projects:	8 (15%, 19%)	
21-50 Projects:	2 (4%, 5%)	
51-100 Projects:	2 (4%, 5%)	
Over 100 Projects:	4 (8%, 10%)	

Comparing the familiarity and use of DB to that of CMGC in Tables 1 and 4, it is revealed that the CMGC delivery system is not as widely known by state DOT agencies. CMGC is also only marginally utilized, and half of the states claim to have no enabling legislation.

Table 4: Knowledge and Use of CMGC Project Delivery Systems by Agency

	DOT Agency of 52 (%)	**Non-DOT Agency** of 13 (%)
Knowledge:	50 (96%)	8 (62%)
Use:	10 (19%)	6 (46%)
No Enabling Legislation:	26 (50%)	

The implementation of CMGC began much later, with one state DOT first using the system in 2003 and eight others since then (it must be noted that one contact could not recall the exact year of implementation, but they noted their use of CMGC was more recent than the use of DB, and they first implemented DB in the mid-1990s). Looking at non-DOT agencies, the earliest implementation of CMGC projects was in 2000 and the latest was in 2009. Table 5 shows the dates of implementation of CMGC for both types of transportation agency.

Table 5: Dates of Implementation of CMGC Project Delivery Systems by Agency

	DOT Agency total (% of 52, % of 10 using CMGC)	Non-DOT Agency total (% of 13, % of 6 using CMGC)
2000-2009:	6 (12%, 60%)	6 (36%, 100%)
2010-present:	4 (8%, 40%)	

Of the 10 DOT agencies that have used CMGC, the number of projects each state has completed ranges from one to 25, with the vast majority having completed under 13 projects (nine states). Looking at non-DOT agencies, the number of projects per agency varies between one and 12. Table 6 shows the number of CMGC projects executed by both types of transporation agency.

Table 6: Number of CMGC Projects Implemented by Agency

	DOT Agency total (% of 52, % of 10 using CMGC)	Non-DOT Agency total (% of 13, % of 6 using CMGC)
One Project:	3 (6%, 30%)	2 (15%, 33%)
2-10 Projects:	5 (10%, 50%)	3 (23%, 50%)
11-20 Projects:	1 (2%, 10%)	1 (8%, 17%)
Over 25 Projects:	1 (2%, 10%)	

4.2 Level 2 interviews

The Level 2 Interviews were conducted on select DOT and non-DOT agencies whose information from the Level 1 interviews showed proof of either prolonged experience with either DB or CMGC or innovative practice of either delivery system. The questions were divided into three sections: the overall approaches in managing post-award design activities; how the agency's methods affect the cost, schedule, or quality of the project performance; and other issues that affect, or are affected by, design management.

With regards to managing post-award design activities, interviewees were asked to comment on specific issues relating to the role of the DB or CM firm as compared with their experiences with typical (traditional) DBB construction. General queries as to the duties of the design team, if coordination processes vary, the level of project management, and if possible to design during "mini phases".

Specific methods affecting the project quality, cost, and schedule are addressed by identifying the occurrence of notable inspection, budget, and delay issues. An agency's approach in responsible and consistent project monitoring was key in amending and averting post-award design conflicts. Constructability reviews and the flexibility in implementing changes, whether in design, construction, or material methods, were markers for successful project administration.

Other observations by interviewees dealt with overall design management. These issues include the following:

- Education and training
- Culture and philosophy
- Industry collaboration

Supplemental interviews conducted with Level 2 interviewees dealt with design management practices, and opinion-based responses addressing perceived problems and noted solutions. Questions were geared towards defining the roles of designers, managing changes and omissions, design and construction costs, and level of risk for the designer/contractor.

4.3 Case studies

Case studies were conducted by reviewing project related documentation (e.g., contractual documents) and interviewing face-to-face project participants. The interview questions were divided into the same three categories as those established from the Level 2 interviews. The interviewees gathered provided varied points of view ranging from the owner and design entity to the project contractor. Interviews lasted an average of 90 minutes.

Those interviewed were asked to comment on matters regarding the percentage of plans completion and noteworthy milestones, including pricing the first GMP, right-of-way acquisition, and bringing in key personnel. Questions were geared towards the following topics:

- Relationship among participants
- Public involvement
- Communication and training
- Allowances for innovation
- Variances in design, versus DBB

Of note is the inconsistent use of project delivery methods between state agencies. In a few instances, it was made apparent that state agencies have varied definitions for the DB and CMGC project delivery systems. Some states claimed to perform DB, but in actuality they used a more modified version. Other states actually performed CMR while asserting they used CMGC.

5. Summary

The transition from the traditional Design-Bid-Build process to the more fast-tracked methods of Design-Build and Construction-Manager-as-General-Contractor has been a steady one. The decreased time and cost growth associated with both of these delivery methods has garnered popularity among transportation agencies that are progressively in search of ways to increase innovation and teamwork. DB has made its way into the mindsets and legislation of the vast majority of transportation agencies, and CMGC is securing its foothold as an innovative alternative. Not surprisingly, of the few states that have implemented CMGC all have prior experience with DB – as the latter lends itself to the easy transition of the former. This also lends credence to the finding that CMGC finds favour with agencies because it returns control of the design process to the owner.

Earlier and more active roles taken upon by the constructor under the DB and CMGC systems provide for projects with added value engineering and improved coordination. The increased control in design associated with CMGC also attracts participants.

Data obtained from the case studies, and supplemented by the Level 1 and Level 2 Interview Instruments, provide a view of the key tasks that affect overall project cost, quality, and scope. Approaching the interviews from the design and contractor points of view has revealed the relationship between design elements and perceived issues.

Changes in educational practices and cultural philosophies are integral processes in the proper management of post-award design activities. Education and training of personnel were also shown as fundamental necessities in properly managing innovative delivery systems.

Fast-tracking critical projects from the planning phase through construction is an ongoing effort and constant objective for progressive transportation agencies. Efforts to lower costs, while increasing job efficiency and delivery, are the current trend in highway construction.

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Construction R&D investments in Denmark

Kim Haugbølle[1]

Abstract

During the 1990s and early 2000s, a range of policy reports argued that the Danish construction R&D investments were lagging behind the OECD level. In 2001-2002, a task force on construction/housing research was established to analyse construction R&D investments and develop a roadmap for new research priorities, increased public/private R&D collaboration, improved dissemination of research-based knowledge, and reorganisation of the technical support infrastructure. This paper 1) describes the organisational setup of Danish construction and housing research, 2) quantifies the Danish construction R&D investments, and 3) provides an update on recent developments in the Danish R&D environment. This study applies an adapted Triple Helix perspective on the interaction between government, academia and business. It is based on a comprehensive quantitative survey and analysis of R&D investments, professional competences and profiles of individual research institutes etc. The survey adopted a resource area perspective, which includes the primary industry, manufacturing industry, supporting industry and service industry. In conclusion, this study points at the following lessons to be learned: 1) it is quite complicated to draw firm conclusions on the level of construction-related R&D investments; 2) public construction R&D expenditures are disproportionate compared with other research fields; 3) private R&D investments primarily take place in the manufacturing industry; and 4) the R&D roadmap has not had a significant impact on construction R&D investments.

Keywords: R&D, innovation, triple helix, resource area, roadmap

1. Background: The national context

During the 1990s and early 2000s, a range of policy reports addressed the challenges of the Danish construction/housing resource area. One of the more prominent reports was the policy report "The future of construction – from tradition to innovation" by the Building Policy Task Force established by the Ministry of Housing and Urban Affairs and the Ministry of Business Affairs (By- og Boligministeriet & Erhvervsministeriet, 2000). The Building Policy Task Force identified a range of problems for the resource area and proposed a number of initiatives to be taken within four areas: 1) the role of construction clients, 2) competitiveness, 3) cooperation, and 4) innovation.

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The Building Policy Task Force noted that the development of R&D investments and patents was decidedly negative within the resource-area of construction/housing. The number of patents had dropped, and the investment level was lower than in OECD countries generally. Corporate R&D investment had fallen over the past 10 years, and in terms of trade and industry investments in R&D, the Danish construction industry invested around 20 % below the OECD level. Thus, the Building Policy Task Force proposed the following benchmark for research, development and patents in construction: “The government's goal is to increase the industry’s R&D investments and the number of patents to the OECD average by 2005” (By- og Boligministeriet & Erhvervsministeriet, 2000: 16, author’s translation). In addition, the Building Policy Task Force suggested i.a. that the government took the initiative to scrutinise the existing construction knowledge system and to develop a national action plan for construction/housing research.

Based on this recommendation, the government set up a task force to draw up proposals for an action plan for Danish public construction/housing research. Taking the work of the task force as its starting point, this paper 1) describes the organisational setup of Danish construction/housing research, 2) quantifies the Danish public and private construction R&D investments, and 3) provides an update of recent developments in the Danish construction R&D environment.

2. Previous studies

A number of surveys and studies of construction-related R&D efforts have previously been carried out. The following highlights the main results of the most notable of these studies in terms of primarily government funded R&D.

On behalf of the Association of Consulting Engineers (FRI), Christoffersen & Bertelsen (1990) described the situation at the end of the 1980s. Based on a questionnaire survey, the study mapped the scale of both public and private construction-related research in Denmark. A few years later, the Ministry of Housing (1993) carried out a survey of construction-related research based on a questionnaire survey. In that study construction-related research was used primarily in the sense of technical research, while e.g. architectural research and social-science research on construction/housing-related issues were not included.

The construction sector's use of technological services was the theme of a report prepared for the Building Policy Forum formed by the Ministry of Housing and Urban Affairs (Bang, 1997). With a focus on communication and technological services, construction-related R&D was only sporadically touched upon. The report primarily focused on how knowledge from knowledge producers could be disseminated to and adopted by the users of this knowledge, i.e. construction companies. In 1997, the Danish Building Development Council (BUR) made a study of knowledge production, knowledge use and knowledge dissemination in the construction sector (Dræbye, 1997). The survey was based on a review and categorisation of articles and other publications of more than 10 pages from mostly public knowledge producers. Knowledge production by private companies was included to the extent that the companies had received support from the public.

In 1997, the Ministry of Housing and Urban Affairs established the Public Research Task Force on Cities and Construction to advice the ministry on research on cities, housing and construction. The choice of method was not described, but by all accounts the conclusions were based on existing knowledge, reports and data (Det Offentlige Forskningsudvalg for Byer og Byggeri, 2000).

In summary, the surveys and analyses reveal that construction R&D has been on the agenda on a regular basis. The previous studies, surveys and policy analyses can be characterised by:

- Common questions: mappings and analyses revolve around two common questions: First, how many resources should be spent on different research themes? Second, how can knowledge dissemination improve from research institutes to companies? Other pressing questions are however left in the dark, like “do we at all have sufficient construction research”, “how can we improve the capabilities of companies to adopt new research results” etc.

- Inward looking perspective: it is striking how little the mappings and analyses seek to compare with other sectors and countries, link to broader R&D policy issues, or utilise theoretical contributions on what fosters R&D investments and how the R&D community operates in general.

- Vague definitions: in general, the very definitions of what to include in the studies are vague with respect to the subject area (housing, construction, planning etc.), research areas (e.g. technical science vs. social science), type of effort (research, development, dissemination etc.), and indicators (funding, outcomes like articles and tools etc.).

- Weak evidence for conclusions: the available resources in the individual surveys and analyses have apparently been relatively modest. It is characteristic of several of the mappings and analyses that the database for firm observations and conclusions are flimsy and inadequate.

3. Research design

3.1 Theoretical framework: Triple Helix

This study applies an adapted Triple Helix perspective on the interaction between government, academia and business. In contrast to other models like the national innovation system approach, the Triple Helix model focuses on the partly overlapping networks of communication and expectations that shape the institutional arrangements between universities, industries and public authorities (Etzkowitz & Leydesdorff, 2000: 109).

In the Triple Helix model, universities, governments and industry are conceptualised as intertwined spirals with different relationships to each other. The spirals are rarely equal:

typically one of them acts as a driving force or “innovation organiser” around which the other spirals orbit (Etzkowitz, 2003).

Thus, the sources of innovation in a Triple Helix configuration is not tuned in advance – they arise and develop at multiple sites in the network of relationships that generates a diversity of strategies and projects that create added value through constant reorganisation of the underlying structure. These are the dynamics of the Triple Helix cooperation, which creates innovation (Etzkowitz, 2003).

3.2 Methods

The survey adopted a resource area perspective – rather than a narrow construction industry perspective, which typically focuses foremost on contractors (for a definition of resource areas, see Erhvervsfremme Styrelsen, 1993 and Danmarks Statistik, 2001). Thus, contrary to most other studies this study includes the four industries: primary industry (e.g. raw material extraction), manufacturing industry (e.g. production of building components), supporting industry (e.g. production and leasing of construction machinery) and service industry (e.g. contractors and consultants).

This study was based on a comprehensive quantitative survey of R&D investments coupled with a qualitative analysis of professional competences and profiles of individual research institutes etc. The institutional profiles were based on an initial screening of all relevant research institutes followed by a more detailed mapping of the most prominent research institutes.

The survey was conducted on the basis of existing sources that were publicly available especially public research statistics, annual reports and websites of research institutions and funding agencies. In addition, special runs in the research statistics of the Research Centre for Studies in Research were conducted.

4. R&D investments

4.1 Organisational structure

It has often been argued that the organisational setup of Danish public construction/housing research is confusing and fragmented. Although construction/housing research is spread over many different actors, most of construction/housing research is concentrated on five key research and educational institutions with construction/housing research as their primary activity. In 2002, the five core institutions were Aalborg University (AAU, primarily the Institute for Building Technology), Technical University of Denmark (mainly BYG • DTU), School of Architecture in Copenhagen (KARCH), Aarhus School of Architecture (AAA) and the Danish Building Research Institute (SBi). By 2007, significant changes in the organisational setup of universities and governmental research institutes had taken place due to a national university reform. Twelve universities and fifteen governmental research institutes merged into eight universities and a few research institutes. During this process, the national building research institute merged with Aalborg University, but has remained an

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independent faculty of the university. At the Technical University of Denmark, the technical and management part of the building technology department was separated. The construction management group became part of a newly established department of engineering management.

In addition, a private independent institution, the Danish Technological Institute (notably the Construction Division) was doing construction-related R&D, which occupied a special role as a bridge between public research institutes and private companies. In statistical terms and in line with OECD definitions, the Danish Technological Institute is considered a private institution and not a public institution despite the public support granted by the government (some 10 % of the turnover).

In addition to the core institutions, a variety of other research and development institutions has regularly carried out construction/housing-related research and development, but not construction/housing research as their primary activity.

There has also been a number of supporting institutions in the form of knowledge brokers that did not conduct research themselves, but provided support for research and development, initiated and coordinated research and development, disseminated knowledge or otherwise acted as catalysts in or for change.

Finally, governmental, county, municipal, self-governing, and private non-profit institutions are considered public funding sources according to OECD guidelines. The main sources of public funding for the construction/housing area's R&D were (not in order of priority) a range of ministries, research councils, private foundations, Nordic Council of Ministers through the Nordic Industrial Fund and Nordtest, and the European Union.

4.2 Public R&D funding

In 1999, the level of R&D by the five core public institutions was approx. 175 million DKK (23 million EUR) plus 55 million DKK (7 million EUR) for the Danish Technological Institute (cf. Table 1).

Table 1: R&D funding sources for core public institutions

	AAU Building Technology	DTU BYG•DTU	KARCH	AAA	SBi	DTI Building Technology
Basic public funding	16.1 (66 %)	29 (66 %)	24 (89 %)	12.2 (70 %)	32.2 (54 %)	6.6 (12 %)
Private foundations	1.2 (5 %)	1 (2 %)	0.1 (0.3 %)	0.7 (4 %)	0.3 (0.5 %)	6.6 (12 %)
Public programmes	3.4 (14 %)	2 (4.5 %)	0.1 (0.3 %)	3.4 (19 %)	3.8 (6 %)	
Public sources	3.4 (14 %)	7 (16 %)	2.8 (10 %)	1.3 (7 %)	20.2 (34 %)	
Private firms	0 (0 %)	2 (4.5 %)	0 (0 %)	0 (0 %)	2 (3 %)	39 (71 %)
International sources	0.2 (1 %)	3 (7 %)	0.1 (0.3 %)	0 (0 %)	0.9 (1.5 %)	2.8 (5 %)
R&D expenditure total	24.3 (100 %)	44 (100 %)	27 (100 %)	17.5 (100 %)	59.4 (100 %)	55 (100 %)

Sources: Analyseinstitut for Forskning (special runs from database on research statistics), annual reports from institutions. Figures in million DKK and per cent.

In the general research statistics (Analyseinstitut for Forskning, 2001a & 2001b), the R&D efforts by other public research institutions for the research purpose "Housing and Planning" was estimated at approx. 90 million DKK (12 million EUR) and some 100 full-time equivalent (FTE) personnel. The reliability of this statement is questionable. For example, the Department of Comparative Literature at the University of Copenhagen estimated 10 % of its overall research to be within the research area of housing and planning. Conversely, the Centre for Indoor Environment at the Technical University of Denmark (where the world-leading professor P. O. Fanger was employed) provided 0 % R&D within housing and planning, although indoor climate in buildings can be considered as belonging to the construction/ housing area. Instead, research was classified under such themes as "Disease control and prevention". It is therefore reasonable to assume that some research relevant to construction/housing has been categorised under other research purposes and vice versa.

All in all, the amount of public R&D by other public research institutions was estimated at around 100-150 million DKK (13-20 million EUR) after a careful examination of their research profiles, project portfolio and research publications. To this should be added R&D expenditures at the core public institutions in the amount of approx. 175 million DKK (23 million EUR). Thus, the total annual public R&D expenditure within the construction/housing resource area was estimated at some 275-325 million DKK (some 40 million EUR).

4.3 Private R&D funding

Table 2 shows the funding of R&D within the resource area of construction/housing distributed on different sources of financing.

Table 2: R&D funding sources for private companies

Source of financing	R&D expenditure (million DKK)	Distribution (%)
Public funding	128	7 %
Own funding	1,446	80 %
Other private companies	113	6 %
Other Danish funding	10	1 %
Foreign funding	101	6 %
Total	1,799	100 %

Sources: Analyseinstitut for Forskning (2000 & 2001c).

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The statistical summaries of the private companies' R&D should not be considered too reliable. Part of the explanation must be sought in the R&D statistics being based on the companies' primary business sector. The company's entire R&D is attributed to this main industry, although companies such as consulting engineers operate in several different markets with different products and services. Another explanation could be that the sample is not representative of the construction/housing resource area. Finally, the weighting applied to scale the data from the sample to the entire study population may lead to a systematic bias (see e.g. Analyseinstitut for Forskning (2001c) for a detailed description of the methodology behind the research statistics).

The estimate above was supplemented with a second lower estimate at 350 million DKK (47 million EUR) based alone on a narrow definition of the research field “building and civil engineering technology”. The total private R&D within the construction/housing area was estimated at approx. 1.2 billion DKK (160 million EUR) corresponding to the R&D efforts in primary and manufacturing industries, and half of the calculated R & D efforts in support and service industries. It should be strongly emphasised that this is an estimate subject to significant uncertainty.

5. Roadmap for construction R&D

5.1 The Task Force for Building Research

In June 2001, the government established the Task Force for Building Research. The task force was composed of six members from the newly established private foundation Realdania (chairman), an architect firm C. F. Møllers Tegnestue, the National Association for Public Housing Associations, and researchers from the Copenhagen Business School, SBi and Aalborg University.

Besides the full members, the task force also comprised four public servants from the Danish Agency of Enterprise and Housing, Ministry of Science, Technology and Development, and the Danish Energy Agency. The task force was assisted by a secretariat

of five people at the Danish Agency of Enterprise and Housing, which in turn was assisted by two external experts (including the author of this paper).

The mandate of the Task Force on Construction Research in Denmark consisted of three main tasks to be undertaken (Haugbølle & Clausen, 2002):

1. Mapping of a) content and scope of existing public Danish construction research, including interactions with private construction research; b) the institutional, organisational and financial issues regarding public construction research in Denmark; and c) the organisational structure of the knowledge system of construction based on existing reports, analyses etc., and an updating of these.

2. Evaluating a) research needs in relation to the vision for construction in the future; b) Danish construction research in an international context; c) interaction between producers, providers and users of building knowledge; and d) how the public construction research can better serve as a catalyst for private R&D investments.

3. Proposing a) prioritisation of public construction research, b) increased interaction between public and private investment in construction research, including initiatives to strengthen the incentives for firms to develop new construction knowledge; c) initiatives to improve the dialogue between research and users of construction knowledge; and d) reorganisation of construction knowledge infrastructure.

In September 2002, the task force published its report (Udvalget vedrørende byggeforskning i Danmark, 2002). It stated that the Danish construction industry faced three significant strategic challenges: 1) the productivity of the industry was too low, 2) the quality of work was too poor, and 3) the profitability of construction businesses was too low. Thus, a transformation of the industry was required. The task force pointed out that if construction were to make it through the transition it would demand strict requirements to the scope and quality of construction research. Research, it was argued, could bring the construction industry into the knowledge society. The task force concluded, however, that the starting point was somewhat different and identified three challenges (Udvalget vedrørende byggeforskning i Danmark, 2002: 7):

- Danish construction/housing research lags behind. The amount of construction research is at a low level compared with other OECD countries, and the level seems to be decreasing.

- Construction/housing research does not match the current challenges facing construction companies. In recent years, publicly funded research has been directed in other directions.

- Interactions between construction/housing research and its users are not particularly good. The dissemination system is perceived as confusing and characterised by too many independent actors.

The task force believed that these challenges could predominantly be attributed to construction research being driven by public support, and that orientation towards the real users had therefore been inadequate. The task force (Udvalget vedrørende byggeforskning i Danmark, 2002: 7) proposed a strategy based on stronger demand orientation, where construction research could contribute to the development of the construction industry by:

- Supporting construction innovation and change effectively.

- Contributing dynamically to the companies' ability to seek knowledge.

- Providing businesses and authorities with relevant knowledge of high quality.

- Creating the conditions for more active involvement of international knowledge.

The task force recommended a long-term strategic framework resting on four main elements (Udvalget vedrørende byggeforskning i Danmark, 2002: 8, author's translation, original emphasis):

- **Increase funding** by an extra 120 million DKK annually for building research to reach the OECD level. The majority of the funding was to be provided by the industry itself, in particular by new construction projects, through agreement with the construction clients, and it was to be directed to construction research through the Building Innovation Fund, to be established to coordinate the implementation of the strategy.

- **A ten-year national action plan** for construction research running from 2003-2012. The action plan is suggested to be established through an agreement between the government, major public and private clients and relevant client groups along with the firms and organisations of the construction industry. The task force stressed the importance of giving the action plan a time horizon, which would ensure an effective implementation of the results of construction research in construction firms. The action plan was to be realised through the establishment of a number of **innovation consortiums** within the most significant development areas.

- A **re-orientation** of construction research towards research areas of importance for the transformation of the construction industry, not least organisation, management, learning and collaboration along with development of large-scale components and systems.

- A systematic effort towards **improved learning** in construction along with coordination of knowledge dissemination. Learning and dissemination should be part of all research projects and innovation consortiums.

5.2 Recent developments

Ten years after the publication of the roadmap, it is worth asking what became of the recommendations of the roadmap in relation to construction-related R&D. Below each of the four elements in the roadmap are addressed.

First, the suggested increase of funding by 120 million DKK annually has far from materialised. The innovation fund as prime funding mechanism based on a percentage of the budget of new construction projects never came into existence due to a lack of support from i.a. the public construction clients and disagreement with the private foundation Realdania on how to organise, manage and finance the innovation fund. However, some increase in funding has been achieved due to significant and sustained contributions from the newly established private foundation Realdania. Over the past 10 years, the foundation has pursued its own proactive R&D strategy, which included spending some 277 million DKK in the period 2003-10 on research activities alone (DAMVAD A/S, 2011). Realdania has initiated a range of stand-alone projects, spearhead projects and research centres. Half of the R&D expenditure (145 million DKK) was spent on the establishment of six research centres within urban spaces, strategic urban research, housing and welfare, construction management, facility management and indoor environment.

The main source of public funding for public R&D is related to the general funding schemes for research-based educational programmes for which funding for basic research is provided along with funding for educational programmes. In recent years, the establishment of new educational programmes on design and architecture, construction management and informatics etc. has created the foundation for some additional funding for public construction-related R&D through the increased enrolment of graduate students.

Second, the ambition to draft a ten-year national action plan was never met, although endeavours were made to create a common platform for the industry some five years later through the newly established Coordination and Innovation Group for Knowledge in Construction (KIG), which embraces all major actors in the industry. A series of meetings were held where KIG sought to develop an action plan based on inspiration from among others the Swedish construction innovation fund and the Danish food industry where a year-long collaborative effort had led to the establishment of an innovation fund. In 2009, anreport was put together by the head of the building technology department at the Technical University of Denmark on behalf of KIG. The report described four focus areas: sustainability and energy; economy and innovation; safety and health; and functionality and experience (Koordinations- og Initiativgruppen for viden i byggeriet, 2009: 3).

A core element in the proposed action plan of the Task force on Building Research was the establishment of innovation consortiums within strategic areas. Although at least three innovation consortiums have been established over the years, they were hardly the direct result of the roadmap. The first initiative was Digital Construction, a development programme initiated in 2000 and officially concluded ten years later, although a follow-up programme has been established for 2011-2014. Digital Construction has been financed in several rounds from various sources. The second initiative is an on-going innovation consortia on sustainable industrialised construction (InnoByg) established in 2010 for a four-year period. The third initiative is the knowledge centre on energy savings established in 2008 for a four-year period. This was established as a knowledge centre, and not as an innovation consortium. None of these three initiatives was directly anticipated in the roadmap as the roadmap only addressed innovation consortiums in rather vague terms.

The third element was to reorient building research through the transition of basic funding by increased competition and new types of performance contracts. The conversion of basic funds did materialise in the case of basic funding of the national building research institute, but not for any other research institute. Despite strong warnings from the national building research institute, including a minority statement in the roadmap, the annual budget of the national building research institute was reduced by 5 million DKK (0.66 million EUR) in 2003 and again in 2011 by an additional 5.5 million DKK (0.7 million EUR). Some of the funds have been redistributed in calls for research proposals on ad hoc themes, which have changed from year to year leading to a strong short-termism and a reduced gearing of the funding available.

Fourth, the ambition to improve learning was based on a range of initiatives related to the establishment of a central knowledge centre (one-stop-shopping), improved dissemination to educational institutions, mandatory dissemination plans for research projects, improved knowledge dissemination from the two national building defects funds, and the strengthening of networks. Especially the creation of one-stop-shopping was considered important, which subsequently led to the initiation of two competing consortiums that tried to develop two different strategies for the establishment of a central knowledge centre. As time would eventually tell, only little changed in the ways dissemination takes place in construction partly due to the financial independence and organisational affiliation of each knowledge broker.

6. Conclusion

In conclusion, this study points at the following lessons to be learned: 1) it is more complicated than that to draw firm conclusions on the level of construction-related R&D investments; 2) public construction-related R&D expenditures are disproportionate compared with other research fields; 3) private R&D investments primarily take place in the manufacturing industry; and 4) the R&D roadmap has had little impact on construction R&D.

First, this study suggests that it is more complicated than that to draw firm conclusions on the level of construction-related R&D expenditures. Careful consideration is warranted when it comes to for example the scope of the study, the definition of what counts as construction or what not, and the difficulties of how to classify and register research activities adequately under different research purposes.

Second, in 2001 the level of R&D expenditures at the core public institutions was estimated at around 175 million DKK. To this should be added R&D by other public research institutions, which are estimated to be approx. 100-150 million DKK. The total public R&D within the construction/housing resource area may amount to approx. 275-325 million DKK. Out of a total public R&D budget of 8.93 billion DKK, the construction-related R&D budget amounts to some 3 % of the total public R&D expenditures, whereas the turnover in private companies of the resource area amounts to some 20 % of GDP. Thus, there is a disproportionate share of public R&D funding for construction-related R&D compared with the economic importance of the construction industry.

Third, the R&D expenditures in private companies within the construction/housing resource area were estimated at 1.2 billion DKK (160 million EUR) corresponding to the R&D efforts in primary and manufacturing industries, and half of the calculated R&D efforts in support and service industries. This estimate is marked by significant uncertainty due to the methodology applied in collating these statistics. Although the exact figures may be questioned, it can be rather firmly concluded that private R&D investments primarily take place in the manufacturing industry.

Fourth, the Task Force on Building Research published a research roadmap for construction-related R&D in 2002. The roadmap suggested a range of actions within four key focus areas: 1) increase R&D funding with 120 million DKK annually; 2) issue a ten-year national action plan; 3) re-orient research priorities; and 4) improve learning. Although some actions have been realised, a range of the initiatives proposed in the R&D roadmap has not been implemented or would most likely have been implemented anyway, for example the increased R&D funding from the private foundation Realdania. Consequently, the R&D roadmap is seen to have had little impact on construction R&D.

Acknowledgements

The original study of construction-related R&D was financed by the Danish Enterprise and Construction Authority.

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Requirements for Firms Designing Megaprojects

Christian Brockmann[1]

Abstract

Megaprojects are interesting objects of study for two reasons. On the one hand, they are the most complex undertakings in construction. They extend the boundaries of our knowledge. On the other hand they work like magnifying glasses; they unveil problems that might remain unnoticed on smaller projects. As such, they help us to better understand the mechanics of all types of construction projects.

The design of megaprojects is based on the conceptualisation of the owner and it poses different problems than execution of works. Understanding the requirements imposed by the design task of megaprojects helps both the owner and the design firm. The owner will be able to make a better choice when awarding the design contract and the design firm can better evaluate whether it possesses the know-how and resources demanded. The framework for such an evaluation is provided by the concept of complexity, which in turn is founded in Luhmannian system theory.

The research methodology takes a qualitative approach by using grounded theory and expert peer interviews. Such interviews are not often discussed in construction research. Eighteen interviews were conducted with a total of 98 interviewees. The groups of interviewees ranged from three to eleven in size and all members were design professionals. The group of the interviewers comprised five members; they were both, academics and professionals.

Two aspects emerged as most important: Megaprojects demand experience and integration is the most challenging task. The required experience comes from a number of sources: megaproject experience, international experience, local experience, management experience, system experience, and specific design experience. All these different experiences are necessary for the integration through technical interfacing, cooperation, coordination, and communication. In sum, the lessons learned are: It's the experience, stupid!

Keywords: Complexity, design, experience, expert peer interviews, megaproject

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1. Introduction

Megaprojects are invariably described by using superlatives (the prefix “mega” is already one of them). They are called the “giants” among projects (Grün, 2004) or the “new animal” (Flyvbjerg et al., 2003). While such projects are large, they are not unparalleled in history. Examples of megaprojects are the pyramids of Giza or the Suez Canal.

Not all authors use the label “megaproject”. Some refer to them as large-scale engineering projects (LSE-Projects, Hassan et al., 1999) and describe them by five attributes: (1) “high” capital cost, (2) “long” duration but program urgency, (3) technologically and logistically demanding, (4) requiring multidisciplinary inputs from many organizations, and (5) leading to a “virtual enterprise” for the execution of the project. Grün (2004) puts the emphasis on the aspect of multi-organisational enterprises and characterizes these by (1) singularity, (2) complexity, (3) goal-orientation (technical, financial, time) and (4) the nature and number of project owners.

When considering these attributes together, then megaprojects are indeed daunting tasks. This is only the more true since cost and time overruns are typical. The list of projects with cost overruns reads like a “who is who” in megaprojects (Flyvbjerg et al., 2003); among these are the Suez Canal (1,900%), the Sydney Opera House (1,600%) or more recently the Boston Artery Tunnel (196%), the Great Belt Rail Tunnel (110 %) and the Channel Tunnel (80%). Reasons given are planning optimism, mistakes, and political lies.

Considering the design of megaprojects, important attributes are based on Hassan et al. and Grün:

- High capital cost and long duration with program urgency leading to a high density of design tasks over a longer period
- Technologically demanding design due to singularity and complexity of the projects
- Multidisciplinary input also for the design
- Virtual enterprise including project owners

2. Complexity

2.1 Definition

Sargut and McGrath (2011) define a simple system by a low degree of interaction and dependable predictability; complicated systems comprise many elements and many interactions functioning according to clear patterns, they are also predictable; complex systems are identified by the terms of multiplicity, interdependence and diversity, their outcomes are difficult to foresee. The same system configuration at the start allows for different results. Gidado (1996) is taking a different approach by concentrating on components (inherent complexity, uncertainty factors, number of technologies, rigidity of sequence, overlap of stages) and interactions between these. For him, complexity purely has a technical character. These positions represent two ends of a continuum for the definition of complexity: the first one is highly abstract and flexible, the latter one specific and more rigid. Seeing complexity not only from a technical perspective is a fairly new topic (Antoniadis et al. 2012). An

abstract definition allows incorporating nontechnical perspectives and for this reason we will approach the definition of complexity from this end of the continuum.

It seems that the efforts of finding a definition converge on three characteristics with two of them (elements and interactions) being fixed and the third one under scrutiny. For this text, we propose the following definition of the term:

> Complexity = (def.) the number of elements, their interactions and the strength of impacts in a defined system with regard to decision making

It should be noted that this definition is a general one referring to any type of system. For a construct of construction project complexity we will need to find further dimensions. Complexity does not remain constant over the life span of the project. In the end, the aim is to reduce it by decision-making. Therefore, we are faced with different configurations of complexity at different times. Construction project complexity is subjected to dynamic change (Girmscheid and Brockmann 2008).

2.2 Dimensions of complexity

The discussion on complexity has progressed from just considering technical complexity to include other categories. Baccarini (1996) for example distinguishes between organizational and technological complexity. Girmscheid and Brockmann (2008) introduced task, social and cultural complexity based on Wilke (2000). Task complexity combines technological and parts of organizational complexity, especially planning and organizing. It excludes leadership, which is part of the social complexity. There can be little discussion that the number and diversity of stakeholders in a project along with the strength of their impact (interest and power – Chinyio and Olomolaiye 2010) increases its complexity; this we term “social complexity”. The same holds true for the influence of culture on construction projects (Tijhuis and Fellows 2012, Kähkönen 2008). In all cultural studies the point is to show how much the stakeholders’ cultural diversity influences project outcomes. The more cultures meet in a project, the more complex it becomes since it requires coordination of an increasing number of different cognitive maps (Brockmann 2009); this we term “cultural complexity”.

Two additional forms of complexity can capture dynamics: cognitive and operative complexity. They both develop over time. Cognitive complexity mirrors how differentiated we think about a construction project; this increases with time as we understand a project better. Operative complexity is the degree of freedom for members of a project with regard to its operations and the project sponsors. Are most operations determined by the sponsors or does the project develop its own more specific operational approaches and thus become more complex? Both, cognitive and operative complexity mirror how much new we learn in a project.

A confined space influences task and social complexity. Restricted space for the tasks (i.e. a limited construction site) and social interactions (i.e. limited office space) increase these two types of complexity. All five types are becoming more complex as less time is available. This is a result of the decision-making perspective. The discussion can be summarized in a graph (fig. 1).

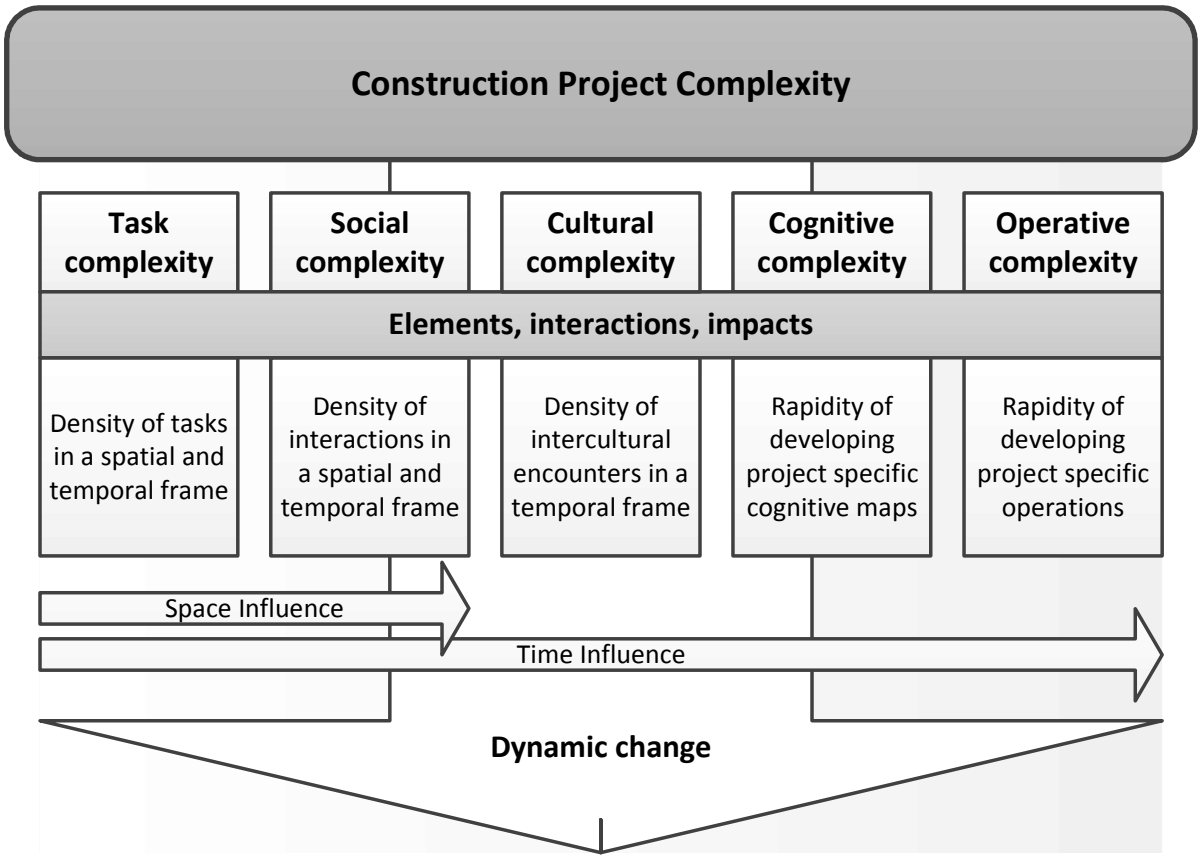

Figure 1: Dimensions of construction project complexity

3. Research Methodology

The research question is: What are important requirements for design firms with regard to megaprojects? In general, we are looking for a set of criteria belonging to the social world. A set of criteria in the social world can only be established through qualitative research. Grounded theory offers a possibility to establish such criteria (Glaser / Strauss 1967). A literature review on prequalification for design firms provided criteria which consequently were discussed by industry professionals and a set was chosen for the interviews. This is not a pure approach within grounded theory as the criteria were derived from the academic world and not grounded in the subject matter. However, the discussion and decision by industry experts remedied the deviation at least partially.

Two principles were applied which are commonly used in economics: (1) principle of individuality, i.e. all data are collected from individuals or actors; (2) principle of a non-individualistic view, i.e. description of a group behaviour or a firm. Propositions are derived from principle 2 through aggregation of data based on principle 1.

3.1 Interviews

Problem-centred expert peer interviews were chosen to collect data. This type of interview is not often discussed in research but it offers new possibilities in case that both, interviewer and interviewee have a similar background. This is true for all researchers in construction engineering management with a strong professional background.

The opposite form of interview is an ethnographic interview (Spradley, 1979). The basic assumption of ethnographic interviews is that the interviewee and the interviewer have different professional backgrounds and therefore use different professional languages with corresponding concepts and meanings. Accordingly, the interviewer must learn the language of the interviewee.

Expert interviews suffer from the same predicament since researchers such as social scientists interview subject matter experts. Design managers in civil engineering learn both during their education and in their business lives to speak in a professional language. They form a speech community. The professional language of a speech community is sharper and better defined than everyday language because of the higher degree of institutionalisation. Part of the university training that is indispensable for civil engineers is to define terms and thus it welds words and abstract patterns. A non-expert researcher will not easily distort the usage of the professional language by experts but misunderstandings are possible: The interviewer must still learn the language of the subject matter experts.

Meuser and Nagel name the following problems with expert interviews (2002): (1) The expert is not a real expert; (2) the expert talks more about internal matters and intrigues than about the interview subject; (3) he assumes alternatively the roles of an expert and a private person and (4) the expert gives a lecture and not an interview. All these concerns can be addressed by interviewing a group of experts and not individual experts and by using a problem-centred interview strategy. Witzel and Reiter (2012) describe such a strategy by its orientation towards a problem (such as requirements for design firms), by developing methods with regard to an object (e.g. megaprojects) and by process-orientation. The latter point is observed by using conversational entry, general and specific prompting and ad hoc questions. In a group of experts, chances of not interviewing subject matter experts decrease as objectivity in the form of intersubjectivity increases. General and specific prompting allows guiding the interview back to the problem.

The language problem can be solved by an interview design where experts interview experts; these are called expert peer interviews. They more or less take the form of a dialog between equal partners (Porter et al. 2009). The only exception is the problem-orientation and the right of the interviewer to guide the dialog back to the problem. Peer interviews allow solving the language predicament and they put both sides on an equal footing. The requirements for the interviewers are the only problem with peer interviews: they must be professionals in the field of research and scholars at the same time.

The most important advantage of expert peer interviews is their quality. Since there is no need to learn a different language, they can start at a very different point on the hermeneutical spiral and then lead to a deeper understanding.

Eighteen interviews were conducted by a group of five interviewers. In total, 98 subject matter experts were interviewed. The experts were representatives from eighteen international design firms. They were interviewed in groups where the smallest group of interviewees had three and the largest eleven members. They were asked about their previous experiences with megaprojects, i.e. a large aggregate of lessons learned.

3.2 Data recording and evaluation

During the interviews, the expert interviewees took notes. These notes do not have the character of paraphrasing. Instead, already during the interview the interviewees performed the process of open coding (Strauss / Corbin 1998). Open coding allows identifying and noting concepts in interviews. Open coding was completed during data evaluation. The final step was axial coding which helps to establish relations between categories and subcategories. The concepts derived from open coding are shown in the following figures (figure 2 to 5) in boxes and axial coding allows us to draw the connections between the boxes.

4. Data collection

Complexity is used as a conceptualisation of the term “megaproject” with its dimensions of task, social, cultural, cognitive and operative complexity. This is helpful for an academic approach; it is not clear enough for expert peer interviews. Therefore, we chose a 40 billion US dollar rail infrastructure project in the Middle East as an example. Rail infrastructure has the advantage of added complexity by the system it presents: Civil infrastructure, electronic signalling and communication, mechanical trains, operation and maintenance as well as financing are the larger subsystems.

It should be noted that all 98 interviewees are design engineers or design managers. They present a certain perspective of the problem “megaproject”. This shows for example in the following data, when reasons for cost increases and claims are attributed solely to owners and contractors but not to designers. Very basic common sense tells us that designer also make mistakes. To repeat, completeness was not an aim of this research only understanding the perspective of design firms. A broader picture of the risk of megaprojects was developed by Flyvbjerg et al. (2003).

4.1 Emerging criteria

Four criteria emerged during the interviews as salient for establishing requirements for design firms with regard to megaprojects. These criteria are:

- Strategic approach to designing megaprojects
- Success factors for the design of megaprojects
- Reasons for cost increases and claims in megaprojects

- Required qualifications of design managers and engineers for megaprojects

The criteria are not independent. Success factors will be part of the strategic approach and qualifications can be part of the success factors and the strategic approach. Mutually exclusive are success factors as they tell us what to do and reasons for cost increases and claims as they tell us what to avoid.

4.1.1 Strategic approach

Very clearly, integration is the most important concept used as strategic approach. Given the very demanding technical task one could expect that specialised knowledge would be named. However, it was not mentioned even once. Specific knowledge seems to be available so that the paramount task is integration of design. Open and axial coding yields the information contained in figure 2.

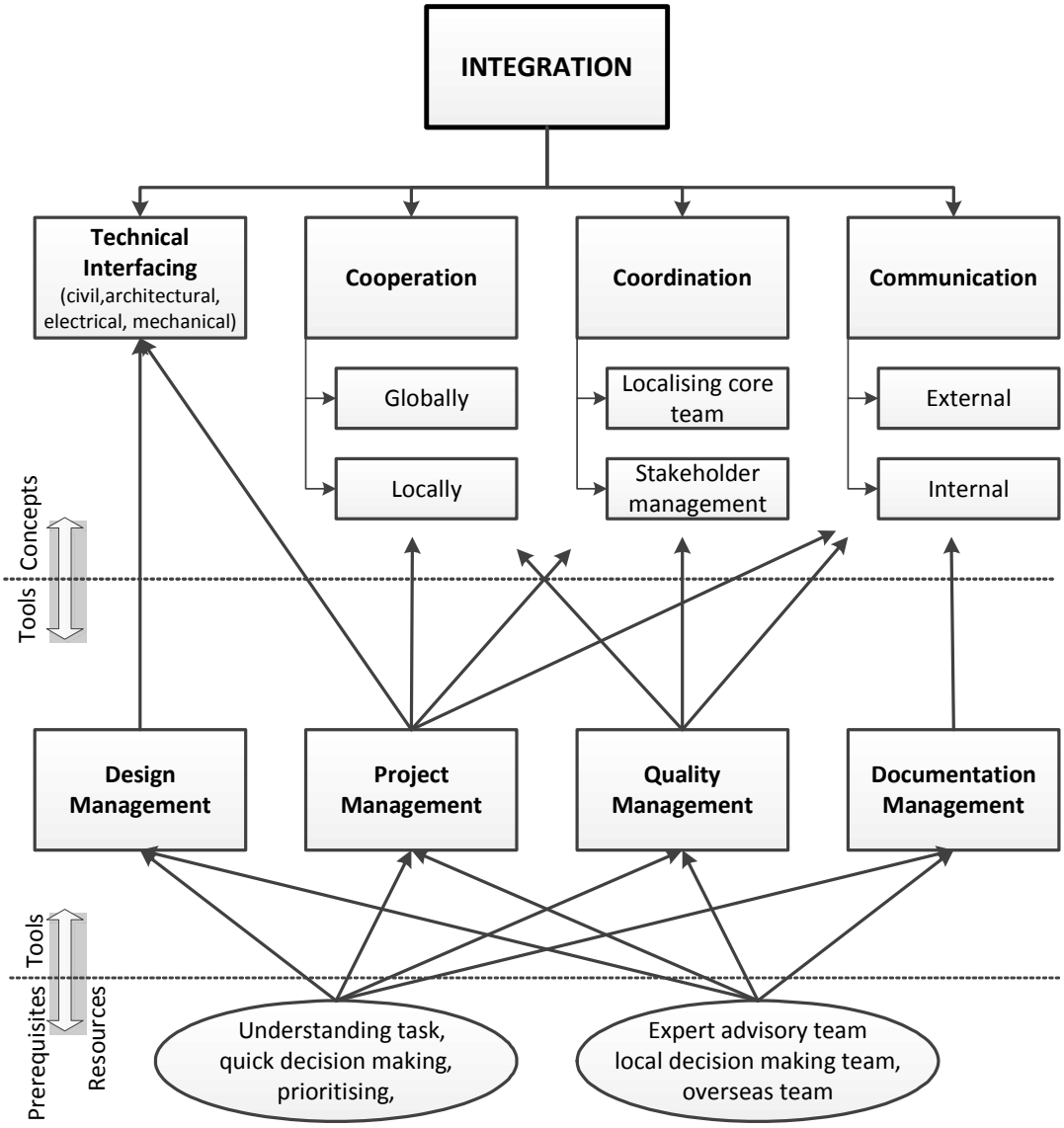

Figure 2: Strategic approach to megaprojects by integration

4.1.2 Success factors

A word of caution needs to be expressed in the beginning: Success factors should not be interpreted as unfailing mechanisms. Rather, they are shared cognitive maps of subject matter experts (Brockmann 2009). As maps they undergo constant updating and thus change. They are developed in a sense-making process that is coupled to the real world of construction. As such they are neither chimaeras nor natural laws.

We can expect a certain overlap between strategic approach and success factors. Nobody would choose a strategy that does not build on success factors. Success factors are seen more on an operative than on a strategic level. They can be divided into three categories: people, methods, and organisation. People and organisation were mentioned as part of the strategic approach. The methods are a repetition of those regarded as important for the strategic approach with a little more detail (figure 3).

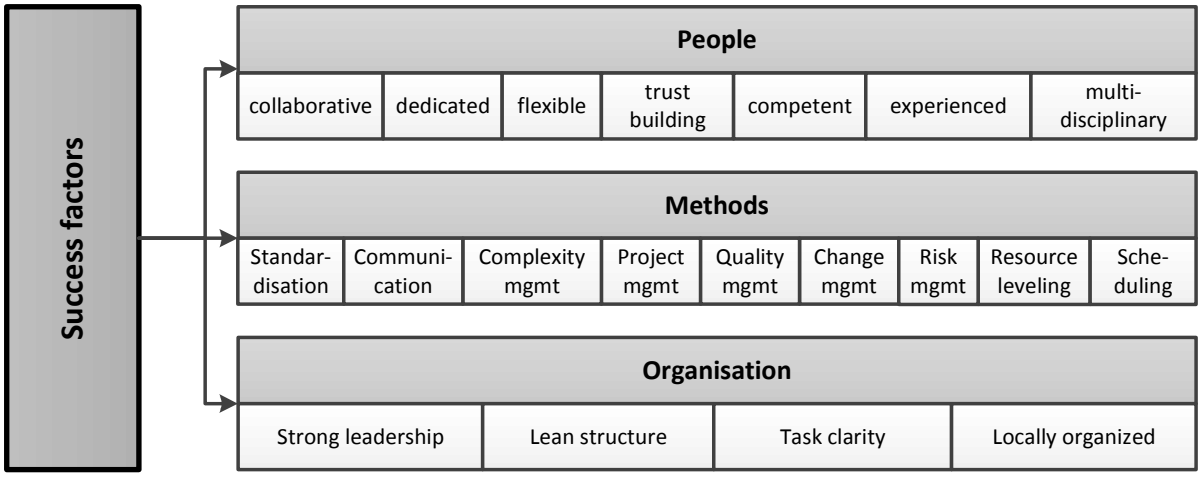

Figure 3: Success factors for the design of megaprojects

The required characteristics of the people working on megaprojects are no surprises. Important are the ability to work in a team (collaborative), to be flexible, and to be multidisciplinary. There is no mention of a need for specialised people. This supports the findings that integration is more important than specialist knowledge.

For the category of organisation the idea of a lean structure with strong leadership for integration is important. Too large an organisation makes solving the design task more difficult. In a lean structure multidisciplinary people are the key to success.

4.1.3 Cost increases and claims

Reasons for cost increases are attributed to the owner or external factors (figure 4). It was already stated that this is a one-sided view, excluding reasons for which designers are responsible. Slow decision-making and scope changes are most often mentioned. When there

are scope changes and no functioning change management procedures coupled with slow decision-making, the situation becomes worse.

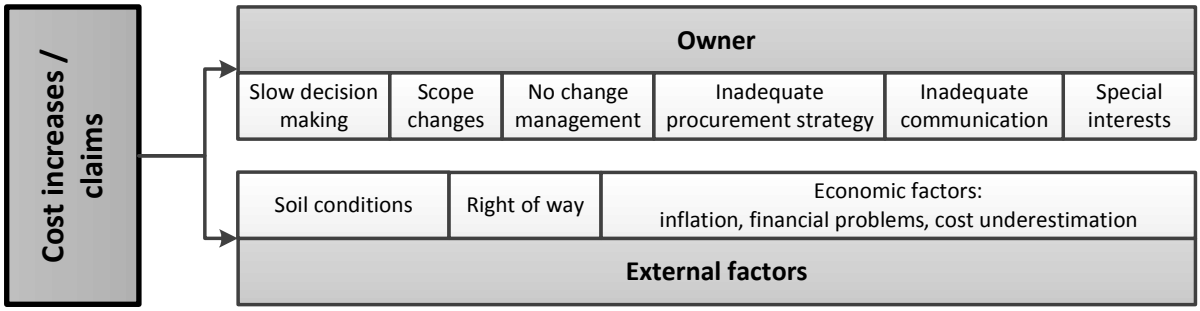

Figure 4: Reasons for cost increases in megaprojects due to design

An inadequate procurement strategy results in joining with the wrong contractors. Their lack of qualification and the choice of wrong contractual mechanisms lead to further cost increases. Additionally, claims are due to inadequate communication between owner, designers, and contractors. Sometimes the owner has other competing goals and he might put more emphasis on these than on the project success.

External factors for cost increases are soil conditions that differ from those given in the contract or a belated handover of the right of way. The owner is responsible for both in most cases, but sometimes he has no influence over them. Cost underestimates might be due to planning optimism or to political pressure. Clearly, the owner has no control over the inflation or financial markets.

4.1.4 Qualifications of key personnel

Reviewing the previous results, it becomes obvious that people are the drivers of the strategic approach, at the core of the success factors and a guarantee against cost increases. They must have the right experiences (fig. 5). The list of experiences is daunting; it seems almost impossible to find a project manager who fits into the picture. Therefore, we need to prioritise the experiences. Indispensable is megaproject experience or in more academic terms the ability to deal with the overwhelming complexity of megaprojects in all its facets (task, social, cultural, cognitive, operative). Managers who do not have command of the corresponding skills will make the wrong choices and the learning process takes time.

In second place come the international experience. International projects might not always be megaprojects but all international projects are large or special. Cultural competence is key to be successful in an international environment. Local experience can be provided by advisors in the beginning, but the key personnel must be able to build up local relationships quickly based on their cultural competence.

Management experience comprises project management, design management, and quality management. A special type of experience is system experience for the chosen example of railway infrastructure. This can be learned on the job as specialists will have the required interfacing knowledge. Specific design experience is then the knowledge base for specialists.

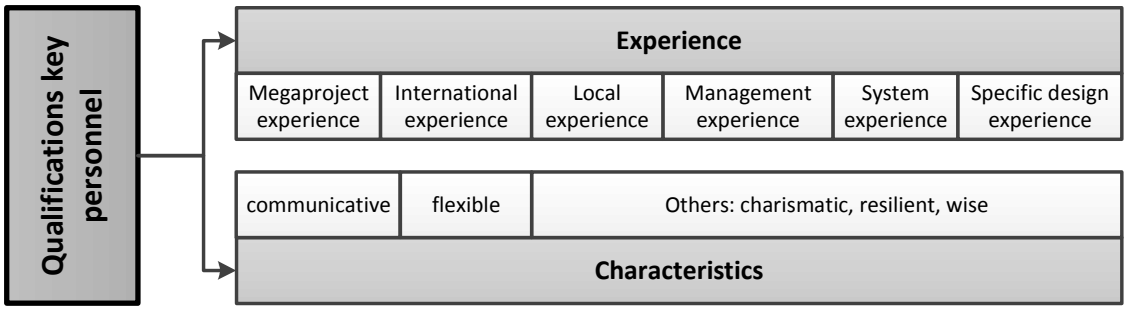

Figure 5 : Qualifications for key personnel

In sum, the project management team must first of all have megaproject, international and management experience. Local and system experience are secondary as they can be learned on the job. Specific design experience is the domain of highly specialised engineers.

5. Conclusion

Experienced people are the key to megaprojects. A balance is required between generalist and specialist experience. The specialists must provide in depth knowledge in their areas as the design of a megaproject often works on the cutting edge of our knowledge. However, the specialists are not the bottleneck to megaproject design success.

The management team which integrates all the different aspects of a megaproject, which breaks down task, social, cultural complexity and which expands the cognitive and operative complexity must be based on a wide range of experiences. It is almost impossible to find managers who possess all the required experiences. So, they must couple their available experiences with the ability to learn. The need to learn is not obvious for all experienced managers but megaprojects demand a respectful approach. Prioritizing the required experiences for the project management team provides the following list:

1. Megaproject experience (condition sine qua non)
2. International experience (condition sine qua non)
3. Management experience (condition sine qua non)
4. Local experience (can be learned)
5. System experience (can be learned)
6. Specific design experience (not required)

The overall conclusion is: It's the right experience, stupid! This seems simple but why do we so often get it wrong? Maybe because we do not heed the lessons learned as described above or maybe because we are not humble enough when taking on the task to manage a megaproject?

The consequences for design firms are clear: They must build up actors with as much required experience as possible. There must be a balance in the project team to cover all areas of experience. The project manager must understand that he alone is most likely not qualified enough for the task and needs the support of the team. The whole team must strongly seek more experience as the project advances and adapt previous lessons learned to the unique circumstances of the focal project. Integration of knowledge is more important than a hierarchical structure.

Companies should also ask themselves carefully whether they have a command of the required experiences. If not, it seems better to forego signing such a contract instead of plunging head over into disaster.

Possible further areas of research are finding out how design firms organise megaproject design and how the adaptation processes with regard to the requirements of a specific megaproject are managed.

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Women in South African Construction

Agherdien[1], Smallwood[2]

Abstract

Worldwide the construction industry is still dominated by men and the issue of gender equity in construction has been the subject of many studies. However, the struggle for gender equality and women's empowerment is central to transformation in the South African construction industry. Despite the increase in the number of women being employed in the construction industry, they still constitute a very small percentage of the industry's workforce which is less than 10%. The primary aim of the study reported on is to determine the status quo and perceptions relative to 'women in construction'.

The following constitute the salient findings: construction is still largely regarded as a male domain; women are not taken seriously as professionals in the construction industry, and society, tradition, organization culture and sexist attitudes play a major role when appointing women in construction. The construction industry should not be male-dominated because it is considered rough and tough, and women should be provided with the opportunity to prove themselves. The study concludes that women are underrepresented in the construction industry and although they may face many challenges and barriers, women are competent to rightfully take up positions in the construction industry. Recommendations include a range of interventions that promote a cultural shift, including the improvement of the overall image of construction.

Keywords: construction, women, challenges, barriers, representation.

1. Introduction

Sang and Powell (2012) contend that the construction industry remains one of the most male dominated sectors as women are under-represented in all construction occupations and professions. This contention is corroborated by Madikizela and Haupt (2010) whose study conducted in South Africa confirmed that most construction firms employed small numbers of women. Pappaya (2007) states that despite having a constitution that entrenches equal rights, discrimination practices, structural inequalities, cultural factors, prejudices, patriarchy and sexism are some of the hindrances that are still rife in the South African construction industry (Pappaya, 2007).

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Given the aforementioned a regional study was conducted among general contractor members of the East Cape Master Builders Association (ECMBA) to determine: perceptions relative to women in construction; perceived competencies and competence of women in construction; challenges faced by women in construction; and representivity of women in construction.

2. Review of the Literature

2.1 Representivity of Women in Construction

Although women account for 41.3% of South Africa's workforce, only 15% are executive managers and just 7% of all directors are women (Pandor, 2005). According to Ozumba and Ozumba (2012), trend analysis suggests that female employment in construction has generally increased, which is attributable to the gender-positive environment in post-apartheid South Africa. However, the rate of increase suggests a very slow improvement.

An increasing number of women are now entering this traditionally male-dominated environment which is not surprising, although the numbers are still minimal when compared with men. The register of the Construction Industry Development Board (cidb) reflects a total of 73 423 construction enterprises of which 48% are owned by women (cidb, 2008). However, 83% of the women-owned enterprises fall within grade one, and a further 12% in grades two and three. Only 5% of all women-owned enterprises registered with the cidb are found in grades four and higher. In fact there are only four women-owned enterprises at grade 8. The study conducted by Madikizela and Haupt (2010) in South Africa confirmed that most construction firms employed small numbers of women, which were mostly employed in secretarial and administrative roles. Where they were employed on construction sites they were typically employed as labourers suggesting that they were regarded as being more suited to administrative than production roles.

Women's increased involvement in the labour force, however, is not paralleled within the management levels of organizations. Women appear to be 'trapped' at middle and junior management roles within organisations (Cross & Linehan, 2006). Hayward (2005) states that while women constitute a fair proportion of the world's work force many women have to experience various challenges from the start in order to achieve success. Furthermore, the world's boardrooms are sadly lacking in women and much has been written over the years about the sexist 'glass ceiling' that hampers women's success beyond a certain point in their career.

2.2 Perceptions Relative to Women in Construction

Since the 19th century women globally have been trying to change how people view them economically, politically, and socially. They have been demanding equality and justice especially in the workplace. Many argue that women's equality has yet to be achieved since the advent of democracy in South Africa in 1994, despite the government's focus on women's empowerment (Naidoo, 2007).

Construction as a career path is still regarded largely as a male domain, and entering this career path is a challenge for most women. Nonetheless, there are women who are active in the entire spectrum of the construction industry, constructing houses, roads, dams, schools, and casinos (Moodley, 2007). During a study conducted by Madikizela and Haupt (2010) professional women strongly agreed with the statement 'I would encourage other young women to pursue a career in construction, because I believe that there is a place and a need for females in the industry'. Women are not taken seriously as professionals in the construction industry. It begins at an early age when girls are not encouraged to pursue technical subjects at school, are taught by mostly male lecturers at college, and continues in the workplace where they are seen as a temporary asset. Women are often paid less than men, are undervalued and regularly not considered for promotion (Fisher, 2002). "The ball is rolling now. We must lift the aspiration of women and encourage them to pursue a career in construction. This issue will not go away. We need to make improvements at all levels." (Fisher, 2002)

Hayward (2005) argues that men who have been developed viewing themselves as superior to women have great difficulty coping with women at management level. However, balanced men will happily accept women in the boardroom and acknowledge that they have worked with men who do accept women on an equal footing.

2.3 Competencies of Women in Construction

A study conducted in South Africa among women participants in construction investigated a range of issues (Moodley, 2012). All respondents agreed that women can build successful careers in construction. However, during a series of workshops conducted in South Africa, Haupt and Fester (2012) determined that most women-owned contractors were not involved in the management functions required to effectively operate construction businesses. They were primarily involved in the planning and organising of resources, and leading the human resources.

Bagilhole, Dainty & Neale (1999) provide an overview within the context of the United Kingdom (UK) and state that most women sought site-based experience in their early career stages; in contrast they tend to seek experience on smaller projects within regionally-based divisional companies. Women felt that smaller projects would allow them to gain a broader range of skills and experience, which would help them to demonstrate their competence to male colleagues who were sceptical of their ability. Women were encouraged by senior male managers to enter supporting roles which tend to be office based. Such positions, which tend to be removed from the production function, were widely acknowledged not to afford as many opportunities for rapid advancement.

Fisher (2002) argues that women have intrinsic values – they are quietly determined, have learnt to read others and understand them, and make good team leaders. Furthermore, women should be recognized for their strong qualities, and society should appreciate the added value women offer. Palomar-Fresnedi in Hayward (2005) says women seem to do well in situations where they need to manage different projects, as that is just in their nature. Guy Mollet in Hayward (2005) maintains women in managerial positions are more

demanding than their male counterparts and tend to be less tolerant of incompetence, because they usually had to fight quite hard to get their job. However, according to Hayward (2005) the glass ceiling is still there, but disappearing in a number of places, and there are definitely some fissures and women now have that confidence to go out and promote themselves knowing that they are able to do the job and to do it well.

In conclusion, Gurjao (2006) says: “Men who have had experience of working with women find they are capable, they fit in well with male colleagues, and they contribute to a quality outcome.”

2.4 Challenges Faced by Women in Construction

A study conducted by Madikizela and Haupt (2010) in South Africa confirmed the gender bias that exists in South African construction. Furthermore, they highlight the male dominant nature of the industry and the gender-based discrimination experienced by women employed in the industry as challenges that need to be overcome if more women are to embark on careers in construction. They also cite the overall poor image of the industry as a further inhibitive factor. They specifically cite the following as medium to high influences on other women choosing careers in industries other than construction: the dangerous nature of construction; challenging work environment; inability to work and influence a male dominated industry; male dominance of the industry; discriminatory work environment, and lack of knowledge of the industry. A further study conducted in South Africa by Moodley (2012) required women respondents to indicate whether they had experienced gender discrimination or harassment. Those that responded ‘yes’ were then required to identify the form. Disrepect (28%) predominated followed closely by limited opportunity for growth (24%), inequality (20%), and treated unfairly (19%). Sexual harassment (9%) was the least identified form.

Menches and Abraham (2007) cite the following as the top five challenges to women participating in construction or barriers to success: slow career progression; difficult work-family balancing act; attitude barriers caused by male dominance; ‘job hopping’ to overcome career barriers of slow advancement, and overtly masculine culture that consists of conflict and aggression. However, the culture of the industry was identified as the single largest contributor to women leaving the construction industry - and women failing to choose construction as a viable career. This is supported by Dainty, Bagilhole, and Neale (2001) who argue that women that join the industry are hence compelled to adapt ‘male values-cum-construction industry values’ for them to survive. Prejudice and bias unfortunately still exist in the work place in terms of performance and salary. Managers sometimes fail women in a role to prove themselves right. Some may go as far as increasing the workload or complexity of the work to ensure failure bearing in mind that even the most experienced men in the same position would not cope (Govender, 2007).

While for men the ‘glass ceiling’ may be just a myth, for many women it is a source of actual frustration and can potentially spell the end of their career unless they can find a way to break through. Why can’t women secure the top jobs? There are several issues. Hayward (2005) argues that there is a huge and widening gulf between the perception of whether

women can successfully take on a management role and their actual talent, ability and skills for doing so. There's also the changing culture of the workplace; the traditionally 'female' skills involving communication and team building are more essential today than they have ever been, which could actually put some traditional male 'macho' men at a disadvantage as their traditional empire crumbles around them.

At the Annual General Meeting of South African Women in Construction (SAWiC), Bici (2002) said: "A milestone does not mean the end of the road. It signifies the end of a stretch and the beginning of another. We are fully aware of the challenges many have to face in order to gain recognition. These obstacles are universal in occurrence and afflict women contractors and women in construction in many parts of the world, including developed countries such as the UK and the USA. Women universally still find it difficult to penetrate and persevere in the male-dominated built environment, including construction." The barriers to women advancement were identified as, inter alia: as arising from the industry's macho image; male-biased construction education courses; selection criteria; recruitment practices; sexist attitudes; male dominated work environment and culture, as well as a general lack of women representation in the industry's many formal structures.

Although Niall Fitzgerald says: "I believe it is increasingly important that women should stop feeling they have to be like men to succeed like men. This is going in the wrong direction." (Hayward, 2005) Fisher (2002) simply says: "Women must seize the opportunities and make things happen."

3. Methodology

The self-administered questionnaire consisted of six sections: general information; perceptions relative to women in construction; competencies of women in construction; challenges faced by women in construction; representivity of women in construction, and general comments. 13 of the 26 questions were five-point Likert scale type questions, and the remaining 13 were a mix of 'Yes' / 'No', and questions pertaining to the responding organisations such as age, type of construction undertaken, and management composition.

109 General contractor (GC) members of the East Cape Master Builders Association (ECMBA) were contacted per telephone and asked whether they would be willing to participate in the survey - 56 responded in the affirmative. Thereafter, a covering letter and questionnaire addressed to the 'Manager' of each of the 56 GCs was forwarded per post, with the exception of 4 GCs who requested that the survey be had delivered and retrieved by the researcher. Despite the attempt to optimise the response rate by personally contacting the GCs, and assuring respondents that the data provided would be treated with confidentiality and anonymity, only 11 responses were received from the 56 GCs that indicated they were willing to participate, which equates to a response rate of 19.6%.

4. Findings

4.1 Demographic

All the respondents were male. More than half of the respondents' organisations employed > 12 < 35 employees, whereas the minority indicated ≤ 12 employees. Only one respondent indicated 100 employees. However, the organization specialises in major building work, and has been in business for over 20 years.

Less than half of the respondents indicated their organisations employed > 1 < 4 women. The majority of respondents indicated that their organisations employed no women. However, one respondent indicated that their organisation employed more than 15 women.

Less than half of the respondents indicated that their organizations employed women in management positions, which varies between > 1 < 4 women. More than half of the respondents indicated that their organizations have no women in management positions.

4.2 Perceptions relative to women in construction

81.8% of respondents indicated that construction is still regarded largely as a male domain, which concurs with the contention of Moodley (2006). 54.6% of the respondents indicated that women are not taken seriously as professionals in construction, and 36.4% differed. This finding aligns with the findings reported by Fisher (2002). Respondents were required to indicate the extent to which four factors affected the appointment of women in leadership positions. Based upon mean scores (MSs) between 1 (minor) and 5 (major), society (4.00) was ranked first, followed by tradition (3.80), organisation culture (3.70), and sexist attitudes (3.60). 72.7% of respondents do not believe that construction should be male-dominated because it is 'rough and tough'. Given the response, it can be deemed that women should be given a chance in the construction industry even though it is considered 'rough and tough'. This finding concurs with that of Green (2006).

The MS of 3.27 between 1 (minor) and 5 (major), indicates that respondents subscribe more to a major than a minor extent, albeit it marginally, to the contention that women in managerial positions are more demanding than their male counterparts.

90.9% of respondents believe that women have the confidence to pursue and motivate themselves in the construction industry knowing that they are able to do the job, and do it well - there were no negative responses. This finding corroborates with the contention of Hayward (2005), who concludes that the 'glass ceiling' is still there, but disappearing in a number of places, as there are definitely some fissures and women now have the confidence to go out and promote themselves knowing that they are able to do the job, and to do it well.

4.3 Competencies and competence of women

Respondents were required to indicate the extent to which six factors affect the core competencies of women in construction. The MSs between 1 (minor) and 5 (major) indicate that they have more of a major than a minor effect: commitment (3.73); dedication (3.73); responsibility (3.73); acknowledgement (3.64); confidence (3.64), and self-promotion (3.28).

81.8% of respondents indicated that women are prepared to work harder in order to be successful if given a chance to prove themselves. Hayward's (2005) conclusion that in today's society women are increasingly making conscious decisions about their lives and taking responsibility for their actions, amplifies the importance of these factors, and validates the aforementioned 81.1% affirmative response.

The MS of 2.45 between 1 (strongly disagree) and 5 (strongly agree), indicates that respondents do not agree with the contention that women cannot secure top jobs or successfully assume management roles due to factors such as actual talent, ability, and skills. 72.7% of respondents believe that women seem to do well in situations where they need to manage different projects all at once. Furthermore, the MS of 3.27 indicates that respondents agree, as opposed to disagree with the contention that woman can succeed in construction using their female skills without having to adopt a masculine approach.

4.4 Challenges faced by women in construction

Respondents were required to indicate the extent to which they agree with the contention that the power men assume over women makes them feel they can label women negatively. Based upon the MS 2.91 between 1 (strongly disagree) and 5 (strongly agree), the response indicates disagreement as opposed to agreement with the contention, albeit marginally so. This finding does not quite concur with that of Mackenzie (1992), namely that sexism occurs when people are prejudiced against others because of their gender.

Construction being regarded as male terrain is frequently regarded as a 'barrier to entry' by women and men. However, the response and subsequent 3.09 MS between 1 (strongly disagree) and 5 (strongly agree) relative to the question 'To what extent do you subscribe to the contention that to participate in construction takes great courage mainly because it is regarded as male terrain?', indicates marginal agreement. This question was followed by 'To what extent do you agree that women have to face many challenges in order to get recognition which makes it difficult to penetrate and persevere in the male-dominated construction environment?' The 3.55 MS indicates greater concurrence than in the case of the former question. 81.8% of respondents believe that women have made great strides in construction, but that the 'glass ceiling' is far from being shattered. This finding concurs with that of Hayward (2005), namely that while current chief executives and chairmen remain those that perpetrate the 'old school' views, it will for a time remain harder for women than men to break through the glass ceiling.

Respondents were required to indicate the extent to which five factors constituted barriers to the advancement of women in construction on a scale of 1 (minor) to 5 (major). Male dominated work environment and culture was ranked first (3.55), followed by women representation in the industry's formal structures (3.36), male-biased construction education courses (3.18), construction's macho image (2.91), and sexist attitudes (2.73). It is notable that the first three (60%) are perceived to constitute barriers to a major extent and the last two (40%), a minor extent. These factors were identified as barriers to women advancement by Bici (2005).

The MS of 3.82 indicates that respondents agree to a major, as opposed to a minor extent with the contention that it is increasingly important that women cease thinking that they have to be similar to men in order to succeed as men do. This finding concurs with the statement made by Niall Fitzgerald: “I believe it is increasingly important that women should stop feeling they have to be like men to succeed like men. This is going in the wrong direction.” (Hayward, 2005) However, the MS of 3.82 between 1 (strongly disagree) and 5 (strongly agree), indicates that there is agreement as opposed to disagreement with the statement ‘When it comes to succeeding in construction, the competition is tough especially when you are competing against your male-counterparts’.

4.5 Representivity of women in construction

Respondents were required to indicate the degree of concentration of women in unskilled, low-skilled, low paid jobs. Based upon the MS of 3.18 between 1 (rarely) and 5 (mostly), the degree of concentration can be deemed to be slightly more than moderate, as opposed to mostly. Furthermore, all the respondents agree that despite the increase in the number of women being employed in the construction industry, they still constitute only a very small percentage of the industry’s workforce. With respect to board level, the MS 3.91 between 1 (strongly disagree) and 5 (strongly agree), indicates that there is agreement, as opposed to disagreement with the statement ‘The construction industry’s boardrooms are sadly lacking in women’.

5. Conclusions

It can be concluded that construction is still largely regarded as a male domain and that women are not taken seriously as professionals in construction. Society, tradition, organization culture, and sexist attitudes play a major role when appointing women in leadership positions. Construction should not be male dominated because it is considered rough and tough, and women should be given a chance to prove themselves in the construction industry.

There is a clear indication that commitment, dedication, acknowledgement, responsibility, confidence, and self-promotion have an impact on the core competencies of women in construction. Women are prepared to work harder in order to be successful if given a chance to prove themselves. Women are perceived to do well in situations where they need to manage different projects all at once. Women in managerial positions are perceived as more demanding than their male counterparts. Women have the confidence to pursue and motivate themselves in the construction industry knowing that they can do the job and complete it successfully.

To participate in construction takes great courage mainly because it is regarded as male terrain. Women have to face many challenges in order to gain recognition in the construction industry, which makes it difficult to penetrate and persevere in the male dominated environment. Women can succeed in construction using their female skills without having to adopt a masculine approach. Women have made great strides in construction, but the ‘glass ceiling’ is far from being completely shattered. Women’s representation in the construction

industry's formal structure ranked first among the factors that constitute barriers to advancement of women in construction, followed by male dominated work environment and culture. It is increasingly important that women cease thinking that they have to be similar to men in order to succeed as men do.

Despite the increase in the number of women being employed in the construction industry, they still constitute only a small percentage of the industry's workforce. Relative to succeeding in construction, the competition is tough especially when competing against male counterparts. It can be deemed that the construction industry's boardrooms are sadly lacking women in managerial as well as chief executive posts in the construction industry.

6. Recommendations

The recommendations are aimed at realising a change in the industry culture. Initiatives aimed at the management of culture have been shown to be more successful when they are integrated into packages of change initiatives. The range of equality measures should comprise a mix of gender-specific initiatives aimed at improving women's careers in construction, and at addressing the barriers to women pursuing a career in construction. If women are to participate optimally in the construction industry, strategies aimed at mainstreaming women into construction need to be embarked upon.

Appropriate steps should be taken to create a more equitable work environment through the development of cultural change within construction organisations. It is only through a genuine commitment to the development of a more equitable industry from the highest level, that women are likely to be able to develop their careers in parity with men. However, if more women can be retained in this way, then this may in turn lead to a further increase in the number of women entering construction as those obtaining management positions provide role models for future entrants. The main implication for organisations in the construction industry is that they need to improve the industry's image if they are to attract women graduates. Organisations need to provide mentors for undergraduates and young graduates entering the construction industry. The mentors should ideally be women who would also act as role models to women entering the industry, although male mentors would help reduce some of the stereotypes of management through increased interaction with women recruits.

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BIM: Rules of Engagement

David Mitchell[1], Scott Lambert[2]

BIM: Rules of Engagement

There are challenges within the collaborative process of Building Information Modelling (BIM). BIM creates the need to consider liability exposures, ownership issues and protection of intellectual property. The authors contend that the right contractual framework is fundamental to fostering and promoting this innovation. An Australian-first, a draft BIM-friendly clause bank is discussed to ensure consistent, agreed to rules of engagement, including its application in the Australian building context. The authors' experience and learnings will have applicability to those seeking collaborative processes for BIM.

Keywords: BIM, collaboration, challenges, clause

1. Introduction

BIM is a process that involves the generation and management of digital representations of physical and functional characteristics. The building information models that are developed become shared knowledge resources to support decision-making, from cradle to grave – that is, from earliest conceptual stages, to design and construction, operation and eventual cessation.

BIM does away with old ways of design where upfront architectural work is traditionally done with little input from other project participants (for example, engineers, contractors and facilities managers). A key strength of BIM is the ability to bring all parties together early in the project and provide a virtual 'design' forum to connect them and enable a review of simulations. A further strength is the ability to ask questions, share information and raise issues for collective resolution.

It is the focus on collaboration in the early stages of a project that sets BIM apart. Everyone is 'on the same page' with increased data sharing between the design and the construction participants and the facilities managers.

Understanding and incorporating the 'Rules of Engagement' is essential to seeking agreement and implementing BIM. Information exchange is core to this understanding as it is when information is exchanged that barriers typically start to appear and impede contractual arrangements.

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1.1 What's happening here and elsewhere?

In the United States, the American Institute of Architects (AIA) recently released for comment a suite of draft contractual documentation 'Digital Practice Documents' which aim to facilitate the use of BIMs in projects (cited in Chen 2012). AIA have outlined several legal issues related to BIMs, including identifying the scope of work and determining participant responsibilities for managing digital data and the BIM model (Chen, 2012).

In the United Kingdom the government is focused on addressing the impacts on contractual obligations and protection of the design and data. The government has mandated the use of Level 2 BIM for all projects commencing from Summer 2012, aiming for fully collaborative BIM by 2016. The Royal Institute of British Architects (RIBA) published the BIM Overlay to provide straightforward guidance on each RIBA work stage to successfully design and manage construction projects in a BIM environment (Cost Solutions, 2012).

The Australian Institute of Architects (2010) recognised and reported on a significant challenge for BIM, namely the lack of a documentation framework to underpin contracts where BIM is used.

In July 2012, the Australian Government's Built Environment Industry Innovation Council advisory body outlined the productivity and environmental benefits of BIM within the built environment (Department of Industry Innovation Science, Research and Tertiary Education, 2012).

With this background in mind, the authors report on their professional experience in implementing BIM and, in doing so, make an important contribution to addressing some of the issues raised above.

2. Identifying and meeting the challenges to establish the Rules of Engagement

2.1 Overview of the Australian design industry today

BIM is not widely used in Australia, at least in a formal structural way to maximise its benefits.

At present the Australian design industry has strong dynamic skills and a comprehensive understanding of the mechanisations of 3D modelling and its parametric benefits. The tricky part comes when people start to explore the exchange of information and barriers start to emerge. These barriers are contractual, rather than technical in nature, revolving around liability, risk and protection of data and intellectual property.

For example, in the quantity surveying space, the authors have added dynamic links to the BIM to allow accurate quantity take-off and estimating, but the information is not passed down the line. The missed opportunity to be capitalised upon is a trusted common set of common quantities that can be easily interrogated by each party as they are visual.

2.2 Key challenges

Three key challenges have been identified.

- Challenge one: People display a degree of hesitancy in implementing BIM on a project because they view the project at its most complex.
- Challenge two: People express liability concerns such as who bares the risk, who controls the design and who owns the BIM. While a company may want to use a BIM, no contract may be in place that allows them to utilise it with security.
- Challenge three: Not many are asking for BIM projects.

2.3 Responses to challenges

Experience highlights achievable solutions to these challenges.

- Challenge one response:
    - Working with BIM on a project is quite achievable.
- Challenge two response:
    - BIM manager helps to reduce liability: As the different companies involved have records of when information is sent to BIM manager, responsibility for an inaccurate model rests elsewhere.
    - Establish a contractual strategy: Provide clauses within the contract to encourage collaborative work arrangements, and provide protection for project participants.
    - Develop a BIM Execution Plan (BEP): This will include the phase of the project the BIM applies to, the level of detail being sought, and the desired level of collaboration between the different fields. A ‘risk cube’ is a useful tool in this context.
- Challenge three response:
    - The client shouldn’t have to ask for a BIM, it should be expected. All stakeholders (clients, designers and builders) must work together to demonstrate the full value of BIM.
    - Ensure contractors can readily demonstrate the value of the BIM in each phase and be confidently proactive.
    - Have fully coordinated designs to resolve issues early in the building process as this saves time and money, and is much more efficient.

3. Rules of engagement

Based on the identification of the challenges and responses above, a framework for use of BIM in the design process was developed. It focuses on a useful tool - a ‘BIM Clause Bank’ - to enable consultants to confidently manage a contractual framework, promote BIM, facilitate the use of coordinated design, protect intellectual property rights and assist with dispute resolution.

The BIM Clause Bank will help address issues associated with current contract documentation in Australia developed for traditional delivery structures. These include Design and Construct (D&C), Design Build Operate Manage (DBOM) and Early Contractor Involvement/Engineering Procurement Construction (ECI/EPC), all of which are not easily used to foster collaborative teamwork which is essential to BIM.

A BIM clause bank set out to implement the Rules of Engagement assists users with the basic clauses that will facilitate the use of BIM in more common scenarios of the traditional contracting environment.

The clauses have to cover the basic permissions and risk allocations without adopting the no fault/no claim ethos of alliance contracting

The key areas that require coverage are:

- Who is controlling/responsible for the model and its development
- Liability for design input and use of the model
- How is the collaboration and model development to occur

These issues are not unfamiliar when there is design coordination. The development of energy/environmental rated buildings has seen many similar issues and clauses which can be drawn upon to manage BIM issues.

4. Conclusion

The authors contend that the prospects for BIM implementation in the design industry in Australia and elsewhere are good, and the challenges and risks can be readily overcome by using a ‘Rules of Engagement’ approach supported by the ‘BIM Clause Bank’. Having the right tools to facilitate collaboration and gain permission to share information is sure to be beneficial to building contracts.

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Analysing Stakeholder-associated Risks in Green Buildings: A Social Network Analysis Method

Rebecca J. Yang[1], Patrick X.W. Zou[2] and Byron Keating[3]

Abstract

In the research of risk associated with developing energy and water efficient green buildings, previous studies had mainly focused on "what the risks are and how the risks may impact on project objectives", which were from an inward looking self-perspective and treated the risks in isolation from one another. While intensive research efforts have been dedicated to risk identification, assessment, classification, prioritisation and mitigation, a research gap exists, that is previous studies had ignored the fact that most risks are interrelated and associated with internal or external project stakeholders. To remedy the gap, this current research developed and presented a SNA (Social Network Analysis) based stakeholder-associated risk analysis method to assess risks in green buildings and the interactions between the risks. A case study has been conducted to demonstrate and validate this method. This research contributes to the development of a new theory to model the interdependent and interactive relationships of risks by using SNA as a methodology. This research should broaden project managers' awareness of the influential risks in green building and enhance their ability to perceive, understand, assess, and mitigate the risks in an effective and efficient way; thereby achieving higher performance in strategic risk management and stakeholder communication in green building development.

Keywords: Green building, Risk analysis, Stakeholder relationship, Social Network Analysis

1. Introduction and Research Aims

Industrial ecology urges industries and organizations to apply ecological theory to "industrial systems or the ecological restructuring of industry" (Rejeski, 1997). Practitioners in the construction industry are also making great efforts on the development of green buildings in order to maximise the construction ecology concept. Similar with the other industries, the implementation of construction ecology encounters the same, if not more, risks and barriers due to the traditional conservative and reactive behaviour of parties/stakeholders in the building environment (Bullen and Love, 2010), and the transient relationship of project teams and stakeholders (Larsson and Cole, 2001).

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Many previous studies have focused on identifying and assessing the risks and barriers regarding various green building development issues. A review of these risks will be presented in the following section. By examining the risks identified in the previous studies, most of, if not all, them are associated with one or several stakeholder(s). As Prum and Del Percio (2009) stated that, risk sources should be analysed and each stakeholder in a green building project needs to assess its risks and take measures to mitigate the possible damages by risk eventuation.

Although previous studies have been conducted to analyse green-related risks and stakeholders, the majority limited themselves to a linear impact analysis which was to assess the impact of risks or stakeholders on green building development without consideration of the association of risks and stakeholders, and the interdependency of risks/stakeholders. The reality is that most green-related risks are associated with different players (i.e. stakeholders) in the construction industry (Cole, 2011) and risk source analysis is an indispensable component in risk management plan/register (PMI, 2010) to facilitate the risk response and mitigation actions. Nevertheless, in green building research, limited effort has been conducted to demystify the risk interrelationship. Discussion about stakeholder interdependency is not a recent topic. However, in green building development, questions imperative to be answered are “who associates with whom and in what ways do these stakeholders depend on each other” for green-related decisions (Van Bueren and Priemus, 2002). The aforementioned studies formed different paradigms regarding risk and stakeholder analysis in green building development.

The aim of this research is to develop a method for analysing the stakeholder-associated risks in green building development from a network perspective. It is in this context, that SNA (Social Network Analysis) based method is used. To demonstrate the application and validation of the proposed method, a real green building project case is studied. It is anticipated that the research outcomes presented here provides an innovative risk and stakeholder analysis method for researchers and practitioners to manipulate and simulate the green reality.

2. Literature Review

2.1 Risks in Green Building Development

Studies on the risks, barriers and critical factors in delivering sustainable building development are aspiring in recent years. Both researchers and practitioners accept the fact that green building development is more complex and problematic because the construction industry is “extremely conservative, and subject to slow rates of change due to regulatory, liability and limited technology transfer from other sectors of society” (Kibert et al., 2000). Therefore, the understanding of barriers in sustainable building project development is critical for industry players to proactively analyse risks, thresholds and develop strategies. Table 1 summarises the risks/barriers identified in previous studies.

The risk identification presented in the current literature usually classify risks into different categories, such as financial, political, and technical risks (Tiong, 1990); internal and

external risks (Yeo, 1990); elemental and global risks (Walker and Smith, 1995); general/country and specific project risks (UNIDO, 1996), technical, commercial, political and regulatory, and economic and financial risks (Medda, 2007), and time, cost, quality, safety, and environment risks (Zou et al., 2007) as well as supply chain risk (Zou and Couani, 2012).

Table 1: Risks/Barriers identified in previous studies

Authors	Barriers/risks	Related stakeholders	Risk category
Hoffman and Henn (2009)	Egocentrism	General stakeholder	Ethics/ reputation
	Internal structure and interaction	General stakeholder	Organization / Management
	Rewards	General stakeholder	Ethics/ reputation
	Organizational inertia	General stakeholder	Organization / Management
	Language and terminology	Government/Professional association	Policy/ standards
Shi et al. (2013); Lam et al. (2009)	Additional costs caused by green construction	Client	Cost
	Incremental time caused by green construction	Client	Time
	Reduction of structure aesthetic	Consultant	Quality
	Uncertainty in the performance of green materials and equipment	Supplier/subcontractor	Quality
	Imperfect green technological specifications	Government	Policy/standards
	Misunderstanding of green technological operations	Contractor/Supplier/ subcontractor	Quality
	Restrictions of new green production and technology	Government	Policy
	Regional ambiguities in the green concept	General stakeholder	Organization / Management
	Conflicts in benefits with competitors	General stakeholder	Organization / Management
	Dependence on promotion by government	Government	Policy
	Lack of support from senior management	General stakeholder	Organization / Management
	Limited availability of green suppliers and information	General stakeholder	Organization / Management
	Lack of quantitative evaluation tools for green performance	Government/Professional association	Policy
	Additional responsibility for construction maintenance	User	Quality
Love et al. (2012)	Clients' knowledge and willingness	Client	Organization / Management
	Communication and relationship among the participants due to the temporary nature of construction projects	General stakeholder	Other
	Regulations / standards	Government	Policy
	Organizational resources	Client	Organization / Management

Although there is no standard classification of risks, in this paper, we tried to group the risks into different categories, as shown in Table 1, mainly because the category names can assist industry practitioners to identify risks in the proposed SNA based method. The identified risk categories include: time (risks related to time management), cost (risks related to cost management), quality (risks related to the product quality), organization/management

(risks related to organizational structure, knowledge, and relationship management), policy/standards (risks related to regulations and standards), safety (risks related to occupational health and safety), ethics/reputation (risks related to social and ethical issues), and environment (risks related to environment protection). It should be noted that the categorisation here is not to exhaust the risk groups, but rather to facilitate the researchers and practitioners' thinking for risk identification.

Another notable point about Table 1 is that most risks identified are associated with different stakeholders (Refer to the third column of Table 1). To mitigate the risks, it is important to indicate the risk sources. However, the difficulties of using the risks listed in Table 1 to track the risk sources are that: (1) many risks are too general and related to different stakeholder organizations. This increased the difficulties for practitioners to develop risk response strategies; (2) the stakeholder groups used by previous studies were not comprehensive, which means that many risks associated with external project stakeholders (except government bodies) were not identified. Stakeholders in the construction industry are far more than those being identified in the table. External stakeholders, such as competitors, Non-Government Organizations (NGOs), media and communities, can also cause problems (hence risks) to green building development (Cronin et al., 2011). Therefore, it is worthwhile to review the stakeholder groups in the construction industry in order to help practitioners and researchers to identify the possible risk sources. This will be conducted in the next section.

2.2 Stakeholders in Green Building Development

Buildings, particularly green buildings, not only affect their immediate users but also impact on a broad range of other stakeholders (Robichaud and Anantatmula, 2011). Several scholars have developed green-related stakeholder lists for possible use in practice. Rivera-Camino (2006) proposed four stakeholder groups in the green project market, where Group 1 includes end user, competitors, distributors and suppliers, who have greatest impact in determining the success of the project. The feedback of end users can highly impact on the client reputation for good or bad environmental management. Qualified suppliers' involvement can positively influence the performance of environmental products (Pujari et al., 2003). Collaborations with distributors will increase the credibility of a firm's actions. Competitors create competitive threats in the green market. Group 2 includes the press and media, environmental organizations, and the local population. As Clarkson (1995) stated, these stakeholders can affect the project reputation by "mobilizing public opinion for or against" the project performance". Group 3 is the "providers of critical inputs" (Rivera-Camino, 2006), which include clients, financial organizations, labour unions and professional institutions/associations. Group 4 and also the last group is governments at different levels, who are responsible for publishing regulations and voluntary agreements. This classification is comprehensive as it identified most of the external stakeholders in green building development.

Similarly, Lorenz and Lutzkendorf (2008) focused on external green-related stakeholder identification. Several groups are added to Rivera-Camino's list, such as insurers who can grant better insurance conditions for sustainable buildings, assessors/certifiers who assess

the sustainability performance of buildings, and researchers/educators who can study and spread the knowledge on sustainable buildings. Theaker and Cole (2001) and Henry and Paris (2009) concentrated on the role of government in fostering green building. Qi et al. (2010) and Cronin et al. (2011) also developed stakeholder lists in green development. Although they used different terms (for example society and community are used to refer to the public and environmental NGOs), the stakeholder groups are basically the same with Rivera-Camino (2006). Although scholars have started to examine external stakeholders, majority studies still emphasized on internal stakeholder analysis (see for example, Van Bueren and Priemus, 2002; Riley et al., 2003; Dammann and Ellet, 2006; and Prum and Del Percio, 2009).

Based on the review of current literature, a stakeholder group list is developed for the use in the SNA-based method proposed in this research. This list includes client, consultant, contractor, subcontractor/supplier, end user, financial organisation, government, environmental organisation, professional association, media, public, labour unions, assessors/certifiers, researchers/educators, and others. Similar with the risk categories, the stakeholder list is only to assist researchers and practitioners to identify stakeholders. In practice, new categories can be added and some organisations may be recognised in multiple-groups.

3. Research and Analytical Methods

3.1 Social Network Analysis Method

Social network is a specific set of linkages among a defined set of nodes, with the additional property that the characteristics of these linkages as a whole may be used to interpret the impact of each node in the network (Mitchell, 1969). The social network theory views a green building project as a system environment, which is joined by various relationships. In the green building project system, stakeholders and risks are connected by anfractuous lines, which represent the relationships among them. The purpose of network analysis is to examine how relationship structures impact on behaviours, and this theory is concerned with the “structure and patterning” of these relationships and seeks to identify both their causes and effects (Scott, 2000).

The network perspective differs in fundamental ways from standard social and behavioural science research and methods (Scott, 2000). Rather than focusing on risks’/stakeholders’ attributes, the social network views characteristics and interdependencies of risks/stakeholders as arising out of the social structural environment in order to better understand the decision-making process. The application of the social network perspective to stakeholder and risk analyses the patterns of stakeholder-associated risk networks which emerge in response to the project missions over time, investigating the forces which shape these patterns, and unlocking risk interactions inside the whole relationship network, all of which are intended to provide a rationale for stakeholder communication and risk response strategies, and facilitate the decision-making process.

3.2 Processes of SNA Method

The general steps of SNA include: (1) identifying the boundary of the network; (2) assessing meaningful and actionable relationships; (3) visualising the network; (4) analysing the network data; and (5) presenting the analysis results (Wasserman and Faust, 1994; Scott, 2000; Cross and Parker, 2004). The method proposed in this paper will follow this general process, which include:

1. Developing a complete list of risks and identify their associated stakeholders in green building development. The stakeholder groups identified in previous sections are used to facilitate stakeholder identification process. Questionnaire survey will be used to identify green-related risks and their associated stakeholders. The risk categories proposed in previous section are used. The outcomes of this stage are a complete list of stakeholders, and risks associated with them. At this stage, the nodes in the risk network can be identified.
2. Interpreting the impacts and likelihoods of stakeholder-associated risks on each other and define the links in the risk network. Interview and workshops were used to obtain consensus of risks interrelationship, impacts and likelihoods on each other. The outcomes will be the defined links in the risk network.
3. Visualising and analysing the stakeholder-associated risk network. Since the nodes and links are identified, a risk network for green building projects can be developed. A conceptual network is shown in Figure 1 (where *R* means risk and *S* means stakeholder). The links in the network are the interrelations among the risks, of which the thicknesses of the lines mean the influence degrees (impact * likelihoods) of the interrelations. Based on the risk network, SNA method can be used to identify critical risks and the ways to mitigate them by communicating with associated stakeholders. Various software packages can be used for visualising and analysing the relationship networks, including UCINET, NetMiner, NetDraw, Pajek. Two methods are useful for risk network analysis: (1) *Centrality*: A key measure that reflects the distribution of relationships through the network; and (2) *Brokerage*: A measure to classify risks into: coordinators (who broker connections within the same group); representatives and gatekeepers (who broker connections between their own group and another), and liaisons (who broker connections between two different groups).

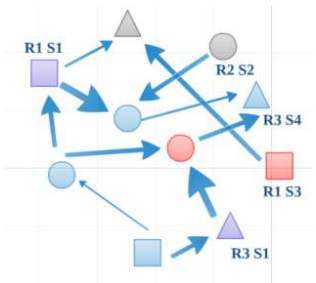


Figure 1: A conceptual stakeholder-associated risk network (Yang et al., 2011)

4. Case Study and Results

4.1 Project Summary

Due to the expansion of a university, additional office space was required. The FF Building (FF is an anonymous name for confidential considerations), three storeys, contract sum over AU$10 million, was constructed using World Leading practises as required by the Green Building Council of Australia to target 6 Stars in both As Design and As Built. The FF Building project presented considerable difficulties to the project team, requiring the adoption of a relationship based collaborative approach to management and project delivery.

4.2 Case Data Collection and Analytical Results

The data was collected through surveys with key project participants together with desktop-studies on the project information provided by the design-and-construct head contractor. The key information obtained includes: project scope, cost, time; the stakeholders in the project; the risks related to each stakeholder; the interdependencies among the risks. In total, 127 risks associated with 20 stakeholders were identified, and a risk interrelation matrix was developed. The data gathered from the survey was analysed by a SNA tool NetMiner (Cyram, 2009). Figure 2 shows the stakeholder associated risk network in this project. To estimate the degree of risk impact, the status centrality concept was used as this considers every connection (even up to infinite length connections) between each node in Figure 2 (Cyram, 2009). If a node has many connections, it may have a large centrality score. As the length of a connection increases, however, influence attenuates exponentially (attenuation factor was 0.5 in this study). Due to the space limitation, only the top 10 risks and their status centrality scores are listed in Tables 2 and 3. The status centrality map, including all risks, is shown in Figure 3. The in-status centrality indicates the extent to which a risk is affected by others; whereas, out-status centrality indicates the extent to which a risk can affect the others (Katz, 1953). Regarding the influence of a risk, the out-status centrality is used as the outcome measure. The higher the out-status centrality values, the greater the impact of the risk. In this analysis, the most significant risk is S5R19 “Reputation affected if Greenstar not achieved”, which is associated to the head contractor. In Figure 3, the risk impacts decrease along with the distance between the risk (node) and the central of the circle. Figure 3 (a) shows the risk locations in the status centrality circle with different shapes to demonstrate the stakeholder groups; while Figure 3(b) shows the locations with shapes to demonstrate the risk categories.

Some interesting findings were identified from Figure 3. As shown in Figure 3(a), the risks related to internal stakeholders, such as client, head contractor, consultant and end user, were located relatively in the central. This indicated higher influence of internal stakeholders in the green building development process. The role of government was not as important as expected by the project team. This finding was also similar to that found in Henry and Paris’s study (2009) where they considered that the change of policies and standards were not sufficient to break down the numerous barriers in sustainable constriction. In Figure 3(b), the ethic/reputation risks related to different stakeholder groups seem to be more significant comparing to other risk categories. This finding is different with the facts in non-green

building project in which the cost, time and quality (triple bottom line) related risks are considered as more important. The significance of ethic/reputation related risks in green building highlighted the change of construction practitioners' behaviours and attitudes within the framework of industrial ecology.

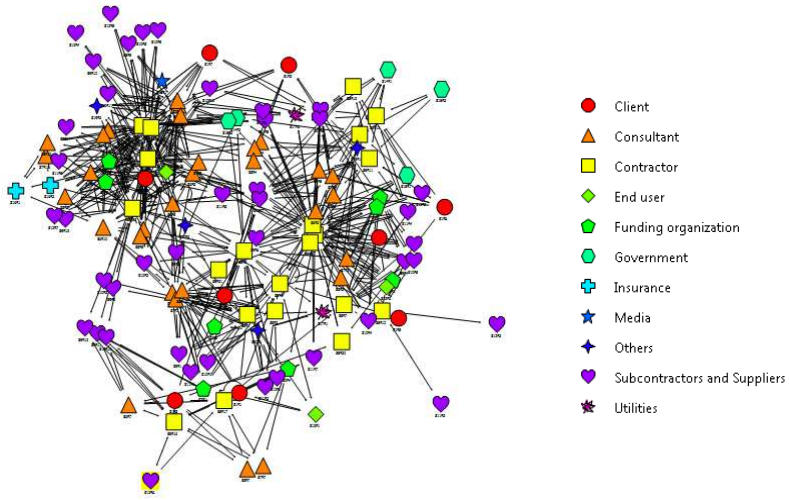


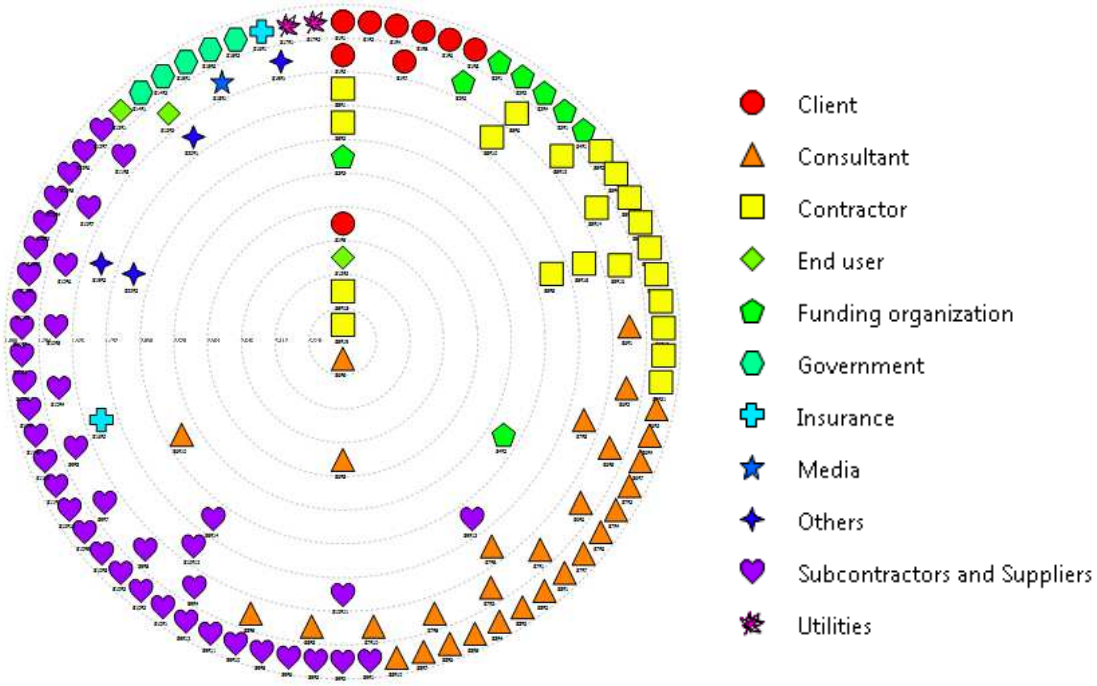
Figure 2: Stakeholder-associated green risks in the case project

Table 2: Top 10 risks in the case project

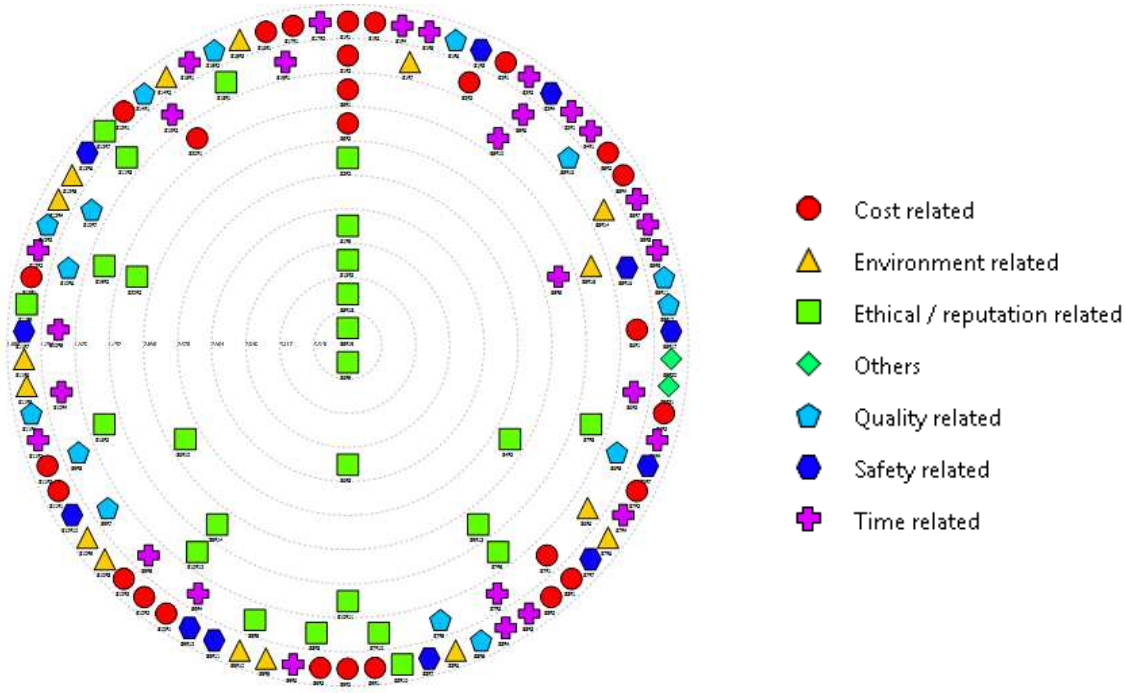
	Risk description	Stakeholder category	Risk category
S1R9	Reputation affected if Greenstar not achieved	Client	Ethical / reputation
S3R2	Reputation affected if Greenstar not achieved	Funding organization	Ethical / reputation
S4R2	Reputation affected if Greenstar not achieved	Funding organization	Ethical / reputation
S5R5	Responsible to ensure project is delivered on time	Contractor	Time
S5R18	Non performance affects repeat business opportunity	Contractor	Ethical / reputation
S5R19	Reputation affected if Greenstar not achieved	Contractor	Ethical / reputation
S6R8	Reputation affected if Greenstar not achieved	Consultant	Ethical / reputation
S6R9	Non-performance affects repeat business opportunity	Consultant	Ethical / reputation
S6R10	PI insurance risk on non performance	Consultant	Ethical / reputation
S13R3	Significant reputation risk if greenstar not achieved, though little responsibility	End user	Ethical / reputation

Table 3: The status centrality scores of the top 10 risks

Risk ID	In-Status Centrality	Out-Status Centrality
S5R19	2.145413	**3.63997**
S6R9	1.55115	**3.604947**
S5R18	2.172007	**3.281075**
S13R3	1.393447	**2.927108**
S6R8	1.55115	**2.822252**
S1R9	1.833032	**2.697951**
S6R10	1.18535	**2.31679**
S3R2	1.143452	**2.085579**
S4R2	1.052875	**2.070235**
S5R5	2.012313	**2.031348**



(a) Different shapes demonstrating the stakeholder groups



(b) Different shapes demonstrating the risk categories

Figure 3: Risk locations in the status centrality map

5. Conclusion

This paper leverages the collective knowledge of risks and stakeholders in a network to generate better risk management solutions in green building development process. The main outcome in this paper is an innovative and practical stakeholder-associated risk analysis model for green building projects from a social network perspective. The proposed method can improve the effectiveness and accuracy of stakeholder and risk analysis by overcoming the limitations of the traditional linear analysis. A case study was conducted to validate the proposed method. Two important findings from the case study are that: (1) internal stakeholders play more important roles in green building as compared to external stakeholders; and (2) ethical/reputational risks are considered more significant for different stakeholders in green development. Although the findings need to be generalised with more case studies, the outcomes of this study are expected to be of interest to decision-makers from both public and private sectors, who are involved in green building projects.

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Managing Context-Specific Cultural Drivers and Barriers to Sustainable and Resilient Building Systems: Lessons from Tanzania

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Abstract

This identifies obstacles to, and opportunities for advancing high performance building systems using context specific cultural and other factors in the East African country of Tanzania. The authors discuss specific ways through which such factors can impede or facilitate the adoption and use of sustainable and resilient technologies in building systems. The case of sustainable earthen masonry in Tanzania is examined in detail as an example of a sustainable building technology impacted by a variety of technical and cultural factors. In addition to identifying some technical flaws that limit the update of the technology, the authors also identify some socio-cultural nuances. They draw lessons on context-responsive design from Swahili Architecture (a style of building along the eastern and south-eastern coasts of Africa). Selected buildings are analysed as elements within wider socio-technical systems consisting also of knowledge, capital, labor, social practice, and cultural meaning. These cultural factors are embedded in everyday practices and routines, social norms and values, and aesthetic preferences. They are also embedded in a demographic context. Over half the population of Tanzania and East Africa in general is under 20 with large waves of migration to cities and among rural areas are already generating an enormous boom in housing and other construction demand in both rural and urban areas that will continue for the next several decades. Communication is has emerged as a key factor in making earthen masonry more culturally responsive. The paper identifies the potential role of famous people such as celebrities and the social media in popularizing a culture of earthen construction.

Keywords: Sustainability, Green Materials, Social-cultural Factors.

1. Introduction

In the recent years, the sustainable construction movement has greatly influenced the design and construction of the built infrastructure across the globe. There is a growing interest in delivering “high performance building” systems. In 2008, the US building

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enclosure community launched a formal initiative efforts directed at delivering high-performance buildings. This initiative underscored the linkages between energy efficiency, durability and the quality of the indoor environment (Bomberg and Onysko, 2009). A "high-performance building" has been defined by the Energy Policy Act of 2005 (EPA, 2005) as: "a building that integrates and optimizes all major high-performance building attributes, including energy efficiency, durability, life cycle performance, and occupant productivity." The authors seek, through the research described in this paper, to contribute to the realization of this goal through focusing on the potential of using earthen masonry to deploy durable, resilient and sustainable houses for low income communities.

Building materials can be classified rated as best for the environment if they contain the following characteristics: 1) materials made with salvaged, recycled, or agricultural waste content; 2) materials that conserve natural resources; 3) materials that avoid toxic or other emissions; 4) materials that save energy or water; 5) materials that contribute to a safe, healthy, built environment (Lazarus, 2002). There has been a specific concern over greenhouse gases (GHGs) that has resulted in several efforts being directed towards reducing their release into the atmosphere. In Condition 2 of LP Hedelberg's movement, The Natural Step, there is a caution against the use of man-made materials that take a long time to decompose where dioxins are explicitly identified as examples of compounds that will almost never be broken down by nature. Given that building materials are largely inert, key areas of concern from an ecological perspective are ensuring that the manufacturing is done with the least impact and also designing the products for easy disassembly and recycling (Kibert, 2005).

Some construction materials are more problematic than others. Cement-based materials such as concrete blocks, which constitute one of the most widely used materials in the building industry, are not rated favorably against this assessment. In the recent years, there have been significant efforts directed at "greening" the use of cement within the construction industry, through for example, incorporating organic components in the mix. Options that have been explored over the years range from using the organic components as additives to using cement as stabilizer for organic component (earth). The latter is often pursued as a way of addressing structural concerns of using earth as a building material in low cost construction. It is not uncommon for additives such as lime and natural fibers to be included in the mix design for such masonry units.

Buildings erected using earth-based technologies are economical and environmentally friendly because of their use of naturally occurring raw materials. They can also be used to promote energy efficiency through leveraging their thermal mass. This notwithstanding, earth-based technologies are still not as widely used as other conventional construction materials. This paper identifies obstacles to and opportunities for advancing their structural use in the East African country of Tanzania. Like many developing countries, Tanzania is faced with shelter problems both in rural and urban areas. Forty to 70% of the urban population lives in slum and squatter settlements characterized by poor and unhygienic living conditions; overcrowding; inadequate and unsafe water supply; and problems in human waste disposal and sanitary conditions. Although the country is endowed with vast resources of indigenous building materials (BRU WR No 8 1978), the formal housing has persistently

depended on imported construction materials, many of which are not affordable for the majority of the population. The reliance on the less sustainable options suggests that there is a social acceptance issue with respect to green materials and products.

This paper aims to identify obstacles to, and opportunities for advancing high performance building systems. In addition to discussing some of the performance-related technical concerns, the authors also discuss specific ways through which social-cultural factors can impede or facilitate the adoption and use of sustainable and resilient building technologies and systems.

2. Research Approach

The research discussed in this paper is a subset of a larger research program directed at advancing the structural use of earthen masonry. The deployment context for the research focus is the hot and humid Tanzania coast. The initial assessment of the quality of walling elements erected using earth-based bricks was done through an NSF supported International Research Experience for Students program in between May and July, 2008 in Tanzania. The deterioration of the brick walls was very apparent. The main problem was moisture damage. Interviews with the Tanzanian stakeholders identified two possible explanations for the deterioration of earth bricks: poor soil quality and breathability. Some of them indicated that some of the flaws could be attributed to flaws in the brick production process. These three possible causes were investigated through laboratory-based testing.

During subsequent field visits to Tanzania in 2009 the brick production processes and their assembly into a masonry-walling unit. The steps involved in the production of CSEB (compressed stabilized earth bricks) were replicated to investigate the block-production process with a view to identify the critical sub-processes that influences the quality and performance of blocks. These activities were done in collaboration with Tanzania's NHBRA (National Housing Building Research Agency). During this field study, a visual analysis of performance of earthen masonry during the post-occupancy phase was also performed. This was based on a comparative analysis of relatively new earthen masonry structure and older buildings representative of Swahili Architecture. Swahili Architecture is used in this context to refer to a hybrid building system that was prevalent along the East African coast between the 17th and 19th Century. It emerged as a fusion of African, Arabic and Portuguese design and construction techniques

Some of the primary data was also collected during a two-day NSF workshop which was held in Tanzania in July 2009. The workshop provided a forum for sharing best practices in earth-based building technologies and developing a research and development roadmap. Top priority research included optimizing the physio-mechanical properties of earth as a building material and managing socio-cultural impediments. The key findings from the field work and the workshop are discussed in details in the subsequent sections.

3. Key Technical Barriers to the Use of Earthen Masonry

Several operational difficulties were observed when studying the entire compressed brick production process through a series of field visits. These difficulties increase the margin of error as far as compliance the existing engineering guidelines is concerned. During the manual soil extraction process, it is difficult to ensure that material from the top soil, a layer known to be rich in organic matter, does not end up in the final mix. The ground is hard making digging very strenuous especially if the extraction process is done on a hot, sunny day. Inevitably, some top soil material will end up in the brick. In addition to visually observing some root fragments in compressed bricks, the presence of organic matter in the finished masonry units confirmed through lab-based testing. Samples of fabricated bricks were crushed into powder. The smoke released when the powder was burnt was indicative of organic matter being present in the final brick. A lab-based chemical analysis using the EDS-SEM technique validated the initial findings (see Obonyo et al, 2010a for the detailed results).

Some performance-based technical concerns can also be attributed to the rules of thumb methods being used to determine the suitability of the soil. For example, the field test executed on the soil appeared to work adequately as far as ensuring that the soil did not have excessive clay. However, it failed to reveal the other extreme problem – too little clay which ended up emerging as an issue for the selected case study projects. The primary author brought some of the soil to the UF Material Characterization laboratories where detailed characterization of its properties was done using EDS/ SEM analysis (Obonyo et al, 2010b). In general, the clay context should be around 20%. From the primary authors' experience it is possible to produce quality bricks with less than 20% clay content through carefully selecting a suitable stabilizer (see Obonyo et al, 2011). However, then this percentage is too low (less than 10%) it will be difficult to produce bricks attain acceptable strength values. The figures for compression can end being as low as 100psi which would not comply with the stipulations of, for example, the Adobe Specification in the New Mexico Building Code.

There were concerns related to the efficiency and the effectiveness of the stabilization strategy. Within the case study context Portland cement is used to chemically stabilize the soil. A manually operated device is used to mechanically stabilize the soil-cement mixture. The manual process of mixing the soil with the stabilizer resulted in a non-uniform distribution of the binder (Portland cement in this case). The manual device used to exert force on the soil also operated very inefficiently. The first few bricks produced disintegrated during ejection indicating that the mix was not fully compacted. In addition to the physical input force, being too high for the average person to sustain over an 8-hour work day, there is no way of ensuring that the more or less the same force is exerted when producing different brick (see Figure 1). Such factors result in variations in performance that remains a key area of concern for compressed bricks (see Obonyo et al, 2010b). While inspecting the use of compressed bricks during the construction of masonry walling on job site it was observed that many units had visible damage (Figure 2).



Figure 1: Manual compression of blocks and example of damage



Figure 2: Cracking during construction

On a different site, there was also evidence of the onset of efflorescence. Over time bricks in such walls can be expected to decay and mould, something that was observed in some 10-15 year old brick buildings in Dar es Salaam (Figure 3).



a) Efflorescence on a building that is still under construction

b) Rotting and Decay on a 10 to 15 year old building

Figure 3: Efflorescence, decay and mould on Masonry

Because of such problems, there are concerns over the structural adequacy of earthen masonry in conventional buildings. Many of these issues can be address through the use of a robust stabilization strategy. The current practice in low cost construction application integrates both chemincal and mechanizal stabilization. Chemical stabilizers such as cement

and lime are added to the soil prior to compression to improve the physio-mechanical properties of the resulting wall. When the process is optimized, the bricks can attain the set building code requirements (Obonyo, 2011, Obonyo et al 2010a, b). Because soil is highly variable, the mix-design must be tailored to a specific context.

In addition to the technical flaws discussed in this section, the widespread structural use of earthen masonry is also impeded by some socio-cultural nuances. To address these, one must develop strategies that are responsive the local cultural and social context. In the subsequent section, the authors illustrate the opportunities for doing just that through drawing lessons from Swahili Architecture, a style of building along the eastern and south-eastern coasts of Africa.

4. Leveraging on the Cultural and Social Context

As previously indicated, a visual analysis of the older buildings (at least 150 years old) that represent Swahili Architecture was included in the study. Many of these buildings use earthen masonry for their walling element. Investigations based on visual inspection revealed that they have performed better during the post-construction phase in terms of resisting weathering and physical deteriorating. This can be attributed to their designers and builders' concurrent use of several strategies to mitigate against moisture damage, a key threat to durability in the hot and humid East African Coast. Earthen masonry, if left exposed (something observed in some of the new earthen masonry buildings discussed in Section 3) will deteriorate progressively through wind-driven rain erosion. From the building in Figure 5a it is clear that the external surface of the earthen masonry in Swahili Buildings was rendered.

The selected render should be compatible with the substrate otherwise it will peel off exposing the vulnerable earthen material. In the previously cited NSF workshop, some participants proposed the use of a soil-cement based render that can also be painted to enhance its weather resistance (Obonyo et al, 2010b). Generally speaking coatings that incorporate green materials can be expected to perform better in terms of compatibility. However, it is important to note that the use of an organic material-based plaster has some disadvantages. Within the hot and humid context moisture-related deterioration can be expected. Without a robust periodic maintenance strategy, the render can progressively fail (peel of). The selection of the render material should also promote breathability, used here to refer to the ability of the material to breath out any absorbed moisture. Failure to factor in such issues can be expected to result in moisture-related problems including but not limited to blisters, cracking, efflorescence, decay and rotting. Figure 5a depicts an extreme case of the protective render peeling off in an abandoned building.



a) Roof overhang, elevated plinth and lime –based coating

b) Abandoned building with desirable features - similar to the building in Figure 5 (a)

c) Clustering around narrow streets, minimizing exposure to sun & wind-driven rain

Figure 5: Swahili Architecture

Other interesting moisture protection features in the older Swahili buildings include use of elevated plinth to minimize damage through rainwater splashing on the ground the provision of adequate roof hang as depicted in Figures 4(a) & (b). Another desirable strategy was the incorporation of narrow alleys at the street level to reduce weather-related deterioration through direct exposure to wind-drive rain and shrinkage-related cracking as the brittle masonry material is exposed to the sun.

From the field investigations Swahili Architecture, which as previously indicated is a fusion of mainly African, Arabic and Portuguese techniques appears to yield structures that are both functionally appropriate and economical. The emergence of this genre of buildings was strongly coupled to the East African Coastal Culture (Swahili Culture). The Swahili Culture-sensitive approach to design and construct has been superseded by Western approach largely because of material scarcity. In addition to requiring the use of traditional mason (a trade that outside a small group of artisans tied to historic preservation efforts is almost extinct), the Swahili Architecture also use coastal resources that have been over-exploited over the years and are no longer widely available. The authors propose the use of these historic buildings as a reference point for defining earthen masonry construction techniques that are context-sensitive. It addition to addressing some of the technical performance issues from a systemic level, such an approach being more responsive to the local culture is expected to be more acceptable to the beneficiary communities.

This approach requires proponents of earth-based technologies to incorporate culture as playing a pivotal role in the key drivers and barriers to its widespread use. Raymond Williams (1983: 11 - 13) in his book entitled “Culture” points out at least four contested definitions of culture: 1) A developed state of mind (for example, a person of culture or a cultured person); 2) The processes of this development (for example cultural interests, cultural activities); 3) The means of these processes (for example, the arts and humane intellectual works), and; 4) ‘A whole way of life’, ‘a signifying system’ through which a social order is communicated, reproduced, experienced and explored. Although all these four definitions of culture are integral to achieving sustainable earthen masonry, the authors consider notion of an “entire social order” (Williams, 1983) as more encompassing. When perceived as an “entire social order,” culture informs the underlying belief systems,

worldviews, epistemologies and cosmologies that shape international relations and human interaction with the environment, which lies at the heart of sustainability.

The area of culture has grown in salience in global development issues. The significant role played by cultural factors in the uptake and sustained use of innovations previously (fronted as appropriate technologies) is emerging as an area of interest among people doing work in the developing communities. As Nurse (2006) pointed out “Sustainable development is only achievable if there is harmony and alignment between the objectives of cultural diversity and that of social equity, environmental responsibility and economic viability.” Consequently, there have been some efforts directed at elaborating on the notion of culture as the fourth pillar of sustainable development along with the social, economic and environmental dimensions (see Figure 6).

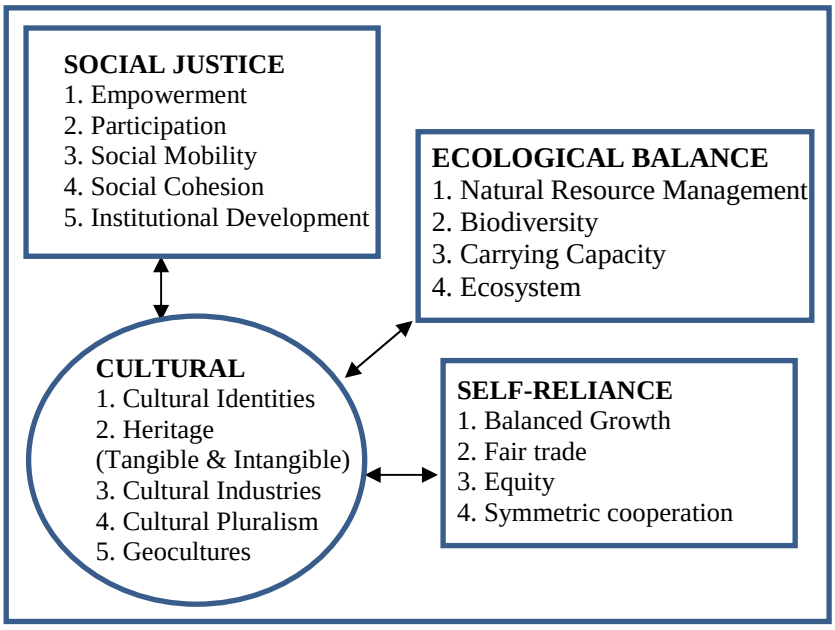

Figure 6: Culture as the Fourth Pillar

The authors operate from the methodological standpoint that “it is the meaning of sustainability in the different contexts to which it is being applied that should be the central concern” (Nurse, 2006 quoting Jacobs, 1994: 241). “Appropriate is not enough” (Frenierre, 2008). Non-conventional approaches required for high performance buildings such as earthen masonry need to be analyzed as elements within wider socio-technical systems consisting also of knowledge, capital, labor, social practice, and cultural meaning (Leach, 1998).

5. Discussion and Further Work

The findings in the preceding section are consistent with problems reported elsewhere. The use of earth-based technologies has been greatly limited by concerns of their physio-mechanical properties. Compressed bricks are also less durable than conventional building materials (Lazarus, 2005, Obonyo et al, 2010a, b). Consequently, there are restrictions on

their use. For example, in the New Mexico Building code Section 12.7.4.23, which governs the use of Compressed Earth Block Construction, a general clause “A” forbids their use in any building more than 2 stories in height.

A significant proportion of the physio-mechanical properties can be enhanced through implementing a robust quality control strategy. Some of the errors triggered by reliance on manual processes can be minimized through the design and development of more efficient and more effective production equipment particularly the device used for compressing the bricks. A hydraulic-operated press should be used where possible as it ensures that the forces exerted on the bricks remains the constant throughout the brick production process. In low cost construction applications, these may not be a feasible option. The primary author has in a separate publication described a prototype that demonstrates that with some improvements, the manually operated compression device can be used to produce better quality bricks (Obonyo et al, 2010b).

Despites these developments in enhancing the structural performance of earthen masonry, field studies done by the authors established that a significant proportion of the targeted end users perceive it as a “cheap” material for poor people. Because of such labeling, there is a social stigma associated with the use of the material. Unless such social-cultural issues are adequately addressed, the progress towards sustainable buildings will remain slow. Factors such as the prevalent view of earthen material as a “cheap” material can impede or facilitate the adoption and use of sustainable and resilient building technologies and systems.

Efforts should be made to educate the general public about the capability and quality of earthen construction. There are some examples of simple and elegant, sustainable earthen structures. However, unless someone is specifically searching for earthen masonry, such examples remain largely invisible to the masses. Prior to Satprem Maini of Auroville earth institute shared examples of such work at the 2009 NSF US-Tanzania earthen masonry workshop (see URL 1), with the exception of the first author (Dr Obonyo), all participants were not familiar with his work. A similar thing happened when Satprem made a presentation at the 2010 NSF earthen masonry workshop held in Colorado in 2010 (see URL 2). The mere fact that access to information even among people working in the areas of sustainable technologies is this limited is indicative of a bigger information dissemination problem that proponents of such technologies need to address. Possible solutions that can be explored include the use of famous people such as celebrities. Such people can play a very critical in shaping a new culture in any society. Specific examples include the extensive media coverage of the green, adobe-style residence Stephen Samuelson designed for Will and Jada Pinkett Smith. Though featured in Architectural Digest (see URL 3), it was cross referenced and broadly disseminated through several other avenues thereby promoting public awareness.

These cultural factors discussed in the preceding section are embedded in everyday practices and routines, social norms and values, and aesthetic preferences (Leach, 1998). They are also embedded in the demographic context. Well over half the population of Tanzania, and East Africa, is under 20. This trend is expected to continue. Large waves of migration to cities and among rural areas are already generating an enormous boom in

housing and other construction demand in both rural and urban areas that will continue for the next several decades. It is very critical therefore for proponents of sustainable and resilient technologies such as earthen masonry to develop a good understanding of what people in this generation are thinking and what is informing their thinking.

Clearly, communication is a key driver of social acceptance. There are some key questions that need to be addressed: 1) At what scale sustainable technologies such as earthen masonry construction being are talked about? 2) What is the role of an indigenous national lingua franca which is Kiswahili in Tanzania in facilitating societal discourse regarding such technologies? Media campaigns targeting the younger segment of the population are beginning to advantage of social media to inform them about sustainable building options. A Google search on low cost housing options revealed a compressed earth brick story posted on one of the Swahili-medium blogs (see URL 4). In follow up research the authors will investigate other specific ways through which such developments can be strategically used to advance the structural use of earthen construction techniques.

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Framework to Appraise the Building Control Systems in the face of Climate Change

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Abstract

The rising concerns about the adverse impacts of climate change demand for energy efficient buildings that timely calls for review of building control regulations. With reference to literatures relating to the regulatory control for energy efficient buildings, this paper identifies core areas that are essential for the reviews of which are common to building control regulations worldwide. The paper attempts to summarize these core areas and its associated information/considerations with a template which provide a solid ground for further research and data collection.

Keywords: building regulations, sustainability, energy efficiency, climate Change

1. Introduction

Building control regulations[3] were once developed to provide protection to the public from safety and health hazards caused by the built environment. Since the oil crisis in 1970s, building control regulations of many countries have been extended or revised to look for energy conservation in buildings. Although there are a variety of regulations governing the energy efficiency of buildings nowadays, the expected saving potential of energy used in buildings are reported not yet realized and the growing pattern of energy used. With the rising concerns about the adverse impacts of climate change, and the need of greenhouse gas emissions reduction, coupling with the social and environmental demands, there are needs for sustainable/green buildings and its associated energy efficiency control regulations to be improved (Chan & Yung 2004). These necessitate timely review of the building control regulations. This paper identifies core areas of building control regulations that govern energy efficiency of buildings, and that are essential to timely review and improvement of these regulations.

2. Buildings, Climate Change and Building Control Regulations

Building development offers substantial social and economic benefits to society, like the provision of employment, housing, and workplace, and offering economic transactions.

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[3] In this paper, building control regulations refer to those regulations enacted under national laws or acts, and include energy efficiency requirements of buildings as stipulated in mandatory standards or codes.

However, the development also poses negative impacts to the environment with regard to land use, material use, waste generation and natural resources during the life cycle of the buildings. Moreover, a great amount of energy is consumed during the life cycle of buildings. For instances, in countries of Organization for Economic Co-operation and Development (OECD), building sector as at 2000 accounts for 25 - 40% of final energy consumption by sector (OECD 2003) while in Asia, the building sector as at 2006 accounts for around 40-50% of final energy consumption (IEEJ, 2006). The energy consumption by the building sector is expected growing at a fast increasing rate and posing vast adverse impacts to the society in terms of economical, health and environmental aspects. The current technology of electricity generation is mainly by burning of fossil fuel. This technology generates in turn carbon dioxide gas which is one of the major greenhouse gases that bring the unwelcome climate change to earth. To mitigate the negative impacts of climate change, the Intergovernmental Panel on Climate Change (IPCC) urged in its 4th report in 2007 a global reduction of carbon dioxide emissions of at least 50% in 2050 from 2015 level.

Although most technologies are available, most of them are non-building control items. For example, high performance of insulation materials, active solar design for heating and cooling, and solar photovoltaic integration in buildings, and improvement to construction process and using prefabrication. Yet, they all have their difficulties and barriers (Chiang, Chan & Leung 2006; Levine et al, 2007). The following are some of the barriers preventing the promotion of energy efficiency of buildings (Chiang, Chan & Leung 2006; Levine et al., 2007):

- High cost of gathering reliable information on energy efficiency measures, the “stickiness” of the techniques practiced by the builders;
- Lack of incentives between landlords who would pay for efficiency and tenants who would realize the benefits;
- Limited access to finance, energy subsidies;
- Fragmentation of the construction industry; and
- Fragmentation of the design process into many professions, trades, work stages and industries

In many countries, there are also problems with a lack of coordination/integration among planning, environmental and building regulations to achieve sustainable buildings at affordable cost to the industry. It either hinders the impetus to deliver sustainable buildings or leads to non-compliance with planning/building regulations (Wong, Chan & Yu 2010; Visscher et al, 2010). With this background of building development, timely review and improvement of building control regulations are considered necessary. Traditionally, the source of authority, enforcement, compliance, and development trend of regulations constitute the core of the review of building control regulations (Garnharm Wright, 1983). In the context of climate change and sustainable development, non-regulatory or voluntary standards and codes, green specifications and non-regulatory incentive play an important role in promoting energy consumption reduction with the degree of success varies under different institutions

and incentive schemes (Lam et al 2009; Qian, Chan & Choy, 2013). With reference to this background, this paper discusses the following core areas:

- National Energy policies' Objectives
- Scope of regulations
- Types of regulations
- Enforcement Strategies of regulations
- Status of non-regulatory standards and codes
- The Use of mandatory labeling /reporting systems
- Planned Development of regulations
- Non-regulatory incentives

For the sake of discussion, the building control regulations and incentives of China (Cn), Hong Kong (HK), Japan (Jp), Singapore (Sg), United Kingdom (UK) and United States (US) are made reference to where appropriate.

3. National Building-related Energy Policies

National laws and acts confer source of authority to government or local government power to make, amend and enforce regulations. They provide framework for the control of energy efficiency of buildings. For instances, in China, the national laws[4] stipulate that building proposals must be designed and constructed to comply with mandatory design standards[5] The national energy policy emphasizes energy conservation along with other principles such as optimization of the energy consumption mix, promotion of environmental protection, and protection of energy security (ABC, 2007). In US, the Energy Independence and Security Act of 2007 mandates new buildings and major renovations to be designed such that fossil fuel-generated energy consumption is reduced by 100 percent by 2030. The bill also created the 'Zero Net Energy Commercial Buildings Initiative," which sets forth a nationwide goal of carbon neutrality in all commercial buildings by 2050.

However, different countries may have different objectives emphasized in their national laws

[4] Article 10 of National Energy Strategy of China, Article 4 of Construction Law of People's Republic of China, and Article 12 of Energy Conservation Law of People's Republic of China govern the design of energy efficiency of buildings.

[5] These are: (a) Design Standard for Energy Efficiency Design of Civil Building Engineering (JGJ26-1995); (b) Design Standard for Energy Efficiency of Residential Buildings in Hot Summer and Cold Winter Zone (JGJ 134 – 2001); (c) Design Standard for Energy Efficiency of Residential Buildings in Hot Summer and Warm Winter Zone (JGJ 75-2003); and Design Standard for Energy Efficiency of Public Buildings (GB50189-2005).

or acts or energy policies. The formulation of national energy policy may also be affected by the international participation of the nation, for example, whether the nation is listed as Annex I or Annex B Parties to the Kyoto Protocol as Annex I Parties are subject to binding targets while Annex B Parties are not. This drives the countries to implement or elaborate policies and measures in accordance with the nation's circumstances. The European Union (EU) has adopted an EU-wide emission reduction commitment that corresponds to the total reduction commitment of individual member states. To support realization of the commitment the European Commission implements legislations to improve the energy efficiency of buildings. The Directive on the Energy Performance of Building (2002/91/EC) is an important instrument that affects most of the EU members (UNEP, 2007). For instance, Hong Kong being a member of Asia-Pacific Economic Co-operation (APEC) has committed to achieve a reduction in energy intensity of at least 25% from 2005 level by 2030 (China View, 2007), (EPD, 2008). Comparable quantities in relation to the national energy objectives include energy reduction targets, energy intensity, energy consumption per capita, energy consumption to gross domestic product, and etc.

4. Scope of Regulations

4.1. Types of buildings subject to regulations

Different building types usually have different requirements for the indoor climate and internal loads. In order to fulfill these requirements, different amount of energy are needed. In this regard, different countries, even local counties of the same countries, may interpret these energy requirements differently and place different degrees of emphasis on the building types. For examples, China, Japan, and Singapore have regulations to govern residential (new) and non-residential (new) buildings as well as major retrofitting of these existing buildings. However, in Hong Kong the residential (new) buildings are not subject to the energy regulation for the time being.

4.2. Elements subject to regulations

Many regulations are initially developed with thermal requirements for the building envelops, and nearly all regulations for new buildings include these requirements nowadays. With the improvements made in the regulations, the HVAC systems are one of the main focuses of the regulations. There are also regulations and codes setting requirements on the energy consumption of equipments and appliances, lighting system is one of the examples. (IEA, 2008)

5. Types of Regulations

Energy efficiency requirements may be set in different approaches, namely prescriptive, trade-off, model building, energy frame and performance. Specific requirements can be set either on a building component (e.g. U-value of component) or as an overall maximum for a calculated value, for example, in Sweden the Building Code specifies that the maximum consumption is 110 kW/m^2/year for residential buildings in South. As each type of regulation has its own merit, it is difficult to conclude which one is the best. (IEA, 2008) Other than this

kind of classification, regulations may be deterrent or non-deterrent in approach. For instances, some countries may develop regulations to encourage good building while some others may develop regulations to prevent bad buildings.

6. Enforcement Strategies

Enforcement and compliance of regulations are commonly through 3 stages of activities, namely approval of plans, inspection of compliance during the construction, and issuance of completion certificate for the occupation of the buildings. These activities may be carried out either by the public authority, or by privileged organizations or by private independent experts. In general, for instances in Singapore and in most common law countries, the public may rely on public authorities to set rules and enforce their compliance. Whilst, as in US rely on third party certifications (Shannon D Sentman, et, al, 2008). For instance,

- **Mandatory Requirements of Public Buildings:** In New York and Philadelphia, public projects of certain cost /or construction should achieve a Silver rating of Leadership in Energy and Environmental Design Green Building Rating System (LEED). In Houston, city-owned buildings greater than 10,000 sq. ft must adopt the LEED system “to the greatest extent practical and reasonable” and target for LEED Silver rating.

- **Mandate Requirements of Public and Private Buildings:** In Babylon of New York, buildings greater than 4,000 sq.ft are obliged to apply for LEED certification. All building projects must deposit $0.03/sq.ft up to a total of $15,000 into the Babylon Green Building Fund. Should the project earn a rating, the deposit will be refund. In San Francisco, commercial and residential projects greater than 25,000 sq.ft or taller than 75 feet are required to achieve LEED Certified rating by 2008. In 2009, the requirement for commercial buildings would be tightened up to LEED Silver and in 2010 to LEED Gold rating. Residential building would require a Silver rating by 2010.

There are penalties imposed in the regulations if compliance of the requirements of regulations is not meet. These penalties commonly include fiscal penalties, imprisonment and withholding of license.

7. Status of Energy Efficiency Standards and Codes

In the context of energy efficiency of buildings, building energy standards or codes are the foundation for building energy policies. They are important for they provide a minimum level of energy performance to ensure that buildings meet a reasonable level of energy efficiency. However, the status of standards or codes in different countries is different. Comparable descriptions are whether they are mandatory, voluntary, or proposed to be mandatory.

8. Climatic Conditions

When building codes or policy measures are to be appraised, evaluated or compared in a meaningfully, the climatic conditions of different countries should be taken into account. There are two systems namely the Köppen Climate Classification and the ASHRAE

standards classifications commonly used. However, the International Energy Agency (IEA) considered that these two methods appear to be too complicated for a general evaluation and comparison, thus recommends a simplified climate zones classification as below: (IEA, 2008)

- Cold climate (2000≤HDD 18˚C and CDD 18˚C <500)
- Heating based climate (2000≤HDD 18˚C and 500≤CDD 18˚C <500)
- Combined climate (2000≤HDD 18˚C and 1000≤CDD 18˚C)
- Moderate climate (HDD 18˚C<2000 and 1000≤CDD 18˚C)
- Cooling based climate (HDD 18˚C<2000 and 1000≤CDD 18˚C)
- Hot climate (HDD 18˚C<1000 and 1000≤CDD 18˚C)

[N.B: HDD and CDD denote Heating Degree Days and Cooling Degree Days respectively]

The 'Cold Climate' is where winter is cold and summer temperature rarely higher than 22-25˚C. Parts of Russia, Scandinavia and Canada are with the Cold climate. On the other hand, Hot climate is where summer is hot and winter warm and the winter temperature seldom lower than 16-18˚C. Florida, northern Australia and Central Africa are examples of 'Hot Climate'. (IEA, 2008)

9. The Use of Mandatory Labeling /Reporting Systems

9.1. Energy Performance of Buildings Directive (EPBD)

The EPBD is an important European policy tool to improve energy performance of buildings. It aims to comply with the Kyoto Protocol to reduce greenhouse gas emissions, and has been implemented in 27 countries.

9.2. Mandatory Reporting System

Japan has implemented mandatory reporting approach such that a report on energy conservation measures must be submitted before commencement of building works. As revealed from (JEC Handbook, 2009), this requirement applies to:

- all new construction, and major renovations of commercial building since 2003;
- all new residential building of 2,000 m^2 or above since 2006;
- all ready-made residences of 150 m^2 or above, small and medium-sized residences and non-residential buildings of 300 m^2 or above since 2010.

9.3. Green Building Rating System

In UK, Building Research Establishment's Environmental Assessment Method (BREEAM) is a green building system, and has been said of being a widely adopted environmental performance rating system in the world. More than 818,943 homes and 22,972 buildings have been registered since its launching in 1990 (J. Cullen Howe, Michael B. Gerrard, 2010). Energy Efficiency is part of the rating system. Although BREEAM is not mandatory on national level, local authorities require a specific BREEAM rating to be achieved as part of planning requirements, and all new government buildings have to achieve an Excellent BREEAM rating. (Defra, 2010)

10. Planned Development

In China, the government has planned wider adoption of mandatory green labeling system, offering of fiscal incentives for energy-efficiency measures in new and existing buildings (N. Zhou et al, 2010). Japan determined in 2009 to accelerate Zero Energy Building (ZEB) development by 2030 (MOE, 2009). Measures for realization of ZEB include strengthening the current standard for the buildings in the Energy Efficiency Act, evaluate energy consumption of the entire building in a comprehensive manner in the regulation, and define milestone on to what extent and when the energy efficiency standards will be strengthened toward ZEB in the future. Japan, Singapore, UK and US have also planned to support voluntary building assessment scheme in which building energy efficiency has been incorporated with.

11. Incentives

The building sector is usually guided by regulations and standards as to the design, construction and operation, including what kinds of energy consumption systems to fit the building with, and how these systems are operated. Within the framework provided by regulations and standards, however, the behavior of the sector is very much depended on economic considerations. These considerations are usually short-term in nature and seldom take into account the long life-span of the building. Studies show that fiscal incentives are therefore recognized as very important for encouraging the building sector to adopt energy efficient approaches in design, construction and operation of buildings (Chan, Qian & Lam 2009). For examples, in Singapore, in order to encourage existing buildings to upgrade their building envelope, Building Construction Authority (BCA) has introduced grant to owners for the improvement of energy efficiency of the building. Also Under the Green Mark Scheme, there are three levels of financial incentives (gold, gold plus, and platinum), corresponding to increasing levels of green technologies and energy savings obtained. For energy performance, the gold level requires energy efficiency at the level required by the building standard. The gold plus level requires energy performance 25% better than standard, while the platinum level requires energy performance 30% better than the standard. The incentives range from SGD\$3/m^2 to SDG\$6 /m^2 of gross floor area for new buildings; retrofit of existing buildings is eligible for about 40% of the incentive for new buildings per square meter (Singapore's National Climate Strategy, 2008). In US, incentives are offered in a wide range of forms, including fast-track building permits, development bonuses, tax credits and fiscal incentives under Energy Policy Act 2005.

12. Core Areas Common to Building Control Systems

Having discussed the core areas salient to the review of different control regulations, it is possible to summarize the core areas common to building control regulations of energy efficiency of buildings in a template as appended in **Annex** of this paper. This template can be used to facilitate review, appraisal and comparison of building control systems to advance common understanding international regulatory systems, and to promote the exchange of information.

13. Conclusion

If building control systems are to be effectively improved, they have to be timely reviewed and appraised, and even compared with other similar groups of countries, so that appropriate actions could be initiated timely. In so doing, it may inevitably involve lots of information to be collected, and analyzed. To facilitate such kinds of review, key subject areas common to building control regulations across a number of countries have been identified and a template has been developed so that information can be gathered in a more coherently.

Acknowledgement

This paper is prepared with the support research grant of Hong Kong Polytechnic University.

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Annex

Core Areas Common to Building Control Regulations of Energy Efficiency of Buildings

Core Areas	Countries (e.g.)					
	Cn	**HK**	**Jp**	**Sg**	**UK**	**US**
National Energy Policies' Objectives						
Energy reduction target						
Energy Intensity						
Energy consumption per capita						
Energy consumption per GDP						
International Participation						
Annex I Parties to Kyoto Protocol						
Annex B Parties to Kyoto Protocol						
EU member						
OECD member						
Others						
None						
Types of Buildings subject to Regulations						
Residential (New)						
Residential (retrofitting)						
Non-residential (New)						
Non-residential (retrofitting)						
Component /Elements Subject to Regulations						
Building envelop and its components						
HVAC systems[6]						
Electrical equipments[7]						
Appliances[8]						
Renewable energy systems[9]						
Types of Regulations						
prescriptive						
Trade-off						
Model building						
Energy frame						

[6] HVAC systems stand for Heat, Ventilation, Air-conditioning and Cooling systems
[7] This include lifts and escalators
[8] These include televisions and computers, etc
[9] These include passive solar devices

Performance based						
Approval of Plans						
By public authority						
By other authority						
By private, independent expert						
No approval of plans						
Construction Phase Inspection						
By public authority						
By other authority						
By private, independent expert						
No inspection						
Completion Certificate						
By public authority						
By other authority						
By private, independent expert						
No inspection						
Non-compliance Penalties						
Fiscal penalties						
Imprisonment						
Withholding licenses						
Status of Standards and Codes						
Mandatory						
Proposed mandatory						
Voluntary						
None						
Climate Zones						
Cold climate						
Heating based climate						
Combined climate						
Moderate climate						
Cooling based climate						
Hot climate						
Use of Mandatory Labeling /Reporting System						
EBDP Implemented						

Green building rating & certification implemented						
Report on energy conservation measures						
Green building rating & certificate to be mandatory						
Planned Developments						
Tightening of current standards						
Wider adoption of fiscal incentives						
Towards zero-carbon building development						
Wider adoption of voluntary schemes into regulations						
Non-regulatory Incentives						
Fiscal incentives						
Development bonus incentives						
Fast-track approval incentives						
Others						

Academics' interpretations of working time, family time and leisure time

Ani Raiden[1], Christine Räisänen[2]

Abstract

Time emerges as an important theme in the study of work-life balance. Working time, family time and leisure time are the focus of this research, which explored the work-life balance of 14 male academics in construction and related departments in Universities in Sweden and the UK. Narrative analysis revealed concerns with focus on work, work-to-work pressures and work/ family time vs personal leisure time. We argue that too much emphasis remains both conceptually and in practice on work-family (rather than work-life) balance to the detriment of employee health and well-being as keen workers' extend their efforts to achieve excellence in the face of demanding performance measures.

Keywords: men, academe, working time, family time, leisure.

1. Introduction

"It's just time these days … something has to give."

'Time' or the absence thereof was a common leitmotif that ran through a set of interviews concerning work-life balance with Swedish and UK academic men within construction-related disciplines. The respondents' main preoccupation with time was related to the domain of work in that many respondents discussed work-work pressures and lack of time especially in relation to research, but yearning for alone time, time for hobbies and companionship time (rather than family time) was voiced more prominently than expected:

".... And there is very little room for personal development, personal reflection, there's very little room for time with friends – I never see friends."

Drawing on academic men's accounts of how they manage their work-life balance, our focus in this paper is on how perceptions may relate to feelings of satisfaction and emotional wellbeing. We contend that research on work-life balance tends to dichotomise the work-life construct into work on the one hand and life (or family) on the other, paying little attention to the overlaps, inter-relationships and ramifications of these two terms. What for example lies in-between them? It is this 'in-betweeness' that we are interested in.

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Our empirical data will show that the 'life' part of the dyad holds several in-between layers of relationships and activities that critically contribute to an individual's health, well-being and emotional satisfaction, but which often remain hidden from research results. In line with an 'emotional turn' in work-life studies (see Brandth 2012), we examine academic men's perceptions of their work-family-life situations.

Research on work-life balance has evolved over recent decades from solely focusing on how to enable women to balance their caring responsibilities with their work commitments to including both women's and men's desires to build successful and satisfying careers while also contributing to the care of family (Johansson and Klinth, 2008). This development has no doubt been largely influenced by the changing nature of work together with demographic and value-based changes in society more generally (Gerson, 2010). Knowledge-based work, for example, can be highly rewarding and self-fulfilling, being often perceived as embedded in life, rather than being experienced as a burdensome chore separated out of life, as the work-life dyad would intimate (Gallie et al, 2012; Ford and Collinson, 2011).

One sector in which intrinsic motivation to 'do well' drives commitment to work is academia, where self-management of 'protean careers' and academic freedom contribute to elevated levels of interest and attention to work (Enders and Kaulisch, 2006). Academia was one of the first sectors to allow staff to work outside the official boundaries of the university and traditional working hours (ibid: 88). It thus provided 'flexible employment' conducive to achieving work-life balance, at least in theory. However, research has found that masculine values prevail here despite the changes in society, gender roles and regulatory interventions (Allard et al, 2011; Berg et al, 2012; Hearn and Niemistö, 2012; Rice, 2012).

The European Commission is particularly supportive of men taking a more active role in family life (Bryson and Karsten, 2009: 40). This aligns with government campaigns and media attention afforded to the emerging notions of the 'new man' (Hearn, 1999; Watts, 2009: 42) and 'working father' (Ranson, 2011). These labels refer to men who do not conform to the traditional male work model, but value personal wellbeing and want to spend time with the family (Bevan and Jones, 2003; Family Friendly Working Hours Task Force, 2010; Linkow et al, 2011). In contrast, the traditional male role has been that of the breadwinner, toiling long hours in the workplace (Watts, 2009: 43; Ranson, 2011). Today, many men rate achieving balance between work and life/ family as one of their most important personal goals, regardless of whether or not they have children (Bevan and Jones, 2003). Across all sectors, a major obstacle in seeking satisfactory 'balance' is the inflexibility of workplaces. Even where part-time work and other forms of flexibility are available to employees, as in academia, research suggests that concerns over career progression and fear of others perceiving that one is working below potential remain very real (Family Friendly Working Hours Task Force, 2010: 20; Linkow et al, 2011).

1.1 Sweden and the UK

The above-mentioned changes have evolved in different ways in different social and cultural environments. Our interest is directed to two countries which the literature portrays as very different: Sweden and the UK.

In Sweden we find a long history of a ‘gender equality project’, and it is generally understood that in Sweden (as elsewhere in Scandinavia) gender equality has progressed in terms of men's involvement with family. Certainly, parental leave campaigns since the early 70s have contributed to the image of a Swedish “new man” that is masculine *and* baby-oriented, and interestingly coined “soft man/soft daddy” in Swedish (“mjukisman/ mjukispappa”). However, uptake of parental leave remains at a moderate 20% (Johansson and Klinth, 2008: 43-44).

In the UK, an increase of men’s input to the family sphere is a much more recent development. While the public (political, expert and media) discourses promote “involved fatherhood”, in practice low up-take of parental leave and limited contribution to childcare generally seem to be related to a traditional male long-working-hours culture (Gregory and Milner, 2011). As a society, the UK has long operated within a more traditional view of gender roles. At the same time it has suffered from the culture of long working hours, which has strengthened and contributed towards maintaining men’s position as the breadwinner and that of women as taking primary responsibility for caring duties.

However, ‘new public management’ and increasing managerialism of academia are common phenomena in both countries (Enders and Kaulisch, 2006: 85; van den Brink and Benschp, 2012: 510). As Berg et al (2012: 406) put it:

“In both countries surveillance, operationalized through performance management regimes, has led to a preoccupation with administrative procedures under the rubric ‘effective leadership’ (Ford, 2005: 236) that monitors behaviour and quality in bureaucratic ways…”

It is this commonality of increasing surveillance and managerialism on the one hand, and professional freedom and intrinsic motivation on the other, that interests us in seeking to better understand how academics manage their time: working time, family time and time with friends and hobbies, in these two contexts. We first review these three themes on time in order to develop an analytical framework for our enquiry. This is followed by an outline of the research methods used to conduct the empirical work before we discuss our findings. An outline of our key contribution and issues for future research bring this paper to conclusion.

2. Working time

Traditionally, working time has been understood and put into practice as a neatly definable construct, which has clear start and end times. Working hours are counted as discrete number of hours in a workday, work week, or sometimes a work year (annualised hours). During a workday, or a shift, work time is divided into reasonable periods of continuous work time, which is interrupted (only) by breaks, say 15 minutes coffee/ tea break or 30-60 minutes lunch break. The assumption is that work time is solely devoted to work, from which a worker has neither the need nor the interest to diverge.

This model applies satisfactorily to environments where, for example, a production facility must be organised and staffing arranged well in advance so that continuous cover is guaranteed. Operationally much of production and service-level work will always be

conducted in the workplace and within specific work hours. Particularly where input is physical, requiring physical effort rather than emotional engagement with the work activity, an organisation can reasonably expect and monitor workers' productivity.

However, this model does not apply to more fluid, perhaps boundaryless, contemporary professional careers such as academic work which often requires thoughtful and creative input. In this environment formal contracts of employment hold looser definitions of work hours, which in practice allow employees' to focus on the units of output rather than to count hours of input when accounting for his/her contribution to a team and/ or organisation. Control and monitoring of input is difficult if not impossible; we cannot measure how much time we spend thinking and planning. Therefore, it is not surprising that the academic environment is often characterised by long working hours fuelled by high commitment to achieving personal and professional success. Both intrinsic motivation (employees) and organisational expectations and culture drive and help maintain the environment despite the potential (and the real) problems it creates with regard to life beyond work.

Curiously though, institutions both in the UK and Scandinavia have recently introduced mechanisms that seek to measure exactly that which is not easily measurable: academics' input. In the UK, for example, the transparency review seeks to quantify worker's input (e.g. teaching, preparation, publications, consultancy, administration) by quarter, in order to demonstrate the full costs of teaching, research and other activities in Higher Education and improve the accountability for the use of public funds (KPMG, 2012: 4). Output, and prestige in particular, is measured by way of Research Excellence Framework submission (see e.g. http://www.ref.ac.uk/). Similar schemas are being put in practice in Sweden.

3. Family time

Similarly to work time, family time is traditionally understood as a specific period of time when one engages with family, say at the weekend or during maternity/ paternity or parental leave. From a working parent's point of view, this functioned well when women stayed at home to look after the children and the main concern in negotiating work time versus family time was that of the father's involvement. Traditional gender roles advocated that men (the breadwinners) were to commit most of their time to work and women focused their time on family. Hence within such a family ideal work-family-time conflict was often a non-issue.

As alluded to in the introduction, at present this is not considered a satisfactory *modus operandi*. Many men are keen to spend time with family, and the number of women who work has rapidly increased. Also, blurring of the boundaries between work time and family time is explicitly recognised. Therefore, one may argue that we have entered an era where an on-going negotiation of flexible constructs is emerging as an alternative to the traditional compartmentalised and linear view of time.

4. Time for friends and hobbies

An important aspect of time, with regards to 'life' in work-life balance, relates to time with friends, time for hobbies and general leisure time. Recent research (e.g. Brown and Perkins,

2012) highlights this as an area neglected by much of work-life balance research, and also an area rarely discussed politically or drafted into organisational policy. However, it is an aspect of time with significant potential to positively influence workers' well-being and satisfaction, both at work and in life (Beatty and Torbert, 2003). Health research shows that leisure activities (such as exercise) improve mental health and reduce the risk of depression (Penedo and Jason, 2005).

What seems to prevent workers from engaging in leisure activities is the shift from male-breadwinner model to dual-career households (Jacobs and Gerson, 2001) as well as a resulting 'combination pressure' (van der Lipper et al, 2006), which is a problem particularly for knowledge workers (Nätti et al, 2012). The above-mentioned self-driven intrinsic motivation to do well at work allows work time to expand to such an extent that it fills time available for 'life'.

5. Research method

In order to investigate academics' interpretations and use of time with regards to work-life balance, semi-structured interviews were carried out with 14 academics (seven from Sweden and seven from the UK) from construction-related departments at universities in the two countries. Assistant Professors (1), Lecturers (4), Senior Lecturers (4) and Professors (5), aged from mid 30s to early 60s, were represented in the sample. Most of the respondents had full-time posts at their respective universities; four had part-time posts. All the respondents were married or were living in a long-term relationship, and all but one had children in 18 months to 32 years age-range. Our sampling strategy was based on a purposive key informant approach. The interviews, lasting around one hour each, were recorded and transcribed verbatim.

The interviews were open-ended since the aim was to gain insight into the lived day-to-day work-life realities of the respondents, and took the form of informal conversations between interviewer and interviewee. Drawing on Polkinghorne (1995) and Lindebaum and Cassell (2012) narrative analysis was applied on the data in order to identify the various storylines that united fragments of talk and built thematic narratives in the interviews. Our joint and reflexive reading, and re-reading, of the transcripts lead to identification of key issues first, and thereafter storylines, allowing us to piece together the narrative streams that collectively rendered a coherent story of the men's experiences regarding work-family-life balance. Our reading and re-reading of the data was iterative, informed by critical discussion of our respective interpretations, complemented by our understanding of the conceptual field. We used NVivo 9 to facilitate our organisation and scrutiny of the data.

6. Research findings and discussion

The narrative analysis revealed several important themes: focus on work, work-work pressure, family time and desire to find 'me time'. We will explore these under the relevant sub-headings below.

6.1 Focus on work

One of the key pressures in work-life balance stem from the increasing flexibility of working hours, which is related to both, intrinsic motivation of the workers and proliferation of communications technologies that allow work to be performed 'anytime, anywhere' (Glavin and Schieman, 2012: 73). Beyond the opportunities to fulfil work duties outside of the usual spatial and temporal parameters of work, many professional occupations, like those in academia, also engage workers psychologically in work roles while physically located in another, for example with family (ibid: 74). Thus the boundaries between working time and time dedicated to family/friends/leisure become blurred.

Indeed, many of our respondents (two from Sweden and three from the UK) reported taking work home after the normal office hours and many more (three from Sweden and four from the UK) said they worked very long hours. One Professor estimated that on average his working week came to 65-70 hours, and one Senior Lecturer mentioned working 12-hour days frequently; they both work in the UK. In Sweden, our respondents estimated working on average around 50 hours a week. One Swedish Associate Professor reflected on the disruption this caused:

"…every evening, or most evenings, I spend an hour or two working, and even if I only work for one hour in the evenings, between eight and nine say, that interferes with everyday life around me. Which means that I can't sit and work for three days at home for one hour, even if that's not much at home, and then the fourth day go away to play music; I have to be free at home."

This illustrates a combination pressure more Swedish than British respondents experienced, as also identified by van der Lippe et al (2006), because of parallel careers in the family. When both parents pursue careers, finding time to spend together can become problematic.

However, the Swedish respondents also very explicitly reflected on flexibility as a positive construct in terms their ability to maintain continued and active engagement with work, while primarily on 'family-time', namely extended parental leave. One respondent said to have kept working one day a week while on parental leave for five months so that he could be available for a doctoral student even while on leave. The following excerpt from an interview with another Swedish respondent illuminates commitment to work:

"The interviewer: Were you on full leave?

Respondent: Yes. I worked, checking e-mails and so on, doing some work, doing some writing on papers."

Although the respondent says "yes" he was on full leave, he clearly maintained an active working role but almost dismisses this. This is common in professional occupations (Glavin and Schieman, 2012: 92) and indicative of affective commitment, an emotional bond that individuals develop towards their organisation or profession/ job (Buonocore and Russo, 2012: 4, 13).

Two British respondents spoke about flexibility in positive terms, both referring to how it allows them to participate in the school run. While many men use their flexible circumstances at work to help with the school run and occasional events like appointments at the dentist, overall their involvement with the family is mostly about being [physically] present and much less about emotional engagement. In line with Glavin and Schieman (2012: 91, 92) we find that *"jobs that offer freedom and control tend to come with the price tag of loftier work demands and responsibilities"* and hence support the greedy-role perspective. While flexible and permeable boundaries between work and family roles clearly allow the respondents to participate in some specific family engagements (such as the school run), their affective commitment and engagement with the work role seem to demand disproportionate amounts of time. The following scenario described by one Swedish respondent was relatively representative of the sample:

"I'm not a very good companion. I'm physically there... she thinks I'm boring because she needs to talk to me – practical issues, or if we should visit some of my family, or hers, whatever… and maybe I reply, or give her an answer to half of her questions, and it's not a very good reply because I just, 'Mm, mm. Ah, ah. You decide. Whatever you think. Let me know so I can put it into my outlook calendar'… Yes, she is running everything at home, almost everything… I know she's not very happy with it. She wants me to be more involved, maybe, not necessarily involved in practical issues, she can do that, but more involved in us…"

6.2 Work-work pressure

The respondents did not feel only a one-way pressure in the direction work-to-family. Many also referred to work-work pressures to do with increasing teaching loads and requirements to source research funding simultaneously. Such role conflict, i.e. work-work conflict, was found very stressful in light of the performance measures that combine teaching, research and administration, and respondents highlighted concerns about how this affected their performance both in Sweden and the UK. One Swedish respondent noted:

"I have talked to my boss about this and said that I'm afraid that I am actually not delivering properly. I'm failing students by actually not having time, and that, of course, pushes my evening e-mailing…"

Many British respondents discussed personal and professional development, which they considered important for maintaining satisfactory performance and more so for achieving the excellence their institutions expected of them. Therefore, lack of time to engage in and reflect on such activities was understandably a critical issue for many interviewees both in Sweden and the UK. As noted earlier, the new research-excellence frameworks require institutions to submit individuals with high quality publications for assessment, and successful submissions benefit from additional resources to fund further research.

Arguably, work-work conflict is amplified in academia due to the varied nature of activities an academic role contains. There is a requirement to continually excel in 'ideas-based work' (such as initiating new areas of research) and creative writing as well as in administrative

and time-bound tasks, like marking within 21-days to increase student satisfaction (a rule in Sweden and in the UK a recent initiative introduced by many Universities). The latter is an example of one managerialist performance-management metric, many of which van den Brink (2012) suggests as being possible ideals impossible to achieve.

6.3 Family time

Although it was clear that work was commonly a priority, and also consumed much time, the majority of the respondents in the UK (and two in Sweden) made efforts to manage the boundaries between work and family time by designating specific periods of time as 'work free', mainly during weekends and holidays. One respondent commented:

"The one thing I do, and I've always done, is I do take long holidays… the time the kids have off, I try and match it. So that's genuine, sort of, down time, quality time."

This suggests a rather instrumental view of being part of a family, and as an approach to managing work-life balance indicates 'segmentation' where work and non-work are seen as two distinct, separate domains of life with little influence on each other (after Guest, 2002). Such segmentation, together with reliance on partners and wives in family matters, lends evidence to a continued 'male breadwinner' model and traditional gender roles which support of Rice (2012) and Berg et al (2012) who noted that masculine values prevail in academia. However, research beyond academia supports this view as well; for example, Aarseth (2009: 425) states that despite recent cultural transformation (such as the emergence of the new man) *"men only appear to be more sensitive and care oriented but in fact do not meet the demand for emotional and practical participation in the domestic sphere."* And further, where families fail to realize the equality project (i.e. to share care and housework equally within the couple as in the case example in Aarseth, 2012: 429) *"she became the administrative and emotional centre of the family and he was increasingly involved in his work"*.

However, due to the work-work pressures many respondents experienced 'creep' and found that even segmentation as an approach to managing work-life balance proved challenging to maintain. One British academic explained:

"There are times of the year when it [work] goes home and it gets done in the evenings or, more particularly, at a weekend, which I hate doing… weekends are too important to you. But that doesn't work here."

Interestingly, three respondents (one Swedish and two British) noted that having to pick up children from school and day-care helped manage the 'creep'. Indeed, starting a family had been a turning point in their careers and lives, which had triggered a change thy had been unable or unwilling to make earlier:

"I suppose having Max (name changed for anonymity) put things into a different perspective..."

"Having Sarah (name changed for anonymity) obviously influenced how we organised our lives, the day-to-day life. I started to leave work on time so I could come home… I wanted to come home… obviously because I wanted to see them, but also because I needed to support my wife."

6.4 'Me time': time for friends and hobbies

An important segment of life that most of our respondents mentioned they were missing out on was time with friends and hobbies. This was because work took over much of their family time and hence there was no time left over 'to steal away', as reflected in the opening quote of this paper. What has to give is time with friends and time that prior to the forming of a family had been allocated to hobbies and/or sports or music, for example. As alluded to earlier, this has potentially severe negative consequences on the overall wellbeing of the workers, not only in terms of their work-life balance and satisfaction with such arrangements, but with regards to their health. Alarmingly, many respondents had had to give up regular exercise (such as cycling, running or hill walking – all known to have positive effects on health and well-being) and all expressed dissatisfaction in having to make this kind of sacrifices. Therefore, in the absence of important time to recharge, it is no surprise that many were left feeling that they had no time to do a good job in any sphere of their lives (work, family and personal life). For some respondents this introduced family-personal time conflict, which generated additional stressors to managing work-life balance. Managing work-life balance then becomes a much more complex negotiation of work-work pressures, work-family balance, work-personal time balance and family-personal time balance.

7. Conclusion

Given the flexibility and freedom in academic jobs, it is curious to find such a strong trend towards compartmentalising different spheres of life – work, family, friends, hobbies – in our study. As work tends to take priority and much time is committed to work roles, as explained by intrinsic work motivation, finding specific 'work free' time is the primary mechanism for managing work-life balance. This is in an attempt to contain 'greedy roles' and limit the workers' own interest and commitment to perform work roles over family roles. Those few men who made use of the flexibility of place and time of work tended to respond to family-unit related pressures rather than to satisfy personal desires to spend quality time with family.

Our research supports the concern that much work-life balance research and most of the organisational initiatives still focus on work-family balance, neglecting the importance of personal time spent with friends and on hobbies. Considering the potential for serious adverse implications for employee health this is an area of study in need of attention. We also suggest that this pilot study should be developed into a more extensive study to explore the themes emerging from our research covering a larger and more varied population (e.g. single men and women, with and without children), possibly utilising techniques from psychology to establish the connect between the individual's focus on work and leisure time and secondary attention on family versus gender roles in the new managerialist academia.

For now, this study has opened up a rich vein of analysis in developing our understanding of time as a multivariate construct with regards to work-life balance negotiations.

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CONSTRUCTION PROCESS IMPROVEMENT USING AN AUTONOMOUS PROGRAMMABLE ELECTRONIC MODULE AND DIGITAL SIMULATION

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ABSTRACT

Civil project executors are constantly dealing with the challenge of increasing productivity by optimizing the manpower or human resources and their interaction; this has been addressed from different points of view using computational tools and manual tools. In the case of Colombia, the percentage of non-value-adding activities in civil projects is 40%, whereas in countries such as Chile it is 21%, in the United States it is 15%, and the world average is 32%.

One of the main principles of value generation in construction processes is the identification, the measurement, and the reduction of non-value-adding activities in the work flow. Traditionally, sample gathering is done manually through direct observation of the working crew and the identification of the flow of human resources.

This article presents a construction process reengineering that integrates time lapse, Lean Construction, and computer simulation techniques. For information capturing, the design and development of an autonomous programmable electronic module, powered with solar energy, is presented; it is used to capture digital construction process images. . This system enables having reliable data and considering the variables involved in the process, in order to create a digital simulation model, useful for simplifying decision-making regarding construction methods and assignment of manpower, to minimize costs and increase performance.

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The results of uniting these technologies allowed studying new theoretical scenarios and making “what if” scenario analysis, which were implemented in the digital model. Finally, this paper discusses implementation in construction projects in Bogota and draws conclusions.

KEYWORDS: Digital simulation, Lean Construction, construction process improvement, programmable module, time lapse technique.

1. Introduction

Construction process improvement has been addressed using different industry and academic techniques. The literature on the topic discusses different applications, some of which are described below.

Ruwampura, Ariaratman (2007) presents six simulation tools implemented to plan and manage a range of several applications in underground infrastructure construction such as tunneling and trenchless construction processes. The paper emphasizes that tunneling and trenchless construction processes are excellent candidates for the utilization of computer simulation due to their repetitive nature.

Mao, Zhang (2008) presents a constructive process re-engineering by including Lean Construction and digital simulation principles. By observing constructive processes, improvement actions are proposed by following “lean construction” principles, which are later modeled by means of a software simulation, specialized in construction.

Ailland et al., 2010 present a construction process simulation in bridge building. They apply an event-based simulation, emphasizing the requirement of detailed construction process data to guarantee the quality of the simulation. The required data must be captured as efficiently as possible during the ongoing working activities. In addition to these developments, the exchange and storage of data via the internet has created new possibilities. Today it is possible to transfer huge amounts of data to any place in the world, to process them in a central location, and to transfer them back to the site.

Alarcón et al, (2009) present a computer methodology that facilitates data collection, processing and analysis for production improvement and safety at the work site, by means of video tapes and digital images. In order to take advantage of opportunities, software was developed, which includes tools designed to retrieve data from video tapes and digital images for conducting analysis aimed at improving productivity.

Other research studies discuss time lapse and digital simulation implementation (Páez, 2007), (Mesa, 2008), and (Echeverry et al, 2008) to name a few. They offer a tool for project planners, which enables a probabilistic assessment of different scenarios, thus allowing better decision making under conditions of uncertainty. The research was applied to the construction of concrete walls and slabs.

There are also productivity improvement research studies that employ time lapse implementation and construction process work flow (Vargas et al., 2009).

Gómez (2009) presents field measuring to determine the work flow, estimated execution times for each activity, and the required manpower in each case. After building a construction process simulation model, theoretical scenarios are used seeking to diminish project execution times. A research study entailing time lapse technology and simulation was conducted in which video images are captured using a camera powered by electricity and the video films are analyzed for a later construction process simulation (Céspedes, 2010).

Those studies show that the construction industry has implemented techniques such as time lapse, Lean Construction, and digital simulation, among others, either separately or in a combined manner. It is worth highlighting that the more construction process simulation has been disseminated, the more it has been used. It is important to underpin that simulation effectiveness depends on the efficiency of the gathered data; indeed, “simulation” refers to a broad collection of methods and applications to mimic the behavior of real systems (Kelton et al, 2010).

This paper presents a system that unites communications and automation technologies for image collection, as well as data analysis technologies that allow construction process characterization, in terms of time, manpower, and executed activity flow, using which a digital simulation model can be built. In the simulation model, improvement proposals are established for implementing the Lean Construction philosophy and process simulation in a building project, using digital cameras to make time lapse videos, seeking to identify cycle times and the work flow of those involved (Gómez et al, 2012).

The module has been implemented in two construction projects in Bogotá, Colombia. It was first used in a project consisting of two 17-story apartment buildings and then it was employed in a project for a building with five stories and 2 basements at the higher learning institution Pontificia Universidad Javeriana.

2. Image capturing

Uniting the technologies proposed in this paper included the first stage of instrumentation for efficient image capturing during which a programmable model was developed with hardware and software equipment, the second stage of model implementation for construction process analysis, and the third stage of creation of digital simulation models, to imitate the construction processes under study and enable “what if” scenario analysis, for the purpose of making improvement proposals.

In the first stage the autonomous programmable model for construction process digital image capturing was developed, powered with photovoltaic energy and with remote communications through via Internet.

Figure 1 presents the block diagram of the implemented model, including hardware and software components.

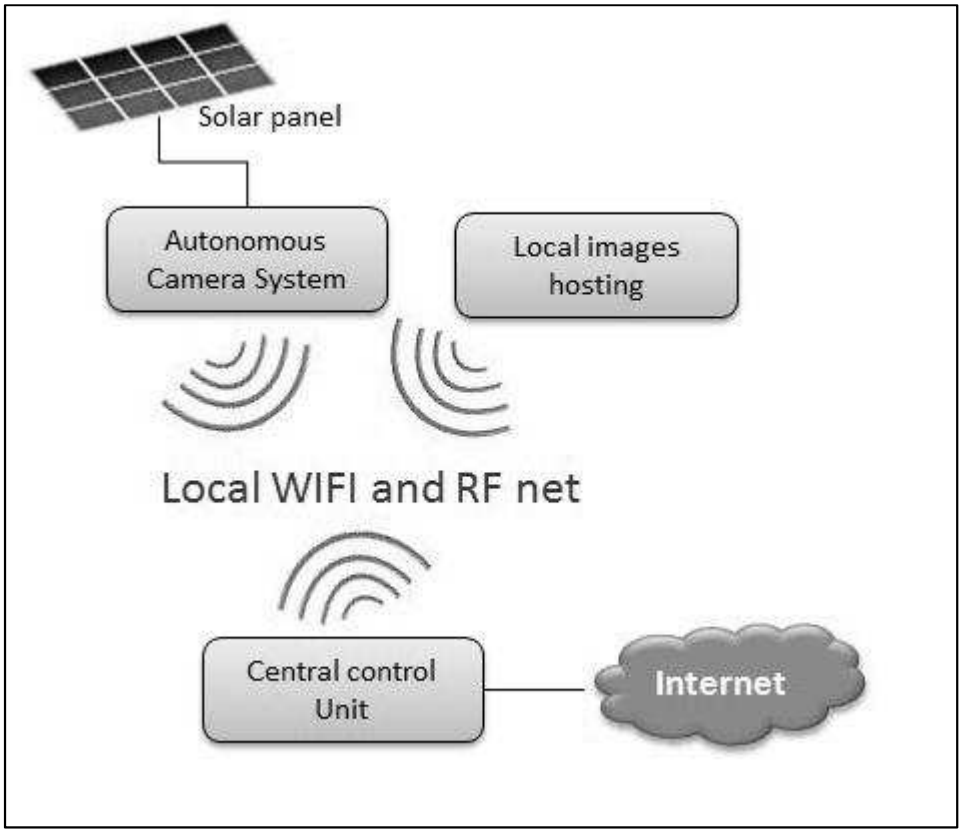


Figure 1. Block diagram of the image capturing system

The autonomous camera system (ACS) comprises a high resolution camera for obtaining the images, a shot controller that takes the photos automatically, and a local memory card with wireless connectivity.

The shot controller is linked via Radio Frequency (RF) to the central control unit that determines when an image must be captured and sends the order to the shot controller for it to trigger the shot.

The local memory card locally stores the captured images and has WIFI wireless connectivity that allows it to send the images to a local storage computer.

The camera system is powered with photovoltaic energy. The solar panel, the battery, and the charger are the components that permit the feed; they are embedded in the system itself.

Because the system has an autonomous feed and all communications are wireless (RF or WIFI), it can be moved to any sector of the work site, which has wireless network coverage, and no additional wiring is required. That enables obtaining images from different focal points, which furnishes more information for data analysis afterward.

Local image hosting consists of an industrial computer with high hosting capacity and WIFI connectivity. The ACS memory card communicates with this computer via the WIFI network, in order to transmit the images captured. The computer runs two main applications. The first

one enables communication with the above-mentioned storage card and the second one allows remote Access to the images stored in the computer from anywhere in the world.

The industrial computer can be installed in a spot with easy access, for rapid access to the images.

The central control unit (CCU) handles the communication among the different system components and manages the automatic photo taking.

The unit is directly connected to Internet through the Internet provider router. In the case of the projects in which the system was implemented, the Internet connection is made using a 3G router. Inside the unit there is a wireless router that handles the local WIFI network that enables communications with the other two components and also an RF communications card that allows wireless communication with the ACS shot controller.

The unit stores and manages a Web page with remote access via Internet. Here a remote user can monitor different system variables:

- ACS photovoltaic feed voltage and current variables and the record of the communication that the ACS has received. That information permits obtaining a remote diagnosis and determining if servicing is needed.

- Image capturing variables: image capturing start time, image capturing end time, and the interval between each shot.

An administrator user with a user name and a password can modify the image capturing variables. Indeed, he or she can remotely program the intervals, start times and end times, as need be according to the construction process being carried out at a given time. That option enables optimizing the data capture.

3. Construction process analysis

Implementing this programmable module makes it easier to obtain reliable data and information that allow using methodologies to increase productivity, safety at the work site, by using video films and digital imagery. Work site instrumentation with this programmable module ensures reliable data for later statistical analyses for the purpose of making productivity improvement proposals. One of the advantages of implementing the module is that the photos and videos may be observed several times, analyzing different aspects for each activity.

3.1 Digital information analysis

First, from the obtained photos, the images were converted to “time lapse” video films using the program Windows Live Movie Maker, which enabled reduced time reproduction of the shots taken of the events that occurred at the work site in a given period during the research.

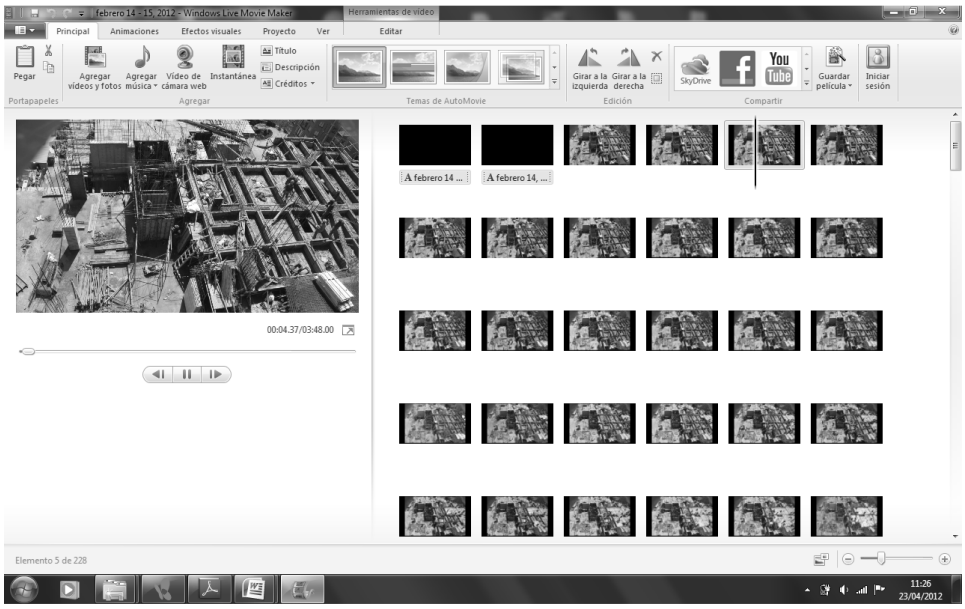


Figure 2. "Obtaining time lapse video films"

Likewise, relocating the shooting spots enables obtaining different levels of detail in the photos, as may be appreciated in the analysis made below:



Shot 1 "Aerial view of the floor structure plate"



Shot 2 "Detailed view of beam trusses"

Also, the photo and video shooting with no need for wiring and with the facility of installing the shooting spots where required enables analyzing work site activities using the tools: work flow, identification of productive, contributive, and non-contributive activities (based on the Lean Construction philosophy), and safety problems, among others.



Shot 3 "Productive activity: Steel truss"



Shot 4 "Non-contributive activity: Break; no instructions were given"

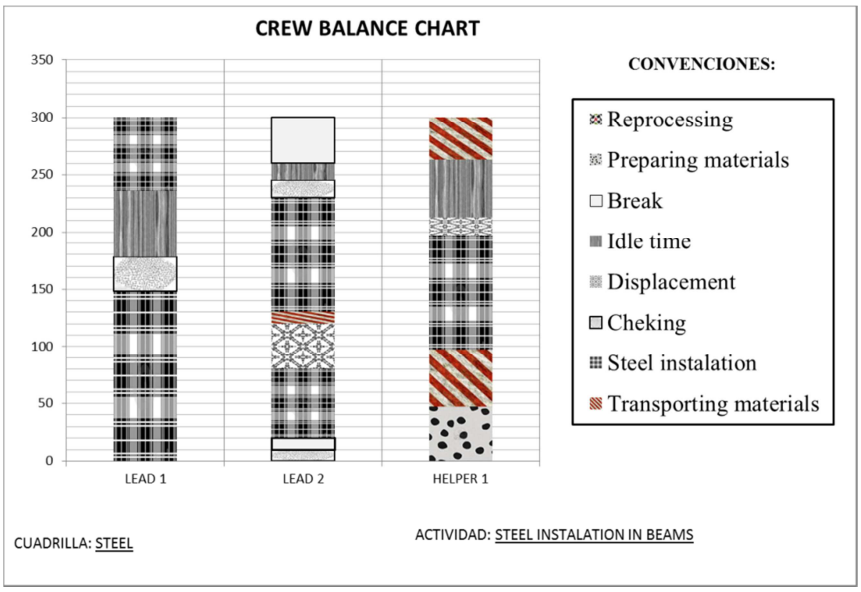


Shot 5. "Contributive activity: Cutting wood"



Shot 6. "Worker not using a lifeline"

Five-minute video films were also made using the Web camera (5-minute rating techniques) to identify productive times, contributive times, and non-contributive times and to apply the crew balance chart methodology.



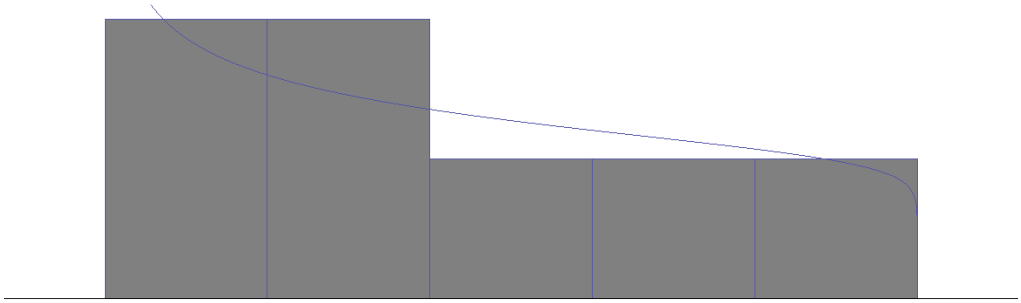
Graph 1 "Crew balance chart for the activity Pouring cement into columns"

3.2 Process Simulations and Improvement Proposals

Analyzing digital materials enables obtaining information for building construction process simulation models, in this case working with Arena software. First, the model is conceptualized, starting with the work flow and the following aspects are defined for each work site activity: duration of the activity, the number of work site activities executed, material resources involved, personnel involved, and downtime.

On-site assembly allows estimating the length of each activity; after tabulating that information, the probability distribution curve for the data fit is obtained. The Arena – Rockwell software tool Input Analyzer was used for the above and also used for the goodness-of-fit testing (Chi-squared or Kolmogorov-Smirnov as the case may be).

An example of the analysis, corresponding to the analysis of the activity “Pouring concrete into columns”, is shown below.



Graph 2 “Histogram obtained from the Input Analyzer software for the activity Pouring concrete into columns”

The distribution obtained in this case was a Beta-type expression: 0.64 + 2.07 * BETA (0.786, 1.07), corresponding p-value > 0.15.

Minimum values, maximum values, and the average for each of the activities identified in the work flow were established, obtained from the measuring done and the probabilistic distribution to which each one of the data series most fits was found.

To build the simulation model, the input information used was the work flow, the probabilistic distributions for each one of the activities, the project start date, and the available required manpower, among other characteristics proper to the work site. An example of how the Arena software simulates construction processes may be appreciated below.

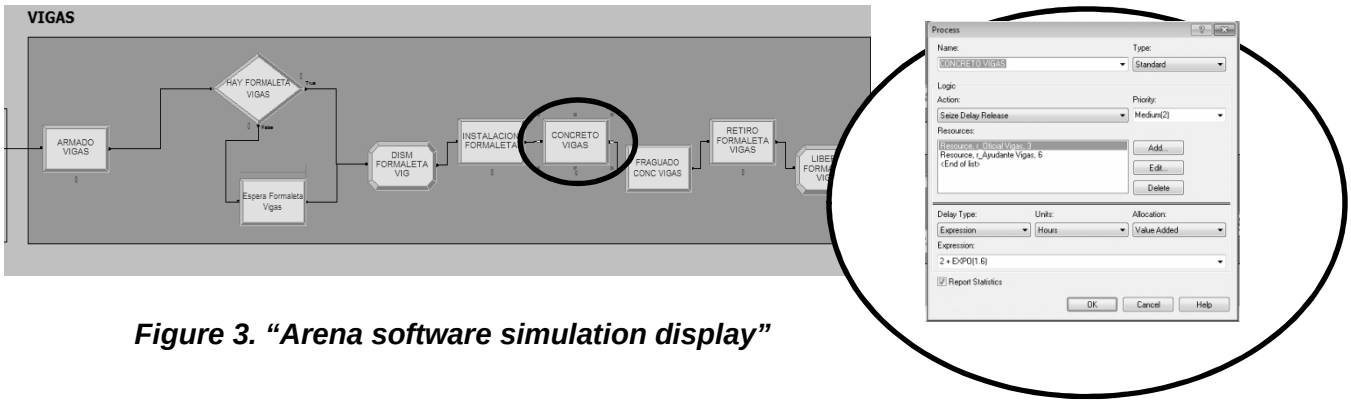


Figure 3. “Arena software simulation display”

After the model is completed, it is subjected to verification and validation. To verify the model, its functioning logic, inventories, and waiting times for the entities are reviewed and a review is done with the work site director. To validate the model, the number of replication required to guarantee 95% data reliability is calculated. The trust interval method was used to do so.

The results for this type of simulation models enable obtaining data such as, for example, the occupancy of each one of the human resources, the average duration of the activities, total project duration, etc.

Seeking to reduce the identified project losses, new theoretical scenarios can be proposed using the model built and analyzing “what if” scenarios. Another advantage that this type of model has is that human resource optimization can be done employing the Rockwell Software OptQuest tool. A target function to be minimized or maximized is chosen and an analysis of the feasibility of the results is made, based on the proposed restrictions.

These models also serve as a tool for planning future projects because they enable predicting durations based on real statistical field data and they may even be used as a knowledge management tool.

4. Conclusions

This paper described an innovative application for construction industry. It makes decision making for productivity improvement easier and It also facilitates the implementation of crew balance chart technique and Work Flow Management.

The information captured using this module can be used to resolve claims, for education and also as a knowledge management tool.

In an ever more competitive marketplace, the implementation of new tools such as simulation techniques represents and efficient strategy toward minimizing non-contributive times. The research demonstrated that the system could be applied successfully in the construction industry.

Analyzing the construction processes based on real data observed in the field represents an advantage over other project planning methods because actions are defined, which can be replicated during the project or in future projects, to thus increase the capability of meeting quality, time and cost objectives.

Implementing this system implies an initial investment in equipment, technology, and software development, which can be taken advantage of for future projects. Indeed, the only additional requirement is to contract an Internet service; the other implements can be reused and are easy to install. That makes for an attractive cost-benefit ratio.

The fact that the system is powered by photovoltaic energy facilitates image capturing at any spot of the work site, minimizing system use due to limitations of electrical outlets and to an absence of electrical power at any given time.

The task force was notified of the use of this module, before the installation. They were told that the objective of this module was the construction process improvement and it wasn´t a performance evaluation. During the project execution phase the workers did not report non – conformities related whit the use of the module and they continued developing the task as usual.

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Marketing, Programme and Project Management:
relationship building and maintenance over project lifecycles

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Abstract

Business development is in transition with its increasing focus upon relationship building and maintenance. Theoretically this represents a shift from the transactional marketing mix towards relationship marketing (RM). Four international main contractors were examined to identify the extent of transition. Semi-structured interviews were conducted amongst Directors with Marketing responsibilities, Business Development Managers, Heads of Procurement, Project Directors and Project Managers in each contractor. The analysis was conducted inductively and evaluation was made against the literature. The analysis presented draws upon three findings common to the four contractors: i) an emergent key account management function (KAM), ii) the lack of a RM system, iii) the absence of an internal relationship and system between procurement and business development (BD). The evaluation of the findings against the literature shows KAM to be partially conceived in different ways by each contractor both at project and programme management levels. It shows that all contractors lack integrated cross-functional systems over the project lifecycle, and the absence of a RM-cum-management systems means that the gaps between functions during the lifecycle are not overcome and RM as a function is compromised. Whilst the procurement function at a programme level was found to be well-developed internally, from which marketing could benefit, the systematic and behavioural dislocation between BD and downstream functions constrains marketing and inhibit the development of value propositions that aligns with RM. The conclusion is that international contractors are in early stages of transition towards RM. The consequence is that configuring and delivering coherent value propositions and quality service experience remain highly constrained.

Keywords: Business Development, Procurement, Key Account Management, Relationship Marketing, Systems Integration

1. Introduction

The twenty-five year shift from the marketing mix (MM) to relationship marketing (RM) in many sectors has marked a move from viewing exchanges as discrete transactions towards building long-term business-to-business (B2B) relationships (cf. Grönroos, 2000). A time-lagged transition is underway in construction (Skitmore and Smyth, 2007). Business

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development (BD) in construction increasingly focuses upon relationship building (Smyth and Fitch, 2009). This is part of a broader shift in project management towards an emphasis upon strategic front-end and "soft" management issues to support technical and engineering expertise (e.g. Walker, 2002). This is conceptually underpinned by strategic input from the corporate centre via portfolio and programme management to project management (Morris, 2013). Marketing and BD are located in this 'hierarchy' at the project front-end.

Firms have restructured since the 2008 "credit crunch". The emergent pattern in construction has been to delayer and reduce costs. The research investigates whether the downturn has affected marketing and BD practices in construction: (i) To what extent have there been any significant changes in marketing and business development since the 2008 "credit crunch"? (ii) To what extent do business development processes interface with other functions? (iii) How is business development evolving as an effective function? The prime focus centres upon serving client interests. Four international main contractors are examined using semi-structured interviews across a range of management roles. The analysis was conducted inductively and evaluation was made against the literature. The analysis particularly draws out the role of key account management (KAM) over project lifecycles as part of programme management, and upon the paucity of RM systems for marketing in relation to other key functions. Conclusions and recommendations follow.

2. Setting the Scene – a short literature review

2.1 Marketing mix and relationship marketing

Levitt (1983) defined marketing as creating and keeping a customer. Kotler *et al* (1996) adopted a catholic approach, as do many professional bodies and institutes. Definitions also arise from paradigm choice. The MM is based on the 4Ps, of product, place, promotion and price (Borden, 1964; McCarthy, 1964) and its variants. RM (Berry, 1983) is based on B2B relationships for intangible services.

The MM is transactional. It dominated project markets (Cova et al, 2002) and still remains a strong force where price is an overriding criterion (Skitmore and Smyth, 2007). BD is largely reactive, soliciting project pipeline information and engaging with clients to prequalify for projects. BD is project specific once market segments are identified, often defined in administrative "silos" by procurement routes and building type (Pryke and Smyth, 2006). RM is client focused. Tailor-made services are configured for segments of one. The objectives are to add product and service value through in-depth understanding of clients to induce improved satisfaction levels and loyalty. Increased repeat business and premium profit are direct benefits to the contractor (e.g. Grönroos, 2000). Suppliers are proactive market managers and shapers of projects (Cova et al, 2002). RM requires support from systems (Storbacka et al, 1994), procedures and through behavioural guidance across networks and interrelated markets (Christopher at al, 2002). Thus, links between the corporate centre and the project, articulated through portfolio and programme management down to the project management level, are necessary for effective RM.

2.2 Marketing and project management

Marketing, which is conceptually strategic, (Preece et al, 2003) in practice is confined to communications and promotion in many construction companies (Preece et al, 1998). It is frequently separated from BD. BD traditionally has been isolated at the start of the front-end of projects (Pinto and Covin, 1992; Turner, 1995), terminating at prequalification or bid submission. BD under RM starts prior to a project being identifiable (Cova et al, 2002) and continues during execution beyond completion and final account towards seeking repeat business, that is, managing sleeping relationships (Cova and Salle, 2005). The relationship value or the client lifetime value to the contractor carries greater significance than project values. Project lifecycles therefore require management from project through programme to corporate management for developing competencies and capabilities that are articulated through the systems, procedures and behaviours (Smyth and Fitch, 2009).

BD is claimed to be transitioning from the MM approach towards RM (e.g. Preece et al 2003). The transition stage reached has yet to established. The effects of the post-2008 "credit crunch" upon marketing need scoping. The extent BD interfaces with project management and other project lifecycle functions has yet to be empirically established. RM conceptually provides one system to be integrated with technical and functional systems for delivering solutions that satisfy clients.

2.3 Portfolio, programme and project management

Portfolio management administers bundles of assets (e.g. Morris 2013). Contractors' assets include technical, technological and social capital. Portfolio management develops fixed capital resources, competencies and capabilities, and their allocation to programmes and projects, including the development of RM systems and procedures (cf. Storbacka et al, 1994). Portfolio and programme levels overlap in order to assess and allocate resources for project management. Morris (2013) claims portfolio management is analytical, operating at a more strategic hierarchical level. Programme management is managerially directional on a day-to-day basis. Programmes have a pool of resources to share and trade-off, choosing between projects on an opportunity cost basis under MM and choosing between clients and their programmes under RM. Programmes focus on strategic coordination, projects focus on task outputs (Morris, 2013). Detailed resource allocation might include a programme of behavioural competencies to consistently serve clients and projects.

3. Methodology and Methods

An interpretative methodology was applied, respecting the information provided and emanating context (Denzin, 2002). Interpretation recognises subjectivity and embodied value judgments (Sayer, 1992), including how facts are selected and articulated in different ways (Krige, 1979). It recognises respondents are subjective (Sayer, 1992). Respecting key actors perceptions enriches understanding of attitudes present, the strengths and weaknesses of organizational artifacts, processes and behaviour, yielding meaning to generate patterns of events, draw out experiences, draw attention to outcomes of significance (Smyth and Morris, 2007). A case study method (Yin, 2003), specifically a case-based approach, was applied

inductively (Eisenhardt, 1989). The UK operations of four major international contractors were examined via semi-structured interviews conducted in the 1st and 2nd quarters of 2012. The number of interviews per contractor varied slightly; the aim being to cover a Board Member with responsibility for Marketing, Head of Marketing/Business Development, two Business Development Managers, Head of Procurement, and two Project Managers. All companies and personnel interviewed are kept anonymous as organizational rather than individual performance and business effectiveness provided the focus – see Table 1.

Table 1: Schedule of case study contractors and personnel

Contractor Alias	Ownership	Primary Activities	Divisions Interviewed	Interview Respondents
EUCo	EU country	Civil Engineering & Infrastructure and Specialist Subcontracting	Civil Engineering & Infrastructure	Chief Executive 2 Regional Business Development Managers (BDMs), 1 Senior BDM and 2 BDMs Head of Public Relations and Communications Contracts Manager Head of Business Processes & Sustainability
EuroCo	European	Building, Civil Engineering & Infrastructure and Specialist Subcontracting	Building, Civil Engineering & Infrastructure	Customer Solutions Director Head of BD Sector BDM BD Coordinator Head of Procurement Commercial Director Technical Service Director 2 Project Directors
AntCo	Antipodean	Construction and Development	Construction	Head of New Business Head of Procurement Bid Manager Head of Project Management
UKCo	UK	Building, Civil Engineering & Infrastructure, Consultancy	Infrastructure & Consultancy	BD Director 2 BDMs Head of Procurement 2 Project Managers

4. Findings from the Field and Inductive Analysis

4.1 Marketing and top down management

The case companies restructured post-“credit crunch”. Headcount loss was conducted by

hierarchical delayering of BUs as opposed to considering markets and what capabilities were anticipated for future competitive advantage. Specialist BD capabilities were lost in AntCo and EuroCo. The claimed benefit is that others took up additional BD roles, resulting in becoming more outward facing. Yet important opportunities were lost, the understanding of clients needs was compromised, and ineffective gathering of pipeline information were consequences. For AntCo, the current aims are to “incubate” markets for entry, although capabilities to optimize this objective may be constrained.

Marketing was found to operate in two ways in the case companies. First, it is considered in terms of Communications and Promotion functions, which operated separately (cf. Preece et al, 1998). This is most evident in EUCo and EuroCo. Second, marketing focuses upon producing a marketing strategy. These are configured at board level as part of an integrated business plan or as separate documentation. Marketing options are constrained by the case companies being structured into BUs around procurement, contract and/or building types/construction types for ease of management. These become procurement and task driven market segments. For example, AntCo is structured around project execution, not around clients in a complementary fashion. Consequently, they are good at developing the “big picture”, but capturing and cascading the implications down the hierarchy and along the project lifecycle from the front-end through delivery is weak. There is an absence of programme management to facilitate coordination in all the cases with the consequence that BD is largely disconnected from marketing. BD is further subdivided by BU and coordination across BUs is sporadic: *They do work fantastically well together if they are joined together in the right way* (Interview with a Bid Manager, AntCo). Recognition of this problem at senior management and operational levels is described as a “silo mentality. These findings inhibit effective implementation and constrain the implantation of RM principles and systems.

BD is perceived as an information gathering to help the companies prequalify. A Senior Business Development Director in EUCo reported he briefs his teams: *Is there anything out there you think we should know?* The next step is to communicate information to the team producing prequalification documents; a division of labour between BDMs and prequalification. The extent to which BDMs were involved in the bid management process varied between the case companies. In all cases BDM is marginalised beyond prequalification, a constraint for service continuity where other managers are performing the marketing and BD functions in subsequent project stages. BDMs largely contribute to winning work as a confined transactional task. A comprehensive marketing management *system* to coordinate action from senior management to the operations level and across projects is absent. Coordination from the corporate centre or through explicit portfolio and programme management (Morris, 2013) is underdeveloped. Although EUCo is rolling out a customer RM initiative, it is said to be “fairly simplistic”, relying upon individuals taking responsibility. There is a rudimentary customer relationship database, a CRM software system, in place to support from below, yet no systematic coordination from above. CRM databases depend upon employee engagement. This is also left to individual responsibility in EUCo, AntCo and UKCo. CRM engagement levels are low.

All the companies stress the importance of relationship building in line with RM theory, which seems to arise from two sources. First relational contracting where several respondents in

AntCo and EUCo stress the benefits derived from internalising the lessons of partnering. Senior management in both companies said informal partnering is necessary to respond to clients, cost drivers and for effective project management. Second BD where relationship building is seen as key to increasing strike rates. There was recognition of its importance along project lifecycles amongst BDMs, in accord with previous claims that contractors are in transition from MM towards RM (Preece et al, 2003). Previous research has failed to clarify the stage reached. This research found that BDMs are a disparate group that understand and build relationships differently in each company. All BDMs cite the importance of relationships, using similar language: *It all about people and relationships* (Interview with a BDM, EUCo); *It boils down to some trusted relationships* (Interview with the Head of New Business, AntCo). The companies are not developing systems for managing relationships, i) for each relationship *type* within BD, ii) for *continuity* along project lifecycles, iii) for cross-functional *coordination* to ensure, a) the understanding of client organisational and project needs beyond stated requirements, and b) value propositions are passed along the project lifecycle for the development of win-strategies and for delivery in execution.

Although all BDMs cite the importance of building relationships, when asked what this entailed, phrases such as “understanding client drivers” are used. To all interviewed, “client drivers” meant building relationships to get information on the project pipelines and requirements, to some it meant understanding the motivations and considerations of the key decision-makers (clients and their professional representatives), to a few it meant understanding client business solutions or organisational purposes projects are addressing, and to one person alone it meant understanding the client’s own core business to get to the bottom of what they perceive as valuable. All levels are important in RM.

Leaving relationship building to individual responsibility has consequences: *You do end up living in an area of ambiguity a lot of the time* (Interview with the Head of New Business, AntCo). There is a lack of awareness and partial implementation of RM principles. There is a great deal of evidence of hiding behind business jargon, such as “right behaviours”. For example it was stated: *It’s all about behaviours and culture* (Interview with a Regional BDM, EUCo); *Behaviours are key to making this a success* (Interview with a Project Manager, EUCo). This lends a false impression of standardization, yet the meanings held for these terms are different and action is inconsistent. BD was repeatedly described in terms of “instinct”. There is no guidance about how to build and manage relationships i) through *relationship systems*, ii) through *procedures* to address types, continuity and coordination of relationships, and iii) *behavioural codes of conduct* to establish norms and specific guidance on behaviour. A code provides a baseline upon which the interpersonal skills of BDMs can flourish. There is sporadic evidence of trying to manage behaviours at a micro-level. It was stated: *There’s a lot of behavioural-cultural work that goes on* (Interview with the Head of New Business, AntCo), which was described as mobilising propositions by “socializing the idea”. This seems reliant upon informal routines and is reactive. This research found weak interface linkage between functions, confirming other research (Roberts et al, 2012).

4.2 KAM, programme and project management

Key account management (KAM) is being adopted in the case companies. KAM is an RM

concept for coordinating client interests across the internal actors responsible for customer contact and service delivery (e.g. McDonald et al, 1997). AntCo first introduced KAMs in the boom market pre-2008. They were appointed from Project Managers with responsibility for client programmes. KAMs are client facing. The ability to resolve client issues was hampered by a lack of an independent budget. The result was inward facing vying for resources and it was abandoned. It was recently reintroduced with the title of Key Account Holders and a banner of “Loving the Customer”. Key clients are provided a single contact point and a consistent approach, supported by “correct behaviours”. The AntCo approach is fragmented. Awareness creation, training and induction for the role have not been addressed. Internal systems and procedures are absent for coordinating KAM. Bidding teams are put together project-by-project. Although a more centralized resource and support are being developed, bid development does not relate to KAMs to generate value propositions of technical and service value. KAMs are not guided as to how to build relationships.

UKCo’s Managing Director of the Civil Engineering & Infrastructure division has sought to build relationships. Core clients have been allocated KAMs. KAM is described as “quite open and loose”, aligning with the lack of formal guidance for relationship building. Information feedback is sought to improve responses in reactive ways, complying with MM rather RM principles. EUCo takes a selective approach to KAM, only allocating “key customer contacts” to key clients. The aim is to improve coordination, however, formal procedures are lacking and informal processes are hampered because some KAMs are BDMs who occupy isolated positions over the project lifecycle. EuroCo adopts a lower profile, the Customer Solutions Director assigning Directors to counterpart key client contacts. Reports at Monthly Board Meetings include monitoring and scoring content to assess attractiveness and progress with the key clients. In practice reports are inconsistent in timing and content.

For project businesses KAM has a twin function: coordination across the interface with clients on and across projects. It covers programme management and project management, potentially providing relationship feedback to inform strategic resource allocation from the portfolio management level. KAM is partial in the companies and without linkage to programme management. There is an absence of resource consideration and how costs can be defrayed against other BD and bid costs by increasing repeat business, improving strike rates and enhancing reputation in the longer term. There also seems to be a lack of awareness throughout the hierarchy as to the conceptual contribution KAM can make to RM and project execution. A stronger integrating function could be developed, extending KAM across project lifecycles for each project and coordinating a programme from the client perspective. Whilst KAM is not an essential component of RM, it could make a significant contribution because the companies have commenced implementation.

4.3 Marketing and the project lifecycle

The companies are structured around projects rather than clients. It was found that project management during execution provides the primary focus, constraining the ability to link client interests identified through BD to the execution phase. Morris and Hough (1987) drew attention to the importance of the front-end to secure project success, and therefore, inductively analysing how this is manifested in marketing and BD is important. EuroCo states

the organisation is structured around project execution and not around clients in a complementary fashion. This is echoed in UKCo, evident in underdeveloped portfolio and programme management. The integration of different BUs is described as a work-in-progress. The company is highly decentralised and tends to focus efforts upon internal matters, inhibiting service integration: *There is an aura of 'we don't like our client and they are very difficult to work with'* (Interview with the Business Development Director, UKCo).

How BD is structured affects handovers between functions along project lifecycles. In EuroCo there has not historically been a strong lead from the centre. This is changing and solutions development is part of the central enabling pre-construction function. Yet, BD is not part of that function. Estimating, bid management and front-end planning are formally and informally dislocated from BD – an absence of formal understanding and informal dialogue. The situation is described as "confusing". Board members have an "engagement process" with counterparts in key client organisations and "Customer Plans" to scope a 5-10 year pipeline and procurement routes. BDMs are not always linked to this action. Relationship or client lifetime value are not considered by EuroCo. EUCo BDMs do not produce the prequalification documentation. Whilst this may be 'efficient', it relies upon effective coordination. Formulating value propositions for win-strategies is poor. EUCo's Chief Executive stated that value identification is now conducted during business development, yet BDMs do not see themselves as identifying value. Prequalification producers, bid managers and subsequent functionaries along the lifecycle do not see the need to work with BDMs to develop value propositions: *It is hard to shoehorn those things in post-prequalification* (Interview with a Regional BDM, EuCo). In UKCo, BDMs focus upon project pipelines and bid opportunities. UKCo BDMs do not consider relationship value or client lifetime value. Bid managers, procurement and project managers address projects from their respective areas of expertise. It is a task orientation rather than a service or client focus. Portfolio and programme management are underdeveloped, the net result being a lack of systematic integration along the project lifecycle. A similar pattern is found in AntCo. One respondent used the analogy that the company needs to move *from an Encarta to a Wikipedia approach to information and relationship management* (Interview with the Bid Manager, AntCo). The same respondent reports the bid team process is rather chaotic, "it's a mess", yet a general belief exists that it is more coordinated than it is. Self-interest amongst BDMs is present: *They want to be able to say, 'I won that job!'* (Interview with the Bid Manager, AntCo).

BDMs are involved marginally in subsequent stages. They do not shape projects towards developing specific win-strategies (cf. Cova et al, 2002). Other functions are insufficiently involved to shape the value proposition at prequalification stage. It is found that bid management and project management are not perceived to add value in later stages. Bid management takes place without reference to the KAM function, lacking detailed understanding of clients and projects at the front-end. The front-end and project management lack integration. Project Managers have no direct involvement or coordinating linkage with BDMs across the case companies. All companies have a cut-off between BD and project management. In every case the procurement and supplier systems are amongst the most robustly developed on their own terms, yet are not linked to other stages and client needs are not specifically linked to procurement. Project managers do not receive guidance on value propositions from marketing and procurement.

Risk is a major consideration for all the contractors, especially EUCo. At tender stage EUCo had a “Financial Bid File” and have recently introduced a “Technical Bid File” to brief project managers. Yet, they do not have a “Service Bid File’ to standardize and add value to the service component of project management. The Director of Business Process stated he is *not quite sure what that would look like*, showing a lack of focus upon service consistency on projects and continuity for (implicit) programme management (Interview with a Director of Business Process, EUCo). It general EUCo think value is lost between prequalification and bid submission. This perception probably arises from regularly coming first or second at prequalification, yet a lower strike rate at bid stage. Inductive analysis suggests the lack of integrated systems, including relationship management systems, is a large contributory factor. Bid teams become locked into the minutiae of operations rather than responding to customer understanding and developing aligned value propositions. Bid managers can be Estimators, Planners or Project Managers. They do not necessarily understand the bigger picture. There is a *tendency for a bid to develop its own strategy* based upon the logic of expertise of engineering and procedures (Interview with a Contracts Manager, EUCo). EUCo knows that bids won are those where they understand the client in detail, yet action to improve this is lacking. Project management focuses upon “the sharp end”. A Contracts Director states there is still work to be done to convince Project Managers that they are “marketeers”. This and other case companies exhibit a project task focus (cf. Handy, 1997) rather than a complementary customer focus now prevalent across most sectors.

At AntCo bid teams are put together *ad hoc* and typically without consideration for carrying forward client understanding, nascent value propositions and requirements. Nor do bid teams engage with KAM functions. There are tensions between Operations Directors that hold the resources and other functions, especially BDMs wishing to have further input. Operations Directors in EuroCo appoint Estimators and Project Managers without reference to BD or bid management. Procurement talk to Bid Managers and Project Managers in response mode rather than proactively. Although EuroCo has not developed an explicit KAM function, there is awareness of the need for integration. A Project Director stated that marketing and BDM have improved and are recognized in project management: *We are just being more professional in our tenders, presentations and all we are putting forward*. Yet the approach tends to be somewhat transactional, pushing information and ideas into its marketplace rather than drawing the client to them. It is described as tactical with a “very short-term view”. The value of a client over extended timescales is selectively addressed, yet the primary focus remains project specific. Project Managers on both the Building, and the Civil Engineering and Infrastructure divisions appear to value relationship building more than their counterparts in other case companies, although how this is achieved is left to individual responsibility. At UKCo BD stops at prequalification and bid management is conducted via estimating and tendering under the commercial management. There is scant evidence of cross-functional working for this case company. Project briefing for UKCo starts with workshops during the bid stage and post-bid briefings before starting on site. There is no direct link for relationship continuity. The project management perspective is that early contractor involvement (ECI) helps align design with construction planning and project management methodologies. Project Managers also perceive ECI to be central to developing effective relationships for execution.

Summarizing, there is a lack of linkage and alignment of systems, added value development and relationship management across the stages of the project lifecycle. Further, there is a similar lack of cross-functional working for support functions such as procurement. This questions whether there is any effective feedback loop into marketing and BD upon project handover and completion. Feedback in the form of key performance indicators (KPIs) and other lessons learned can be seen as purely operational functions. Yet, lessons can be the raw material for improving value propositions from a marketing perspective. In addition, there is a need for relationship continuity to enhance opportunities for repeat business, especially from an RM perspective. Several of the case companies use marketing and BDM personnel to solicit KPI data. Customer feedback for UKCo, especially from a major infrastructure client, shows the company as offering generic services, lacking the specificity to give "confidence" at prequalification and bid stages. This is a management concern at multiple levels; continuous improvement and investing in capabilities is reported as being poorly understood by top management. The decentralized structure and absence of cross-functional working also results in proposed improvements meeting resistance down the hierarchy. AntCo's KPI processes tend to focus upon contract and client compliance rather than embedding feedback and applying lessons learned for developing and delivering value propositions. EuroCo do not apply KPIs as learning opportunities to develop enhanced technical and particularly service value propositions.

Client and consultant relationships that EuroCo claim to nurture during projects tend to "disappear" during defects liability – closing the loop with BDMs is largely absent. A Project Manager recognized this as "a huge inefficiency in the industry". This is because junior staff tend to close out projects, lacking awareness of the benefits and the link with repeat business. It is not picked up in BDM, probably as it detracts from meeting targets on prequalifying for new opportunities.

5. Conclusion and Recommendations

International contractors were found to be in early stages of transition towards RM. Some partial understanding and implementation of the main concepts and principles were found. Relationship building and KAM were most prevalent, but were not linked into investment and capability development from the corporate centre. Relationship management systems to support RM were absent. Other functional systems and procedures did not enable formal or informal integration. Explicit and implicit portfolio and programme management systems were not in place. This was apparent in the partial implementation of KAM as a programme function. Configuring and delivering value propositions remain highly constrained.

Main contractors have become less responsible site production. There were some in-house capabilities, but these were exceptions. In-house providers were treated as 'subcontractors'. Main contractors have become systems integrators. Integrating a range of professional, supplier and subcontractor activities requires integration between contracts and work packages to deliver value whilst spreading risks. It requires internal integrations, which was found to be absent. They may be selling systems integration (Davies et al, 2007), but delivery falls short of solutions that go beyond requirements compliance. A task focus rather than enhanced and complimentary service orientation and value was lost or compromised.

There have been changes in marketing and BD since the 2008 “credit crunch”, yet reversion to a transactional MM under cost driver pressures in the downturn has not occurred. Cost drivers have encouraged the case companies to internalize relational contracting benefits, even where formal partnering has ceased. This trend informs a gradual transition to RM practices. Those firms that effectively embed processes are likely to be the most successful.

BD processes remain disconnected to other functions hierarchically, cross-functionally and over project lifecycles. Functions operated under distinct and separate systems that constrain delivering effective value propositions. Marketing and BD were organisationally isolated, not only due to a lack of systems integration but also poor understanding of marketing and BD amongst senior management, other management and amongst many BDMs. Appropriate systems for RM were lacking. In the absence of “hard” systems to integrate stages on the project lifecycle and ensure cross-functional working, the “soft” systems of RM become more significant to counterbalance hard system deficiencies (cf. Storbacka et al, 1994). This was another aspect of the lack of awareness amongst senior management levels. The task focus resulted in the service value component being overlooked. Adding service value continues to be something of an anathema, which is rather telling for a sector classified as a service industry. This research confirms a number of claims and suppositions about the way marketing and BD are organized (e.g. Preece et al, 2003). In-depth comparative case studies have not been developed previously. This study also maps for the first time the extent of transition from MM to RM approach in construction.

The primary recommendations for research are to i) extend study into construction in several nations and contractors of different sizes, including SMEs; ii) extend study into other project sectors. The primary recommendations for contractors are to: a) improve awareness of marketing and BD functions; b) introduce systems, procedures and behavioural processes to coordinate marketing along the project lifecycle and from the senior management level through portfolio and programme management to project level (front-end and execution).

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Factors Leading to Successful Implementation of the Prison Capacity Development Programme in New Zealand

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Abstract

Following establishment of the Prison Capacity Development Programme (PCDP) a major programme of work was scoped to increase available prison capacity in light of forecast increases to prisoner populations and to replace end-of-life prison facilities. This paper reports on research evaluating a project to implement double bunking accommodation at four sites in New Zealand.

The research employed a case study methodology. Qualitative information was gathered from four prison sites. This enabled multiple site-specific perspectives to be captured which enabled commonalities and differences across cases to be identified. The fieldwork included interviews with 20 participants reflecting various roles and responsibilities associated with the construction project.

Collaboration was unanimously cited as a primary explanation for the project's success. Collaboration was integral to each component of the project and was referenced in connection to the relationship between national office and prison staff, the Department of Corrections and the construction companies. The importance placed on collaboration was evidenced in the use of collaborative work practices at each stage of the project. In addition, collaboration was garnered through a multi-tiered and multi-located management model. In this model national office provided strategic leadership and a strong coordinating role while each of the prison sites, in an appreciation of site specific expertise, were empowered to make the majority of the on-site decisions. This helped ensure the final build met the users' requirements. Other factors that influenced the success of the project include clear expression of imperative, characteristics of the physical environment and adoption of strategies to maintain business as usual.

Keywords: **stakeholder collaboration, construction project management, prison construction**

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1. Introduction

The Prison Capacity Development Programme (PCDP) was established by the New Zealand Department of Corrections in December 2008. A major programme of work was scoped to increase available prison capacity to meet a Ministry of Justice forecast of prisoner population numbers and to replace end-of-life prison facilities. The first project to be progressed was the addition of capacity through double-bunking parts of the existing prison estate. Double bunking has been implemented in other western countries to deal with steadily increasing prison populations. In 1995 Canada was double bunking 25% of its prisoners (Daubney 2002) and the American Bureau of Prisons currently allows for 25% of its maximum security prisoners and increasing to 100% of low security prisoners to be housed two to a cell (Higgins 1996). Other researchers suggest that prisoner population intensification by double bunking can raise concerns about civil liberties and prisoner welfare (Higgins 1996; Bennett, Flanagan et al. 1997) however this paper does not traverse these issues. They are considered outside the scope of the research, which is to identify factors that have contributed to successful implementation of the projects.

Double bunking was seen as the only practical option that could deliver the necessary capacity in the required timeframe and in 2009 Cabinet gave approval to begin double bunking four existing regional prison sites as well as to allow for it in the redevelopment of Mount Eden Prison in Auckland. By double bunking existing cells, the Department was able to add, at a cost significantly under what had been budgeted, capacity equal to three prisons in less than 12-months. These achievements were seen to be significant in light of the fact all four projects were completed in populated prison environments, where usual operations were required to be maintained throughout the construction period. Full integrity of the security system was required in circumstances that could see up to 150 contractors on site at any one time. This was further exacerbated by the security risks posed by the number of tools contractors needed to bring on site, the risk that contractors might introduce contraband and the risk of prisoner escape.

Given the budgetary and timescale successes (Waterhouse 2010), and especially in light of the fact that no security breaches occurred during the construction period, the Department of Corrections commissioned an evaluation to understand factors leading to the project's success (Roguski, Kingi and Gjerde, 2010). This paper presents the findings of that report and in the process contributes to knowledge about construction projects undertaken in populated prison environments.

Traditional, sequential procurement methods are by far the most popular in the New Zealand construction context as they are considered best to enable the contracting parties to limit their exposure to financial and time risk (Wilkinson and Scofield 2003). However, such methods are also considered to take longer and create adversity between the contracting parties, as attention to risk management dictates behaviour in the relationship (Barrett and Barrett 2006). In response, owners may insist on higher levels of contractual control which in turn leads to diminished levels of trust between the parties. The nature of the double bunking projects, their

settings in live prisons and the imposed restrictive time constraints gave cause for the Department to explore alternative procurement and contract management methods.

Partnering arrangements are presented as useful methods to improve construction project performance and there is evidence of increased use of these forms of contractual relationship over the past 20 years. Murray and Langford (2004) identify three key objectives that underpin current interest in partnering; helping establish agreed mutual objectives, providing a methodology for problem resolution and creating a culture of continuous, measured improvement. A fundamental tenet of partnering is the sharing of responsibility and risk, which can enhance collaboration between the contracted parties (Bresnan& Marshall 2000). However, partnering does not appear as a *one-size-fits-all* concept, it is a term applied to a wide spectrum of management approaches. Thompson and Sanders (1998) suggest that partnering occurs over a broad continuum with applications coalescing around four key stages – competition, cooperation, collaboration and coalescence. The traditional owner contractor relationship is represented as competition in this continuum, which the authors argue takes place in the absence of partnering. The other three stages incorporate increasing levels of alignment and commitment between the contracting parties. As contracting parties move away from their competitive stances, Thompson and Sanders argue that cooperation becomes commonplace and the desire to work jointly or to collaborate arises, particularly around efforts to improve project processes.

Normative theories of partnering and collaboration have been dominant in the literature since the 1990s, when interest in collaborative working relationships began to emerge. Comparisons are made with other industries such as manufacturing, where long range views enable development of strategic relationships rather than a focus on short term, one off projects. Partnering and collaborative working arrangements are often researched and presented as stylised models and abstractions. Participants in the construction process can find such models difficult to adopt and put into practice. Bresnan (2009) argues that what is needed is better evidence from local practices where interaction is negotiated rather than ‘applied’. The present research addresses this need.

Trust, when it is allowed to flourish in a working relationship, is said to reduce transaction costs and enable sharing of sensitive information. As trust has a positive influence on the strength of inter-organisational relationships in a construction project it can be argued to have a positive influence on project success (Akintoye and Main 2007). Indeed, it is consistently shown to be a desirable way of helping align teams behind goals and objectives in a project context (Bresnan 2009).

Shelbourn and Bouchlaghem, et al. (2007) developed a framework through which to investigate the UK construction industry’s requirements for and general uptake of collaboration in projects. Based on their findings they propose six essential requirements for effective collaboration:

- A clearly articulated model for working together in collaboration

- Processes that enable collaborators to agree a common vision and priorities for the collaboration and to promote trust
- Standards that enable technologies to work effectively
- Examples of good practice
- Design of technologies taking into account people
- Clarification of liabilities for outcomes of collaborative processes

It would appear that formal collaborative efforts require considerable planning and structuring to ensure success of the outcomes.

A number of factors must be managed to avoid perceptions of failed collaboration. These relate to lack of trust and consultation between collaborators, lack of experience and poor business fit (Akintoye and Main 2007). The most important factor leading to failure is the failure of one of the partners to the collaboration failing to uphold their end, in terms of meeting the agreed goals and objectives.

Akintoye and Main (2007) investigated contractors' perceptions of collaborative relationships in construction. They were found to be generally positive about collaboration and to come into such arrangements in order to share risk, access innovation and technology, make efficient use of scarce resources and to meet client requirements. Beyond this Akintoye and Main found that success in collaborative project settings is strongly influenced by levels of resourcing, the extent to which the partners are contractually on equal footing, the extent to which non-financial benefits are understood and accepted and clarity in expression of the project objectives.

2. Research Methods

A qualitative evaluation methodology was used. The study aimed to gather multiple perspectives on issues influencing the construction. Initially findings were analysed for each prison separately and then findings were compared across each of the prison sites. This enabled commonalities and differences to be located.

To ensure that a variety of perspectives were gathered, the research drew on individual and small group interviews with national office staff, the project team and construction companies. Regional and construction company perspectives were gathered at the following four Double Bunking project sites. Inmates were not interviewed as the study focused on the success of the construction and not on inmates' attitudes of double bunking.

In total 20 participants were interviewed. Participants were selected to reflect the various roles and responsibilities associated with the construction project. Interviews followed a semi-structured interview format. Individual interviews were carried out with national office representatives and with the two participating prison managers. Small group interviews occurred at prison sites with site team members. Interviews ranged between 60 and 90 minutes and, on all but one occasion, were audio recorded with participants' consent.

Interview data was analysed to locate patterns and themes relating to the research objectives and wider contextual issues. In practice, a process of constant comparative analysis was used throughout the lifespan of the research. In the first instance this meant that emerging findings were consistently tested to determine the extent to which they were common or unique to each individual prison's participants. Next, the findings for each of the four prisons were compared with similarities and differences identified.

3. Findings

The project's success was initially attributed to a strong mandate to increase available prison capacity within a short-timeframe. The mandate was supported by funding of double bunking projects at four existing prison sites.

Project participants unanimously cited collaboration as a primary explanation for success as collaborative organisational cultures developed within each of the construction sites and also between the site and national office. The importance placed on collaboration was evidenced in the use of collaborative work practices at each stage of the project. For instance, the initial design and costing phase of the project was achieved in a short timeframe due to the strategy of bringing together a team of relevant consultants to scope and cost the project. The group worked intensively together over a four week period to develop the required plans.

The emphasis placed on collaborative work practices was attributed to a combination of the Project Director's influence and prison manager leadership. The Project Director reinforced collaboration through a recruitment and procurement process that used a commitment to collaboration as an important assessment criterion. Collaborative work practices were also attributed to prison managers and staff professionalism. For instance, Prison Service staff explained that their initial concerns about the extensiveness of the double bunking project were alleviated through prison managers having involved prison management teams in jointly scoping the project requirements. As an outcome of this process each site developed a sense of ownership of the project which provided the foundation for professional pride (working towards deliverables and timeframes) and viewing the project as a collaborative endeavour.

3.1 Organisational structure

Rather than an autonomous and centralised approach to management this example highlights that a factor in the success of the project was a multi-tiered and multi-located management model. In this model the national office provided strategic leadership and a strong coordinating role while each of the prison sites, in an appreciation of site specific expertise, were empowered to make the majority of the on-site decisions. The combination of centrally located strategic leadership and on-site expertise engendered collaboration throughout each project phase and each level of responsibility. This ensured that the final build met end users' needs.

Time and communication efficiencies were generally attributed to the structure of each of the prison-specific project teams and the fact that these teams were located at each of the four prison sites. The prison project team primary structure was framed around the Site Liaison Officer, the Site Project Manager for Construction, the Prison Construction Security Officer and the Construction Project Manager. Table 1 outlines roles and responsibilities of each position.

Table 1: Roles and Responsibilities of Prison Construction Project Teams

Project Role	Primary Responsibilities
Site Liaison Officer	Reported directly to the Prison Manager. Primary responsibility was to ensure that the Double Bunking Construction Project occurred without impacting on business as usual. Major components of the role included: ▪ Managing the project line and ensuring that prison operations were not negatively affected ▪ Overseeing security arrangements ▪ Ensuring there were sufficient prison personnel on-site ▪ Scheduling the decanting and recanting process. Decanting of prison units involved moving inmates to other units or prisons to allow the double bunking construction to occur and recanting involved arranging for prisoners to be moved back into completed/double bunked units ▪ Working alongside the Prison Manager to recruit and place new staff ▪ Communicating to the Prison Manager and Prison Services (National Office)
Site Project Manager for Construction	Reported directly to the Department's Double Bunking Project Director. Primary responsibilities included: ▪ Avoiding and minimising any effects of the construction on business as usual ▪ Administering the contract with the construction company(s) ▪ Issuing instructions to the contractor ▪ Managing interactions with the contractor concerning the design and implementation of the design. ▪ Acting as the interface between the contractor and the project on-site team
Prison Construction Security Officer	Reported to the Site Liaison Officer. Responsible for developing, implementing and maintaining construction security protocols and practices throughout the duration of the project
Construction Project Manager (Construction company)	Reported directly to the construction company's senior management. Primary responsibilities included: ▪ Primary interface with Site Project Manager for Construction ▪ Managing all aspects of the construction and ensure that the project deliverables are met within required timelines ▪ Attending all on-site project meetings ▪ Securing subcontractors ▪ Ensuring the construction workers adhere to security protocols ▪ Pricing each aspect of the project and liaising between the construction companies' Quantity Surveyor and the Department's Quantity Surveyor.

While the way in which the project team was structured and located provided the foundation for efficient on-site communications, this does not fully explain the success of the project team per se. In this regard participants drew attention to a number of additional factors. First, participants discussed key attributes, specific to each role, that go some way in explaining much of the success of project teams. These attributes provided the basis for recruitment to each role and or the project. Next, the success of the project teams can be attributed to efficient selection processes. Prison managers related having a clear understanding of the attributes needed for

the roles of Site Liaison Officer and the Prison Construction Security Officer and appointed accordingly. Each of these positions was appointed from within the prison staff at each site.

3.2 Procurement and contractual relationships

Historically, the Department has used traditional (often referred to as 'confrontational') contractual arrangements that have involved contractors being invited to tender on a set of completed designs. A major criticism of this method is that it is less suited to changes in scope and in detail, which were considered inevitable because design was largely incomplete at the time of contractor appointment. Another is that it does not allow the builder to give input to the design phase regarding buildability. The traditional model treats design and construction as separate entities leading to risk that ineffective communication, difficulties coordinating activities or conflict between the designers and the contractors will arise. A fast-track approach was adopted for each project site with the design activity overlapping into the construction phase.

Standard forms of contract in the New Zealand context allow for the engineer or architect to act in a third party capacity to oversee the project's management. A significant modification to the Department's previous practices saw them remove the role of the engineer to the works, the administrator, from the construction contracts in the Double Bunking Project. In doing so, the Department took on the roles of contract administrator and project manager, requiring a direct working relationship with the contractor. A collaborative arrangement was integral to the success of the project because project design was on-going throughout most of the construction period. With many decisions required to be made on-site removal of the third party administrator forced the client and contractor into a closer working relationship, which facilitated collaboration.

As the project developed as a dynamic build (design, pricing and constructing took place in quick succession or they were overlapped) the tender process was designed to engage construction companies that demonstrated technical ability and a willingness to participate in collaborative working arrangements. The importance of collaboration was reflected in the tender assessment criteria with up to 70 percent of the assessment based on non-priced attributes. Much of the emphasis placed on collaboration was based on Prison Services participants' previous unsatisfactory experiences with projects that had used confrontational (rather than collaborative) contractual relationships. In these situations the confrontational relationship was reported as pitting the construction company against the client when variations to the design might result in increased costs. Further, in regard to companies with a large bureaucratic structure, variations to design within such a model were perceived to result in a protracted re-costing process that risked slowing the construction process down.

Throughout the procurement process potential contractors were given clear messages that any collaborative arrangement needed to jointly exist at the national and prison site levels. This occurred most obviously through:

Pre-tender submission scoping exercises – prior to submitting a tender for the Double Bunking Project contractors were invited to visit the prison sites with the expectation that understanding the prison environment would provide an efficient knowledge base to inform their tender preparations. As an outcome of this process prison staff informed contractors about the challenges of working within a secure prison environment and that a close collaborative arrangement, between the prison and the contractor, would be expected

Tender presentations - all companies that had submitted a tender were asked to provide a presentation to the procurement panel which, while primarily comprised of national office staff, included a representative from each of the prison sites. Through this process contractors were questioned about how they would maintain site security while carrying out the build and how they would work alongside the prison to maintain business as usual (including security).

Traditional construction projects have involved contractual arrangements around a specified design and related pricing structures. As aspects of the Double Bunking Project's design were incomplete, and given the project's time constraints, the Department was not able to enter a price specified contractual arrangement. Rather, the Department utilised a contract variation process that allowed the works to continue while pricing occurred simultaneously. This enabled the design-construction process to occur dynamically whereby the aspects of the build were designed, priced and built in quick succession.

The fact that the procurement process successfully secured contractors committed to collaborative working arrangements appears to have provided the Department with a sufficient level of trust to be able to instruct unpriced contract variations. This way of working was reinforced through contractors providing transparency around costs and decisions underpinning their cost-related decisions. For instance, in relation to prices for material, subcontractors' quotes and any breakdowns of prices were provided to the Department. Both parties' use of their own quantity surveyors provided a sense of assurance over costing which in turn facilitated a greater sense of trust and reinforced the use of contract variations that enabled the build to continue while costs were approved later.

3.3 Communications

A detailed communications plan guided the development of multi-tiered communication streams. These streams threaded through and across prison sites and occurred bi-directionally whereby prison site communications were channelled to national office staff and vice versa.

The various communication streams reinforced and maintained the collaborative working model established by the Project Director. The following describes the types of on-site communication strategy used at one prison to plan for and maintain business as usual. Through the various communication streams each of the prison sites were able to learn from the others and the national office team was able to have an in-depth overview of what was occurring at each of the sites.

Case Study: Otago Regional Corrections Facility

Every Thursday the site project team [Site Liaison Officer, Site Project Manager for Construction, Prison Construction Security Officer] would meet with the contractor and sub-contractors for a Tool Box. The meeting provided an opportunity for the contractor and sub-contractors to discuss what work had been undertaken the week before and scope out the work that was coming up the next week. It needs to be understood that the Tool Box meeting is generally held between contractors and sub-contractors only. It was because of our collaboration with the contractor that we {the project team] were invited to sit in. It was an excellent way for the project team to know what was going on.

After the Tool Box meeting the project team held a Weekly Coordination meeting to discuss issues arising out of the Tool Box meeting with a special emphasis on those construction activities planned for the coming week. We would discuss the coming week's construction activities and issues that might affect prison operations. Because of the very nature and speed of the project it was import to meet and anticipate problems and work out solutions.

Outside of this formal weekly coordination meeting the Project Manager and I would meet daily to discuss any arising issues. We each had an open door policy. I would brief the Prison Manager on a weekly basis and he may or may not choose to come to one of our weekly coordination meetings.
Site Liaison Manager

3.4 Prison security

External consultants who had not worked within a prison environment or knew little about secure environments were able to rely on the experience of prison operational experts who provided input at each project phase. Each of the construction companies had anticipated, on average, a 20 percent reduction in productivity because of the time taken to comply with prison security measures. For instance, the time associated with entering and exiting the secure environment as well as delays associated with waiting for deliveries to arrive at the construction site or those associated with having to travel to dedicated buildings for lunch and toilet breaks. However, through a number of on-site efficiencies productivity remained at a high level. Participants attributed the majority cost savings to these on-site efficiencies as initially anticipated delays were circumnavigated.

Security-related efficiencies were discussed in reference to processing construction workers and in terms of providing environments in which construction workers felt sufficiently secure to be able to work efficiently. Each of the prisons established a security clearance and training system that, once completed, resulted in construction workers accessing the prison in a time efficient manner. To be eligible for clearance all construction workers were required to undergo a health and safety induction and training on security requirements for working within the prison. They were also required to obtain a security clearance.[3] Once security clearance was received appropriate photo identification was issued. Identification cards were found to reduce the

[3] Initially all contractors were required to obtain a Ministry of Justice security clearance. However, because of up to six week time delays each of the prisons used a Police security check which they were able to do through the prison's on-site database.

amount of time required to process a worker through the sally port as it indicated to the Corrections Officer that all security checks had been done.

A 2.4 metre fence was constructed around each of the construction areas (including units and new infrastructure builds). Placed within these sites were contractor sheds, toilets and a secure utility area that allowed the workers to lock their tools away at the end of the working day. Having a secured site enabled the construction workers to stay in the one place the whole day and mitigated the risk of tools being lost in the process of bringing them on site and the number of officers need to escort the workers throughout the working day. Hessian, scrim and/or sheets of black plastic were placed around each of the 2.4 metre fenced sites. This provided a demarcation between prisoners and construction workers and was reported as giving workers a sense of safety. It also prevented communication between prisoners and workers which was regarded as an important intervention as communication risked solicitation.

4. Conclusions

Although the literature does not provide examples of construction carried out in a secure prison environment, we can note previous research that supports the findings of this research. Barrett and Barrett (2006) posit that good outcomes can be driven by project constraints. Constraints can be in the form of either resourcing or time constraints, which require the project team to work in a collaborative and creative manner resulting in a demonstrable benefit to the community. In the case of the Double Bunking Project the tight project timeframe drove the collaborative working processes and innovative practice evident at each prison site and across the four sites where the double bunking occurred. In addition, there were open lines of communication which continually facilitated learnings across sites and speedy decision-making processes at a local level and strategies to maintain business as usual expedited the completion of the build with significant cost savings to the client. Trust is of paramount importance in such a process, along with ongoing consultation, underpinned by the level of experience of those working on the project.

The literature also includes a growing number of best practice examples for collaboration and partnering in construction projects (see for example Bresnan and Marshall 2000; Barrett and Barrett 2006; Akintoye and Main 2007; Badenfelt 2010; Yang, Huang et al. 2011). The efforts to examine practice in this manner and disseminate the findings enable practice to be informed by rigorous examination of practice activities, rather than relying solely on guidance from normative theory. Table 2 outlines best practice indicators alongside our findings.

Table 2: Best Practice Indicators Exemplified by the Double Bunking Project

Best Practice Indicator	Success Rating	Qualification
Initial values and objectives of a project should be agreed by all parties at the outset in the format of the brief	High	The project was driven by a strong imperative which provided a foundation of shared agreement

Briefing should continue throughout the project and when the brief does adapt and change it should be clearly communicated to all parties, as the brief is the benchmark against which project success must be measured	High	Collaboration also arose from multi-tiered communication streams. These streams threaded through and across prison sites and occurred bi-directionally whereby prison site communications were channelled to national office staff and vice versa
Change is a trigger for collaboration between contracting parties and constraints introduced through change help to focus the efforts	High	Each of the contracting companies demonstrated a strong willingness to adapt and to bring innovative ideas to the build
Trust is a dynamic quality in a contractual relationship and it should throughout the project be actively nurtured by all parties. Project managers have a particular role to play in this and teambuilding efforts can help engender a trusting relationship between the parties. Trust in staff – trust between client and construction company, trust that builders would deliver, trust that client would be fair in the on-going design, pricing, building process	High	Trust underpinned the Department and contractor relationship. This was initially secured through the procurement process and reinforced through the mutual use of Quantity Surveyors and site specific project teams
Trust allows parties to collaborate more effectively as there are perceived to be fewer barriers to participation and creativity. Problem solving – contractors took ownership these and came back with innovative solution	High	Multiple examples were provided of innovative and creative practice
Systems to harvest and pass on knowledge within the project team and participating organisations will help enable fruitful collaboration. Innovative practice, often undertaken in a collaborative setting, grows on a foundation of appropriate knowledge and experience. Reporting structure, site visits, onsite presence of architect, QS and Costing	High	A combination of site-specific project teams and multi-tiered communication streams resulted in a high degree of knowledge management. This was most obvious in relation to: ▪ Each of the prison sites were able to learn from one another ▪ The national office team was able to have an in-depth overview of what was occurring at each of the sites ▪ External consultants who had not worked within a prison environment were able to rely on the experience of prison operational experts

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The role of hospital infrastructure in building healthcare system resilience to extreme weather events in Australia

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Abstract

Extreme weather events can pose extraordinary risks for hospital infrastructure and by extension to community health and well-being. Not only can extreme weather events cause physical damage to hospital infrastructure but they can challenge the design capacity of hospitals by changes in the level and types of admissions. To explore the role that built assets play in their current disaster planning strategies a detailed analysis of twenty one (21) databases and a thematic content analysis of fourteen Australian hospitals disaster plan and supplementary plans is presented. Using Holling's adaptive cycle and Nonaka and Takeuchi's knowledge creation SECI model a Hospital Resilience Learning Cycle (HRLC) framework is developed which can help hospital stakeholders adapt their built environment to changing healthcare needs during EWEs.

Keywords: Extreme weather events, resilience, built environment, hospitals, thematic content analysis

1. Introduction

Extreme weather events (EWEs) are those that "exceed a particular threshold and deviate significantly from mean climate conditions" (Linnenluecke and Griffiths, 2010). Evidence indicates that many hospitals are vulnerable to such events. For instance some hospitals were completely destroyed during 2004 Hurricane Katrina in the USA (Rodriguez and Aguirre, 2006). Likewise in Australia many hospitals have been damaged and cut-off from surrounding communities during recent severe cyclones, storms and major flooding events in the last five years (Hunter New England, 2007, O'Brien, 2009, Schulenberg, 2009). Given that EWEs have the potential to impact significantly on community health and well-being, there is an urgent need for research into the factors that determine hospital resilience to such events. Given that building users in the health sector are largely unaware of the influence which buildings have on their day-to-day activities (Zimering et al 2005), the aim of this paper is to explore the importance that is given to built infrastructure in the development of disaster management plans in the health sector.

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2. Reconceptualising resilient hospital infrastructure

The concept of resilience is not new and emerged in the 1960s along with the rise of systems thinking. Resilience refers to a system's ability to react and respond to shocks and return to a previous stable state (engineering resilience) or to new future improved state (ecological resilience) (O'Rourke, 2007, Holling, 2001, Gunderson and Holling, 2002). A greater understanding of human and environment interactions that influence system resilience has in recent years led to a hybrid concept of socio-ecological resilience which is based on the human capacity to learn, innovate and adapt their behaviour to enhance a system's resilience. To explain this process, Gunderson and Holling (2002) developed the adaptive cycle (Figure 1) which involves four continuous phases of exploitation, conservation, release and reorganization. Exploitation (r) refers to the mature or stable state which tends to develop in systems as they exploit resources around them. Over time, the system accumulates and conserves resources (K) which are then released when faced with a disturbance (Ω). As the new disturbance abates, the system begins to reorganize (α) renew itself and eventually enter the exploitation phase once again.

The model of the adaptive cycle was derived from the comparative study of the dynamics of ecosystems. However, it can also provide new insights into how hospitals can become resilient to EWEs. For example, hospitals like all organisations become stable over time and develop organisational routines. They accumulate resources and build-up redundancies which are then used to cope with the extra demands imposed by an EWE. After the EWE event, the system then reorganises itself by learning lessons from how it coped with the EWE and incorporating these into new disaster policies and plans. Through this process the hospital enters a new state of improved resilience and equilibrium until a new EWE event throws it into the same cycle. Over time, as the hospital faces more EWEs, the hospital system strengthens its resilience to such events although never becomes perfectly resilient since the nature of these events are constantly changing. This of course is the theory. In practice the process is not likely to work as perfectly as described here.

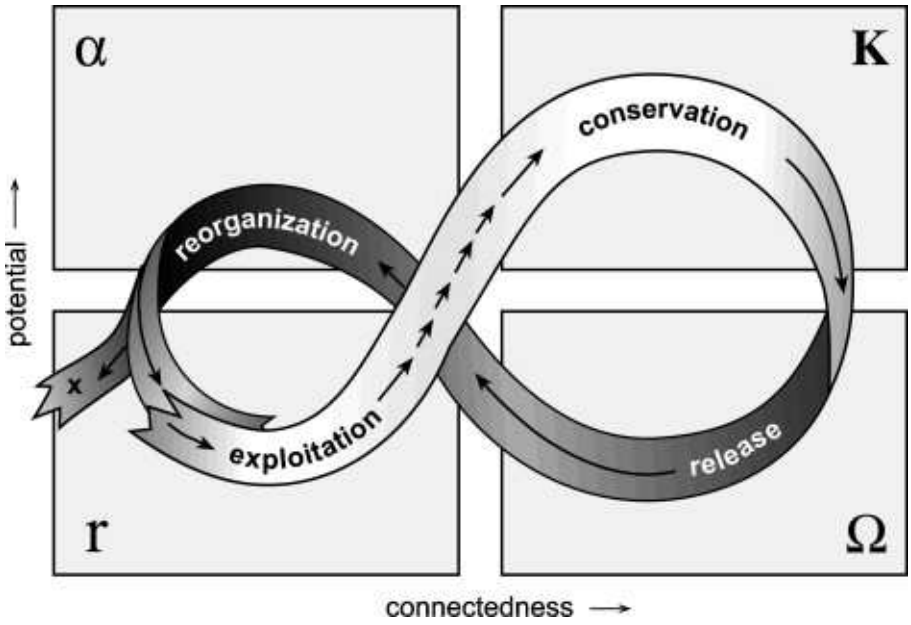

Figure 1: The adaptive cycle (Source: Gunderson and Holling 2002)

Central to the effectiveness of the adaptive cycle is the learning that occurs from each disturbance. However, the process is learning is not explained by the adaptive cycle. Nonaka and Takeuchi's (1995) model of organisational knowledge creation (SECI Model) helps to explain the process of organisational learning in more detail (Figure 2).

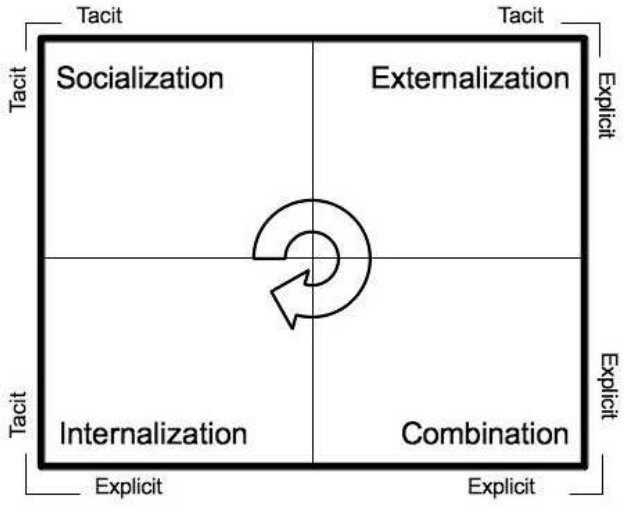

Figure 2: The SECI model (Source: Nonaka and Takeuchi 1995)

In Figure 2, socialisation is the process by which organisational members share tacit knowledge. By doing so they learn the norms and values of the organisation so that, they become part of that organisation's culture. This involves the sharing of feelings, emotions and experiences which allows people to break down interpersonal barriers and "get to know each other". In responding to an EWE this process is very important since people often have to move outside formal procedures to cope with unexpected situations. It also recognises the importance of understanding the needs and issues from individual hospital stakeholders perspective. Externalisation is the process of articulating tacit knowledge as explicit knowledge in the formulation of disaster management procedures which attempt to document how people should behave during an EWE. Combination is the process of connecting discrete elements of explicit knowledge (perhaps relating to different parts of the organisation) into an integrated disaster management plan which recognises that different parts of an organisation perform specific but interdependent functions during an EWE. In the context of responding to EWE's, this process might also involve the formulation of disaster management plans and policies which attempt to resolve conflicting interests and document how people from different parts of the organisation and external agencies should coordinate and interact during an EWE. For instance disaster planners and facility managers working together to inform appropriate disaster response and adaptation actions in the face of EWEs. Finally, internalisation is the process of embodying explicit knowledge as tacit knowledge, and when this happens, individuals'/organisation's existing tacit knowledge is broadened, extended, and reframed. This is the stage where a shared mental model is achieved so that

stakeholders respond automatically and instinctively during an EWE rather than having to resort to reading the rules and procedures and thus delay the response. This may be achieved through educational processes, repeated disaster drills, and scenario analysis. When this embodied tacit knowledge is shared with other individuals it creates a culture of resilience and sets off a new spiral of knowledge creation through socialisation etc.

Combining resilience theory with learning theory it is possible to propose a new conceptual framework called the Hospital Resilience Learning Cycle (HRLC) (Figure 3).

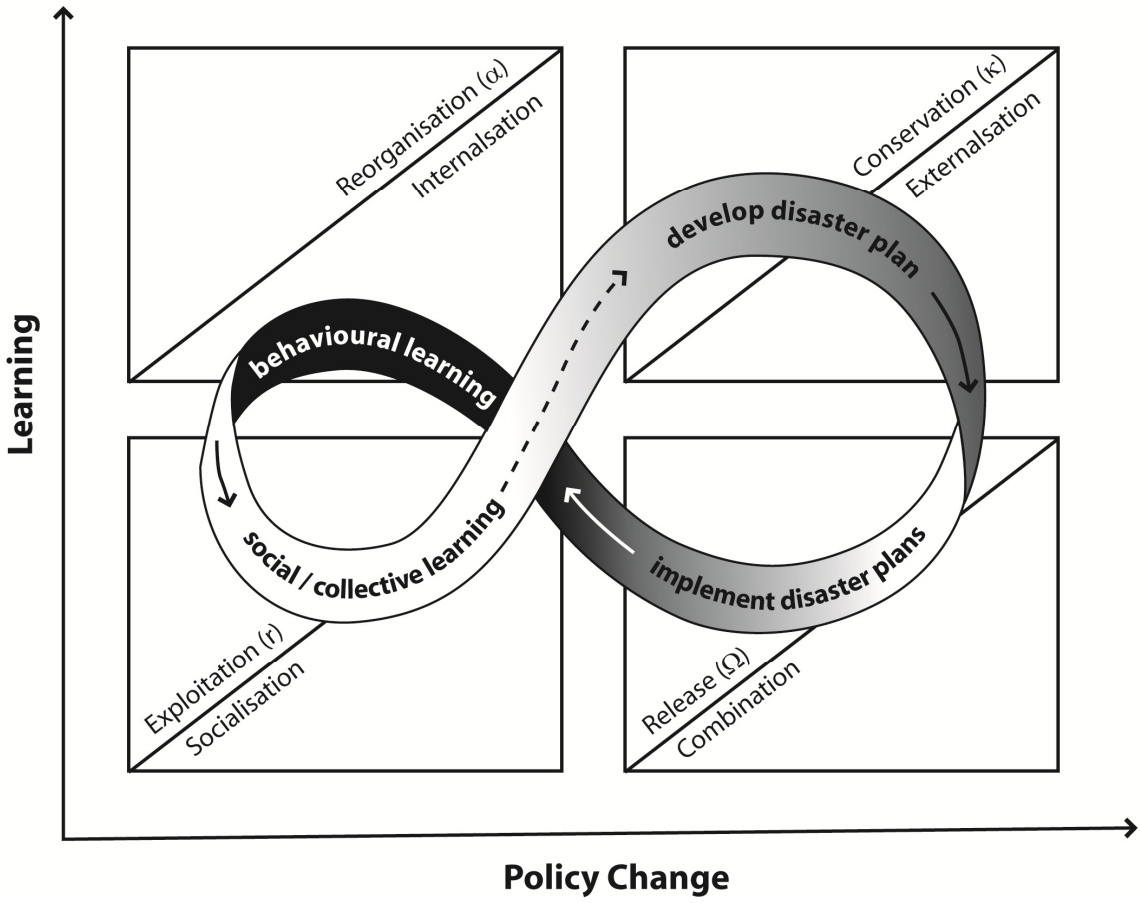

Figure 3: Hospital Resilience Learning Cycle (HRLC) (source: Chand and Loosemore 2012)

The HRLC model illustrates that the process of learning and adaptation are inextricably linked in the process of building organisational resilience to EWEs. It consists of four phases where the four phases of the adaptive cycle are combined with the SECI model. To interpret the HRLC model practically, the cycle begins with phase one: develop disaster plan.

Phase 1 (Develop Disaster Plans), is the conservation phase of the adaptive cycle where the hospital develops an organisational memory in the form of disaster management plans. This phase relates to the externalisation phase of the SECI model where tacit knowledge is made

explicit and recorded in the form of written procedures such as disaster plans. During the development of disaster plans as the new knowledge accumulates better understanding and agreement, it increases conformity and harmony amongst the hospital stakeholders. As a result disaster planning process can become rigid. For instance, emerging challenges such as the uncertain scenarios of EWEs are either ignored or not considered important. This increases the chance for disaster plans to fail or not being able to deal with new challenges during a new non routine EWE that is not accommodated in the Disaster Management Plans (DMPs).

Phase 2 *(*Implement Disaster Management Plans) is the release phase of adaptive cycle where stored resources in phase one are released. This relates to the deployment of resources through the implementation or activation of disaster plans developed in the conservation phase to deal with an EWE. It also relates to the combination phase of the SECI model since it involves integrating individual expertise from different parts of the organisation that are required to work together to collectively deal with an EWE. The effectiveness of hospital disaster plans and their preparedness to disasters are tested during this phase and provide the foundation for fundamental lessons in the next phase of the HRLC model.

Phase 3 (Behavioural learning) is equivalent to the reorganisation phase in the adaptive cycle and the internalisation phase in the SECI model where both these phases signify the generation of new knowledge and learning. The reorganisation phase indicates the re-structuring of the organisation post disaster as the lessons learnt from the implementation phase are absorbed. In the context of responding to EWEs, this can be related to behavioural learning amongst individual hospital stakeholders which is critical for re-organisation. Behavioural learning can results from both failure and success of disaster plans to deal with disaster impacts. People learn individually and also learn from each other. These lessons learnt from past experience are then internalised to broaden individual tacit knowledge that provide new insights for future disaster planning and thus relates to the internalisation phase of the SECI model.

Phase 4 (Social and collective learning) is the exploitation phase in the adaptive cycle where there is a rapid accumulation of resources such as new tacit knowledge. For instance, hospital stakeholders involved in a disaster response, come together and share their experiences. This sharing of individual tacit knowledge relates to the socialisation phase of the SECI model. This accumulation of tacit knowledge is converted to explicit knowledge in the form of changes in the existing policy or development of new policy in the first phase of the HRLC model (develop disaster plans) which continues the on-going adaptation over the life of a hospital to maintain its resilience.

3. Method

It is not possible within the confined of this paper to explore the entire HRCL model. For this reason we focus on phase one (Develop Disaster plans) where a hospital learns its lessons from previous EWEs and incorporates them into future disaster management plans. To investigate how this occurs in reality we undertook a thematic content analysis of disaster

plans and supporting supplementary plans across thirteen major hospital facilities in New South Wales (NSW). Supplementary Plans mainly included Critical Operations Standard Operating Procedures (COSOPS) and Business Continuity Plans (BCPs). The hospitals in our sample (Table 1) were selected on the basis of that they had been affected by EWEs in the recent past and therefore, theoretically at least, should have learnt from those experiences and incorporated these lessons into their disaster management plans. Another criterion for the sample selection was the significance of the hospital's service delivery in its local area during disasters. For instance, the hospital is used as a referral facility during disasters.

Table 1: Sample structure and descriptions

Hospitals	Description
A	**200 beds, major forensic facility in NSW, sustained damaged to hospital building, infrastructure and vehicles during 2007 severe weather**
B	**50 beds, district hospital service and an extensive range of health services, sustained damaged to hospital building, infrastructure and vehicles during 2007 severe weather**
C	**200 beds, Major hospital facility, service a population of 750,000. Sustained major damages to facility during 1999 hailstorm and minor damages in 2006**
D	**50 beds, hospital, sustained damaged to hospital building, infrastructure and vehicles during 2007 severe weather**
E	**200 beds, Major hospital facility, sustained damaged to hospital building, infrastructure and vehicles during 2007 severe weather**
F	**200 beds, hospital contains major training institute, sustained damaged to hospital building, infrastructure and vehicles during 2007 severe weather**
G	**26 beds and 19 age care beds, district hospital service and an extensive range of health services, such as age care, affected by regular bush fires, floods in 2009, 2010 and 2011 and extreme heat in 2011**
H	**100 beds, district hospital service and has a range of allied health services, sustained damaged to hospital building, infrastructure and vehicles during 2007 severe weather**
I	**88 beds and serves a population of 20,131, major hospitals. affected by regular bush fires, floods in 2009, 2010 and 2011 and extreme heat in 2011**
J	**50 beds, hospital, sustained damaged to hospital building, infrastructure and vehicles during 2007 severe weather**
K	**35 beds, important regional multipurpose service facility with age care and respite care subsidy, major impact of their service delivery during 2009 dust storm**
L	**600 bed, major hospital contains 3 children's hospitals, sustained damaged to hospital building, infrastructure and vehicles during 2007 severe weather**
M	**150 beds, main hospital for the population of Lake Macquarie, sustained damaged to hospital building, infrastructure and vehicles during 2007 severe weather**

The framework for analysing the hospital disaster plans and supplementary documents was based on Markus's BPRU model (Markus et al., 1972). According to Markus et al, a building facility and its stakeholders can be seen as an 'adaptive system' which comprises five key elements (sub-systems): the building system; the environmental system; the activity system; the objectives system and the resources system. The Building System comprises the external envelope; the structure; the division of internal spaces, services and contents. The Environmental System refers to the internal building environment created by the building system. The Activity System represents what happens within the facility and the Resources

System represents the external environment from which the other sub systems draw to enable them to function effectively. This includes the supply of physical, financial and human resources. The first four systems determined the coding themes for thematic content analysis. The disaster plans were examined using *NVivo*, the content analysis software. The use of this content analysis software allowed a thorough analysis of each document enabling frequency count of particular words and provided analysis of surface (manifest) and underlying (latent) meanings (Babbie, 2007). The content analysis software allowed searching for the synonyms and stemmed words of the individual variable of interest. The findings of the analysis are discussed below. Table 2 below presents the coding framework used for thematic content analysis.

Table 2: Content Analysis coding framework

Themes	Variables
Building	Building, window, fire alarm, lifts, stairs, roof, access, door, room, façade, structure/structural damage, Water, power/electricity, generator, light, air conditioning, phone line /telecomm, sewerage, equipment
Environment	Corridor, ventilation, heat, cold, humidity, lighting, air quality, temperature, air flow, smoke, infection control
Activity	Training, drill, staff, evacuation, transport, maintenance, repair communication, retrofit
Objective	Plan/Planning, debriefing, Service continuity, Business continuity, preparedness, patient treatment, emergency supplies

4. Results

Figure 4 presents the percentage of coded variables for all four themes in Markus's BPRU model.

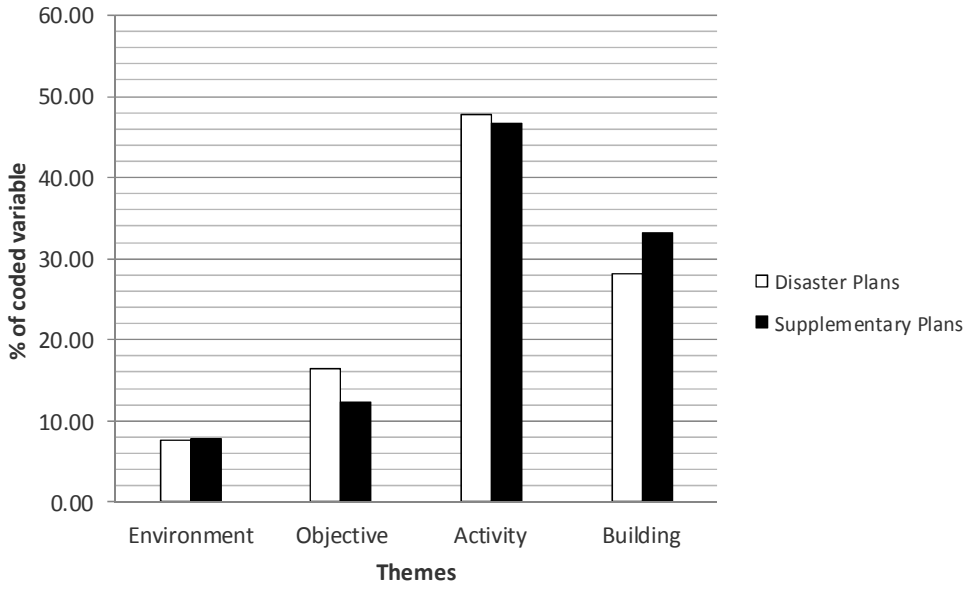

Figure 4: Percentage of coded variables

The BPRU model indicates that the four systems are equally important in delivering the organisational goals such as hospital service delivery and ensuring their facility resilience to EWEs. However, the variation across the four themes indicates that each hospital disaster plan is developed with consideration of their special issues. It is interesting to note that the internal environment that supports hospital service delivery has largely been ignored. Reflecting using the HRLC model, it can be associated with the lesson learnt from each hospital's past experiences. For instance, either their internal environment was not affect during the past events so the hospitals are less concerned about it or the disaster planners failed to internalise all the lesson learnt from the ground floor staffs across the hospital.

The low focus on objective theme which relates to governance issues to sustain hospital service delivery indicates that the hospitals are less concerned about the actual disaster planning process but more focused on the disaster response activities and building related issues. The HRLC model recognise the significance of governance structures that are comprised of the shared reasoning and decision making amongst the range of hospitals stakeholders involved in disaster planning, the adaptation process and the policies such as the disaster management plans that provide directions for hospital disaster preparedness and response.

The high focus on activity issues relates to both disaster preparation actions and response activities to ensure safety of staffs and patients during and after an event. For example, evacuation and transfer of patients to another facility, staffing issue, communicating with the external agencies that include police, ambulance, service utilities, roads authorities as well as conducting maintenance and repair activities. It is important to note that hospital service delivery is critically dependent on various external factors such as linen supply, medical supplies, fuel for backup generators, food supply, roads and utilities services such as power, water, sewage and communication. Thus, from the high focus on activity theme, it is can be assumed that the sample hospitals are well aware and able to deal with these activities in their plans. It can also be assumed that hospitals operational capacity to deal with EWEs is high and thus contribute toward the overall facility resilience.

Lastly, the building theme focus is relatively high as well which can be credited to the impacts of recent events on hospital infrastructure generating greater awareness and concerns regarding the building vulnerabilities. To determine the level of focus across the fourteen sample hospitals, the coded variables were plotted in figure 5.

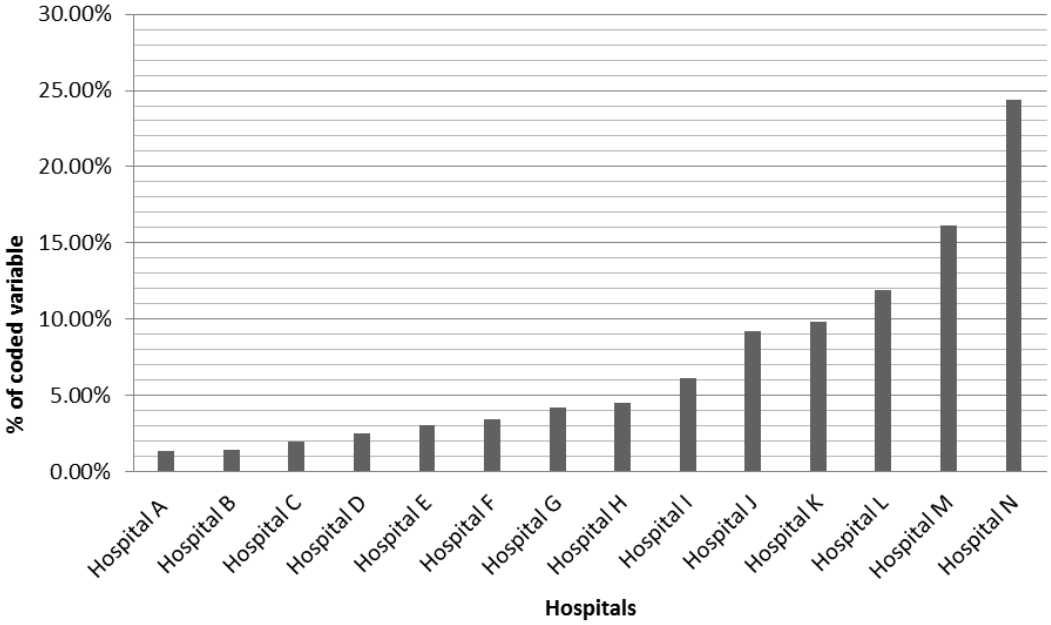

Figure 5: Percentage of coded variables for building theme for hospitals

Despite using a state template for both plans the variation on the level of focus on the building theme across the fourteen hospitals reveals the variation in hospital priorities. For instance, each hospital has its distinct issues due to their geographical locals, demography, and age of the facility. Additionally, it can be assumed that each hospitals level of focus is influenced by their past experiences. Alternatively, it can also be assumed that hospitals with low focus consider their built infrastructure is highly resilient to EWEs and thus ignore the link between their facilities and their healthcare activities. However, the purpose of this thematic analysis was to determine the focus on built infrastructure issue in the disaster plan, which is only part of the building theme. The building theme consists of service issues, content issues and construction related issued according to the BPRU model. As such, further breakdown of the building theme was carried out to identify the actually focus on building fabric issues. Table 4 shows the breakdown of focus on building theme particularly on building fabric issues in both plans.

Table 4: Focus on building fabric in the plans

Disaster Plans	**Supplementary Plans**
28% of disaster plans focused on Building theme	33% of supplementary plans focused on Building themes
11.76% of disaster plans focused on construction subtheme (which is 42% of building theme)	5.61% of supplementary plans focused on construction subtheme (which is 17% of building theme)
1.76% of disaster plans focused on hospital building fabric issues (which is 15% of construction sub theme)	0.29% of supplementary plans focused on hospital building fabric issues (which is 5% of the construction sub theme)

While the overall focus on building theme in both plans was relatively high around thirty per cent, a further breakdown of the building theme revealed that in reality only approximately two per cent of the disaster plans and less than one per cent of the supplementary plans focused on built environment related issues. This finding is important as it reveals that the actual focus on built environment issues in both plans is limited. Thus, it can be assumed that either hospital consider that their built facility is resilient to EWEs or fail to see the significance of the building fabric in their day to day hospital service delivery and during disasters.

Hospital facility resilience to disasters is dependent on a number of factors such as the hospital's organisational capabilities to learn from their past experiences and develop appropriate policies in consultation with the range of stakeholders identified earlier (Amaratunga et al., 2008). The robustness of the building fabric and its related services and content also contribute toward hospital facility resilience (Cimellaro et al., 2010). Additionally, the overall community resilience is also critical for hospital facility resilience. For example, the resilience of the hospital interdependent agencies such as age care and other healthcare facilities in dealing with EWEs issues, service utilities resilience, individual resilience of people in the community including hospital staffs and community patients (Loosemore et al., 2012). All these issues are represented by the four systems (building, environment, activity and objective) of the BPRU model. Thus, we argue that understanding the relationship between these four systems can promote hospital facility resilience. Alternatively, the HRLC model demonstrates that learning from past experiences is crucial for future planning. The findings of this thematic content analysis are significant in drawing more attention towards holistic planning in hospitals in promoting their facility resilience to EWEs.

5. Conclusion

The aim of this paper has been to present a conceptual framework, based on resilience and learning theories, that indicates how hospital stakeholders learn and adapt their built environment to EWEs. The limited focus on the building fabric in our hospitals indicates that despite a close link between the quality of healthcare delivered to communities and the quality of built infrastructure, low priority is given to built infrastructure issues in disaster responses, compared to the activities that happen inside those hospitals. This indicates a widespread assumption that the hospital built infrastructure is highly resilient to EWEs and an ignorance of the relationship between hospital facilities and the healthcare activities that go on inside them. Clearly the first assumption is wrong and the second finding reinforces the health facilities management literature which has consistently found over a long period that hospital are the forgotten resource in the health care system.

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Earthquake Engineering Research Framework toward CIB Research Roadmap Based on the Lesson Learnt from the Great East Japan Earthquake

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Research and Development Roadmap for Earthquake Engineering and Building

The Building Research Institute in Japan (so far referred to as the BRI) has conducted various activities such as research and development on housing, building and urban planning technology, and international training on seismology and earthquake engineering, systematically and continuously from the fair and neutral perspective of a public-sector research institute. In the spring of 2012, the CIB Regional Office of Japan was established by the BRI. The BRI will play a leadership role of CIB activities in Japan. Meanwhile, the Great East Japan Earthquake occurred on March 11, 2011 and caused tremendous damage to buildings and houses and enormous human losses by ground motion and tsunami. Based on lessons learnt from this earthquake disaster, the BRI has decided to develop a roadmap for earthquake engineering research and development for buildings. The roadmap will be utilized in the activities of the current working commission W114 (Earthquake Engineering and Buildings) in CIB. Firstly, this paper introduces the activities of the BRI after the Great East Japan Earthquake and summarizes the lessons from this tragedy. Then, the draft of Earthquake Engineering Research Framework toward CIB Research Roadmap for research and development for earthquake engineering is described. At the beginning of the proposed framework, the “Vision” describes the final objective of the roadmap. Then, “Mission” describes the research and development items to realize the vision. The “Goals and Objectives” follows describing more specific contents corresponding to each item of the Mission.

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Keywords: Earthquake Engineering, the Great East Japan Earthquake, CIB Research Roadmap

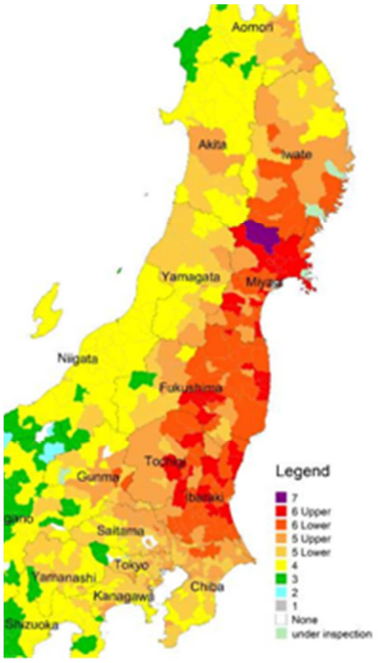
1. Introduction

This paper presents the earthquake engineering research framework toward CIB research roadmap based on the lessons learnt from the 2011 off the Pacific coast of Tohoku earthquake (the Great East Japan earthquake) (hereinafter referred to as the Tohoku earthquake). Firstly, this paper introduces the outline of the Tohoku earthquake, the strong motion observed mainly by the Building Research Institute (BRI) Strong Motion Network, the motion induced building damage and the tsunami induced building damage by the Tohoku earthquake. Joint activities to establish technical standards by the National Institute for Land & Infrastructure Management (NILIM) and BRI collaborated with the administration are also introduced briefly. Based on the experiences of damage survey for the Tohoku earthquake and BRI's research activities and CIB's secretary's helpful suggestions, the earthquake engineering research framework for research roadmap is described.

2. Lessons Learnt from the Great East Japan Earthquake

The Tohoku earthquake of moment magnitude (Mw) 9.0 occurred at 14:46 JST on March 11, 2011 and generated gigantic tsunami in the Tohoku and Kanto Areas of the north-eastern part of Japan. This was a thrust earthquake occurring at the boundary between the North American and Pacific plates. This earthquake is the greatest in Japanese recorded history and the fourth largest in the world since 1900 according to U.S. Geological Survey [1]. An earthquake of Mw 7.5 foreshock preceded the main shock on March 9 and many large aftershocks followed including three Mw 7-class aftershocks on the same day of the main shock. As the epicentral distribution of the aftershocks of the Tohoku earthquake (hypocentral region) is widely located off the coast of the prefectures of Iwate, Miyagi, Fukushima and Ibaraki with approximately 450km in length in North-South direction and 150km in width in East-West direction. The distance from these prefectures to the fault plane is almost the same, thus the places with the seismic intensity of approximate 6 (6+ or 6-) according to the Japan Meteorological Agency (JMA) widely spread in these prefectures. The maximum JMA seismic intensity of 7 was recorded by the strong motion recording network (K-NET) [2] of the National Research Institute for Earth Science and Disaster Prevention (NIED) at Kurihara City (K-NET Tsukidate) shown by the purple color in Fig. 1.

Field survey by NILIM and BRI was started from Kurihara City and was followed by the locations shown in Fig. 2. In the coastal area from Aomori Prefecture to Miyagi Prefecture, the tsunami induced building damage was mainly surveyed. The area facing to the Pacific Ocean in Fukushima Prefecture was excluded from the survey in the cause of the accident in Fukushima Daiichi Nuclear Power Station. At the catchment basin area of Tone River in the border between Ibaraki and Chiba Prefectures and Urayasu City on the Tokyo Bay, damage of residential land associated with liquefaction was surveyed.



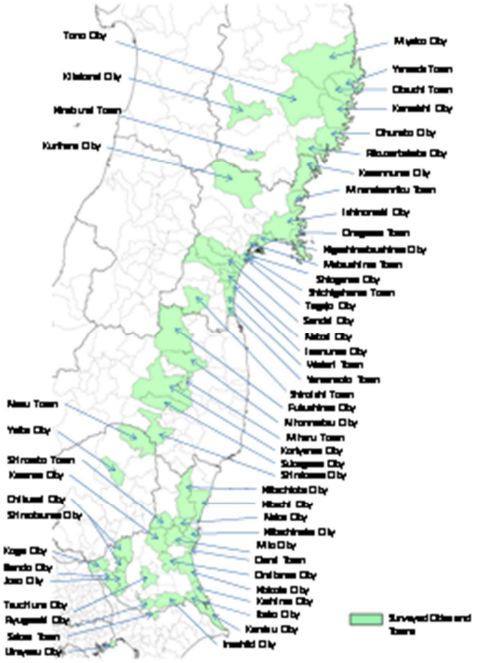


Figure 1: JMA Seismic Intensity Map ***Figure 2: Locations of Surveyed Areas***

2.1 Earthquake and Ground Motions

2.1.1 Characteristics of Earthquake Motions

During the Tohoku earthquake, severe ground motions were observed in wide area, and massive amounts of strong motion records were accumulated by K-NET of NIED [2]. From the acceleration records, a maximum acceleration in the N-S direction is understood to have reached almost 3700 cm/s^2, representing that the main shock caused excessively severe earthquake motions. A response in the N-S direction with a period of about 0.2 seconds becomes particularly large. This indicates earthquake ground motions that are dominated by short periods.

2.1.2 Results of BRI Strong Motion Network

The BRI conducts strong motion observation that covers buildings in major cities across Japan [3]. When the Tohoku earthquake occurred, 58 strong motion instruments placed in Hokkaido to Kansai Areas started up. Locations of the strong motion stations are plotted in Fig. 3 and Fig. 4. Among them, about 30 buildings suffered a shaking with seismic intensity 5- or more. This section presents some characteristic strong motion records.

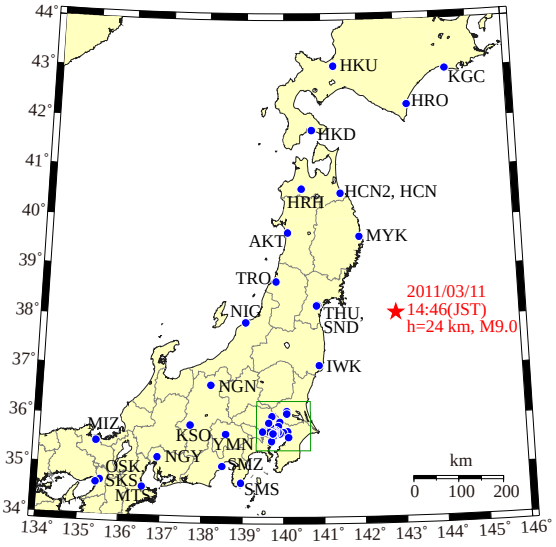


Figure 3: Locations of Epicenter (★) and Strong Motion Network (●)

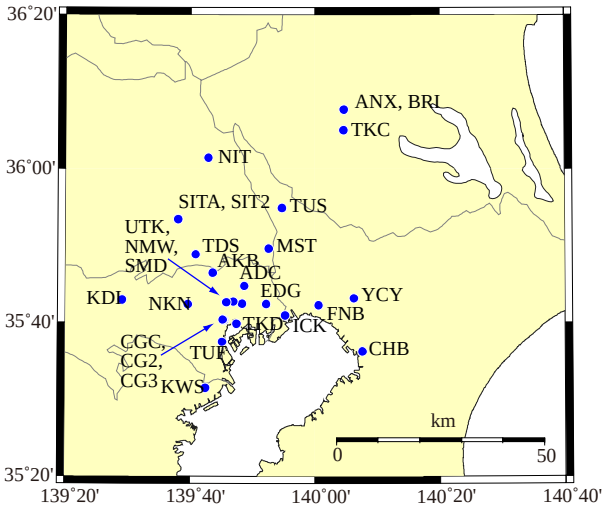


Figure 4: Strong Motion Network in Kanto Area (corresponds to green rectangle in Fig. 3)

Among buildings in the BRI Strong Motion Network, at least 4 buildings suffered severe earthquake motions and then some damage. One example of the damaged buildings is the building of the Tohoku University. This is the 9-story steel reinforced concrete (SRC) school building located in the Aobayama Campus. This building has a history of strong motion recordings. Strong motion records on the ninth floor of the building obtained in the 1978 Miyagi-Ken-Oki earthquake have represented a maximum acceleration of more than 1000 cm/s^2. During the Tohoku earthquake, multi-story shear walls suffered flexural failure and other damage. Thick and thin lines in Fig. 5 (a) and (b) represent acceleration waveforms on the first and the ninth floors, respectively. Maximum accelerations on the first floor exceeded 330 cm/s^2 in both of the directions. A maximum acceleration on the ninth floor was 2 to 3 times larger than on the first floor, and exceeded 900 cm/s^2 in the transverse direction. The fundamental natural periods in Fig. 5 (e) represented about 0.7 seconds at the initial stage of the earthquake motion in both of the directions, but increased to about 1 second in the first wave group at the time of 40 to 50 seconds, and increased from 1.2 seconds to about 1.5 seconds in the second wave group at the time of 80 to 100 seconds. Due to the seismic damage, the fundamental natural period finally became twice longer than that at the initial stage, and was reduced to 1/4 on a stiffness basis. In other case, long-period earthquake motions and responses of super high-rise buildings that are shaken under the motions have been socially concerned in recent years. When the Tohoku earthquake occurred, long-period earthquake motions were observed in Tokyo, Osaka and other large cities that are away from its hypocenter. This section presents two cases in Tokyo and Osaka from the BRI strong motion network. Fig. 6 shows strong motion records that were obtained from the 55-story steel office building on the coast of Osaka Bay that is 770 km away from the hypocenter. This figure shows absolute displacements in the SW-NE and in the NW-SE directions on the 1st floor, absolute displacements in both of the directions on the 52nd floor, and building displacements (relative displacements of 52th floor to 1st floor) in both of the directions, from the top to the bottom. A ground motion displacement was not large, or less

than 10 cm, but the 52nd floor in the building suffered a large motion with a zero-to-peak amplitude of more than 130 cm. The coincidence of the fundamental natural period (6.5 to 7 seconds) in the steel office building with a predominant period of the earthquake motion is considered to have caused a resonance phenomenon and then large earthquake responses were observed at the top.

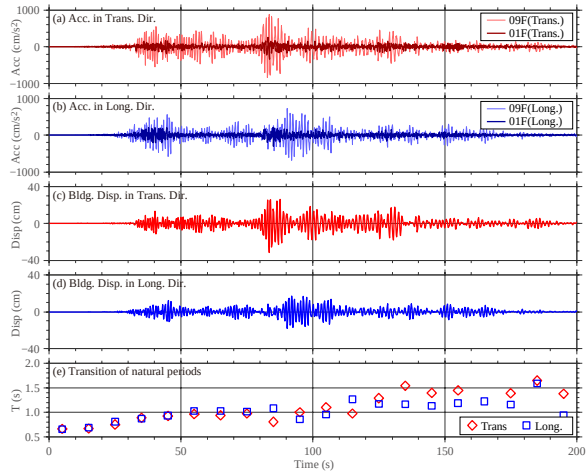


Figure 5: Strong Motion Records of the Tohoku University and Transition of Natural Periods

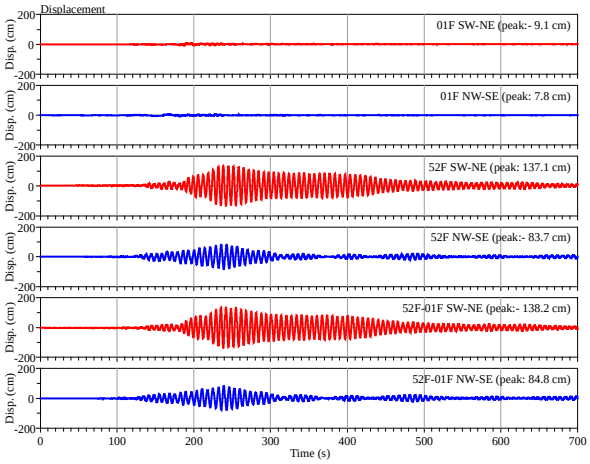


Figure 6: Displacement observed at a 55-story Office Building in Osaka Bay Area

2.2 Damage of Buildings due to Earthquake Motions

2.2.1 Damage of Wood Houses

As a result of damage survey on the wood houses due to ground motion in each city, the followings were provided.

1) The damage on the many wood houses due to ground motion was confirmed in Osaki City in Miyagi Prefecture, Sukagawa City in Fukushima Prefecture, Nasu Town in Tochigi Prefecture, and Hitachiota City and Naka City in Ibaraki Prefecture. 2) Though the seismic intensity 7 was recorded in Kurihara City, Miyagi Prefecture, the damage on wood houses were not so severe. 3) The damage on the wood houses caused by the failures of residential land was confirmed in Sendai City, Miyagi Prefecture, and Yaita City, Tochigi Prefecture. 4) The damage of the roof tile in Fukushima and Ibaraki Prefectures was much larger than Miyagi Prefecture where an earthquake occurred more frequently. 5) The possibility that the ground motion was amplified on the land filled up from meadow or rice field, even if the residential land did not fail, was suggested in Kurihara City, Osaki City in Miyagi Prefecture, Nasu Town in Tochigi Prefecture, Hitachiota City, Naka City, Joso City, Ryugasaki City in Ibaraki Prefecture, and so on. 6) In Osaki City, Miyagi Prefecture, the plural rare damage examples that residual story deformation of 2nd floor was larger than that of 1st floor were confirmed.

2.1.3 Damage of Reinforced Concrete Buildings

The types of the damage of RC and SRC buildings that were observed through the site investigation are classified into those for structural and non-structural elements in the following.

The damage of structural elements are; 1) Collapse of first story, 2) Mid-story collapse, 3) Shear failure of columns, 4) Flexural failure at the bottom of column and base of boundary columns on multi-story shear walls, 5) Pullout of anchor bolts and buckling of longitudinal reinforcements at exposed column base of steel reinforced concrete (SRC) buildings, 6) Shear failure or bond splitting failure of link beams of multi-story coupled shear walls, 7) Building tilting, 8) Destruction, failure or tilting of penthouses, 9) Damage of seismic retrofitted buildings. The damage of non-structural elements are; 1) Flexural failure at the bottom of column with wing wall, 2) Damage of non-structural wall in residential building, 3) Damage and falling of external finishing, 4) Tilting or dropout of components projecting above the roof, 5) Collapse of concrete block wall and stone masonry wall

2.1.4 Damage of Steel Gymnasiums

The damage of the gymnasiums was classified into the types of 1) to 7). The types of 1) to 6) and the type of 7) refer to structural damage and to non-structural one, respectively.

1) Buckling and fracture of brace member and fracture of its joint, 2) Buckling of diagonal member of latticed column, 3) Damage of connection (bearing support part) between RC column and steel roof frame, 4) Deflection, buckling and fracture of roof horizontal brace, 5) Cracking of column base concrete, 6) Other (Overturning of floor strut, etc.), 7) Non-structural damage such as dropping of ceilings and exterior walls and breakage of windows

2.1.5 Damage due to Failures of Residential Land

The outline of the damage situations in the investigate scope is as follows.

Regarding damage caused by liquefaction, extensive damage such as sand boiling or ground transformation associated with liquefaction was confirmed in the catchment area of Tone River and the coastal zone of Tokyo Bay. Highly tilted buildings were seen, but visual cracks or fissures on the foundations investigated were not observed. Regarding damage to housing area, large damage with transformations such as ground sliding was observed mainly in the elevated and developed housing area (particularly marginal part). In some areas, transformations occurred again in the developed lots that had been affected by the past earthquakes.

2.1.6 Response of Seismically Isolated Buildings

Investigation results of Seismically Isolated (SI) buildings in Miyagi Prefecture and one SI building in Yamagata Prefecture is summarized as follows;

1) Super-structures of SI buildings suffered almost no damage even under strong shaking with JMA intensity 6 upper. It verifies the excellent performance of SI buildings. 2) There are 8 buildings with scratch boards to measure displacement of the SI building floor. In most cases, the maximum displacement has been estimated as around 20 cm. There is one case with the maximum displacement estimated over 40 cm. 3) In some buildings, damage was observed at the expansion joints. It seems that parts of expansion joints were not well operated due to the large displacement of SI building floor during earthquake. 4) Subsidence of ground around the building was observed in some buildings. 5) Many cracks were found in lead dampers. These cracks might be increased by the aftershocks. 6) Peeling off of paint was observed widely for U-shape steel dampers. In some cases, residual deformation of steel was remained.

2.2 Damage to Buildings in Inundation Areas due to Tsunami

The purpose of this investigation is to understand an overview of buildings damaged by tsunami, to obtain basic data and information required to evaluate mechanisms for causing damage to the buildings and to contribute to tsunami load and tsunami-resistant designs for buildings such as tsunami evacuation buildings, by means of collecting building damage cases by tsunami, classifying the damage patterns for different structural categories, and making a comparison between the calculated tsunami force acting on buildings and the strength of the buildings. The NILIM and BRI jointly created a tsunami damage investigation team that consists of 27 members. The joint team collected national and international standards and codes concerning tsunami evacuation buildings and tsunami loads and surveyed about 100 buildings and structures in three site investigations.

The damage types of RC buildings observed through the site investigation are classified as followings; 1) Collapse of first floor, 2) Overturning, 3) Movement and washed away, 4) Tilting by scouring, 5) Fracture of wall (fracture of opening), 6) Debris impact. The damage types of steel buildings observed through the site investigation are classified as followings; 1) Movement and washed away by fracture of exposed column base, 2) Movement and washed away by fracture of capital connection, 3) Overturning, 4) Collapse, 5) Large residual deformation, 6) Full fracture and washed away of cladding and internal finishing materials. As for wood houses, in the case of a maximum inundation depth of about 1 m, most of houses could be remained. Some wood houses were damaged considerably due to debris impact. In the case of a maximum inundation depth of about 1 to 6 m, some wood houses where located behind the relatively substantial building for tsunami load such as a reinforced concrete building remained. In addition to that case, a tsunami load was reduced possibly due to many openings in the direction affected by tsunami, or a wooden house remained despite washed away of columns and external walls at the corner of the building. Several houses which have a reinforced concrete storey on the first floor, or a mixture of wooden and reinforced concrete structures, remained.

2.3 Joint Activities by BRI and NILIM

For political response based on the lessons, the following studies should be especially resolved by means of technical investigations. 1) Study on the design of tsunami evacuation

buildings, i.e. Estimation of tsunami load, 2) Study on advanced seismic resistant design of suspension ceiling system, 3) Study on verification of seismic safety performance for super high-rise buildings and seismically isolated buildings under long-period earthquakes, 4) Study on information indication of liquefaction for residential houses

NILIM has been developing the draft of technical standards for the resolution. As for the research and development for the resolution, the research organizations designated by the Building Standard Development Promotion Program [4] of Ministry of Land, Infrastructure, Transport and Tourism (MLIT) and BRI have been implementing as joint research. Thus, BRI has been playing the role for establishment on a domestic structural code with NILIM in Japan.

3. Earthquake Engineering Research Framework toward CIB Research Roadmap

The structure for CIB roadmap is shown in Fig.7. “Conceptual Framework” in Fig.7 could be common interest among each institute and organization and the other items in Fig.7 depends a great deal on the specific interests and situations of each institute and organization. Once “Conceptual Framework” will be determined, the other items could be discussed among each institute and organization. Thus, first of all, the comprehensive and strategic research framework should be shown. Based on the lessons learnt from the Tohoku earthquake, this paper presents the earthquake engineering research framework corresponding to “Conceptual Framework” in Fig.7 toward CIB research roadmap with reference to other materials [5,6]. The outline of framework is shown in Fig.8. The framework is triangle shape and consists of the following items; 1) Vision, 2) Missions, 3) Goals and Objectives. Based on the proposed framework, research agenda for BRI is finally shown as an example in the paper to show the relationships between the framework and specific research agendas.

3.1 Vision

Based on the experiences of The Tohoku earthquake, we recognized the importance of not only seismic safety performance of buildings but also post-earthquake continuous functionality against severe earthquake. Thus, the Vision which earthquake engineering research can contribute is “Safe and Secure Society” and “Resilient Society for Minimizing Disaster Loss”. Especially countries where frequent earthquakes occur like Japan should prepare the appropriate actions against before and after earthquake for realization of above mentioned society.

3.2 Missions

The Missions to achieve the vision are shown as follows, M1）Research for Earthquake Disaster Loss Mitigation, M2）Development of Technologies and Tools for Earthquake Disaster Loss Mitigation, M3）Dissemination and Promotion for Earthquake Disaster Loss Mitigation Measures, M4）Global Multidisciplinary Partnerships for Earthquake Disaster

Loss Mitigation, M5）Upgrading and Utilization of Required Resources for Earthquake Disaster Loss Mitigation.

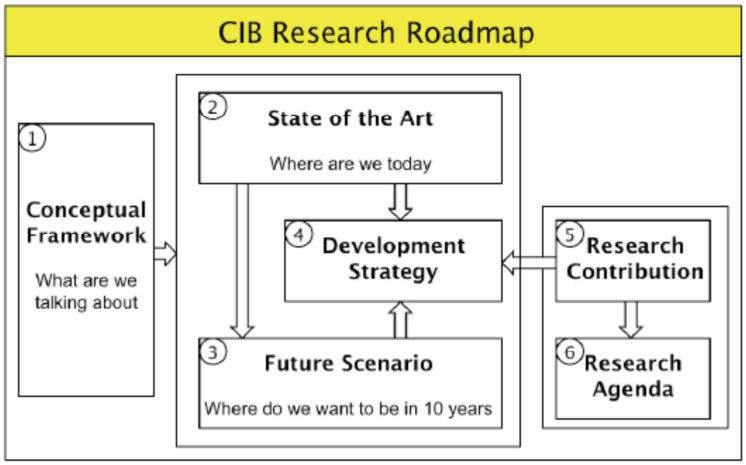


Figure 7: Structure for CIB Research Roadmap

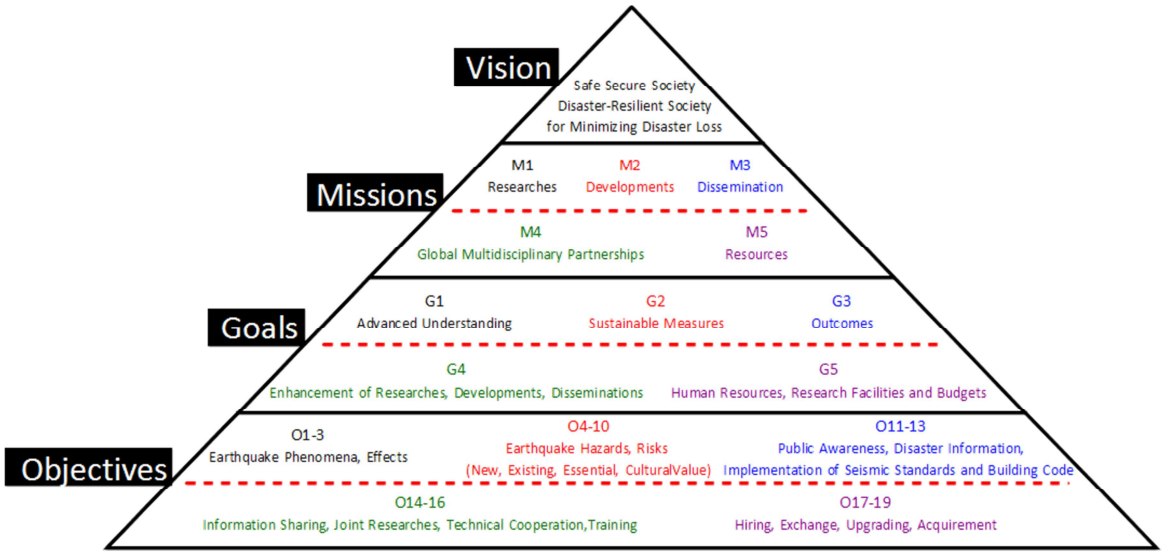


Figure 8: Structure of Earthquake Engineering Research Framework

3.3 Goals and Objectives

The Goals to achieve the Missions are shown as follows, G1) Advanced Understanding of Earthquake Phenomena and Impact, G2) Development of Sustainable Measures to Mitigate Earthquake Disaster Loss and Impact on Individuals, the Built Environment, and Society-at-Large, G3) Dissemination and Promotion of Earthquake Disaster Loss Mitigation Measures for Earthquake Professionals, Owners, Users, G4) Enhancement of Researches, Developments, Disseminations for Earthquake Disaster Loss Mitigation Based on Global Multidisciplinary Partnerships, G5) Acquirement and Upgrading, Utilization of Required Human Resources, Research Facilities and Budgets for Earthquake Disaster Loss Mitigation.

Those Goals are long-term targets to support the Missions and associated with the Objectives. The relationship between Goals and Objectives is shown in Fig. 3.3. G1, 2, 3, corresponding to M1, 2, 3 respectively are closely linked and G3 is generally disseminations and promotions with the outcome of G1 and G2. G4 corresponding to M4 is the important item to enhance G1, 2, 3 globally. G5 corresponding to M5 is the basis of activities for other Goals. Each Objective is related to the Goals and set to achieve the Goals.

The Objectives relevant to G1 are follows, O1) Advanced Understanding of Earthquake Generation, Propagation and Relevant Phenomena, O2) Advanced Understanding of Earthquake Effect on Structures and the Surrounding Built Environment, O3) Advanced Understanding of Earthquake Effect on the Societal Activities. For better understanding, each example on O1 to O3 is mentioned as followings, O1) Fault model evaluation, Earthquake propagation evaluation, Near fault evaluation, Tsunami force evaluation, O2)

Effective Input motion evaluation based on strong motion records, sophisticated method on strong motion observation for structures, Response evaluation for structures, Liquefaction evaluation, O3) Post-Earthquake damage information, Post-Earthquake scenarios.

The Objectives relevant to Goal2 are follows, O4) Development of Technologies and Tools to Assess Earthquake Hazard, O5) Development of Technologies and Tools to Assess Earthquake Risk Scenarios, O6) Development of Technologies and Tools to achieve Seismic Safety Performance of New Structures, O7) Development of Technologies and Tools to Improve Seismic Safety Performance of Existing Structures, O8) Development of Technologies and Tools to Enhance Seismic Resiliency of Essential Structures in Large Urban Areas, O9) Development of Technologies and Tools to continue Post-Earthquake Serviceability of Structures with Cultural Value, O10) Development of Seismic Standards and Building Codes Corresponding to Social Needs. For better understanding, each example on O4 to O10 is mentioned as followings, O4) Updating of existing hazard map, Technical standards of earthquake load, Earthquake evaluation techniques corresponding to construction sites, O5) Earthquake loss and risk evaluation, Performance evaluation and indication tool including excessive load, Risk communication tool, Rapid and detailed assessment techniques for damaged structures, Damage evaluation techniques for structures based on strong motion records, O6) Seismic safety performance evaluation techniques for new structures, New materials, technologies and structural systems, O7) Seismic safety performance evaluation techniques for existing structures, Seismic retrofit technologies, O8) Earthquake damage evaluation techniques and damage mitigation measures, Post-earthquake functionality evaluation techniques for essential structures, O9) Seismic damage evaluation techniques and mitigation measures for structures with cultural value, Serviceability performance evaluation techniques for structures with cultural value, O10) Structural design guidelines for tsunami evacuation buildings, Standards related to long-period component of ground motion and base-isolation/seismic control.

The Objectives relevant to Goal3 are follows, O11) Technical Supports for Implementation of Seismic Standards and Building Code Corresponding to Social Needs, O12) Information on serviceability of Structures after Strong Motion, O13) Support for Public Awareness on Comprehensive Earthquake Hazards and Risks. For better understanding, each example on

O11 to O13 is mentioned as followings, O11) Educational activities (seminars, lectures) to contribute smooth implementation of current structural relevant codes for structural engineers, O12) Rapid earthquake announcement, Offer of information on continuous use of structures using strong motion record network, O13) Support of activities to enhance the public awareness and preparedness of earthquake hazards and risks mitigation, Support for making guidebooks on earthquake risk mitigation measures, Support of earth-sciences and earthquake-engineering education, Application of earthquake risks evaluation methods in each region, Application of performance indication methods considering serviceability of structures after earthquake.

The Objectives relevant to Goal4 are follows, O14) Implementation of Information Sharing, Joint Researches and Surveys for Earthquake Disaster Loss Mitigation, O15) Technical Cooperation to Enhance Earthquake Disaster Loss Mitigation in Developing Countries, O16) Trainings for Earthquake Engineering Professionals. For better understanding, each example on O14 to O16 is mentioned as followings, O14) Sharing information with CIB and other international institutes, Joint survey with international institutes, Promotion of International joint research, O15) Cooperation to project on technical support for developing countries, O16) Training courses for knowledgeable specialists on earthquake hazards and risks in developing countries.

The Objectives relevant to Goal5 are follows, O17) Hiring and Utilization, Exchange of Researchers with High Level of Expertise, O18) Upgrading and Utilization of Advanced Research Facilities, O19) Acquirement and Priority Allocation of Research Budgets. For better understanding, each example on O17 to O19 is mentioned as followings, O17) Establishment of system for human resources required in each institute, Sharing information and joint research with visiting scholars, O18) Upgrading and utilization of facilities for experimental tests using scale-merit of laboratories and hybrid tests using IT technologies, O19) External research funds and the prioritized allocation for earthquake damage mitigation.

3.4 Investigation on validity of the Framework using BRI's research agendas

In order to investigate validity of the framework by showing the relationships between the research framework proposed and specific research agenda, BRI's research agendas will be introduced as an example in this section. BRI has specific research agendas in the medium-term plan based on the medium-term goal under the direction of the Minister, and has been promoting research and development efficiently. The specific research agendas are related to "Objectives" in the framework. BRI has two research agendas, one is priority research agenda which are socially significant and urgent, and the other is basic research agenda which are academically fundamental and leading. Regarding the earthquake engineering, BRI has 2 priority research agendas and 10 basic research agendas. The priority research agendas are "Study on explicit criteria for proper engineering judgement required in structural calculation" and "Study on advanced response evaluation technique for high-rise building structures under long-period earthquake." The former agenda is related to Objectives 6, 10. The latter agenda is related to Objectives 8, 10 and is also an issue to be countermeasured as a lesson of the Tohoku Earthquake. On the other hand, the typical

basic research agendas are “Study on advanced mitigation techniques against earthquake and Tsunami in developing countries and training courses with latest, useful contents” and “Strong motion observation for buildings and the technology for application”. The former agenda is related to Objectives 15, 16. The latter agenda is related to Objectives 2, 12 and is also an issue to be solved as a lesson of the Tohoku Earthquake. Through above investigation, it is shown that the framework has an appropriate function to relate to specific research agenda using BRI’s current research agendas. We hope that the framework will be improved furthermore in W114 (Earthquake Engineering and Buildings) of CIB and be utilized among the relevant CIB members as the CIB Research Roadmap on earthquake engineering.

4. Conclusions

This paper described the earthquake engineering research framework toward CIB research roadmap based on the lessons learnt from the Great East Japan Earthquake and current BRI’s research activities. This framework consists of Vision, 5 Missions, 5 Goals and 19 Objectives and specific research agendas are related to Objectives and it is shown that the framework has an appropriate function to relate to specific research agenda using BRI’s current research agendas. It is expected that this framework will provide the basis of a framework for CIB Research Roadmap on earthquake engineering and be discussed among the related institutes and organizations.

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Evaluation of assessment practices for Bachelor of Construction Management (BCM) program

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Abstract

This project proposes a method to evaluate the current assessment practices for the Bachelor of Construction Management (BCM) program at the University of Newcastle, Australia. To ensure the assessment tasks within the program are constructively aligned to the learning outcomes and be able to provide a cohesive learning experience for students, an assessment checklist has been developed and used to evaluate the assessment tasks for courses within the program. The checklist, namely Assessment Development Checklist (ADC) was intended to be used as part of the Course Outline Peer Review exercise for quality assurance purposes. As a pilot study, this project examined the assessment tasks in the first-year courses (a total of eight courses offered in the 2012 academic year) regarding their alignment to the learning outcomes and their appropriateness to the first year students. Several recommendations and action plans were made in response to the findings of the evaluation. It can be seen that the present study has taken a strong initiative to improve the assessment practices for the BCM program.

Keywords: Constructive alignment, assessment development, assessment checklist

1. Introduction

Recently, an external program review was undertaken for the Bachelor of Construction Management (BCM) program at The University of Newcastle (Australia). The review panel raised concerns and made recommendations about the need to improve the constructive alignment of assessment tasks with learning outcomes. The panel also pointed out that there was inadequate mapping of assessment tasks to learning outcomes to enable students to track their achievement and progression, and some learning outcomes were unspecific and not helpful to students. The program management team needed to ensure there is constructive alignment of assessment methods with learning outcomes. The panel also stressed that a particular area of student dissatisfaction in course experience within the program was the perceived lack of timely, good quality feedback about assignment performance. The panel recommended that essential measures should be taken to address these issues in an innovative and pragmatic view.

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One of the keys to successful learning and teaching is the aligned curriculum (Biggs, 1999): this means that carefully designed assessment tasks allow students to demonstrate achievement of clearly communicated learning outcomes. Ensuring the constructive alignment is one of the key responsibilities of educators (Biggs & Tang, 2007). To ensure the assessment tasks are designed to align with the learning outcomes for the course and be able to provide a cohesive and deeper level of learning experience for students, an assessment checklist has been developed by the authors with reference to the literatures in Australian higher education (Gjibels and Dochy, 2006; Anderson and Krathwohl, 2001; Biggs, 1999; Bloom et al, 1956; Calder and Hanley, 2004; CTL, 2011a; CTL, 2011b).

This checklist, namely Assessment Development Checklist (ADC) was used to evaluate the assessment tasks for all core courses within the Construction Management program. As a pilot study, this project mainly examined the all assessment tasks in the first-year courses regarding their alignment to the learning outcomes and their appropriateness to the first year students.

2. Transition issues and assessment practice in first year courses

The Bachelor of Construction Management (BCM) program was underpinned by the problem-based learning (PBL) approach since its inception in the 90's. The BCM program is offered on-campus and by distance. First-year students in BCM program are often dealing with a lot of transition difficulties. Guidance Mentor Report shows that our first-year students often experienced difficulties with assessment items and in connecting with university facilities and services in general (De Vitis et al, 2010). Indeed there is ample literature have reported that first year students usually struggle with transition issues to both PBL and higher education (Calder and Hanley, 2004; McInnis et al, 2000; Teakle, 2008). Adjusting to studying at university can be a challenge for students whether they are studying on-campus or by distance education (Byrne and Flood, 2005). In Australia one quarter of first year students who started as full-time enrolees but then shifted to part-time enrolment as a result of transition difficulties (James et al, 2010). Multi-campus universities and those with large proportions of distance education often had high attrition rates among the first year students because it was harder for their students to access services (Ross, 2011).

One of the potential ways of overcoming the transition issues is to properly design the learning activities and assessments to take into account the fact that students are first year student and need some basic skills in particular areas. Academic literacy and communication skills are therefore important, so the need for these meant they needed to be identified and embedded in the assessment tasks. Assessments must be both formative and summative in order to simultaneous give value to the first year student and be valued by them (Byrne and Flood, 2005). Heavy weighting of the assessment half-way through the semester should be avoided as this may increase high levels of drop out (De Vitis et al, 2010). The appropriateness of the assessment items for the first year courses should be regularly evaluated and reviewed. This can be done by the newly developed assessment checklist.

3. Methodology

3.1 Developing the Assessment Development Checklist

It is of great interest to design assessment tasks that will tell us whether and how well each student achieves the learning outcomes. The assessment tasks should be guided by a grading criteria scheme which allows for judgments of the quality of student performance, and by determining how well learning outcomes have been achieved during the course. The guidelines in developing effective assessment tasks have been extensively discussed in Australian higher education literatures (Gjibels and Dochy, 2006; Anderson and Krathwohl, 2001; Biggs, 1999; Bloom et al, 1956; Calder and Hanley, 2004; CTL, 2011a; CTL, 2011b). In this study, the Assessment Development Checklist (ADC) was developed with reference to these literatures and intended to be used as part of the Course Outline Peer Review (COPR) process for quality assurance purposes. The course coordinator will use this checklist to evaluate their assessment tasks to ensure there is constructive alignment of intended learning outcomes and assessment. With the aid of this checklist, the course coordinator also understands the process of developing effective assessment tasks to drive the student academic experience and hence student learning. Besides, course coordinator is also aware of the importance of providing timely and good quality feedback about assignment performance. Figure 1 shows a sample of ADC. The checklist consists of 3 sections. The first two sections address the course learning outcomes and learning activities, whereas Section 3 is related to the development of the assessment items. The course coordinator shall tick the check box to confirm if each task is completed or otherwise give comment if applicable.

3.2 Scope of the project

This project aims to evaluate and improve the current assessment practices for an undergraduate construction management program in response to the outcome of the external program review recently. Due to time and resource constraints, this project will not evaluate the assessment tasks for all the courses within the BCM program (29 core courses). To be more manageable, the project only examined the assessment tasks in first-year courses. A total of eight first year courses offering in the 2012 academic year (4 for each semester) were studied and their assessments were evaluated by the course coordinators using the Assessment Development Checklist. By means of the checklist, the alignment of assessment tasks with the learning outcomes and their appropriateness to the first year students were evaluated. Table 1 shows the course names, the offering semesters and the enrolments.

Since the focus of this project is on the evaluation of assessment practices across first year courses within the program, therefore the contents of the assessment and the teaching and learning activities (TLAs) have not been discussed, though it is important to ensure that the TLA is appropriate for the intended learning outcome and any subsequent assessment tasks. The course outline of each first year course was also examined to check whether all the necessary information related to the assessment tasks has been properly given.

Course Information		
Course Name:_____	Course Code:_____	Semester:_____

Section 1 – Course Intended Learning Outcomes (CILOs)		
▪	The learning outcome statements contain action verbs[1] that help classify learning outcomes according to their perceived complexity[2]	☐
▪	Learning outcome statements for the course clearly identify criteria which will indicate that students have achieved the intended learning outcomes.	☐
▪	The course learning outcomes are explicitly mapped to the program objectives/graduate attributes	☐
▪	The course learning outcomes are related to the students' prior knowledge.	☐
Section 2 – Teaching and Learning Activities (TLAs)		
▪	There is a clear alignment between expected learning outcomes, what is taught and learnt, and the knowledge and skills assessed.	☐
▪	The teaching and learning activities are linked to the assessment items	☐
Section 3 – Assessment Tasks (ATs)		
3.1 Define objectives		
▪	Objectives of assessment tasks are explicitly mapped to the course learning outcomes.	☐
▪	Assessment tasks are aimed to assess subject-specific knowledge and skills as well as relevant generic skills.	☐
3.2 Decide on assessment instruments		
▪	Assessment tasks have been chosen that will appropriately assess the learning outcomes. (Please tick the type of assignments being used; can tick more than 1 if applicable) ☐ Report ☐ Reflective journal ☐ Blog ☐ Test ☐ Quiz ☐ Essay ☐ Thesis ☐ Group project ☐ Oral presentation ☐ Research proposal ☐ Portfolio ☐ Graphical drawings ☐ Others (please specify) _____	☐
▪	Assessment tasks are capable of detecting the higher-order learning outcomes that characterise higher education.	☐
▪	Assessment tasks are weighted to balance the developmental ('formative') and judgemental ('summative') roles of assessment (Avoid 50% assessment half-way through the semester).	☐
▪	The overall balance of assessment activities across tasks can fairly reflect the balance of learning outcomes for a course.	☐
▪	Assessment tasks are checked to ensure there are no inherent biases that may disadvantage particular student.	☐
▪	Plagiarism is minimised through careful task design, explicit education and appropriate monitoring of academic honesty.	☐
▪	The submission requirements such as format and referencing style are clearly described.	☐
3.3 Criteria and Marking System		
▪	Criteria specified clearly to allow judgement as to student's performance.	☐
▪	Qualitative standards or levels of expected performance for the assessment tasks have been described.	☐
▪	Grades are calculated and reported on the basis of clearly articulated learning outcomes and criteria for levels of achievement.	☐
▪	Moderation has been planned with markers to develop shared understandings of the expected standards and facilitate consistent application.	☐
3.4 Guideline on Date and Method for Submission of Assignments		
▪	The day, date and time by which assignments must be submitted have been clearly specified in the course outline	☐
	The required methods of assignment submission have been stated in the course outline.	☐
3.5 Guidance and Feedback to Students		
▪	Provision of assignment information, guidelines, descriptions, examples, tips, resources and rubrics.	☐
▪	Provision of academic integrity guidance and link to referencing guide.	☐
▪	Explanation of the marking rubrics to students prior to the task	☐
▪	Provision of feedback on the assessment item to each student within three weeks of submission.	☐
▪	Provision of explanatory and diagnostic feedback as well as grades to each student.	☐
▪	Provision of feedbacks for further improvement on coursework.	☐

[1] Action verbs are organised into a hierarchical structure or levels such as in the SOLO and Bloom's Taxonomy
[2] Steady progression in the complexity and demands of assessment requirements in the later years of courses.

Figure 1: Sample of the Assessment Development Checklist

Table 1: First year courses offered in 2012 academic year

Course Name	Offer in	Class Enrolment
ARBE1100 Communication in the Built Environment	Semester 1	341
ARBE1101 Construction Technology 1	Semester 1	337
ARBE1102 Construction Ecology 1	Semester 1	325
ARBE1303 Introduction to the Construction Industry	Semester 1	203
ARBE1301 Law and Legislation	Semester 2	215
ARBE1304 Building Code and Compliance	Semester 2	225
ARBE1103 Communication in the Built Environment 2	Semester 2	295
ARBE2100 Construction Technology 2	Semester 2	286

4. Evaluation results and discussion

4.1 Overview of Evaluation of Assessment across First Year Courses

The evaluation results (the completed checklists) were collected and analysed. In general, the assessment items in first-year courses were well designed showing clear and appropriate learning objectives. A variety of assessment methods (both traditional and modern) such as report, group project, portfolio, blog, technical drawings, reflective journal and quiz etc. were used across the first year courses. The assessment tasks were generally weighted to balance the developmental ('formative') and judgemental ('summative') roles of assessment. The criteria and marking system were properly designed and specified clearly to allow judgement as to student's performance. Adequate guidance and supports were provided to assist student to complete the assignments. However, many courses due to high enrolments were found not able to provide timely and good quality feedbacks about assessment performance. The following sections discuss the major findings from the assessment evaluation results. In response to the findings, the appropriate responses and recommendations were made to the program management team for the continued improvement of the practice of assessment within the BCM program.

4.2 Evaluation of the Course Learning Outcomes

The course intended learning outcomes of all first-year courses were found contained action verbs according to the revised Bloom's Taxonomy (Anderson and Krathwohl, 2001). The use of these action verbs would help classify learning outcomes according to their perceived complexity. In the first-year courses, the lower-order learning outcomes were commonly used (e.g. describe and explain their understanding of the subject matter) to build up students' factual and conceptual knowledge.

For some second semester courses (ARBE1103 and ARBE2100), it was assumed that students would have achieved a level of knowledge of the subject area that would prepare them to cope successfully with the content of the course, through the first semester courses (ARBE1100 and ARBE1101). Students who do not have the recommended level of assumed knowledge were not prevented from enrolling in a course, but they may be placed at a

considerable disadvantage. Though the assumed knowledge was clearly indicated in the course outline, there was no guidance/advice to those students enrolling in a course without the recommended assumed knowledge.

Recommendation and Action plan for improvement

The course coordinator will inform students about the importance of “assumed knowledge” and its implication in the first week of the semester. Any students who have not achieved the recommended level of assumed knowledge will be advised to seek for assistance from the student tutors and/or the learning advisers offered by the Centre for Teaching and Learning at the University of Newcastle.

4.3 Evaluation of the Teaching and Learning Activities

In general, there was a clear alignment between expected learning outcomes, what was taught and learnt, and the knowledge and skills assessed. The teaching and learning activities were generally linked to the assessment items. However, the external review panel identified some feedbacks from students stating that the delivery techniques could be improved in certain courses e.g. ARBE1100 and ARBE2100, where the content was considered to be ‘dull’ and ‘dry’.

Recommendation and Action plan for improvement

The teaching and learning activities should be varied and appropriate to the student profile. These activities should also be able to assist students actively participating in an online learning community. Teaching staff are encouraged to take the teaching certificate courses offered by the Centre for Teaching and Learning at The University of Newcastle to explore the use of interactive teaching and learning methods to enhance both on-campus and distance student learning and engagement. Moreover, teaching staff are encouraged to contextualise the contents of a course by relating the course contents to relevant job roles and to invite industry professionals to expose students to professions and diverse career paths.

4.4 Evaluation of Assessment Practices

4.4.1 Define objectives

The assignments items were explicitly mapped to the course learning outcomes for all BCM courses. However, the objectives of the assessment item were not clearly defined.

Recommendation and Action plan for improvement

Objectives of each assessment item should be clearly defined and mapped to the course learning outcomes. This action will be implemented in the next course outline peer review process.

4.4.2 Decide on assessment instruments

A variety of assessment methods were found in the first year courses. To assess the achievement of the goals of PBL, several unconventional assessment instruments such as reflective journals and authentic tasks as identified by Wetherell et al (1999) were commonly used in the first-year courses. Other modern assessment instruments such as blogs reflective journals and online quizzes as formative assessments were also used. The use of authentic tasks in the assessments is believed a key principle of any PBL assessment. The uses and advantages of authentic tasks are discussed in situated learning by Cognition and Technology Group (CPG, 1993). Through the use of a range of authentic assessments, the BCM students were able to perform real-world tasks that demonstrate meaningful application of essential knowledge and skills.

The assessment items in the first year courses were generally designed aiming to develop students' academic literacy and communication skills helping them to cope with the transition challenges. Moreover, the objectives of assessment were commonly defined to achieve the lower-order learning outcomes (e.g. factual knowledge).

For some courses (i.e. ARBE1301 and ARBE1304), the assignments were weighted 50% or more half-way through the semester. The formative components in these courses were considered inadequate.

Recommendation and Action plan for improvement

The BCM program, underpinned by the PBL approach, should continue exploring the use of unconventional assessment methods to assess students' skills and knowledge. Assessment tasks should be weighted to balance the developmental ('formative') and judgemental ('summative') roles of assessment. Selecting assessment methods according to how well they assess students' achievement of course learning outcomes will promote valid assessment. Some learning outcomes are more effectively assessed by particular methods of assessment. The effectiveness and appropriateness of each assessment method will be discussed in the course outline peer review meeting. Course coordinators will be advised to avoid 50% or above assessment half-way through the semester.

4.4.3 Evaluation of Criteria and Marking System

For all assessment tasks, the grades were calculated and reported on the basis of clearly articulated learning outcomes and criteria for levels of achievement. Moderation was planned by the course coordinators with markers to develop shared understandings of the expected standards and facilitate consistent application.

Recommendation and Action plan for improvement

The program management team should review and monitor the criteria and marking system on a regular basis for continual improvement. A well designed marking scheme can be a useful way of providing feedback to students following marking. More specific rubrics provide

better guidance and/or feedback to students (Marzano, 2002). The criteria and marking system for each assessment will be examined in the course outline peer review meeting. The course coordinators will be advised to make reference with the tips developed by Hughes (2007) in formulating clear criteria for assessment tasks.

4.4.4 Evaluation of the guideline on date and method for submission of assignments

The date and time by which assignments must be submitted were clearly specified in the course outline. However, many major assignments in the various courses were found all due on the same day and this would be very stressful to students and could lead to problems.

Recommendation and Action plan for improvement

The program management team should review and monitor all the submission dates to avoid significant clash of submission dates. In the course outline peer review meeting, all the submission dates for assignments in the various courses undertaken in each year level of each course will be, to the extent possible, evenly spread over the semester, and that they do not clash with the dates of in-class tests and assessments of other courses.

4.4.5 Evaluation of Guidance and Feedback to Students

Many courses (e.g. ARBE1100, ARBE1101 and ARBE1102) due to large class size (more than 300 enrolments) were often found not able to provide timely and good quality feedbacks about assessment performance. This was also a concern raised by the panel members during the external program review. The assignments used in these courses were generally in the form of written reports, graphic drawings, blogs and quizzes. Feedbacks on these assignments were just given in 2-3 short sentences without much interpretation. Besides, the feedback for future improvement was also considered to be inadequate.

The assessments for the courses (from the design, to the evaluation and reporting of student achievement) should be developed not only could guide student approaches to study through providing them with appropriate feedback on their performance, but also could help them to determine their readiness to proceed to the next level of study, to judge their 'fitness to practice' and ultimately protect and guarantee academic standards in higher education as stated by the Centre for the Study of Higher Education (CSHE, 2011). In Scott's (2005) analysis of student evaluations of their university experience in Australia, a common theme was that students wanted more meaningful and timely feedback. Timely feedback is effective if students receive it when it still matters to them and in time to use it to improve performance (Gibbs and Simpson, 2004). However, this is not easy in mixed-delivery courses with a range of assessors, including sessional staff, and where genuine efforts are made to ensure quality control of the marking process by post marking moderation (TDU, 2008).

Recommendation and Action plan for improvement

For many first year students, the submission of the first assignment can be a very stressful experience because it brings together a range of requirements that may be quite alien to

students who may not have previous experience of university study. Provision of adequate supports includes online writing and referencing tutorials, examples of previous assignments in the course by way of providing positive and negative exemplars and various other preparatory sessions should be made available to students.

To address the needs for the timely provision of good quality feedback, in particular for large classes in first year, our program management team has just developed a new automated personal feedback system. The system not only allows for easier marking, but also provides constructive individualized feedback emailed directly to students from the marking sheet. It also makes the entering of marks into Blackboard a very fast and simple procedure. Figure 2 shows a sample of the automated personal feedback emailed to the student.

For each assessment item to be graded, the marking rubric from the course outline is incorporated directly into an Excel marking sheet. The sheet allows the marker to enter individual feedback comments as well as adjust grades for late penalty for each student. Once all assignments are graded the course coordinator is then able to send emails to all students in one go, and at the same time enter grades into a spreadsheet then be uploaded directly into Blackboard. This process could previously take several days for an academic to both individually email students their feedback, and also enter grades in Blackboard.

Currently the system is in the first stage of development, and initial feedback from both staff and students has been very encouraging. A more advanced version of this system is currently in development. The program team will continue monitor and review the current feedback practices to ensure it is meeting students' needs for the timely provision of good quality feedback for further improvement.

Dear XXX (Student Name),

Here is your feedback for ARBE4102 - Assignment 2 (Integration of Building Services).

Here is the rubric feedback for XXXX (Student Name and ID) -

Criteria 1: Lift services (Weighting 20%)
Very good analysis of lift services. (D)

Criteria 2: Mechanical and Electrical services (Weighting 25%)
Very good attention to analysis of mechanical and electrical services. (D)

Criteria 3: Hydraulic services (Weighting 25%)
Very good attention to analysis of hydraulic services. (D)

Criteria 4: Building Compliance - BCA etc (Weighting 15%)
Very good discussion of building compliance issues. (D)

Criteria 5: Report structure - Presentation, References etc (Weighting 15%)
Very competent level of presentation. (D)

Here are additional comments from your marker:

High quality report, good use of diagrams and referencing throughout to convey understanding. Well researched and well setout. Student has shown they have a good grasp of the various building services required.

Your provisional grade for this assignment is 80.7 out of 100.

Thanks!
Course Coordinator Name

Figure 2: Sample of the automated personal feedback emailed to student

5. Conclusion

The assessment tasks in the first-year courses within the BCM program were evaluated using a newly developed checklist. The checklist identified areas for future improvement in assessment practices for the program. Several recommendations and action plans have been made in response to the findings of the evaluation results. It can be seen that the present study has taken a strong initiative to improve the assessment practices for the BCM program. However, this project only examined the assessments in first-year courses subject to the time and resource constraints. Further study on the assessment items in higher level courses should be carried out to give a thorough understanding of the assessment practices across the years of the program. Moreover, the effectiveness of the checklist should be reviewed and monitored on a regular basis.

6. Acknowledgement

This work was supported by the Centre for Interdisciplinary Built Environment Research, The University of Newcastle, Australia.

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A Review of the Performance of the Malaysian Construction Industry

Toong Khuan Chan[1], May Chuan Theong[2]

Abstract

The Malaysian construction industry developed the Construction Industry Master Plan 2006-2015 to achieve world class status by 2015. Industry stakeholders identified seven strategic thrusts together with twenty one strategic recommendations, eighty two action plans and 453 activities to achieve this vision. Six years have elapsed since the launch of the master plan in 2006 and it is now prudent for the stakeholders to review the outcome of all its strategic thrusts and activities towards achieving the goals set earlier. A set of performance measures were developed previously resulting in a list of some 34 unique indicators. Tentative targets were set by benchmarking the performance of the local industry to other national initiatives and modified to suit local conditions. The objectives of this study are to determine the performance measures for the 2011, to compare the performance with the 2005 base year and to assess the achievements made in the last six years. Results of this study indicate that although construction demand has increased substantially, worker productivity remained sluggish, safety performance did not improve, export of construction services declined as many companies reduced their presence overseas. The only encouraging observation was a marked increase in construction quality. These results indicate that a thorough reassessment of the construction industry master plan in now necessary to ensure that the strategic actions produce the required outcomes.

Keywords: Benchmarking, Performance evaluation, Malaysia

1. Introduction

The Malaysian construction industry has largely been supported by substantial public spending to fund the construction of basic infrastructure in order to enhance economic activities and to provide affordable public housing. Due to a decline in public spending in 2003 and 2004, the construction sector value added dropped 0.9%, 1.8% and 0.5% in 2004, 2005 and 2006, respectively. Towards the end of 2007, the Malaysian Construction Industry Development Board (CIDB) published a ten-year master plan (CIDB, 2007) that will be implemented from 2006 to 2015 with the objective of refocusing the strategic position and charting the future direction of the industry. The main driver for the strategic plan was the

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fact that the industry has recorded an average annual growth of only 0.7% during the period between 2000 and 2007 compared to an average annual gross domestic product growth of 5.5% over the same period. There were concerns that the construction industry, being a main pillar of industrialisation and major contributor to economic growth, was not performing at its best and thus not able to meet the dual challenge of open markets and greater global competition. The master plan was therefore initiated to establish an innovative, sustainable, professional, profitable and world-class construction industry.

The objectives of this study are to determine the performance measures for 2011, to compare the performance with the 2006 base year and to assess the achievements made in the last six years. A list of 34 performance measures were previously suggested for the master plan by examining similar national initiatives in Canada, Chile, Denmark, New Zealand and the UK (Chan, 2009).

Previous studies (Landin and Nilsson, 2001; Kagioglou et al., 2001; Mohamed, 2003; Takim et al., 2003; Beatham et al., 2004; Bassioni et al., 2004; Lin and Shen, 2007; Nudurupati et al., 2007; Yu et al., 2007) have mainly been focused on evaluating project outcomes or company performance and implemented primarily for the construction companies, consultants and managers of construction projects. Other stakeholders, such as clients, suppliers, regulatory authorities and the community were not assessed or taken into account.

2. Performance Measurement Framework

Many performance measurement frameworks have been suggested and adopted for the purpose of improving performance over the last decade. Good overviews of performance measurement frameworks in construction together with discussions and critiques of the deficiencies can be found in Kagioglou et al. (2001), Bassioni et al. (2004) and Costa et al. (2006). These frameworks include performance measures which can be implemented at the project, company or industry level where the measures for the project perspectives are sub-sets of the measures for the company performance, and the aggregation of company measures evolve into measures for the industry. Kagioglou et al. (2001) extended the framework for an organisation to the construction industry by adding the ‘project’ and ‘supplier’ perspectives. Bassioni et al. (2004) reviewed the three main performance measurement frameworks in the UK construction industry – the key performance indicators (KPI), Balanced Scorecard, and the EFQM Excellence Model, and highlighted a range of issues that requires further research. These include how existing performance measurement systems interact with newly developed systems, the setting of targets and standards for performance measures, aggregation of measures, hurdles to implementation, and using performance measures to take managerial action. Some of these concerns were addressed by Costa et al. (2006) which highlighted the role of performance measurement to enable a company to benchmark its performance against that of other similar organisations in key business activities. Five performance measurement initiatives, some implemented with the intent of establishing a benchmarking programme, were discussed in a previous publication (Chan, 2009)

The review above has given a broad overview of the various performance measurement and benchmarking initiatives at various stages of implementation, beginning with the UK which has a mature system of reporting KPIs since 1998, the Chilean initiative, and more recently the Danish (BEC, 2006), New Zealand (NZCAE, 2007) and Canadian efforts (Rankin et.al.,2008) have made significant progress although initiated only in the mid-2000s. These programmes have indicated that the performance measures for the construction industry necessarily include a combination of metrics for projects (time and cost target, quality), companies (profitability, turnover, return on capital) and the industry (safety, growth, labour productivity, innovation, training, construction demand).

3. Methodology

The list of performance measures was designed to focus on the seven strategic thrusts described in the master plan. A number of measures were adopted from other initiatives, mainly from the UK, Danish and Singapore performance measures. Other measures were created to reflect the specific foci of the industry: e.g. percentage of contracts awarded to local construction companies, number of companies with quality assurance programmes, number of construction patents and spending on information and communications technologies. Ideally, this mid-term review should encompass the entire set of performance measure but as the industry has not collected sufficient data to produce a comprehensive account of its performance, this study will be limited to publicly available data and information. The performance measures examined in this review is therefore limited to (a) annual construction demand, (b) percentage of projects awarded to local contractors, (c) export of construction services, (d) worker productivity (measured as value-added per worker), (e) building quality, (f) occupational safety and health, and (g) investments in IT. Data on project values, exports, quality and safety was obtained from the CIDB, while worker productivity and investments in IT were obtained from the Department of Statistics.

4. Comparing the Performance of the Industry in 2005 and 2011

Annual construction demand from both the public and private sectors are important measures of the financial viability and sustainability of the construction industry. The total value of construction projects awarded in 2006 consists of RM 22.5 billion from the public sector and RM 38.5 billion from the private sector, leading to a total of RM 61.0 billion. A marked increase was observed in 2007 (see Figure 1) when the government announced significant investments for infrastructure to boost construction demand. The government through its five-year economic development plan for 2006-2010 and Economic Transformation Programme (ETP) has increased total construction demand to RM 93.3 billion in 2007, an increase of more than 50%. Construction demand remained high in 2008 to 2011 with private sector spending contributing an ever increasing share of the total demand due to the government's efforts to enhance development projects under the Public-Private Partnership Programme (PPP). In 2011, the public sector share of construction demand has dropped to a mere 23% (DOSM, 2012).

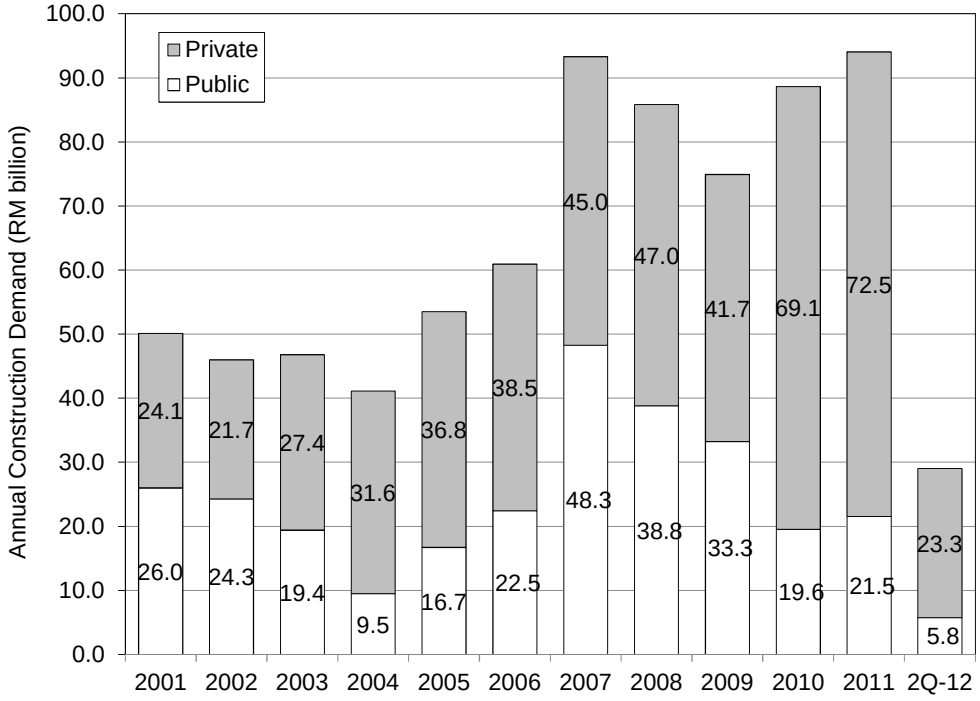

Figure 1 Construction Demand reported as value of projects awarded (Source CIDB Quarterly Information Bulletins)

The ratio of value of contracts awarded to Malaysian contractors compared to foreign contractors has consistently exceeded 80% since 2000 as shown in Figure 2 and is expected to remain above 80% indicating that local contractors were able to effectively compete against foreign contractors operating in Malaysia. One perturbing observation was the sudden increase in the proportion of work won by foreign contractors to 18.5% in 2011.

The total value of overseas construction activities directly measures the export potential of the construction industry and its efforts to penetrate markets overseas. It was reported that Malaysian construction companies won a total of RM 18.5 billion worth of contracts overseas in 2007 and another RM 19.5 billion in 2008 (see Figure 3). These figures seem to indicate that the industry is well on its way to realise its target of RM 45 billion in overseas project value by 2015. However, the global financial crisis which hit many of the countries in the Middle East and South Asia severely affected this overseas expansion. The overseas projects won by Malaysian companies only totalled RM 4.0 billion in 2011.

The construction sector in Malaysia has long been perceived as a low productivity sector due to the employment of a large number of migrant workers and the lack of investment in technology and equipment. A major strategic thrust of the CIMP was to encourage the use of Industralised Building Systems (IBS) reduce the industry's reliance on migrant workers and to improve quality and productivity. Productivity (value-added per worker) is obtained by dividing the total construction sector value-added by the total number of workers in the sector. Based on the data for value-added shown in Figure 4, the value-added for the construction industry when reported in constant 2000 prices was observed to increase at an annualised rate of 5.6% from 2006 to 2010. However, when this figure is divided by the number of workers in the industry the value-added per worker for 2005 was RM 26,615 whereas the figure for 2010 dropped drastically to RM 18,697. This significant drop in

productivity was due to a large increase in the number of workers from 602,694 in 2009 to 974,488 in 2010.

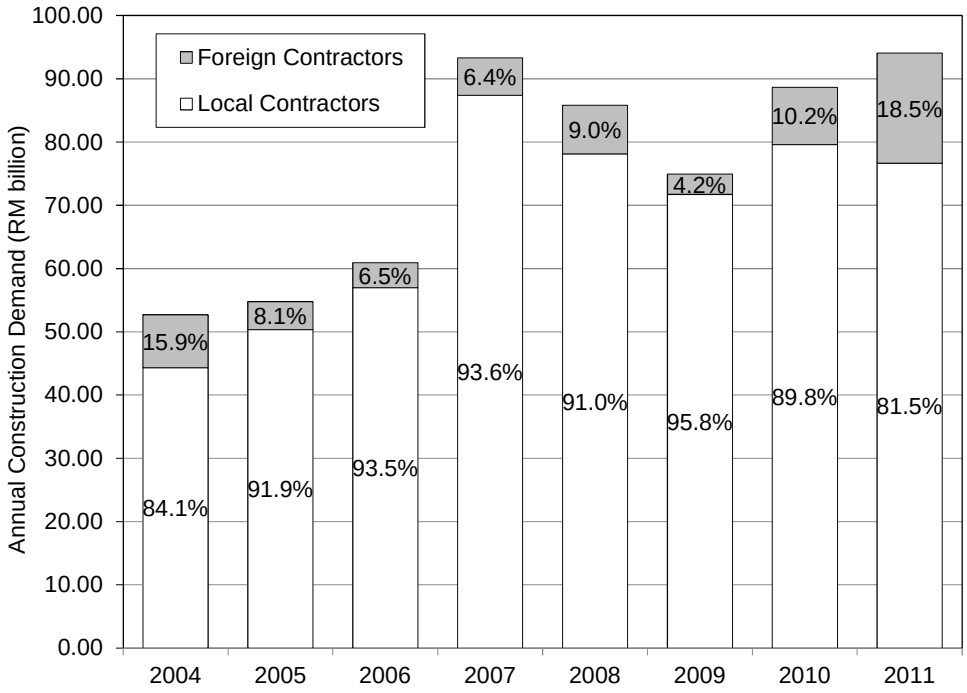

Figure 2 Percentage of project value awarded to local and foreign contractors (Source CIDB Annual Reports)

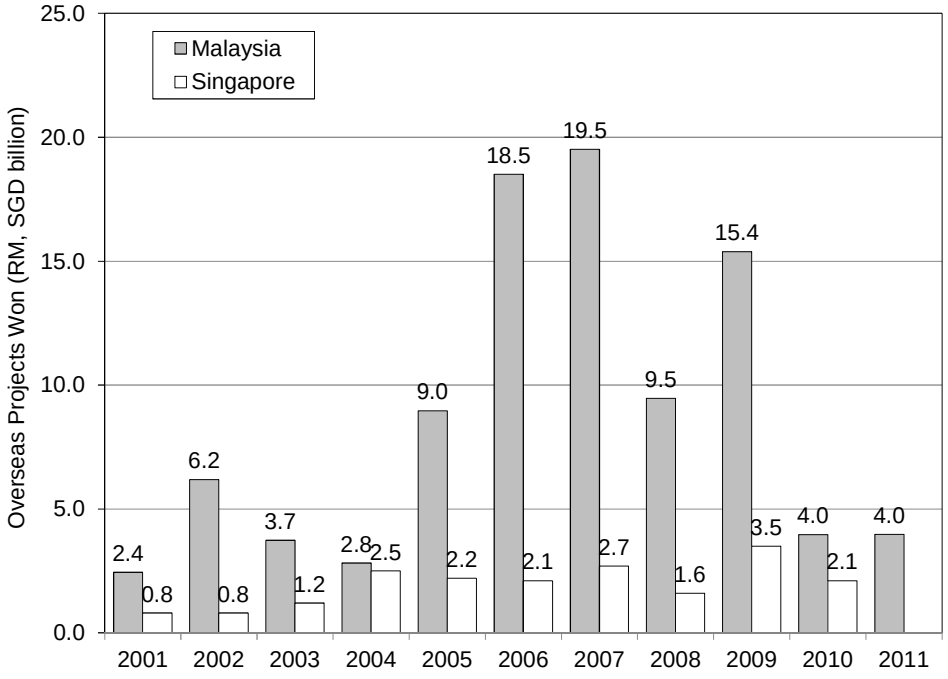

Figure 3 Export of Construction Services reported as value of projects won overseas (Source CIDB Quarterly Information Bulletins, BCA Annual Reports)

In 2001, the CIDB introduced the QuaLity Assessment SyStem In Construction (QLASSIC) to evaluate the quality of a completed building and covers workmanship in three components; structural, architectural and external works. Existing projects which have been assessed in accordance with QLASSIC have achieved a median score of 60-65 in 2006 and improved to a median of 70-75 in 2011. The number of projects evaluated remained low at 73 projects in 2006 and only 120 projects in 2011 which may not be representative of the quality of the output of the entire construction industry. The distribution of QLASSIC scores is shown in Figure 5 below.

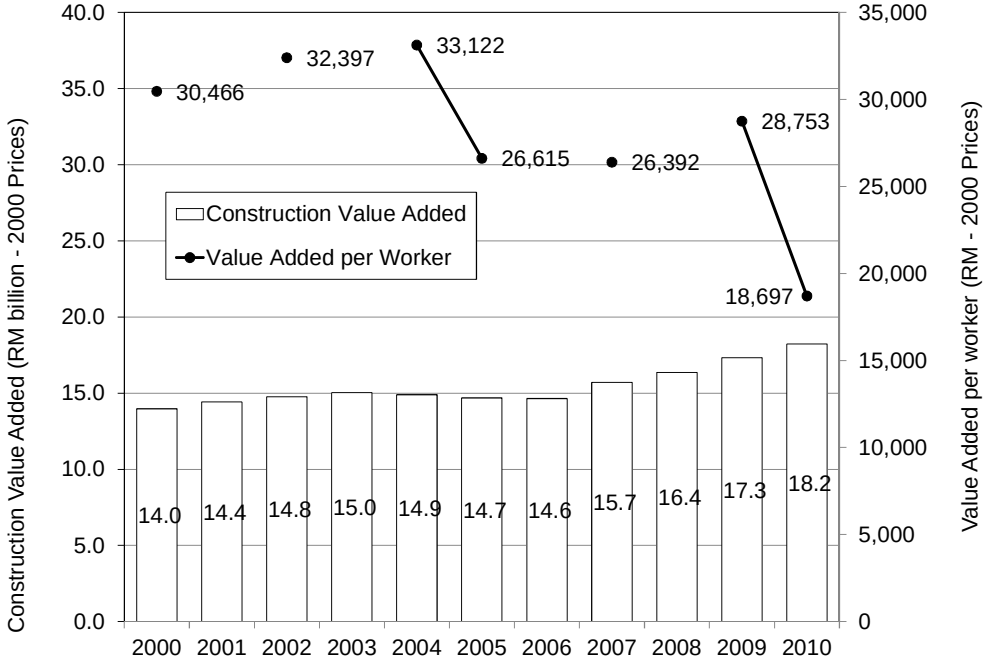

Figure 4 Value-added per worker of the Construction Sector in Constant 2000 Prices (Source DOSM, 2005, 2012a, 2012b)

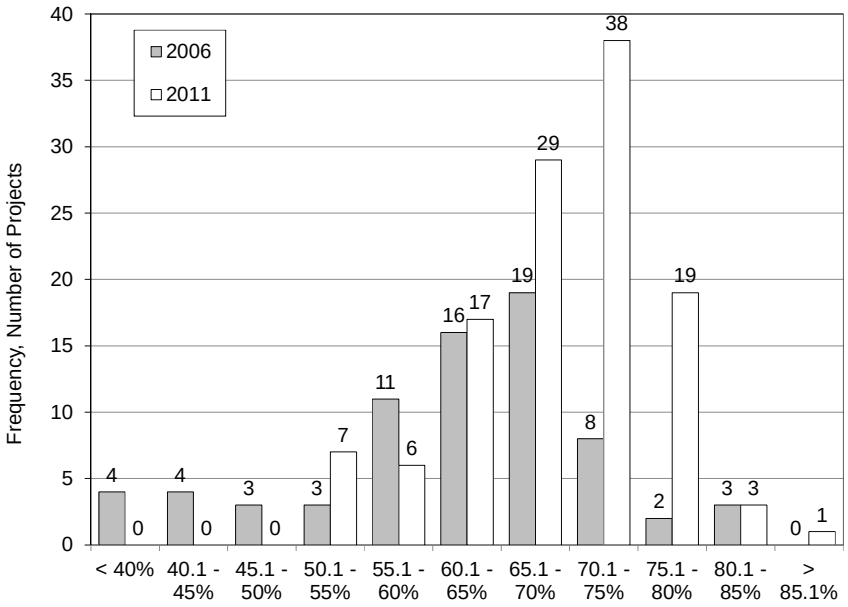

Figure 5 Distribution of QLASSIC score between 2006 and 2011 (Source CIDB Annual Reports)

Industry stakeholders have insisted on major improvements in occupational safety and health performance. Data on benefits claimed from the Takaful Insurance Scheme organised by the CIDB and the Social Security Organisation (SOCSO) can be classified into fatal accidents, accidents resulting in permanent disability and hospitalisation. The Department of Occupational Safety and Health (DOSH, 2008, 2009, 2010) also investigates accidents at construction sites and provides the accident data shown in Table 1. The data from these three sources, although vastly different because of distinct member profiles, does not seem to indicate any improvement in safety performance at the worksite.

Table 1: Summary of Accident statistics from CIDB, SOCSO and DOSH

Consequence of Accident	CIDB Takaful		SOCSO		DOSH	
	2005	2011	2005	2010	2005	2011
Fatality	23	25	76	88	63	51
Permanent Disability	75	61	618	815	7	5
Hospitalisation	69	108	3948	4813	66	43
Total	167	194	4642	5716	136	99

In order to leverage on information technology to improve the design process and to increase the efficiency of the building approval process, measures such as total IT spending by construction companies on computer hardware and software may be tracked; data for which is compiled during the census or surveys of construction industries. Data for 2005 and 2010 (DOSM, 2006, 2012b) shows that capital spending and net book values for computer hardware and software approximately doubled in this period.

Table 2: Detailed capital expenditure and fixed assets for construction companies

Type of fixed assets	Net Book Value: 1-Jan	Capital Expenditure	Net book value: 31-Dec
2005 Total Assets	7,598,075	1,294,220	7,486,517
2005 Computers:			
Computer hardware	(1.0%) 73,130	(1.3%) 16,356	(0.9%) 63,876
Computer software	(0.4%) 27,868	(0.3%) 3,906	(0.3%) 19,252
2010 Total Assets	14,368,220	2,197,803	14,476,140
2010 Computers:			
Computer hardware	(2.2%) 310,919	(0.8%) 18,097	(1.9%) 268,454
Computer software	(0.5%) 76,078	(0.1%) 3,202	(0.5%) 67,930

5. Discussion

The surge in domestic construction demand from RM 60.7 billion in 2007 to RM 91.3 billion in 2011 resulted in only a minimal increase in the percentage share of contribution to the gross domestic product from 2.9% to 3.0%. A consequential increase in gross output for the construction industry was only observed in 2010 indicating that there is generally a 2 or 3 year delay for the increase in demand to be converted to an increase in output. Even though the construction value added increased from RM 16.1 billion to RM 21.4 billion in constant 2005 prices, the national economy increased from RM544 billion to RM 709 billion. As such the contribution from construction remained small.

It is worthwhile to note that this large increase in demand was met largely by local contractors, with foreign contractors picking up less than 10% each year until the sudden spike to 18.5% in 2011. The value of the projects won by foreign contractors amounted to RM 17.4 billion in 2011. There is currently no information from the industry whether the award of these projects to foreign contractors is due to the technical complexity or if the demand has exceeded the capacity of the local contractors.

Malaysian contractors were very successful in winning projects from overseas in 2007 and 2008 but these activities have been curtailed substantially with overseas projects at RM 4.0 billion each in 2010 and 2011. The major thrust for local contractors to venture overseas was the lack of opportunities within the local market in the 2004 to 2006 period. The government was also very aggressive in exporting construction services to India and South-East Asia with a number of government-to-government projects initiated during that period. Once the effects of the 2008 global financial crisis were felt in the Middle-East, construction demand slumped and many successful contractors returned to focus on the local market. In contrast, the Singapore contractors have remained mainly in their local market as the government attempts to smooth out the spikes and troughs of the construction market by bringing forward or delaying large scale infrastructure projects. The export of construction services by Singaporean contractors has risen gradually in recent years as shown in Figure 3.

The large increase in construction demand was met with a surge in the number of construction workers in 2010. It is now clear from the data that the increase in output is not due to an increase in worker productivity but met by putting additional manpower resources to work. This increase in the number of workers, many of whom are migrant workers from Indonesia or Bangladesh now poses a serious concern to the government as a large proportion enter the country illegally or are poorly trained.

Quality has improved substantially since 2006 although the number of projects that are currently being assessed using the QLASSIC scoring system is still small. It is indeed encouraging to note that large increases in construction quality can be achieved in a short period of 5 years.

Safety in the construction industry remains a major concern to stakeholders. Data from three separate sources seem to indicate that the overall safety performance has not improved. It is possible that with the accident rate reported by CIDB and SOCSO increases due to a rise in

reporting to collect compensation benefit whereas the accident rate reported by DOSH decreased due to the punitive measures applied to the contractors when an accident occurs at their worksite.

Data on IT spending indicates large increases in the purchase of hardware and software by construction companies to support their operations. This bodes well for the increased utilisation of software tools for the design, quantification and planning of construction works.

6. Conclusion

All available data for 2011 was collated and analysed to determine the performance of the Malaysian construction industry. The performance of the industry in 2011 was compared with its previous performance in 2006. The findings indicate that although construction demand has increased significantly from approximately RM 60 billion in 2006 to RM 90 billion from 2007 onwards, this increased demand was delivered through the employment of more workers and resulted in lower overall worker productivity. Building quality has improved significantly but the industry's workplace safety performance remains unsatisfactory.

Malaysian contractors have also drawn back from their initially aggressive ventures overseas after the local construction market recovered from the lack of investments in the period from 2004 to 2006. Spending on both IT hardware and software has increased. Other aspects of industry performance could not be analysed due to a scarcity of data.

These findings indicate that a number of initiatives may have to be reviewed and revised to ensure that the outcomes envisioned in the construction industry master plan are achieved. The implementation plan will have to be substantially strengthened and intensified in the next phase as Malaysia experiences the full effects of trade liberalisation and global competitive pressures.

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Success or Failure: The NRAS

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Abstract

Many Australian families are unable to access homeownership. This is because house prices are very high to the severely or seriously unaffordable level. Therefore, many low income families will need to rely on affordable rental housing supply. The Australian governments introduced National Rental Affordability Scheme (NRAS) in July 2008. The scheme aims to increase the supply of affordable rental housing by 50,000 dwellings across Australia by June 2014. It provides financial incentive for investors to purchase new affordable housing that must be rented at a minimum of 20% below the market rent. The scheme has been in place for four years to June 2012. There are debates on the success or failure of the scheme. One argues that the scheme is more successful in Queensland but it failed to meet its aims in NSW. This paper examines NRAS incentive designed to encourage affordable housing supply in Australia and demonstrates reasons for developing properties that are crowded in areas where the land prices are relatively lower in the NSW using a discounted cash flow analysis in a hypothetical case study. The findings suggest that the high land values and the increasing cost of development were the main constraints of implementing the scheme in the NSW and government should not provide a flat rate subsidy which is inadequate to ensure that affordable housing projects in high cost areas.

Keywords: Affordability, NRAS, Housing, Australia

1. Introduction

Many families in Australia aspire to have their own home but with house prices increasing and staying high, it is proving very difficult for the low- and moderate-income families to reach the goal of home ownership. These families have limited options but are forced into the rental market. However, the rental prices are ever increasing and have reach a point where they are very high to the severely unaffordable levels. The vacancy rates have fallen in all Australian capital cities to below the bench market level of 3 per cent (Schlesinger, 2012). Figure 1 shows the average weekly rents of the capital cities in Australia in January 2012. According to a report by the Australian Property Monitors, Darwin was the most expensive city with median rentals of $505 a week each, compared with the national average of $411 a week in January 2012 (Koremans, 2012). In Sydney, the average weekly rent for houses and units are $500 and $460 respectively. In Brisbane, the average weekly rent for houses and units are $480 and $350 respectively. The median personal income in

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the 2011 census was $577 a week and median household income was $1,234 per week (ABS, 2012). This implies that around 40 per cent of a household's income go to their accommodation each week, which is termed 'housing stress', i.e., housing costs are more than 30 per cent of a household's gross income defined by the Australian Government (National Housing Strategy, 1991). Due to the limited stock of public housing, many low income households will need to rely on affordable rental housing supply provided by the private rental market.

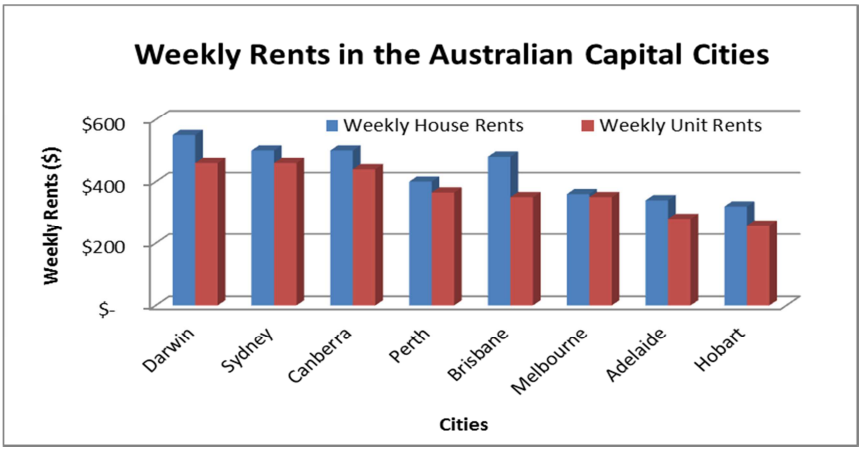

Figure 1: Weekly Rents in the Capital Cities of Australia (Koremans, 2012)

This study uses the term affordable rental housing in the private sector as the housing which is rented below market rent. However, the investors of the affordable rental housing will receive a lower rental income than market rate. In order to attract investors into this sector, government incentives are crucial in providing tax incentives for them. The Australian government introduced the National Rental Affordability Scheme (NRAS) in July 2008 to increase the supply of affordable rental housing.

The NRAS provides financial incentive for investors to purchase new affordable housing that must be rented at a minimum of 20 per cent below the market rent for 10 years (FAHCSIA, 2011). The Secretary of the Department of Families, Housing, Community Services and Indigenous affairs (FaHCSIA) is responsible for the management of NRAS, in consultation with the Australian Taxation Office (ATO). The assessment of applications is undertaken jointly between the Australian Federal, State and Territory Governments (FaHCSIA, 2011). The scheme has been implemented through four funding rounds totaling up to 40,151 incentives allocated among a total 138 participants to September 2012 (Figure 2).

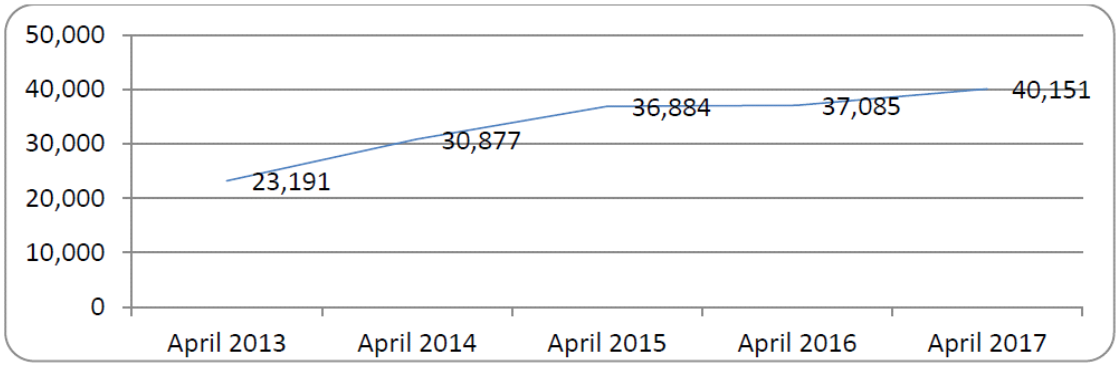

Figure 2: Cumulative participant reported delivery (Australian Government, 2012)

The actual delivery and realization of these incentives was only 10,112 to the end of September 2012 (Figure 3).

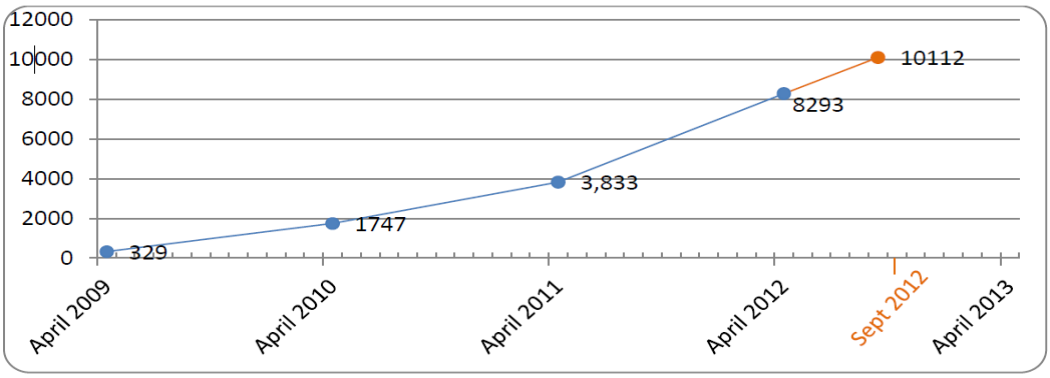

Figure 3: Cumulative Actual delivery of incentives (Australian Government, 2012)

There are debates on the success or failure of the scheme. One argues that the scheme is successful in the Queensland (QLD) but it failed in the New South Wales (NSW). According to Table 1, there were 16.8 per cent (6,729 incentives) allocated to NSW and 28.1 per cent (11,281 incentives) to QLD of total incentive scheme (Australian Government, 2012). The QLD allocated 67 per cent more incentives than NSW. This paper investigates the reasons why many investors are attracted to invest in QLD rather than in NSW through the NRAS scheme. The research is important since it tests the factors that influence the implementing the NRAS scheme. The findings can be used as a reference for government when the incentive scheme is revised.

Table 1: Incentive Status by State/Territory

State	Incentives Allocated	National %	Incentives Reserved	National %	Total Incentives	National %
ACT	1,299	12.80%	1,396	4.60%	2,695	6.70%
NSW	1,462	14.50%	5,267	17.50%	**6,729**	**16.80%**
NT	105	1.00%	1,591	5.30%	1,696	4.20%
QLD	3,128	30.90%	8,153	27.10%	**11,281**	**28.10%**
SA	1,298	12.80%	2,493	8.30%	3,791	9.40%
TAS	477	4.70%	986	3.30%	1,463	3.60%
VIC	1,619	16.00%	5,203	17.30%	6,822	17.00%
WA	724	7.20%	4,950	16.50%	5,674	14.10%
Total	10,112		30,039		40,151	

(Australian Government, 2012)

The paper will begin with an introduction of the NRAS program, followed by comparison of how the NRAS were implemented in both Queensland and NSW. The main factor that influence the program implementation will be identified and analysed through a case study using DCF modelling and sensitivity analysis next and followed by a conclusion of the scheme's success or failure.

2. The National Rental Affordability Scheme

2.1 The structure of the scheme

The NRAS was enacted by the *National Rental Affordability Scheme Act 2008, the National Rental Affordability Scheme (Consequential Amendments) Act 2008*, and the National Rental Affordability Scheme Regulations 2008 (FaHCSIA, 2011). The objectives of the scheme are to *a) stimulate the supply of up to 50,000 new affordable rental dwellings; b) reduce rental costs for low and moderate income households by making these dwellings available for rent at a rate that is at least 20 per cent below the prevailing market rate; and c) encourage large-scale investment and innovative delivery of affordable housing* (FaHCSIA, 2011). Establishment Phase (01 July 2008 – 30 June 2010) and Expansion Phase (01 July 2010 – 30 June 2014) were the two phases implemented by the Scheme.

Financial institutions, property developers and non-for-profit organisations are encouraged to apply for the incentives. Individual investors can be involved in the scheme through joint venture, purchasing NRAS dwellings from an Approved Participant, a superannuation fund or property trust (FAHCSIA, 2011). The tax incentive is provide by federal government as a refundable tax offset through the lodgment of investor's income tax return. The amount of credit is $6,000 dollars per dwelling (in 2008/09) indexed in accordance with the rental component of the Consumer Price Index for ten years, subject to annual compliance of the rules of the scheme (Gilmour and Milligan, 2008). An annual cash payment is allocated for the non-for-profit organisations participating in the scheme that are registered charities with the Australian Tax Office (FaHCSIA, 2011). The State and Territory Governments have roles to provide in-kind incentives to the Approved Participants by ways of contributing land (gratis or discounted), reducing rates and fees, contributing infrastructure, or others. In addition, State and Territory Governments may provide their contributions to the NRAS scheme for future years in advance, and the Contributions may not be deferred (FaHCSIA, 2011).

Approved Participants must meet the mandatory conditions in order to receive the NRAS incentives. The mandatory conditions include dwellings will be rented to 'eligible tenants' for at least 20 per cent below the prevailing market rate. The eligible tenants of the NRAS are those in low- to moderate- income households. Household income and the number of people including children are taken into consideration for their eligibility. There is no asset test in determining tenants' eligibility, except for tenants in Queensland. The dwellings must not be vacant for more than 13 weeks cumulatively or continuously and a statement of compliance for each approved rental dwelling must be lodged at the end of the NRAS year. The Secretary will issue a tax offset certificate to the Approved Participants, who are entitled to claim the NRAS incentive as a refundable tax offset under the NRAS. The Approved Participants must make sure the approved rental dwelling has complied with eligibility and reporting requirements of the Scheme for the NRAS year in order to receive a tax offset certificate (FaHCSIA, 2011).

The investors of the NRAS have no obligation to remain in the scheme. They may terminate from the scheme at any time during the 10-year period without penalty and merely foregoes the future benefits for the remaining balance of the 10-year term. The title of the NRAS

property remains with the investors and the government has no legal or equitable claim over the property (McAuliffe, 2011).

2.2 The NSW and the QLD

As explained in the previous section, the tenant eligibility requirements are the same for NSW and QLD. However, the housing costs (weekly rent) in NSW are higher than that in QLD. This conditions compounded by the increasing housing needs in NSW have forced the housing developments to the lower land cost areas and smaller size of dwellings. The sizes of dwellings approved in NSW and QLD under NRAS as at 30 April 2012 are listed in the Table 2. In QLD, larger dwellings dominate the approved NRAS incentives (3 and 4 bedrooms is 55%). On the other hand, 47% of NSW NRAS stock consists of 2 bedrooms and 42% of studio and 1 bedroom dwellings.

Table 2: Size of Dwellings approved as at 30 April 2012

State	Studio	1 Bedroom	2 Bedrooms	3 Bedrooms	4 Bedrooms	Total Dwellings
NSW	1,143	1,726	3,163	624	116	6,772
	17%	25%	47%	9%	2%	100%
QLD	290	1,827	3,060	4,364	1,743	11,284
	3%	16%	27%	39%	15%	100%

(AMC, 2012)

The State and Territory governments are responsible in providing in-kind incentives to the NRAS program. According to the NSW government (2010), two forms of incentives are provided. The *NSW NRAS A* program is for not-for-profit registered community housing provides. There are $40 million is available for the State contributing upfront capital to the approved projects. The NSW government announced that it will limit the number of incentives available to for-profit applicants to 1,250 dwellings (NSW government, 2010), undermining the federal government's more ambitious targets.

The *NSW NRAS B* is for all eligible organisations and $2,285 per year per unit, in addition to the Commonwealth Government incentive of $6,855, is contributed by the State for 10 years (NSW Government, 2010). The applicants must not only meet the mandatory conditions set by the federal government, but also demonstrate to meet the State/Territory priority needs.

In Queensland, the annual income-tax free incentive is currently $9,981 per dwelling and is indexed annually to the rental component of the CPI for 10 years. The incentive comprises a) the Australian Government contribution of $7,486 per year for 10 years as a refundable tax offset or payment, and b) the Queensland Government contribution of $2,495 per dwelling per year for 10 years as a cash payment for dwellings in Queensland (Queensland government, 2012a).

A one-off lump sum payment, e.g. a lottery and income earned from e.g. dividends or interest are considered as income (FaHCSIA, 2011). There is no asset test in determining tenant eligibility except for tenants in Queensland. Table 3 shows the difference in the

selection of eligible tenants for the NRAS program in NSW and QLD. It clearly shows that the QLD government is closely involved in monitoring and implementing the NRAS scheme.

Table 3: Selecting Eligible Tenants

	NSW	QLD
Tenant Selection	Approved Participants are responsible to select eligible tenants	Queensland Department of Housing and Public Works (Housing Services)
Citizenship	No requirement	Citizen, Permanent Residence, Temporary or Bridging visa
Waiting lists	Tenancy management organisation keeps the waiting lists	Queensland One Social Housing Register
Decision Justification	Approved Participants are not required to justify their tenant selection decisions	Approved Participants are able to download lists of potential tenants

(NSW Government, 2012; Queensland Government, 2012b)

3. Analysis of the Costs and Benefits of the NRAS to Investors

Australian dwellings are considered as severely unaffordable according to the survey conducted by the *8th International Housing Affordability Survey* (Bruegmann, 2012). The survey uses the 'median multiple', i.e. the median house price compared to median household income, to measure the housing affordability. The score under '3' is considered affordable. Given the measurement, the Australia national median is 5.6, this falls in the severely unaffordable category (Refer to Table 4).

Table 4: Median Multiple Survey 2012

Rank	Major Metro Market	Median Multiple
1	Sydney	9.2
2	Melbourne	8.4
3	Coff's Harbor	8.3
4	Gold Coast	7.6
5	Sunshine Coast	7.5

(Source: Bruegmann, 2012)

In particular, the multiple for Sydney is 9.2 and Melbourne is 8.4, among the highest in the world. This is because both cities are highly desired by most of people that creates pressure to house prices when house supply is inelastic. Table 5 presents the some of the survey data that shows demographic census results in 2011. The greater Sydney area is double the size of the greater Brisbane in term of the population, families and private dwellings. This indicates the demand for housing in NSW is higher than in QLD. The median weekly household income and weekly rent in the Sydney are relatively higher than the Brisbane. The information also implies that 35 per cent of median monthly income has been used for mortgage repayments in the Sydney while 32 per cent in Brisbane.

The supply of rental dwellings in the QLD performs better than that in NSW. The rate of rental stress in NSW was 47.6% and in QLD was 42.5%; both states are above the national average 41.7% in 2009-2010 (COAG Reform Council, 2012). According to the Shelter NSW

(2012), 40.8% of households or 155,357 households were in rental stress in 2011. There was a shortage of dwellings for rental in the private market for households with very low to moderate incomes in NSW. Only 10 per cent of rental stock was affordable for very low income households; 27 per cent was affordable for low-income households and 63 per cent was affordable for moderate-income households. The vacancy rate for all types of residential properties was around 1.7 per cent on September 2012 in Sydney, the lowest nationally (SQM Research, 2012). Comparing the same period with Brisbane, the vacancy rate was 1.5 per cent and 3 per cent in the Gold Coast. It is claimed that 184,031 households are at risk of financial hardship and poverty in Queensland (Queensland Shelter, 2012). Building more affordable housing in high needs locations to provide lower priced housing for key tenant groups are one of the objectives for the QLD government. The Queensland Government has important roles to allocate the NRAS project and direct the incentives to the area that most needed. However, Lawson, et al. (2009) pointed out that the flat rate subsidy is inadequate to ensure that affordable housing projects in high cost areas.

Table 5: Australian 2011 Census information for the Greater Sydney and Brisbane

	Greater Sydney	Greater Brisbane
People	4,391,674	2,065,996
Families	1,152,548	548,496
Average people per household	2.7	2.7
Median weekly household income	$1,447	$1,388
Median monthly mortgage repayments	$2,167	$1,950
Median weekly rent	$351	$325

(ABS, 2012)

The point was supported by the BVSC (2010) that most new properties have been built in middle and outer suburbs and in larger regional towns where land prices are lower due to limited funding through the scheme. These properties are crowded and developed in areas where the land cost are relatively lower in the NSW since low yield, high costs and risks (Berry, 2000) are claimed as being the main factors for the situation. As a result, the NRAS projects are a mismatch and might not be located in the area most needed affordable housing. To test whether developers are affected by the land costs for housing development and what benefits are there for the investors to invest in the affordable dwellings under the NRAS schemes, a discounted cash flow model is applied to test the effects of the policy based on the a hypothetical project. Profit maximization, i.e., minimising costs and maximising returns, is assumed as the aim for both developers and investors. Thus Net Present Value (NPV) and Internal Rate of Return (IRR) are used for measuring the benefits of the developments and investments. The calculation of NPV is denoted as follows:

$$NPV = \sum_{t=1}^{n} \frac{C_t}{(1+k)^t} - C_0$$

C_t = net cash flow generated by the project at time t
C_0 = initial cash outlay
n = the life of the project
k = cost of capital

Development and investment decisions can be made when NPV is positive and IRR is greater than the required rate of return. The estimating procedure involves

a) investigating the costs and revenues of developments and investments that include the costs of land, selling prices, rental income, etc.
b) the government incentives for the development and investment.
c) building cash flow models and calculating NPV and IRR for developers and investors.
d) conducting sensitivity analysis and discussing the results

The hypothetical NRAS project is located 23 kilometres west of the Sydney central business district on the bank of Parramatta river Parramatta (postcode: 2150). The Parramatta has a population of 19,745 with the average age of 30, comparing to a national average of 37 according to the 2011 Census. The majority of dwellings in Parramatta were apartments (72%), compared to a national average of 14%, and 58% of all dwellings were rented compared to a national average of 27%. The median sale price is $379,400 and the median rent in Parramatta was $400 per week (indicates a rental yield of 5.5 per cent for 9 months Feb-Oct 2012) for all type of properties (Suburb View, 2012). The median weekly household income is $1,288 and median monthly mortgage repayments are $2,063 (ABS, 2012).

There were 175 NRAS dwellings allocated in the suburb of Parramatta includes North Parramatta. It is assumed that the average cost of $1,500 per square meter for land cost and an average of $2,000 per square meter for constructing the 175 dwellings in the area. Fifty per cent of the units can be sold off-the-plan prior to the commencement of construction. The completed units will be purchased by the investors and rented to the low- and moderate-income families for 10 years then the units will be sold at the end of 10-year term.

Other general assumptions include average interest rates and inflation rates (CPI) are assumed 7 per cent and 3 per cent respectively. Interest only loan is used. The investment properties are managed by a professional team who will ensure the eligibility of the NRAS tenants, process the tax credits and compliances. The fee charged is assumed to be $1,750 per year per dwelling including all management fees. Other fees such as strata and council rates are assumed to be $4,000 and insurance and maintenance costs are assumed to be $1,000 per unit. Market growth rate of 4 per cent is applied for the final sale. All expenses are adjusted by the CPI. No vacancy rate is assumed since there is a long waiting list of eligible tenants.

Assumptions also include

- Both the Federal and State government will contribute $9,981 tax free to the investor in 2012.
- The tax free contribution is indexed for the 10 year term of the agreement at CPI.
- Brand new properties are rented at 20 per cent lower than the market rent.

The Results

A discounted cash flow model is built and results of the modelling are in favour for both developers and investors given the assumptions. According to the sensitivity analysis, it shows that land cost is one of the crucial elements affecting development decisions. The higher the land cost, the lower the development profits. Figure 4 depicts land cost and development profits are inversed. When the land cost per square meter increases the NPV

and IRR decreases. The IRR decreases from 31% to 28% when the cost of land increases from $1,400 to $1,500 per square meter.

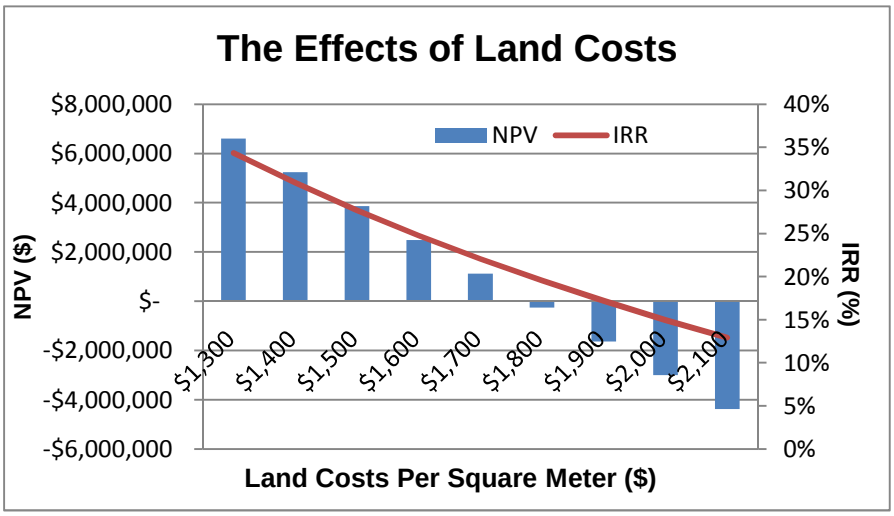

Figure 4: The effects of land costs to development returns

Similarly, Figure 5 shows a negative relationship between investment values and returns under the NRAS scheme. The higher the value of investment, the less the return will be. When the investment value reaches $550,000 at the given assumptions, the investment will barely breakeven or a loss will be realised.

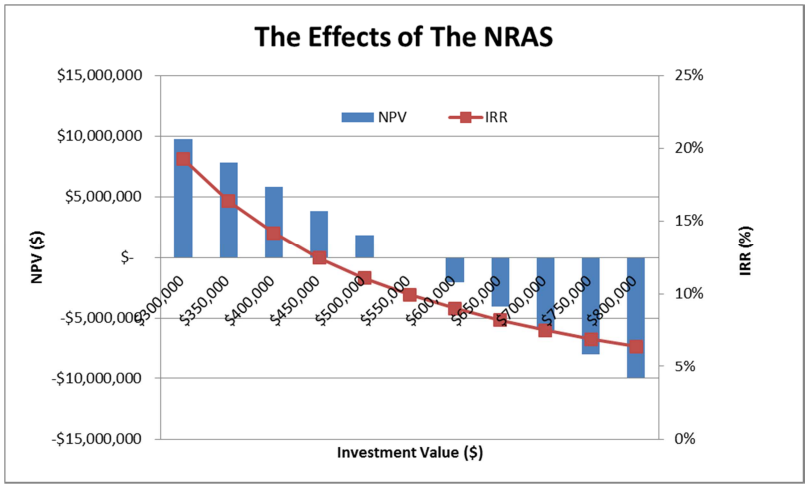

Figure 5: The effects of investing the NRAS affordable housing

The hypothetical case study explains the reasons why some of the high priority areas identified by the NSW government such as Sydney, North Sydney, Willoughby etc. where there is less affordable housing developments and low investment participations due to the high price of land and investment costs in these areas. The findings also explain why QLD has attracted more investors participating in the NRAS scheme because of less expensive cost of land comparing to NSW. Investors are attracted to the less expensive projects which are normally located a long distance from the central business district. This can create a number of problems. The first problem is that the low- and moderate-income households

may have difficulty to access employment; Secondly, the higher transportation costs could offset the lower rental costs subsidised by the governments; Third, social issues can be created when numerous low- and moderate-income families are all crowded together in suburbs competing for limited available public resources and facilities.

The criticisms to the NRAS also include insufficient funds to build new properties for the current provided scheme and thus other contributions such as land donations, bank loans and use of the planning system are needed (BVSC, 2010). Institutional investors are not encouraged to participate with the scheme as low return and high risks under the current economic climate (Gilmour and Milligan, 2008). This is because the NRAS was introduced at a difficult time during the Global Financial Crisis (GFC). Many investors were overexposed to the property asset class as a result of the decline in list equity markets (Thornley, et al., 2011). The Australian bank deposits were guaranteed by the Australian government and the banking system was much more resilient, nevertheless, banks have tightened up their credit and lending policies to against the unforseen risks. As a result, it was relatively difficult for institution and individual investors to access debts from the banks. On the other hand, many institutional investors reduced their risk exposures by adjusting their balance sheet to lower the level of debts to around 30 per cent.

In addition, the NRAS scheme was criticised that the supply of affordable rental housing is not sustainable because that a) the use of the dwellings produced after the expiry of the 10-year tax credit period are not restricted (Lawson, et al, 2009); b) no regulations apply for dwellings may be sold after the tax incentive period (Milligan and Pinnegar, 2010). The federal and states are both directly administering housing programs and having overlapping monitoring and regulatory processes (Plibersek, 2009). If the State and Territory governments do not perform or they disengage over time to match for all available incentives is of concern (Milligan and Pinnegar, 2010). There is also a risk that the federal government abandons or withdraws from their administrative roles and leaves the states to manage it alone. Evidences suggest that the NRAS scheme should set as long-term policy and provide tax credit formula in accordance with elements such as area priority, land value and costs of developments.

4. Conclusion

The NRAS scheme plays an important role in the supply affordable rental housing for the low- and moderate-income households. The NRAS scheme is successful in term that the scheme has offered a strong incentive for small scale investors to increase the affordable rental stocks. The scheme has performed better in QLD since the land cost and property values are relatively lower than that in NSW. The high land values and the increasing cost of development were the main constraints of implementing the scheme in the NSW. There are not enough incentives to attract Institutional investors to participate in the scheme. Most of the NRAS incentives were allocated to the areas located at long distance from CBD since the costs of these investments are relatively lower that can ensure positive returns on investments. The findings suggest that a) the relative more incentive should be provided to ensure that affordable housing projects in high cost areas; b) The government incentives provided in the scheme should work in partnership with other policies to ensure sufficient

funding security; and c) stable economic conditions and long-term policies can ensure the NRAS scheme run successfully. To develop analytical matrix to study the effectiveness and efficiency of the NRAS scheme and its implementations are considered for further research.

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Initiating Projects: Front-end management experience of clients and architects

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Abstract

The early stages, which occur both before and as a part of the planning of a construction or civil engineering project, are often decisive in determining the success of a project. In many cases, the prerequisites for a project are decided before the project is fully formulated. Very early stages require both a creative and a systematic product-definition and design process. This study examines how these initial phases are planned and implemented, who is involved, and what ways actors participate. Drawing on a comprehensive interview study (including interviews of clients and others stakeholders such as planners, architects, consultants and contractors), this paper scrutinizes vital questions about how to manage front-end activities. A reference group has also contributed their opinions and reflections on the results. The research project aims both to develop deeper understanding about these early stages and to develop work methods and know-how about client and architect cooperation during conceptual stages. The project has been carried out in collaboration with the National Construction Clients Forum and the National Association of Architects and has been made possible by a grant by the Board of Housing, Building, and Planning.

Keywords: needs, business objectives, pre-planning, goals, collaboration.

1 Introduction

1.1 The pre-conceptual phase in design and construction

Architects, builders, and engineers frequently use the terms “early stages”, “pre-conceptual phases”, or “front-end activities” (Emmitt 2007, Kamara et al. 2002, Cross N 2011). Although the majority of these professionals and real estate professionals agree that these activities are crucial, neither practitioners nor researchers have written much about the unique circumstances of these early stages. As the global market economy expands, society has demanded better product performance, price, quality, customisation for customers and end users, serviceability, safety, identity, and environmental performance. This rapid pace of change also drives the development and customisation of our properties as a result of ever-shorter organisational lifecycles, while environmental requirements lead us in roughly the opposite direction. Up-to-date and coordinated operational and facility planning with a focus on value creation has become a critical function (Tompkins et al. 2010). Technological

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development has increased interaction between clients, contractors, architects, and users of the built environment with a focus on the initial value creation process. Consequently, today's market demands have increased customisation and quality. In addition, the building industry has increased integration of operational development and strategic facility planning to transform a client's strategic needs into an architect's project needs (Ryd and Fristedt, 2007). Simultaneously, properties are also often highly complex, containing a number of different technologies, which – coupled with the demand for shorter development times – place significant demands on efficiency and project work. This interview-based study explores pre-planning and front-end activities from the clients' and architects' perspectives by focusing on two questions: How do clients and architects approach this phase and what implications and critical factors should be considered? As part of a lager research project about built environment stakeholders and their needs (supported by the Swedish Research Council Formas), this approach intends to develop a deeper understanding of the early stages of a project.

1.2 Perceptions on stakeholder needs - in general

When providing any new product or system, it is critical to understand a client's needs. Discovering, expressing, and managing stakeholder requirements is a large topic that has been discussed in several areas such as manufacturing, architecture, requirements engineering, product development, product design, system projects, and software projects (Goffin, Lemke, Korners 2010). This study explores design management (Emmitt 2011, Cross 2011) and systems engineering according to problem definition and needs identification. In addition, this study considers pre-planning activities in relation to decision-making theories, especially the role of uncertainty (Tversky & Kahneman 2000). Moreover, this study considers the perspective of business re-engineering and value management (Green and Simister 1999) with a focus on brief management (Blyth and Worthington 2010). The understanding and fulfilment of customer needs is also closely related to the concept of quality – a measure of the extent to which requirements and expectations are satisfied in relation to values (e.g., the Kano model of product features in Kano 1996). Furthermore, as Miles (1961) concluded, there are four values for an item: use, esteem, cost, and exchange. *Use value* is defined as the quality and properties that follow with a use, job, or service. *Esteem value*, on the other hand, is why an item is sought, which could be its features, properties, or attractiveness. *Cost value* is purely the total sum of costs needed to produce an item. *Exchange value* describes the qualities and properties of something that enables it to be exchanged for something else (Miles 1961). However, the construction client and the architect have distinct roles in the value creation process for developing built environments. Finally, to explain communication and interaction between parties, this study uses contingency theory (Hatch 1997) to develop empirical claims about the relationship between situational conditions, organizational structures, and organizational members' behaviour.

1.3 Overcoming the peculiarities in design and construction

The product definition and design process within the built environment has traditionally been based on intuitive judgments – the art of architecture and engineering. Work has been based either on earlier solutions or on architectural or engineering ideas. This bottom-up approach

progressively works toward a higher system level until a building or facility is finished. Evaluation and improvement often takes place by evaluating sketches, drawings, and physical and digital models (Lawson 2007). This approach can be expensive and can require extensive resources when the final project does not meet the customer's expectations. Both architects and clients rarely refer to formalised procedures, handbooks, or guidelines (Emmitt 2007). Re-design, modification, and new construction can cause delays and increased costs. More often than not, these mistakes arise from poorly defined needs. Today's ever-shorter development and production times may be encouraging the development of a more systematic process, integrated through close cooperation between architecture, construction, and production functions (Eriksson 2008). This systematic process prevents unnecessary late-stage revisions. Work is largely based on operation-specific performance requirements that define the artefact/product in greater detail, a top-down approach. A number of alternative solutions are produced based on performance requirements that are then evaluated. From this evaluation, the best solution (concept) is selected and the process is then repeated on a more detailed level, a strategy that ensures the right problem is solved. One interviewed client described this process as follows: *The term "early stages" can also unnecessarily hinder the clarifying of questions that need answers before the project starts and before a subsequent sequential construction process: a practice that is rarely compatible with present day construction, but which is performed increasingly in parallel and iterative processes.* Consequently, it is difficult to coordinate planning, designing, and constructing projects. This difficulty can be largely resolved by formalizing industry level processes and technical components although this approach is not available during the early stages as similar practises are lacking (Ryd and Fristedt 2007).

1.4 The aim of the front-end planning stage

Although some believe creative processes oppose systematic and controlled processes, both are necessary. Creativity is required at all levels, even within controlled processes where goals and rewards are more clearly defined. Front-end planning requires determining the client's needs or business objectives, the scope for a potential project to fulfil the mission or objective, project validation, basic project definition in terms of briefing or requirements management, an outline of the general design, approximate benefits, values and costs, funding, risk assessment, a basic organizational structure for the project, and a preliminary project execution plan (Ryd 2003). Based on the information developed in this phase, construction clients approve, terminate, or modify a project. Unfortunately, this activity often takes place with insufficient attention from the architects, who often are unaware of the early process and its success or failure (Kamara et al. 2002) Hence, construction clients who do not adequately incorporate an early planning stage will probably spend time fixing problems at a later stage.

1.5 Is it possible to identify when the early stages starts or stops?

Design theory literature includes both synthesis and analysis and distinguishes the work of clients and architects from the traditional academic discipline, which comprises the design and construction process. The framing of the problem is open; i.e., there are many solutions (Cross 2011). Consequently, both analysis and synthesis are used in the early stages.

Analysis involves examining the properties and behaviour of an existing system, either real or virtual. Synthesis involves creating new solutions based on performance specifications through combinations of existing knowledge and known or unknown technologies or components. Later literature (e.g., Blyth and Worthington 2010) describes the briefing process as an on-going process, a view that contradicts earlier theories or praxis (Peña et al. 2012). Furthermore, the terminology surrounding the early stages is not standardised. Many terms are used by different practitioners and by different researchers to mean different things. Or as one of the respondents stated: *The term "early stages" includes a paradox in so much as that it purports to be first in a chronological order at the same time as it is distinct in the division of stages; that is, it is assumed to have an end at which point an activity of another type begins.*

1.6 Initiation of a project

Typically, project management sees project initiation as the beginning of a project – i.e., without initiation, a project does not exist. However, initiation can consist of a decision brought about through the meeting of a management group, a political initiative, or an order placed by a client. The key is that there is a purpose and a goal, that the project is accepted by the organization, and that it has been allocated a budget. Next, comprehensive work must be done during the early stages before a decision about implementation can be made. In addition, the word project, which means to "throw forward", can best be translated as to "put forward suggestions for changes or solutions to a problem". Thus, this study clarifies what the reference group identifies: *That the early stages of design and construction planning include many different types of development, both when it comes to the business area, physical buildings (artefacts) and services, purchasers and builders, the complexity of the property and the project and the level of innovation, as well as the primary motivating forces. Traditionally, one can distinguish two motivations: technology and the market.* A third force – the community – also plays an increasingly important role. Technology, construction, or product-driven development (technology push) requires the use of new technology that opens up applications the market could not predict. For example, creating more efficient hospitals requires new medical facilities that place demands on the physical environment. The focus on industrial construction is another example of technology-driven development. It can take a long time before new technology is practical and established in the market. Simultaneously, we have seen the demand for integrated information and communications solutions as our properties expanded exponentially from the 1990s to the present day – a demand now addressed by solutions that less and less affect the physical structure of the building. *Market-driven development* (market push) is based on the market's demands and competing products and services in relation to the development of trade and industry. Here, the key is to both make effective use of as well as combine both tried and tested technology in new ways that satisfy well-established customer needs. Organizations, clients, consultants, and contractors whose operations are affected in one way or another by our built environment act differently to different market conditions. Knowing the market in relation to the community's continued planning and the development of trade and industry is a prerequisite for creating value within all areas, both in the short- and long-term. At the same time, market-driven development often requires adjustments according to trends. *Community-driven development* is based on legislation and regulations such as those

related to the environment and safety. Because the market often involves a more short-term attitude towards profitability based on competition, construction and real estate-related development entities do not always look for long-term sustainable solutions. Therefore, some social regulation through legislation is needed to eliminate solutions that do not address environmental and safety issues. Community-driven development is becoming increasingly important. In addition to environmental regulations, development within the EU and ISO as regards to safety requirements and standards can also be noted in this context. Responsibility for ensuring that a building meets the standards and terms established in the National Board of Housing, Building and Planning's construction regulations, and in the case of workplaces, in the directions given by the National Work Environment Authority, lies entirely with the client. As to the environmental adaptation of our properties, a clear trend can be seen towards development that was previously initiated by statutory regulations and which now is being driven by demands from informed tenants, users, and clients. The motivating forces behind environmental adaptation are gradually shifting from the community to the market.

1.7 When does it become a project?

Most of the interviewed clients and architects referred to their experience of working in projects. But when is it a project and what differentiates a project from other so-called continuous work? If one is formal and follows the definition given in project theory (Maylor 2005, Pollack 2007), then it is neither the size nor the length of the task that defines whether or not it is a project, rather a project is a project when it has a clearly defined timeframe. A project is a work method or a type of task that is strongly goal-oriented. A project has deadlines and uses specially allocated resources. As such, the goal must also be clearly defined and a budget must be drawn up for the project manager. There are are four qualities that define a project: 1) A clearly defined goal – unique task; 2) A defined timeframe – given a timeframe; 3) Specially allocated resources – own budget; and 4) Particular work methods – temporary organization. If these criteria are met, then the task is considered a project. The last criterion refers to the fact that everyone taking part in the project only works with it as long as the project is in progress. This fact and that the focus is on achieving the goal often makes it permissible to use new work methods and deviate from standard routines. Consequently, when uncertainty is high, traditional techniques-based project management (Pollack 2007) may not be sufficient; if too strictly applied, however, achieving essential project goals can be challenging. This study indicates that in the early stages it is common that not all project criteria are fulfilled (e.g., a budget may not be prepared until after a project starts). The initial phase includes fulfilling these criteria.

2. Methodology

This study provides a comprehensive description of aspects important to ensure an effective start to a project. Information gathered via semi-structured interviews, literature, training, and practical experience revealed the factors involved at the start of a well-functioning project. These factors have been analysed and preliminary grouped into several themes: Goals and Visions, Communication, Identifying Needs, Cooperation, and Procurement. Each of these factors will be discussed. These themes cover a number of factors that influence clients and

architects in the early stage and are interdependent and overlapping. In addition, these factors should be seen as a way to group experiences and understandings about the early stage and not as a theoretical model or a formula. The interview study, complementing the literature study, investigates the conditions under which front-end activities are carried out in several client organisations and projects. The interviews encouraged the respondents to share stories that represented critical moments from their experience with front-end activities. Interviews lasted between one and three hours. In total, 23 in-depth semi-structured interviews were conducted with clients and other stakeholders such as planners, architects, consultants, and contractors. Each interview was tape-recorded and transcribed (Coffey and Atkinson 1996). The respondents were sent transcripts, so they could correct and add or change the content if necessary. In addition, some respondents had another opportunity to revise their descriptions after some time (approximately one year). During follow-up phone conversations, we asked the interviewees if they wanted to clarify any of their answers. We also reviewed relevant project documents supplied by interviewees. A reference group also contributed their opinions and reflections on the work. These people actively followed and influenced project development. The panel included six senior architects and seven construction clients from both the private and public sector. The study was a collaborative effort with the National Construction Clients Forum and the National Association of Architects and has been made possible by a grant from the Swedish National Board of Housing, Building, and Planning.

3. Findings

Drawing on the literature, interviews, and experience from the reference group, we identified the following five themes or areas related to the challenges facing clients and architects with respect to front-end management: 1) Goals and visions; 2) Communication; 3) Identifying needs; 4) Cooperation; and 5) Procurement.

3.1 Goals and Visions

During the interviews, clients noted that projects must be firmly supported in the operational plan of the organization. The formulation of the project's purpose and the establishment of short- and long-term goals are essential in defining a project. As one architect stated: "*The construction clients didn't specify a lot of requirements before we began work, but gave us relative freedom to design and formulate the project ourselves.* It would probably have been better if we had been given more direction". Construction and civil engineering usually require significant investments. A project requires management to take a position regarding their facilities, a decision that will influence the organization well into the future. Construction and facility projects can be equated with – and in many cases are – business projects of a considerable size. A credible operational plan is needed when carrying out a business project if investment is to be approved by the relevant decision-making body. Several of the respondents stated "*that a project must have a firm foundation in the operational plan of the main operation".* The formulation of the project's purpose and the establishment of short- and long-term goals are important in defining a project. Implementation strategies and those activities and resources needed to achieve the designated goals must also be determined. I addition, the reference group pointed out that project goals and desired impacts are not

always synonymous. Project goals are related to what the project will deliver. They can be formulated for different levels and for different areas of responsibility. Desired impacts are related to what the results of the project will achieve. Factors external to a project also have a bearing on whether desired impact goals are achieved. Respondents also stressed that project goals can be formulated as one or several main goals that can be measured through a number of quantifiable sub-goals. Desired impact goals (i.e., what the results of the project can achieve) affect the stakeholders. As such, stakeholders either desire or require or fear the various impacts. Examples of project goals include delivery time, functionality, characteristics, and/or costs. Examples of desired impact highlighted include user impact, market share, profitability, and/or environmental impact. It was also concluded that projects can be divided into main goals, sub-goals (quantifiable and verifiable), and limited areas. For the client, the project form is often an effective way of realising visions and operational goals. However, one of the interviewed architects stressed that "construction clients often are relatively poor at communicating their goals for the project from the point of view of their operation". However, what is it that separates the client's continuous operational planning from the planning of an individual project? According to the generally accepted view of a project, it is not the size or the length of the commission that determines whether it is a project, but it is a clearly defined timeframe that determines its status as a project per se. As such, a project is a work method or a type of task that is strongly goal-oriented. Because the project should be carried out within a set timeframe and often uses borrowed resources, it should be delimited and prescribed a budget. It is rarely the case that a project is born out of thin air. A project always has a background – a historical aspect that has led to the desire to effect a change. Or as one respondent stated: "It can be said that all clients' projects are change projects and that the goal of the projects is to act as links in a chain of change".

3.2 Communication

"As a rule, all projects – especially in their early stages – include communicative tasks", one of the respondents stated. Much of respondents referred to their experience as inter-disciplinary cooperation in project teams, with different agendas and experiences, coming together to achieve a project goal. As such, it is important to have a good understanding of how to communicate well. As one client noted, this serves two purposes: *Firstly, to ensure the quality of the results from the outset by making use of stakeholders' knowledge and taking into account their requirements in relation to the building or facility. Secondly, to save time by allowing different teams responsible for various activities with different degrees of association to the project to work in parallel and with a continual exchange of information between them.* An information exchange requires advanced forms of communication. In this context, the simplest communication models describe senders and recipients (Craig 1999). The sender has an intention, something he or she wants to convey, which is called the intended message. However, most often there are also things that the sender does not want to convey, but which are conveyed nonetheless. This is termed static. When we communicate with others in the early stages, the reference group stressed the following: *It seems that it is easier for most of us to convey our intended message through our text than in our words and briefing sketches. It is often also the text that we prepare most. It is this that we (for various reasons) put our energy into when it comes time to communicate.* Because the subtext, which is conveyed alongside the words, represents the greatest part of the

message, it is interesting to see just what is conveyed. Not surprisingly, seeing as the majority of us do not have such good control over our subtext, static is seen most clearly there. Subtext refers to everything that lies under the text. This includes body language, tone of voice, and facial expression. Vocation, title, status symbols, gender, age, and other factors are also included (Craig 1999). The latter are examples of attributes that the reference group pointed out, which are often accorded far too much importance within the building industry, even if they are quite important for understanding and developing communication skills – especially considering that the majority of communication researchers (Craig 1999) seem to agree that in the majority of cases the subtext comprises a larger part of the conveyed message than the text. Nonetheless, in all communication it is the recipient who decides. That which is ultimately understood is that which remains after the message has been filtered through the recipient's frames of reference, prejudices, and experiences irrespective of whether the recipient is an architect or a client. For different reasons (such as any previous knowledge they possess), a recipient may understand what is conveyed in a completely different way than the sender. For example, one interviewee from the reference group noted this: "*A recipient (an architect or client, i.e.) who does not have a great deal of confidence in contractors may choose not to listen at all when meeting one".* At times, the recipient's filter is so fine that the only thing that remains is "I hear what I want to hear and see what I want to see", an attitude that those involved are sometimes accused of adopting in the early stages and that both interviewed architects and clients endorse.

3.3 Identifying Needs

There are challenges related to identifying needs, since inadequate identification of requirements often is a source of mistakes in the early stages. This theme reviews questions about the identification, prioritization, and the documentation of needs, desires, opp-ortunities, and requirements. Several respondents noted that practical, useful techniques were required for identifying needs and that a lack of consistent terminology and theory hampered success. One architect stated the problem as follows: *Many professionals have just one or a few ways of doing things. They continue to use the same techniques they have tried before because they know that they worked well the last time. This is fine, but it's even better to have mastered several alternative approaches because techniques are more or less effective depending on their area of application. An interviewed client stressed that "a successful briefing can significantly increase and ensure the quality of the finished project. An inaccurate needs analysis can lead to significant quality issues''.* However, these issues can stem from the wrong data being gathered from the wrong person using the wrong technique that are documented in an ineffective way. The reference group concluded that [i]t *is true that the consequences can sometimes be small (such as when less important functions don't work as they should), but unfortunately, it is common that inaccurately identified needs have much more serious consequences, such as that a project is delayed, that it exceeds its budget, and/or that the construction client, client, users, and tenants become, to a greater or lesser degree, dissatisfied with the way the expected characteristics of the finished product have been realised.* Identifying relevant needs within the planning, building, and real estate sector is becoming more and more complex and to a certain extent, more difficult with each passing year. The strong movement of the 1960s towards efficiency

resulted in a segmented construction process, divided into separate stages, with the purpose of monitoring, rationalising, and controlling the cost of the process: relay-like stages, each of which were relatively isolated from one another. This became a tradition in which completed final documentation formed the basis for the work performed in the subsequent stage. The development work of the following decades has focussed on the rationalisation of the management of ever-increasing amounts of information with the intention of reducing information loss. Today, many processes are carried out simultaneously, even if they progress at different rates. Requirements management processes entail a great need for coordination and communication because there are many more players involved in today's projects. At the same time, a maturity and wisdom exists that accepts that it is not possible to identify every need within a project. The work is very much about specifying what can be defined and identifying the points needed for compromise. On the other hand, one client expressed the following: *"The challenge will be to make the process between idea and product as efficient as possible using different methods. For this model to work, a complete understanding is required – a complete picture of the requirements".* Nevertheless, another client added that "[t]he approval process often times requires answers to questions that have not yet been investigated or clarified".

3.4 Cooperation

Recently, there has been a great deal of interest shown in new forms of cooperative engagement within the built environment sector. Characteristic key components are workshops, teambuilding and training in collaborative techniques, joint risk management, and value management sessions. The idea that everyone wins by working cooperatively towards the established project goals has slowly but surely gained a foothold (Pollack 2007). In more complex projects, additional stakeholders are involved and the goals are more ambitious regarding client and architect integration. Of course, there are still many hurdles to clear (Tamm and Luyet 2004), both structural and cultural, but the big breakthrough for a shared view and cooperation between the sector's different players and between the early stages, planning, production, and management has in fact taken root according to those interviewed: *The increased realization that cooperation in itself is a method for achieving better quality and profitability is a very significant step forward. . . .All successful projects are carried out through some form of collaboration – whether it be more or less articulated, formal or informal.* The interviewees emphasised that cooperation when working towards the project goals established by the client is the primary purpose of project work. Some still experience obstacles in the form of purchasing rules, for example, which limit possible collaboration over time between the client and architects and other consultants as well as between different groups of players. Competent participants in the early stages have the ability to identify, interpret, translate, and communicate the heart and soul of the project in order to have everyone involved push towards the same goal. The increased realization that collaboration in itself is a method for achieving better quality and profitability is a very significant step forward. An experienced senior architect put it this way: *The early stages have a lot to do with balancing the evident interests: those of users, construction clients, financiers, politicians and others from the standpoint of those who make demands on the project, with those made by project engineers, contractors and real-estate companies from the standpoint of those who implement.* One professional client echoed this sentiment: "*To a*

large extent it's about getting inside the customer's head – about a really close collaboration through which a project's real purpose/impact is defined and communicated". Similarly, the reference group concluded that the best projects are the ones in which those who have analysed and formulated the needs and requirements often meet together in a process that promotes support for their achievement, a process that demands lots of time but which must be allowed to take time. This study identified time pressure as one driving force behind increased collaboration in the early stages. As such, it is even more important to make effective use of all of the participants' experiences. Moreover, the very early stages are often informal in nature, which is often favourable and opens up opportunities for cooperation. Forms of agreement are gradually being formalised and guidelines (e.g., partnering) are being developed to support and simplify the process even in the early stages. At the same time, as one client stressed, "opinions have been voiced to the effect that it is not possible to force or legislate trust; this is something that must be earned".

3.5 Procurement

The reference group emphasised that the procurement strategy is "a qualified task to procure services for a construction or infrastructure project, not least of all when it comes to procurement in the very earliest stages". However, as one architect stressed, "the services that are to be purchased can never be specified in detail or be quantified during the actual procurement process as the quality and idea content of the services cannot be fully evaluated until they have been performed". Nevertheless, the purchasers of the services make their decision on the basis of the assumed ability of those who provide the requested services: "Identifying a competence profile and desired qualities and experience is important in this context and is something to which the client should attach a great deal of importance when requirements and the basis for procurement are being formulated" (an architect). It can be expected that a client who frequently initiates and implements projects conducts this kind of work continuously: *A client's marketing work should always include the element of being familiar with where different skills are to be found on the market, how they are developed, and in what way they can make the best use of them. Keeping up-to-date with the skills available on the market requires continuous surveying and follow-up.* The reference group concluded that "it is also important for the client to know which factors in the project influence cost and in which stages of the project the long-term cost has the highest risk of being impacted". One respondent stated that "[e]very client knows that the possibility to influence cumulative cost development is greatest in the very earliest stage. The further the project progresses, the more you are bound to a cost development which is not entirely open to revision". As such, it is of the greatest importance for the client to have the right focus from the very earliest stages of the project and from the outset include in their team people with knowledge of how the project can be planned and directed in the most value-added way.

4. Conclusion

This research explores pre-planning and front-end activities from the clients' and architects' perspective to contribute to the development and deeper understanding of the early stages of a project. Preliminary analysis of interviews and literature has identified five thematic areas that relate to initiating a building project. In this paper, these challenges have been

preliminary defined although not fully analysed. Still, this concluding part summarizes the identified theoretical frameworks based on the challenges presented in the major empirical part of the paper (Table 1). When organisations encourage collaborative work and trust, they can create opportunities for knowledge integration, learning, and improvement between clients and architects. Before relationships between the client and architect are established (when planning the early phases of a project), it is important to consider how relationship development can be reconciled with both knowledge integration and disagreement in order to secure a proper identification of needs and a novel start of a project. Tamm and Luyet (2004) have identified five skills, which can be learned and developed, needed by those who want to develop their collaborative abilities: 1) The desire to cooperate: to have a non-defensive attitude; 2) Truth and openness: to be aware and honest and share both facts and feelings; 3) Personal responsibility: to take responsibility for one's own choices and their consequences; 4) To have a sense of self-awareness and understanding of others' needs, opinions, and motives; and 5) Problem-solving and negotiation: to use a method that supports a cooperative climate. One interviewed architect expressed this idea as follows: "Early cooperation between parties creates the conditions necessary for achieving a higher level end-product quality, shorter process times, better communication between all and more efficient systems for experience-related feedback".

Table 1: A summary of findings and related theoretical frameworks for further work

Identified themes	**Identified theoretical framework (to be developed in the future)**
Goals & visions	Requirement Management, Path-Goal theory of leader effectiveness
Communication	Information and Communication theory, Prospect theory in decision making
Identifying needs	Systems Engineering, Value Management, Maslow's hierarchy of needs
Cooperation	Organization theory, Team Behaviour, Cooperation theory
Procurement	Transaction cost economics theory

Unfortunately, the empirical results reveal that many projects start without clear and quantifiable desired impact goals. It is often the case that the evaluation of the building industry focuses on individual project goals and the end product rather than the value the project was intended to create for the client. However, according to the reference group, construction clients steer the projects in many ways: a) initiating, following-up, and concluding the project; b) ensuring that the project is in line with business and/or operational goals; c) allocating resources; d) coordinating projects within the operation; e) providing tools for directing the project and project models; f) managing the organization's business opportunities and risks; and g) placing requirements on the project manager for each particular project. As a result of the interviews and through confirmation by the reference group, the purposes of the early stages were identified: through *creative* work to transform the user's (construction client's) requirements concerning *function* and *quality* as well as other desires into an *architectural* and *engineering* solution and a basis for *production* that is *economical* for both the *user/client* and *contractor/supplier* and which also allows for *other requirements* stipulated by society and affected parties (stakeholders) and satisfying *existing buildings* regarding *safety* and the *environment*. One architect summarised this idea as follows: "*The early stages should perhaps be called 'strategic stages', as they more correctly highlight the need for important, determining factors to be identified, translated, and applied*

in the appropriate stage". A client confirmed this conclusion: *"As a term, 'the early stages' does not indicate the value of the tasks that should be performed before the start of the project, as opposed to 'strategic stages', which does*".

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The Interplay of Organisational Culture with Business Development for the TMO:
service (in)coherence and the implications for marketing

Hedley Smyth[1], Illona Kusuma[2]

Abstract

Business development (BD) has an important role in identifying and levering value to optimize value propositions and for their consistent delivery. Solutions generated are only as effective as the systems linking stages along the project lifecycle. Organisational culture as a factor influencing cross-functional systems integration provides the research focus. The *objectives* are to explore, (i) the effectiveness of relationship marketing (RM) and BD, (ii) the extent of integration over project lifecycles, (iii) the influence of organisational culture upon marketing and integration. Case material is provided from four international main contractors. Based on Douglas' grid-group model, a snapshot of four different organisational cultural orientations was taken and analysed. Systems integration in marketing for projects is mobilized and RM principles are drawn upon to analyse BD. A qualitative research method was employed using semi-structured interviews. Findings suggest variations in RM and BD practices. Four barriers – misconception, inadequate resources, inadequate delivery, and underrated/exaggerated promises – were identified and were linked to a lack of systematic integration. Risk spreading, rather than value and service coherence, was found to be the current emphasis of integration. Constraints were identified at two main levels – vertical hierarchy and horizontal functioning over project lifecycles – amplified by the prevailing organisational cultures. There is a need for awareness towards the implications of organisational culture – and sub-culture – *metamorphosis* for each of the different stages of BD; a skilful steering oscillating between the different functions and perceptions according to the embedded value proposition. This provides the basis for recommendations made.

Keywords: Business Development, Organisational Culture, Systems Integration, Service Incoherence, Relationship Marketing

1. Introduction

Contracting organisations focus on the *provision of products and services as integrated solutions to individual customer's needs* (Davies et al, 2007: 183) carried out by coordinating and integrating various external firms in the form of activities to be conducted by a temporary multi-organisation (TMO). The main contractor and TMO are a *complex system of interest*

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groups, some congruent, some competing (Cherns and Bryant, 1984: 181). Pertinent "soft" management issues complement "hard" expertise, conceptually challenging business development (BD) to find opportunities to raise productivity and service quality – continuity of value leverage within the gaps over concurrent production (project artifact) and consumption (service experience) provision (cf. Grönroos, 1990; Pinto and Covin, 1992). Although the analysis circles around main contractors, the term TMO is used to emphasise the involvements – the need to consider other internal stakeholders (mainly the clients) as primary drivers for BD, value leverage and seamless project delivery at the front-end. In this sense, traditional client drivers, dynamic environment (Aijo, 1996) and fragmentation between actors and phases in the main contractor operations affecting TMO operations in turn, where managing continuity from inception to completion is more dependent on *their coordination than by the form of the contract* (Cherns and Bryant, 1984: 182). Effectiveness relies heavily on managing the project's transition periods from the front-end to ensure service coherence between functions through *a holistic view of the parties and processes involved in marketing and business* (Aijo, 1996: 8) – appropriate RM systems.

Although the fundamentals of integrated solutions have been explored (e.g. Davies et al, 2007), little has been done surrounding the interplay of organisational culture as a factor for lack of systems that span across functions for value identification and leverage throughout the project lifecycle. As direct interactions with clients and other stakeholders underline the characteristics of services firms, organisational cultural interplay as a factor influencing capabilities to build and manage relationship calls for further investigation; particularly for (i) each *type* of relationship within BD, (ii) *continuity* along the project lifecycle, (iii) cross-functional *coordination*. Further, organisational culture in construction remains under-researched at the corporate-project interface.

The aim is to contribute to this knowledge gap, exploring RM and BD processes within four project firms and their resonance with the organisational culture, including the interface with projects. The key research issues are to explore, (1) the effectiveness of RM and BD, (2) the extent of integration over project lifecycles, (3) the influence of organisational culture upon marketing and integration, i.e. relationship building (RB) and relationship management systems. Through evaluating the organisation's cultural orientation against marketing and BD, mapping RM and BD in the form of a matrix to guide development and transition, an analysis from the top management to the project level to reflect the dynamics of the corresponding culture and processes is provided. A matrix for a more symbolic interpretive mapping style (cf. Lowe et al, 2012) is proposed to guide seamless development and transition relative to organisational culture. Finally, conclusions and limitations are offered.

2. The Role of BD and RM

The significance of BD and RM in providing integrated solutions starts with (1) simultaneity (customer contact) – production and consumption occur at the same time (cf. Kelley et al, 1990); (2) heterogeneity – unique and customized solutions in every project (cf. Clegg et al, 2002); (3) intangibility – difficult to evaluate in advance (cf. Hollins and Shinkins, 2006); (4) perishability – consumption is distinct to individual market settings, and context at a particular time and in space (cf. Pinto and Covin, 1992). Therefore, different approaches

emerge in the process of coordinating integrated solutions, requiring exceptional understanding for RB and marketing efforts (Cowell, 1995). Davies et al (2007) argue, firms providing integrated solutions position themselves in three ways: i) forward integration into the provision of services, ii) developing close relationships with customers, and iii) creating customer-focused organisations. Thus, integrated solutions emphasize the creation of a customer-focused organisation where goals shift from being constrained within the single project boundaries to include a goal of superior service to optimize value propositions from the customer's viewpoint (e.g. Pinto and Covin, 1992), i.e. co-creation of value.

There are two value dimensions that are widely misunderstood in construction from a marketing viewpoint: (1) the traditional project view where technical content and technology are the 'product' focus and efficient task completion is the project management focus, differentiation being marginal and weakly connected to project management during execution; (2) simultaneity engages clients throughout the process, perceived value delivery being highly influenced by the contractor and TMO ability to manage transition periods for the project. Service value therefore, extends further to customer lifetime value beyond single projects via repeat-business (cf. Webster, 1992).

Meeting time, cost and quality or scope against the project requirements is expected as a matter of course despite being difficult to achieve in practice due in part to client decisions. Doing so does not equal value as value creation goes beyond increasing value for money. It depends upon understanding client needs from the perspective of customer strategy and core business drivers from the senior to the operational decision-makers for their projects. Value therefore, is more about perception and matching action to perception is important (Vargo and Lusch, 2004). Following this logic, the role of BD is to identify effective solutions that lever value that is project specific yet also generic to client programmes, thus build long-term relationships that transcend individual projects. Ideally, this means a seamless delivery of promised benefits (value distribution) paired with flawless execution for projects through horizontal integration between functions for continuity throughout the project lifecycle (cf. Cooper and Budd, 2007) and supported by programme management. Means to nurture relationships at the front-end of the project through RM is important for service continuity. It is the difference in the quality of relationship between purely transactional, functional, and relational integration within the contractor and TMO that determines the extent of seamless transitions throughout the whole project delivery. Cova and Salle's (2005) three dimensions of project marketing relationship networks will be used to articulate these issues – see Figure 1.

Project Network	Relationships are nurtured within the boundary of individual projects. RB is highly transactional, focusing upon satisfying minimum requirements. Insufficient as a mean to stipulate a system that span across functions.
Buying Network	This concerns a lifecycle of systems that are relationally integrated. Relationships are nurtured through on a programme management level. Solutions are proactively designed into the service system for delivery.
Milieu Network	Relationships are nurtured in and around the customers. Leans more towards building long-term relationship where functional integration is considered, relationship personalised, and service customised.

Figure 1 Dimensions of Project Marketing Relationship (Cova and Salle 2005)

Cova and Salle (2005) argue in their approach for *project marketing*, that value propositions should be identified from the client's perception of the project for seamless systems integration between functions and contribution to its development. Understanding client drivers has several conceptual depths from building relationships to get information on the project requirements, understanding the motivations and considerations of the key decision makers (clients and their professional representatives), understanding business solutions or organisational purposes projects were addressing, and understanding the client's own core business to get to the bottom of what they perceive as valuable. Regarding Figure 1, the effectiveness of BD lies on the ability to anticipate client interplay rather than being reactive. In this sense, RM must be employed to take the "broader view of the milieu" (Cova and Salle, 2005) to build relationships that can anticipate the client's contractual behaviour, hence, enabling the TMO to respond consistently to the demand variance between sales and operations. Whilst each dimension are important for effective RM, for each *type* of relationship within BD, *continuity* along the project lifecycle, and cross-functional *coordination*, the deeper the level the greater the implications coming from the interplay of organisational culture (from facilitators and resistors) due to increased commitments in financial, social, and structural bonds. This brings us to the next section.

3. Linking Organisational Culture to Relationship Marketing

Understanding the forces behind cross-functional diversity is fundamental for organisational effectiveness (cf. Shapiro, 1977; Cooper and Budd, 2007). Organisational culture is argued to be that force and the shaper of other forces. Webster (1992: 10) claims that marketing comprised of three distinct dimensions: culture, strategy and tactics and defines culture as, *A set of values and beliefs about the central importance of the customer that guide the organization…[and] is primarily the responsibility of the corporate and [BU]-level managers.* Now, Lacoste (2012) and Crespin-Mazet and Ghauri (2007) argued that a minimum level of shared knowledge between goals and expectations must be present to build high-level interaction and cooperative relationship. In other words, organisational culture must be able

to facilitate integration not only internally between functions but also externally to acknowledge client and market drivers. In this sense, organisational culture serves as a fundamental factor to achieve effectiveness and service coherence between the different business units (BUs) inter- and intra-organisation(s); e.g. between BD team, bid team, and execution team. It is not as simple, however, as Clegg et al (2008; 224) claim, who stated: *There often is not a singular organizational culture and* [organisational culture] *are often not easily amenable to being managed*. This entails the different norms held by different BUs that are often an issue for seamless integration given the vast number of different roles played in each stages of the project lifecycle. Schein (2010) categorized the complexity of organisational culture into macro-cultures, organisational cultures, sub-cultures, and micro-cultures where frictions and tensions emerge due to differences in norms between inter- and intra-organisational functions and hinder the contractor and TMO's ability to achieve consistency of service. Hence, the different cultural values held between the various BUs within the contractor can be equated as the *bits of coloured glass in a kaleidoscope* (Liddle, 1996; 143).

Further to Liddle's claim, Auch and Smyth (2010: 44) argued, *cultural diversity could be interpreted as either management strength in accommodation or a weakness associated with a lack of coherence and investment*. Although cultural diversity can constrain service coherence on and between projects, any powerful cultural assumption will stereotype opportunities regarding action to add service value. Schein (1985: 19) stated, *not only is it difficult for the ex-engineer to conceive of marketing in the way that the professional marketer perceives this function, but the implementation of a marketing strategy may be undermined by the kind of people who are in the sales force, the incentive systems operating, the issues that executives pay attention to, and so on.* Again, the importance of organisational culture in influencing cross-functional systems integration between vertical and horizontal organisational elements is emphasised. It is suspected that traditional and transactional arm's length methods in the post-2008 era eclipse yet influence organisational culture, the implication being that marketing and BD are internally embedded in procedures of functional disconnection.

In sum, the interplay between organisational culture, BD, and RM supports Cova and Salle's (2007) conception of front-end–back-end organizational processes. The front-end deals with coordination of relationship with the customer through RM, the back-end reflecting BD's role in producing integrated solutions through value identification and propositions and is charged with contributing towards assured delivery. Yet in practice BU routines and expertise constrain integration in the project lifecycle. The glue that provides the marketing norms to link systems and optimize value propositions for consistent delivery is the interplay.

3.1 The Douglas Grid-Group Model

The Douglas grid-group model (1999) recognizes four types of organisational culture. The model addresses culture in relation to its external regional cultural orientation that are organisationally internalised as norms. For example, the hierarchical type of organisational culture, with its ranked levels and symmetrical branching, depends on the adoption of hierarchical values and the expression of matching judgments (cf. Douglas, 1999: 411). The

four culture types are based on the cultural bias, which is the steady preference for one or another set of institutional forms and consequently, the commitment to associated kinds of knowledge. The model argues that every cultural conflict is about the type of organisation. For this reason, the model parsimoniously assumes there are only four stable organisational forms: hierarchical, egalitarian enclave, isolated fatalism, and competitive individualism (Figure 2). Others are considered to be transitional in dynamic negotiation. The model provides an interpretative lens for analysis.

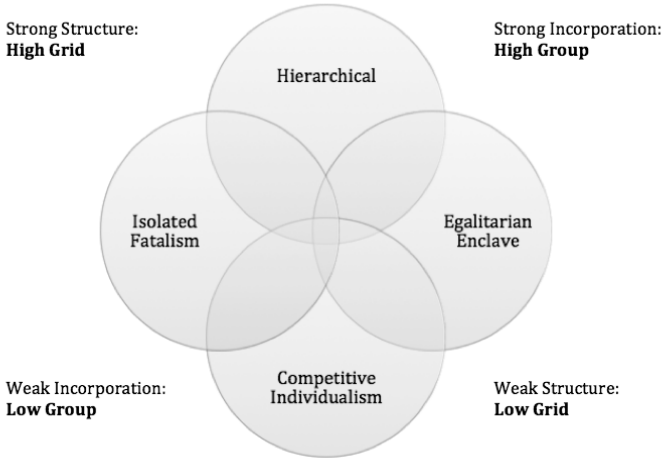

Figure 2 Grid-Group Model of Culture (Auch and Smyth, 2010: 46)

4. Methodology and Methods

Regionally based teams ranging from the top management to the project level in different construction BUs amongst 4 case companies derived from around 30 semi-structured interviews provide the source about conduct and implementation, reflecting the dynamics of the culture. As organisational culture, BD and RM are processes and context embedded; the aim is to allow for identification of similar and contrasting situations. The grid-group model provides the interpretative lens, participants having been asked to rank 2/4 statements that mostly accord with the organisation, the statement representing the characteristics of each organisational culture, providing organisational snapshots. Findings are further analysed through 4 marketing barriers: inadequate resources, inadequate delivery, misconception, and promise fulfilment (Jobber, 2007). The snapshots are mapped against market drivers and organisational culture as factors influencing BD. Lowe et al's (2012: 362) mapping styles, seen as a navigational metaphor, is used. The authors recognize that problems of understanding emanates from *the fact that network actors may be accustomed to different cultures, cognitive frames, terminologies, and management philosophies*. Thus, successful navigation enables a skilful steering, oscillating between the different functions and perceptions according to the embedded value proposition. The mapping styles helps capture the inherently dynamic setting that the snapshots alone cannot accommodate.

5. Evaluating Organisational Cultural Orientation against Marketing and Business Development

The summary findings of the organisational cultural orientation between the 4 case studies are presented in the figure below.

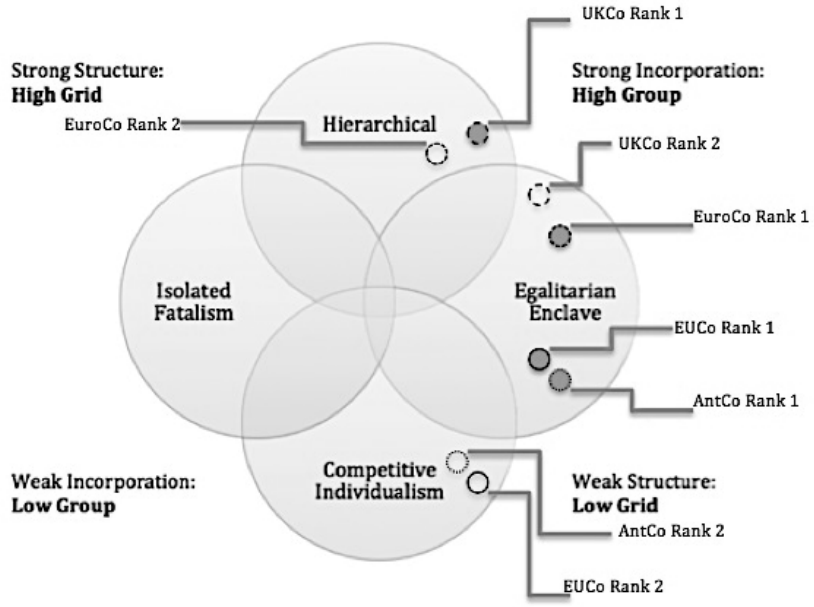

Figure 3 Organisational Culture Orientation of the 4 Case Study Firms

One mean of micro-management for RM is the behavioural codes of conduct although there is no evidence of this even though respondents interviewed repeatedly referred to “correct” and “right behaviours”. In this sense, RM systems were also lacking. In their absence, cultural factors are to the fore. This section begins with 4 short interpretations of the organisation’s cultural orientation. Taking the interpretations both at face value and how they manifest on the ground, the 4 case studies evaluate the implications upon marketing and integration for service coherence over the project lifecycle. Each case is addressed in turn.

EUCo was described as being akin to a franchise operation. It operates with the belief of autonomy, both from its European counterpart as well as internally across functions. EUCo focuses on collaboration in an open and loose hierarchical structure. This is reflected in the practitioners’ egalitarian orientations – see Figure 3. Interpreting the overall organisational culture through the grid-group lens, the organisational culture is negatively inward looking steered by internal norms and given rules to ensure equality amongst members. There is a reluctance to address external changes. This is illustrated in the Contracts Manager’s response; EUCo *tends to fall back into compliance and regulations*. Paradoxically, the firm is client driven in the sense that it is submissive in the market. The commercial emphasis is upon driving down costs rather than adding value – especially service value. Reactiveness does not lead to competitiveness or a focus on developing coherent project content, for example integrated service provision across the board. The over-emphasized egalitarian

orientation is risk-averse, leading to a lack of systematic integration and feedback. “Reinventing the wheel” often occurs due to spasmodic knowledge sharing: *Knowledge sharing is a bit of a mixed bag, as people do not know each other or others’ expertise* (Interview with the project manager). Hence, where external influence is felt, adoption of associated practices is slow, comparable to the rigidities of path dependency (cf. Auch and Smyth, 2010). The sentiment is supported by the Regional BDM’s reaction where he stated that the hardest sell is internally as opposed to externally. Processes are coordinated as a whole through largely risk focused business case forms that are passed along the lifecycle, yet continuity of service hampered by enclaves that lead to departmentally and functionally fragmented systems. This poses a barrier for seamless and effective transitions between stages. This is clearly evident when another Regional BDM responded, *We have excellent submissions teams of professional writers, technical editors, whilst engineers can construct anything except a sentence*. Thus, the egalitarian culture is a strong integrator internally than the enclave tendencies in the culture.

AntCo’s culture is an example of a homogeneous organisational culture. The egalitarian orientation has the same elements as those of EUCo. At a detailed level, however, AntCo’s culture has attributes of sectarianism. AntCo’s approach towards marketing and BD during the bid process is very fragmented. BUs and departments are disconnected. A Bid Manager noted, *Work fantastically well together if they are joined together in the right way*. This contrasts with the traditional belief of an automatically created effective and multifaceted organisational system (cf. Clegg et al, 2002). There are silos between functions and silo thinking too. The Bid Manager further noted that there are spatial divisions by floor allocation, which structurally reinforces the silos and amplifies the negativity of enclaves. It is an ironical for a coherent and homogeneous organisational culture as presented in the market. AntCo’s egalitarian enclave represents closed intra-organisational communities with their own sub-cultures and elaborate rules. The business silos do not yet quite understand each other, and consequently clients do not fully understand and appreciate its capabilities. Coupled with the coherent secondary culture(competitive individualism), the emergence of a sense of inequality with weak incorporation and linkage between functions. The extent of evident distrust between BD and front-end support, and execution teams promotes discouragement, fragmented communication, and incoherent processes.

EuroCo’s culture is a mixture of strong incorporations and weak structures. The high group orientation is seen positively by and resonates with respondents, for example the Technical Services Director stated, *There is a “Red Book” to ensure the right people in the right place and the right organisations are developed and followed up*. When people are more outward facing, the company is unable to keep a robust control due to the closed enclaves, resulting in time management problems, which is later stated as a “nightmare”. One example of weak structure is the ineffective relationship management system. RB is conducted informally and one fundamental flaw is the shortfall in updating information. A Project Manager stated: *We are too inward facing. We are not brave enough approaching clients*. From a marketing perspective, this is dysfunctional, sapping energy and effort away from serving clients and other stakeholders in favour of serving internal personal and factional interests. The hierarchical organisational culture resonates consistently with the different functions, primary orientation being to get things done against the formal pecking order. Respondents talked in

terms of *formalized*, *cautious*, *it is all done at a higher level,* and *talking to his team about how he expects things to be*. The process of coordination and integration with the external systems is very fragmented from the top-down. Since information processing and RB are interwoven within the company, the Business Development Coordinator admitted this causes a disjointed feedback system, stating, *It seems to disappear into the ether*. Although the spirit for collaboration with clients is mentioned, the integrative efforts only go as far as adding the short-term technical value for projects. Internal and externally relationships are not systematically spanning whole project lifecycles. The focus is solely building a superficial buying network rather than service value where shaping integrated solutions for prospective projects stem from. This is explained by the influence of the inward-looking enclaves that that are further amplified by old adversarial views of the industry. Yet, it can be argued that it is due to the defensiveness arising from the European parent.

UKCo comprises different parts that are fragmented and not fully integrated since its amalgamation three years ago. Fragmentation is prevalent in and between BUs. The overall organisational culture leans towards primarily hierarchical plus egalitarian enclaves. The introduction and consequences of change measures are not fully understood at the top and meets resistance top-down during implementation. A similar pattern exist at operational level illustrated as an example by the BD Director when stating, *It is difficult to commit resources. First there is an authoritarian legacy from estimating who used to call all the resource shots*. These fragmented perspectives are classic examples of *cultural efficacy* to the degree that success follows, e.g. winning the tender in that the practitioner becomes trapped in their own isolated world. As a *besetting fault … they become fossilized in their moment of glory* (Keegan, 1993: 31), The resultant cultural interplay is internal organisational divergence and unresponsive and un-customized solutions in the changing marketplace that no longer aligns with customer perceptions or needs and lacks an adequate feedback system at any project lifecycle stage. UKCo's culture *resists change and despises environmental complexity* (Jaafari, 2003: 53). Different functions have their own particular ways of doing things and are disinterested with issues of other functions. Cost is too much to the fore on a project-by-project basis rather than looking at long-term profitability. Hence, UKCo lacked ability to grasp the service issues. The vertical *disintegration* within the company impedes the internal development of the functions at times of transition. There is no overarching norm to link the systems in each function. A seamless service is not provided. This affects the capability to integrate other parties in any TMO and from supply networks. The divisions are very task orientated, motivated by functional habits and experiences justified as expertise. Mapping RM and BD to Guide Development and Transition

The above cross-sectorial case studies exhibit patterns of interplay in the organisational culture. Market drivers are experienced in the culture as an interplay that helps form and preserves fragmented structures top-down and along project lifecycles. Marketing and BD are isolated to different degrees in all the cases. Marketing and BD are reactive, which is amplified by external market drivers and the culture. There is a lack of understanding of how organisational cultures affect operations in relation to market drivers and internal capability development. This results in disjointed vertical and horizontal systems. Relationships are informally built within internal and external resource networks yet need to be supported by formal systems. Behavioural initiatives may be necessary to generate common norms

across functions. An egalitarian culture can be an effective amplifier for service coherence but currently enclaves exist at functional levels inducing service incoherence. Successfully integrated 'hard' systems require parallel 'soft', human systems to make the hard systems work. In the absence of integrated hard systems, the soft systems become more critical. Hard and soft integrating systems were absent, rendering marketing and BD ineffective and isolated to varying degrees across the cases, in which RM practices were particularly constrained. RM routines might entail, i) *an integrated system at programme level to coordinate relationships, information, value propositions and delivery, focusing on client satisfaction and lessons learned across projects to manage and monitor relationship investment, costs and relationship value for key or core clients*, ii) *a system reaching into all areas affecting value propositions to complement the task orientation.*

The four case studies echo a view that projects are competing areas of expertise. Risk minimisation is the main organising component of shared meaning, yet its management echoes the fragmentation. There are weak systems between (1) *Marketing functions and BD*, (2) *Marketing-BD and other functions*, (3) *The corporate centre and TMOs for effective development and delivery of value propositions along project lifecycles*. In sum, the fundamental aspects of the interplay between organisational culture, marketing and BD in the cases are categorized into four different barriers, as shown in Figure 4. It has been found in the cases that market drivers are translated into client requirements in ways that narrow their scope, increase project uncertainty, complexity, and reduce perceived value options to a limited range technical content and cost reduction. In the cultural absence of a set of formal and informal routines, there is nothing to compensate for linking incoherent cross-functional stages along the project lifecycle, reinforced by rigid views of resource commitments and risk management. These implications have been mapped in Figure 4 across two dimensions to form a matrix. The weight of the barriers lean towards the extremes: tight market drivers and organisational culture, constraining perceptions and the development of support mechanisms for coherent systems integration and service development.

Market Driven	*Loose*	*Tight*
Tight	**Inadequate Resources Barrier** 1. Focusing on driving down costs and short-term profitability; unable to commit resources due to risk concerns. 2. Hollowed out capabilities and resources. 3. Budget constraints for adding value, resource allocation being seen as trade-offs. 5. False beliefs that clients are hard to work with; unwillingness to go the extra mile.	**Misconception Barrier** 1. Focusing on the "big picture", information not drilled down and handed between project phases. 2. Work packages ignore service attributes to meet internal and client requirements. 3. Value and added value remains perceived through a residual cost reduction lens. 4. Past success leads to besetting faults in seeing market change as narrow risk reduction matters.
Loose	**Promise Fulfilment Barrier** 1. No integrated human system to formally match actions with perceptions. 2. Relationships are built randomly. 3. Lack of authority to make promises to differentiate and to integrate solutions. 4. Lack of organisational culture to support operational stability.	**Inadequate Delivery Barrier** 1. Procedures primarily serving adversarial accountability rather than consistency of service. 2. Incoherent systems integration, discipline and confidence for effective service development. 3. Transactional understandings result in poor client facing communication platforms. 4. Staff disinterest in issues in other functions.

Organisational Culture

Figure 4 Barriers for Service Coherence and the Interplay of Organisational Culture

As illustrated in the case study companies, at a tactical level of implementation, there was an absence of guidance on how to build and manage relationships in different markets and in different functional roles. Tight organisational culture creates cross-functional enclaves and silo thinking that impedes coherent follow ups for levering value. The importance of key decision makers and the role of "right behaviours" were appreciated by some respondents, but all companies left behaviour and RB to individuals and cultural norms, which varied amongst BD managers. This renders previously built relationships to be unexploited at times. Figure 5 maps the barriers against typical norms that could guide RB for the next stages of transition to RM.

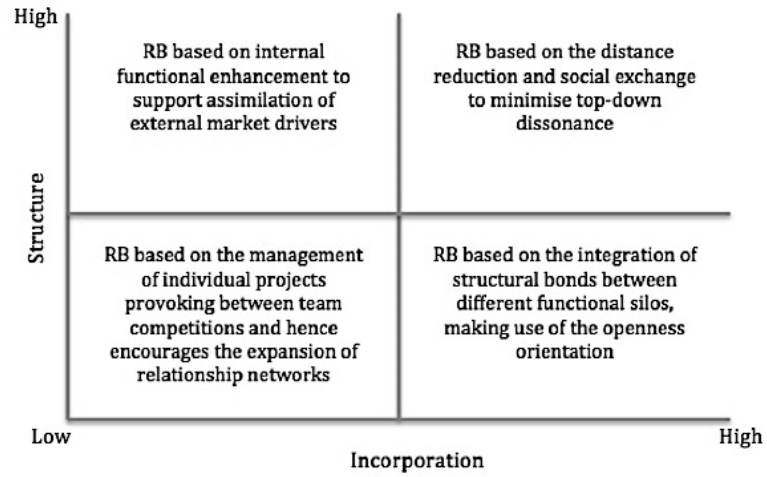

Figure 5 Behavioural Codes of Conduct based on The Grid-Group Model

Using the Douglas grid-group model of culture, constraints were identified in vertical hierarchy and horizontal functioning over project lifecycles, especially (i) between the different stages of BD, and (ii) between BD and execution. This framework presented in Figure 5 normatively allows for a steering that oscillates between the different functions and perceptions according to the embedded value proposition. In other words, rather than suggesting a change in the organisational cultural orientation, the framework focuses more on a delicate interplay by exploiting the cross-functional weaknesses of the structure and turning it into a norm that can help the companies and TMOs in building a relationship network that transcends across projects. For example, EuroCo and AntCo's egalitarian orientation has led to silo approaches (traditional project performance focuses) – an internal barrier, disconnected systems and leads to a waste of resources by incurring "so much repetition" which could have been channelled to co-creation through a range of enhanced collaborative practices. Promoting a norm of openness to support integration between functions will foster collaboration, spreading certain ideas to other areas and increasing the resilience of the functional enclaves towards external changes for coherent service and value delivery. This helps transition the egalitarian enclaves within organisations to the organisation becoming an enclave organisationally that has internal coherence and a basis for engaging constructively with TMOs as another challenge.

6. Conclusion

This paper focused on the interplay between organisational culture and marketing plus BD and the implications for TMO operations. Culture is a factor influencing cross-functional systems integration. It was found that organisational culture was not performing an integrating role for levering value, resulting in service incoherence. Appropriate internal systems for cross-functional integration – a key means for service delivery – are indeed a precondition for effective BD and developing integrated solutions for TMOs to perform systems integration for clients (Davies et al, 2007).

The presence or absence of a systematic approach with companies may not always be apparent to clients and suppliers, sometimes not to other TMO members. The role of organisational culture for each firm and for the TMOs as an integrating condition is seldom apparent. This research has provided concrete evidence to support the notion that there is a misconception within the case companies about the role of and understanding organisational culture, which is sufficiently widespread to suggest it is a general condition amongst contractors. When strategically aligned, different organisational cultures provide a positive force to accommodate long-term RB. Two interrelated frameworks have been developed to guide internal development and transitions relative to the external market drivers. The first framework identifies which barriers are likely to surface given the interplay between market drivers and organisational culture, providing guidance as to the elements to be considered and enabling prioritisation in identifying and levering value during BD. The second framework takes upon Douglas' cultural model and translates the barriers into typical norms that can be developed and *internally* marketed to enhance RB.

Overall, this paper has attempted to take the first steps toward guiding the organisation in developing cross-functional integration and service coherence in the dynamic construction market through understanding the elements that make up an effective BD. The evidential implications towards marketing, business development and integration provide an original contribution to knowledge. Some limitations are acknowledged, first of all is the snapshot methodology in identifying the organisational cultural orientation of the four case studies. A second limitation comes from the one-way analysis of the issues from the empirical focus upon the contractor as the object of analysis. Future research should therefore apply a holistic approach in identifying the organisational culture first, complemented by a developed analysis from the client viewpoint.

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An evaluation tool as a means of improving architectural design quality: the results

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Abstract

Development of the Architectural Design Quality Evaluation Tool was based on a live research project with a Metropolitan Council in the North of England. The aim was to improve the quality of design in residential sheltered housing, procured through the Private Finance Initiative; and has been applied to a programme that will see the replacement of the Council's entire sheltered housing stock. The Private Finance initiative has been subjected to particular criticism for its lack of design quality. The Research Team worked alongside the Local Authority Project Team, and together they developed and refined the Tool through the competitive dialogue phase of the PFI programme. At the CIB World Congress 2010, the authors reported on the development of the Tool (Paper ID: 535). This paper will briefly review the nature of evaluation tools and this tool in particular, before analysing its use in practice and the results. The Tool has two functions. It is a substantial part of the assessment process, which selected the preferred bidding consortium from the original six bidders, through a series of stages. However, it was also directed at improving the quality of all the submitted designs through an iterative process. There are several mechanisms available for evaluating the performance attributes of buildings and these are important, but few also tackle the less tangible amenity attributes, which are vital to the feeling of home. This Tool emphasises the amenity attributes without neglecting performance. The complete Tool and User Guide can be found on the Homes and Communities Agency website under Design and Sustainability at http://www.homesandcommunities.co.uk/architecture-design-quality-evaluation-tool

Keywords: **sheltered housing, architectural design quality, evaluation of design quality, private finance initiative, local authority.**

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1. Introduction

1.1 Summary of CIB World Congress 2010 paper: Architectural Design Quality in Local Authority Private Finance Initiative Projects (Giddings et al, 2010).

Since the 1990s, when the Private Finance Initiative was developed as the primary method for delivering major public capital projects, it has been criticised for lack of design quality in the buildings that it produced. The British Government became sufficiently concerned about this deficiency that it encouraged the Commission for Architecture and the Built Environment and the Office of Government Commerce to develop recommendations to improve design quality; and it was greatly assisted by the 2004 EU Directive that enabled authorities to discuss all aspects of the proposals with the bidders. This paper reported on a research project being carried out with a metropolitan local authority in North of England, which is replacing its entire sheltered housing stock in one Private Finance Initiative project. The paper reviewed the Private Finance Initiative management processes in relation to architectural design quality at each of the selection stages, including the generation and application of the design assessment criteria, and the role of user groups; and evaluated the outcomes against the objectives of maximising design quality within workable financial models. The methodology was that the researcher was based in the local authority project team, and has therefore been able to use participant observation techniques in the management processes that include competitive dialogue and user consultation. The principal aim of the local authority is that it should receive these buildings as assets, rather than liabilities at the end of the 30 year period. It was concluded that a design evaluation tool would need to be employed to ensure that design quality was being improved throughout the bidding process. Having assessed the existing design quality evaluation tools, it was concluded that none of them suited the PFI selection process. A new tool based on the hierarchical model, was generated mainly from academic literature. It was specifically devised to become increasingly more detailed at each stage. In its stage 3 form, the tool was making a significant contribution to the final selection of the consortia, who will undertake this ground-breaking project for the Council.

The novelty of this research is in three main areas. First, the competitive dialogue enabled bidders to develop their proposals through feedback based on the evaluation tool. Secondly, the engagement of the design champion, independent design advisers and the user group ensured that design quality remained a high priority throughout the selection process; and enabled different perspectives to be incorporated. Thirdly, the evaluation tool itself could be used by future project teams without the need for explanatory seminars or approved facilitators, such as those required by the Design Quality Indicator. In addition, it offers objective decision-making in staged selection of proposals, and bidders have observed the unprecedented rigour of the feedback; both in the selection of unsuccessful candidates and improvement in specific aspects of successful designs.

1.2 The Project

An ageing population represents one of the most extraordinary social transformations that has characterised and will continue to characterise British society. The heightened hope of living longer and the increase in the number of elderly citizens represents a challenge for all local authorities. North Tyneside Council, a large metropolitan local authority in the north east of England, faces a particularly radical social change with housing stocks that are unlikely to meet future needs. Therefore the Council included in its strategic plan (North Tyneside Council 2007) provision to replace its existing sheltered housing schemes with 10 new build developments and 16 refurbishments. The intention was to increase both the quantity and quality of its provision. The Council concluded that the only feasible method of funding this huge transformation was through the Private Finance Initiative, and successfully applied to the Government for over £100 million of PFI credits. From the beginning, the Council was keen to produce high quality buildings, and its first priority was to act on the recommendations of CABE (2005) and the Treasury Taskforce (Office of Government Commerce 2007).

2. Assessment of Design Quality

Table 1 shows existing evaluation tools that could be applied to sheltered housing.

Table 1: Existing Evaluation Tools

tool and who developed it	**year started and building type**	**critique**
Housing Quality Indicators (HQI) The Housing Corporation, and inherited by the Homes and Communities Agency (HCA)	1996 housing projects	Useful structuring for assessment and scoring scheme. Devised for general purpose housing and therefore does not map directly onto needs of sheltered housing. Responses in terms of *yes/no/not applicable* limits quality assessment, especially in the case of multi-part questions eg *2.2 Are the buildings in context with local buildings, street, patterns (form, mass, detail and materials)? Enter not applicable for-surrounding local environment is of poor visual quality.* http://www.homesandcommunities.co.uk/hqi Following the establishment of the HCA, it inherited differing design standard requirements. In spring 2010, it consulted on a potential set of core future design and sustainability standards. In November 2010, the Housing Minister confirmed that the HCA would have to retain the existing standards. http://www.homesandcommunities.co.uk/ourwork/design-and-sustainability-standards
Sheffield Care Environmental Assessment Matrix (SCEAM) University of Sheffield	1999 nursing homes	The objective of this tool is to systematically investigate relationships between the physical environment of nursing homes; and the quality of life of residents, and the job satisfaction and morale of care staff. Thus it is applied to buildings in use and not really applicable to the evaluation of design proposals (Parker et al., 2004).
Building for Life CABE	2001 houses and neighbourhoods	Based on only 20 criteria and therefore generic issues. Produced to assist local authority planners, and therefore includes planning issues that are not applicable to sites that have already been selected; and only a proportion of the criteria are related to the actual design quality of proposals. Devised for general purpose housing and therefore does not map directly onto needs of sheltered housing http://webarchive.nationalarchives.gov.uk/20110107165544/htt

		p:/www.buildingforlife.org/criteria/
Design Quality Indicator (DQI) Construction Industry Council	2002 all building types	Originally created to assess completed buildings – later expanded to five phases including design. The calculation of scores is based on an aggregation of a set of individual opinions provided by various people (Eley, 2004) identified as stakeholders. The process involves a questionnaire and workshops. The 90 questionnaire statements are generic (to cover the range of building types) eg *the lighting is versatile for different user requirements* (CIC, 2003) which could be difficult to assess at design stage – especially by lay people. The explorative style of workshops is inconsistent with the competitive dialogue procedure - in terms of specification of the contracting authority, confidentiality and equal treatment of bidders (HM Treasury, 2008).
Evaluation of Older People's Living Environment (EVOLVE) University of Sheffield and University of Kent	2010 sheltered housing and care homes	Established to assess occupied buildings but notes that it can be used to evaluate buildings at design stage. It is well structured in six sections. However, the assessment of design only relates to internal matters. There is a section on site and location, but it is restricted to access to local services. This is not especially useful as the sites will be pre-selected. Thus, there is not evaluation of context, external space and building form. Nevertheless, there are nearly 2000 questions for the remaining two thirds of the issues. In addition, the responses are – *yes/no/not in use/not applicable* – so it would be difficult to achieve assessments in terms of qualitative gradings for a number of schemes and several bidders in a competitive environment. http://www.housinglin.org.uk/Topics/browse/Design/DesignGuides/?parent=6594&child=7997

While the existing evaluation tools provide useful benchmarks, and some offer a means of structuring the evaluation - none were totally applicable in the context of competitive bidding, competitive dialogue, raising the standard of all design proposals, and contributing to decisions as to which bidders should proceed to the next stage; and ultimately the selection of the preferred bidder. Nevertheless, the urgency of the PFI programme led to the inevitable conclusion that one of the existing tools would have to suffice. On 6 May 2010 both the General Election and Local Elections took place. Immediately, the new Mayor halted all capital projects while a review took place. This was closely followed by the new Government's Comprehensive Spending Review. As the PFI project was unable to progress for several months, the opportunity was taken to develop an Architectural Design Evaluation Tool for Sheltered Housing.

3. The Architectural Design Evaluation Tool for Sheltered Housing

3.1 Literature Review

The Royal Fine Arts Commission had been enquiring into designs for buildings of public importance referred to it by Government Departments, since 1924. However, the New Labour Government from 1997 attacked what it perceived to be poor design quality in all aspects of the built environment and pledged a radical improvement – not least in the design of housing (Carmona, 2001). In 1999, it replaced the RFAC with a better resourced, more focussed adviser in the Commission for Architecture and the Built Environment (CABE). This Commission employed skilled staff and leading consultants to produce an extensive literature on how to achieve high design quality. The period from 1997 to 2011 represents

unprecedented attention to design in the built environment of this country. In addition to the design guidance, many academic journal papers were published. Therefore, the literature review for the development of the Design Quality Evaluation Tool consulted 120 of these papers to determine which they perceived as the seminal works in the study of the nature of home and the principles of design quality. The publications in Table 2 were referenced more extensively than any others and therefore formed the basis of the literature review for the formulation of the tool. In addition, a review of reports and guides on design quality in homes and housing over the 1997-2011 period, provided performance data for the Tool, and these publications are listed in Table 3. Unfortunately, the new Conservative Government withdrew CABE's funding, and as a result from 2011, its operation was seriously diminished.

3.2 Scoring the Criteria

A small group comprising the Researcher and three members of the Project Team assessed all the schemes against the criteria. The quality of design response to each criterion was measured on a 7 point Likert Scale (Miller and Salkind, 2002) as follows:

6 – Outstanding
5 - Excellent
4 - Very Good
3 - Good
2 - Average
1 - Minimal

0 – Criteria not met

In addition, the assessors were required to provide a written justification for each score.

Table 2: Seminal Publications referenced in the Tool

Alexander 1977;1979;2002	Low 1990;1992;1996
Altman 1975;1976;1977a;1977b,1985a;1985b; 1991;1992;1993;1994	Macmillan 2003;2004;2005,2006
Appleyard 1979	Marcus 1974;1976; 1995;1997;2006
Barnes 2001;2002;2006	Maslow 1943; 1954;1968
Benjamin 1995	Moore 1991;1993;1995;1998;2000a;2000b
Buttimer 1976;1980a;1980b	Newell 1992;1994;1995
Canter 1977;1983;1993	Newman 1972;1973
Chaudhury 2005	Nezlek et al. 2002
Day 1990;1998;2002;2004	Norberg-Schulz 1965;1971;1979;1980
Douglas 1980;1991;1998	Porteous1976;2001
Dovey 1978;1985;1990;2005	Proshansky 1978;1983
Duncan 1989;1992a;1992b;1993;1996	Rapoport 1980;1981;1982;1990;1995;1998;2005
Dupuis and Thorns 1996;1998	Relph 1976;1981;1993;1996;1997;2000;2008
Feldman 1990;1993;1996	Rowles 1983;2005a;2005b;2006
Gann 2001;2002;2003a;2003b	Salingaros 1995;1998;1999a;1999b;2000
Gesler 1991;1992;1993;1996;1998; 2009	Saunders 1988;1989;1990a;1990b
Giuliani 1991;1993	Seamon 1979;1980
Gurney 1990;1996;1997	Shumaker 1981
Hanson J (2001)	Sixsmith 1986; 1990;1991
Hay 1998a;1998b	Smith1994;2001
Hayward 1975,1977	Somerville 1992;1994;1997
Heidegger 1962;1971;1993	Thorns 1996;1998;1999
Hertzberger 1998;2000	Tognoli 1982; 1987
Lawrence 1987a ;1987b;1995;2002	Torrington 1996;2001;2004;2007
Lawson 2001;2003;2005	Tuan 1974;1977;1980
	Ulrich 1983;1984;1991

Lawton 1975;1980;1985;1989;1990;1994;1996; 1997;1998;1999;2000;2001	Werner 1985;1986 Whyte 2001;2003a;2003b

Table 3: Reports and Design Guides referenced in the Tool

Association of Chief Police Officers Crime Prevention Initiatives (2004) Secured by Design Principles
CABE (2008) Delivering great places to live: Building For Life
CABE (2009) Homes for our old age: Independent living by design
Care Services Improvement Network (2008) Design Principles for Extra Care
Department of Justice (1994) 28 Code for Federal Regulation Part 36 ADA Standards for Accessible Design
Design Principles for Extra Care (2008)
Goodman C (2011) Lifetime Homes Design Guide, IHSBRE press
Housing Corporation (2007) Design and quality standards, London, The Housing Corporation
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Thorpe S and Habinteg Housing Association (2006) Wheelchair Housing Design Guide (WHDG) (2nd edition), BRE Press

3.3 Conceptual Framework and Weighting the Criteria

The debate about measurement of design quality has a long history, and this is reflected in the literature, especially from the era in which the Design Quality Indicator appeared as the first comprehensive system 'to measure quality of design embodied in the product – buildings themselves' (Gann et al., 2003). However, the importance of differentiating between performance and amenity goes back to Burt (1978). Therefore, any assessment of quality would benefit from an appropriate means of evaluating both performance and amenity, in addition to assessing their integration into the design as a whole (Giddings and Holness, 1996). This notion was supported by Manning (1991) who established the distinction between Environmental Quantities and Environmental Qualities; and by Thomas and Carroll (1984) who identified a continuum between Practicality and Originality.

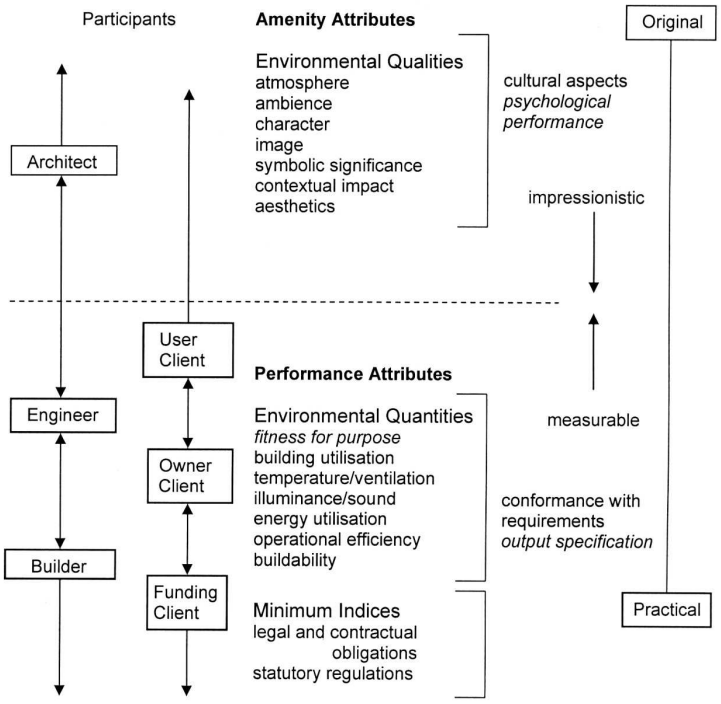


Figure 1: Quality Hierarchy Diagram

Exploration of all these attributes led to the development of a Quality Assessment Hierarchy. Although originally devised for use in design award schemes; as Gann et al. (2003) point out, it can equally well be applied to the quality of design proposals. Figure 1 represents a summary of the Quality Assessment Hierarchy. For further information about its development, please see Giddings and Holness (1996). From the beginning, the importance of the amenity attributes was emphasised. At the presentations by the independent advisers' from Northumbria University in December 2008, the primary objective was to provide supplementary guidance for bidders. Councillors (including the Design Champion) and representatives of the Users' Group were also present. The presentations focussed almost entirely on amenity attributes, and were based around people and places. This follows the principle of the Quality Assessment Hierarchy in which performance cannot be neglected but criteria demonstrating greater amenity are weighted higher on a linear scale, ie 1-3 for performance attributes and 3-5 for amenity attributes (Sudha and Baboo, 2011). The mean weighting of the criteria in each category is shown on Table 4. It is presented with the categories in hierarchical order, ie communal spaces have the greatest tendency towards the amenity attributes whereas service spaces tend mostly towards the performance attributes.

Table 4: Summary of Categories

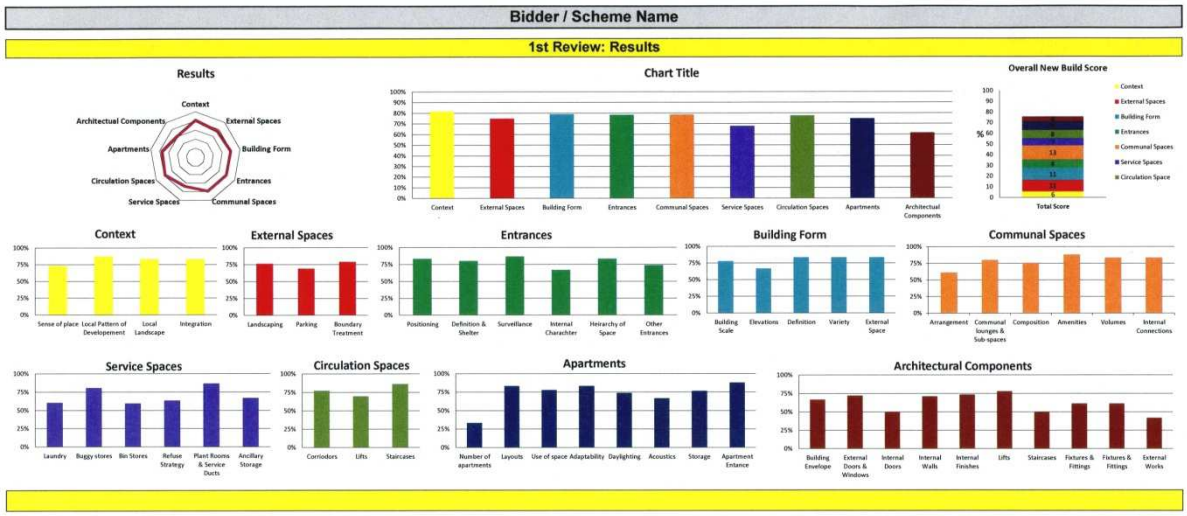
category	percentage allocation		mean weighting
	new build	refurbishment	
Communal Spaces	17%	20%	4.44
Context	7%	7%	4.10
Building Form	14%	10%	4.00
Apartments	11%	10%	3.00
Circulation Spaces	10%	10%	2.93
External space	14%	13%	2.80
Entrances	10%	11%	2.63
Architectural Components	7%	7%	2.00
Services Spaces	10%	12%	1.90

Once all the criteria have been scored, each is multiplied by its weighting and the total weighted score for the category calculated. This figure is multiplied by the percentage allocation (as shown in Table 4). The resulting scores from each category are then aggregated to find the total score for the scheme (see Table 5). The percentage allocations had been previously agreed between the Project Team and the Users' Group. It should be noted that they vary between new build and refurbishment. Participants in future projects may decide on different percentages to suit their particular needs.

4. Visualisation of the Results

The evaluation took place in three stages. The first stage was aimed at reducing the original six consortia to three bidders. The second stage reduced the number from three to two, and the objective of the third stage was to select the preferred bidder. At the final evaluation stage, ie selection of the preferred bidder, designs for all 26 schemes were produced. The

Research and Project Teams concluded that, even at this late stage, there should be opportunity for the bidders to improve their designs through an iterative process resulting from a series of reviews. However, it should not be forgotten that both the revision of designs and the review process are very resource intensive in terms of time and money. The balance was struck at three reviews. Thus, there was output from 26 schemes x 3 reviews x 2 bidders = 156 results. It was concluded that the most effective way of presenting the results would be one graphical sheet per review – generating 156 sheets. Each review sheet needed an overview but also sufficient detail to enable bidders to target specific areas for improvement after Reviews 1 and 2. The top row of the sheet includes a spider diagram as a summary showing overall strengths and weaknesses. The score for each category is also shown in percentages, together with a build-up of the total score from



the categories. The remainder of the sheet illustrates the nine categories with percentage scores for each group of criteria (see Figure 2).

Figure 2: Results of Evaluation of Design for Crummock, Bidder S, Review 2

All the results from the final evaluation stage are summarized in Table 5.

Table 5: Results for all designs – Stage 3, Bidders S and T, three Reviews

Summary of Results: New Build (in %tages)

Bisley		Bristol		Broadway		Chapelville		Clifton		Scheme
S	T	S	T	S	T	S	T	S	T	Bidder
59.1	42.8	59.5	57.1	52.8	60.6	63.4	56.2	77.6	65.3	Review 1
80.5	66.1	76.0	61.1	70.3	71.7	73.5	66.7	83.0	77.2	Review 2
80.7	70.3	78.4	66.3	72.2	73.8	74.0	68.5	83.7	80.6	Review 3

Crummock		Eldon		Marsden		Phoenix		Roseberry		Scheme
S	T	S	T	S	T	S	T	S	T	Bidder
66.0	62.5	74.5	59.3	61.1	51.4	55.6	57.5	58.4	38.5	Review 1
76.3	70.9	76.9	67.3	71.1	61.4	73.8	66.0	77.4	70.4	Review 2
76.6	72.5	79.2	69.1	72.2	62.5	74.2	71.3	77.6	72.4	Review 3

Summary of Results: Refurbished (in %tages)

Carlton		Carville		Cheviot		Eccles		Scheme
S	T	S	T	S	T	S	T	Bidder
64.4	56.8	57.8	53.1	57.2	47.0	50.7	47.7	Review 1

75.9	62.2	74.2	69.4	74.8	61.3	76.8	60.5	Review 2
77.9	64.0	74.6	73.3	75.1	65.0	77.2	64.8	Review 3
36.7		33.5		36.1		20.6		Existing
41.2		41.1		39.0		56.6		Value Added

Emmerson		Feetham		Ferndene		Fernlea		Scheme
S	T	S	T	S	T	S	T	Bidder
50.7	50.6	62.5	51.9	50.1	47.6	61.0	57.3	Review 1
60.5	56.5	72.1	70.4	73.5	68.5	70.2	67.0	Review 2
61.9	59.5	73.7	72.3	78.0	75.3	70.8	67.7	Review 3
35.6		44.3		33.3		28.3		Existing
26.3		29.4		44.7		42.5		Value Added

Orchard		Preston		Rosebank		Rudyard		Scheme
S	T	S	T	S	T	S	T	Bidder
57.6	59.1	61.9	55.6	54.5	47.5	58.0	53.1	Review 1
67.3	61.7	73.0	66.9	70.5	60.1	72.6	56.5	Review 2
68.7	62.2	76.6	71.7	70.6	63.8	74.1	59.9	Review 3
28.2		41.9		30.4		45.6		Existing
40.5		34.7		40.2		28.5		Value Added

Skipsey		Southgate		Tamar		Victoria		Scheme
S	T	S	T	S	T	S	T	Bidder
58.2	48.5	58.6	66.1	64.6	42.9	61.7	65.3	Review 1
68.5	59.8	77.7	68.3	74.9	63.3	68.2	70.1	Review 2
69.4	61.2	78.2	68.7	77.1	64.5	69.4	70.6	Review 3
35.3		53.4		30.3		36.6		Existing
34.1		24.8		46.8		32.8		Value Added

5. Analysis and Discussion

In new build and refurbishment proposals, both bidders received relatively low scores at Review 1, although Bidder S scored higher than Bidder T for virtually all schemes. The spread of results, as indicated by the standard deviations, was relatively large for new build but less in the refurbishment schemes. The feedback from Review 1 seems to have been effective, as on average Bidder S improved their score by 20.9% for new build in Review 2, and Bidder T by 23.2% while the standard deviations reduced by 3.98 and 3.68 respectively. The improvement in the refurbishment schemes was similar as Bidder S improved their score by 23.8% and Bidder T by 20.3%. The standard deviations started from a narrower position and therefore the reductions were less dramatic at 0.32 and 1.85 respectively. The improvements from Review 2 to Review 3 were noticeably more modest. For new build the change was only 1.3% for Bidder S and 4.1% for Bidder T; with equally small changes in standard deviation (0.16 and 0.06). In the refurbishment projects the change was only 1.9% for Bidder S and again 4.1% for Bidder T. The standard deviation for both bidders actually increased by 0.21 and 0.22 respectively (see Table 6). The Review Team concluded that the introduction of two Reviews had been worthwhile as there had been significant improvements, but that Review 3 would probably be discontinued in future. The objective of raising the design standard of all schemes was achieved, but Bidder S maintained a clear advantage throughout all the Reviews. The notion of scoring the existing buildings and demonstrating the value added was adopted quite late in the process. The differences between the existing and proposed for Bidder S are shown on Table 5. The average increase in value was 106%. It was eventually realised by the Project and Research Teams

that the potential of the tool could be enhanced if all existing buildings were to be scored at an early stage as part of the decision-making on prioritising cases for redevelopment and refurbishment.

Table 6: Analysis of Results

Reviews	Bidder S		Bidder T	
	mean	standard deviation	mean	standard deviation
New Build: 10 Schemes				
1	62.8%	7.92	55.1%	8.55
2	75.9%	3.94	67.9%	4.87
3	76.9%	3.78	70.7%	4.81
Refurbishment: 16 Schemes				
1	58.1%	4.65	53.1%	6.59
2	71.9%	4.33	63.9%	4.74
3	73.3%	4.54	66.5%	4.96

The Project and Research Teams were confident that the Tool had provided both a means for improving the design quality of all the schemes and demonstrated which bidder offered higher quality design. However, the Treasury Task Force (2007) had stated the need to ensure that design proposals are consistent with the budget available for the project. There have been anecdotal assertions, especially in PFI projects, that an increase in design quality would render the projects unaffordable. The use of the Tool and the presentation of results from the Reviews, enabled Bidders to model specific design changes in relation to their effect on projected expenditure. Informal feedback from the Bidders made it clear that they had tested different options for particular design changes, against the model for the budget. The financial projections are shown alongside the budget on Figure 3. Contrary to unsubstantiated opinion (Evans and Hartwich, 2005), both bidders were within budget and followed a similar profile. Overall, Bidder S was more economical than Bidder T, through the tactic of accelerating the construction period by 12 months. Increasing the rate of construction emphasises the need to carefully monitor the build quality; and highlights a critical period when expenditure equals the budget. If Bidder S is selected as the preferred bidder, the Project Team will need to be vigilant about these two issues during the construction period.

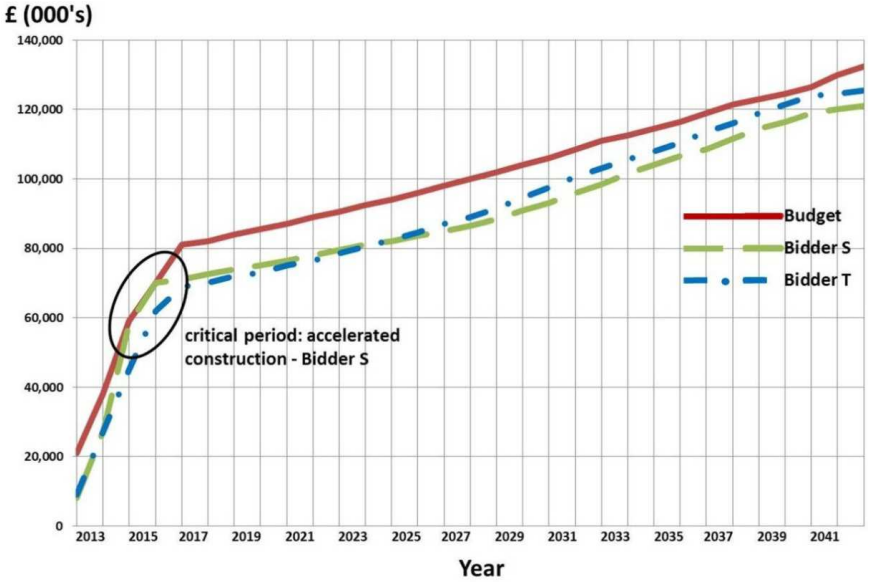


Figure 3: Financial Projections for Bidders S and T set against Budget

6. Conclusions and Further Developments

This paper charts the introduction of a large scale PFI project into a metropolitan local authority in England; against a background of concern about design quality. The establishment of a new competitive dialogue procedure was arguably the biggest change in relationships with the bidders and this was perceived by all parties as crucially important. However, it soon became clear that the deficiency in the process was how the designs would be evaluated. A review of existing evaluation tools revealed that they would not meet the specific requirements of the revised PFI procedure. Delays due to the Government's Spending Review enabled sufficient time for a new evaluation tool to be developed. The objectives were to inform the decision-making process in terms of selection of the preferred bidder, and to improve the design quality of all proposals. The tool was progressively applied to the selection stages and the results offered clear direction as to where the designs could be improved. It also quantified the improvements to the refurbishment schemes in comparison with the existing; and provided invaluable data to assist the selection of the preferred bidder. The results showed a significant improvement in design quality through the iterative process, although it was concluded that two reviews at stage 3 were probably sufficient. They also revealed the potential for assessing the quality of existing buildings as a means of informing redevelopment and refurbishment programmes. The Tool produced 156 evaluations from which clear patterns emerged. Nevertheless, the real outcome in relation to design quality will only be known when the post-occupancy evaluations are carried out in several years' time.

The Tool has been examined by the Homes and Communities Agency (HCA), the British Government's national housing and regeneration agency for England, whose the aim is to deliver high-quality housing that people can afford; and it is now included on the website at the following address, as an instrument setting new standards in design. http://www.homesandcommunities.co.uk/architecture-design-quality-evaluation-tool.

Discussions have taken place with RIBA Enterprises' National Building Specification (NBS) Team about the CREATE Specification Tool, which will be developed over 2013 to deal with briefing and design; and this will incorporate many of the ideas developed from the Tool and/or interoperate with the Tool itself. Following a presentation at the PPP/PFI Conference for Social Housing (London, September 2010), interest has been expressed by other English local authorities with early stage, large scale redevelopment proposals; and exploratory seminars have been undertaken. A condensed and more generic edition of the tool has been offered to MArch students at Northumbria University, to enable them to evaluate the development of their own studio design projects. A medium term objective is to identify the core of the Tool as a replicable standard, and generate specific sections for different building types. It was devised to suit the competitive dialogue phase of a PFI project, however it does

not necessarily need to be limited to that form of procurement. The development of the tool with the National Building Specification team will undoubtedly require adaption to different building types and different forms of procurement. The favoured approach is a generic core with specific criteria tailored to the particular building types.

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Purchasing Family Homes: Feng Shui versus Sustainability

XIN JANET GE[1] AND MICHAEL Y MAK[2]

Abstract

Feng Shui is an important element to be considered for purchasing real estate property for many Chinese families. The concepts of Feng Shui has been gradually adopted and accepted in the western world. It has been found that, in many perspectives, there are similarities between the concepts of traditional Chinese Feng Shui where harmony between environment, buildings and people are created; and western style of sustainability that focuses the harmonious relationship between human and nature. This paper reviews the Feng Shui elements considered by Chinese families and explores the main features considered by the Western families when purchasing a home. The results will be used as criteria for developing significant factors in future empirical study. Through case studies in Sydney, the findings will be compared and the elements that are similar or different will be discussed. The implications of the research will also be investigated.

Keywords: Feng Shui, Sustainability, Home purchase, Sydney

1. Introduction

The purchase of real property for most families is a big decision because of the large amount of capital investment and commitments to a mortgage. In addition to the finance, Feng Shui is an important element to be considered for purchasing real property for many Chinese families. Many Chinese families may be willing to spend a little bit more on a property if the property has *good Feng Shui*. On the other hand, if a property is cheap and affordable but may have *bad Feng Shui* elements, many Chinese families may decide not to buy the property. Why Feng Shui matters?

The term Feng Shui is an ancient art and science for harmonious of the built and natural environment developed over 3,000 years ago in China. The word Feng Shui can be translated literally as “wind-water” in English. Wind and Water are associated with good environment and health in Chinese culture (Lip, 1979). It was first taught in the classic text *The Book of Burial* published in the Jin Dynasty (276 - 420), some 1,700 years ago (Mak and So, 2011). Feng Shui is a complex body of knowledge that reveals how to balance the

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energies of any given space to assure the health and good fortune for people inhabiting it (Tchi, 2012).

In many perspectives, there are similarities between the concepts of traditional Chinese Feng Shui where a harmony between environment, buildings and people are created; and western style of sustainability that focuses the harmonious relationship between human and nature (Dong and Zuehl, 2009). In the Western culture, families tend to buy houses that contain features such as close to water, quieter street, nice neighbourhood, bright rooms and so on. In Australia, north facing houses seem much in favour by the buyers. Air circulation, energy efficiency and safety are the main concerns implied at building design process in the Western world (Mak and Ge, 2010).

This paper studies the Feng Shui considered by Chinese families and explores the main features considered by the Western families when purchasing a home. The study is considered significant as the findings can be a guide for designing the exteriors and interiors when developing properties. It can be also serve as a reference for town planning in the built environment contexts. The paper is first to review the Feng Shui concepts and the Form School of Feng Shui. The concept of Feng Shui design criteria and their implications on property purchases will also be discussed. Second, a desktop survey on features expected by the Westerners in their home purchases will be reviewed. The Feng Shui concepts and Western family's views and expectation in purchasing a property will be compared through a case study. Conclusion and implications will be drawn last.

2. Feng Shui Concepts

Feng Shui is about the interaction of humans and their environments, i.e., creates harmony between heaven, earth and human (Mak and So, 2011). One of the most basic principles is unity between heaven and human, i.e., brings harmony between the universe, earth and human energy. The energy is valued in both the physical and the invisible form knows as "*Qi*" (or "*Chi*", natural energy or breath of life) in the traditional Chinese Feng Shui culture. Skinner (1982) suggested that Feng Shui designs aims at a balance and harmonious environments that can produce an ample amount of good *Qi* (positive energy) and filter out the bad *Qi* (negative energy). This is one of the reasons why Chinese families look for good Feng Shui properties to attract "positive energy".

The second concept is the Five Elements Cycles, which are fire, water, metal, wood and earth. Its theory is that everything in the universe has an attribute according to these five elemental groups of substances. The relationships of the five elements consist of productive and destructive cycles (Walters, 1989).

Yin and Yang harmony is the third Feng Shui principle. Yin represents the passive principles in nature exhibited as darkness, cold and wetness. Also the moon, femininity and passive, the realm of the dead and tombs are represented Yin. Yang represents the active principles in nature exhibited by light, heat and dryness. Also sun, masculinity and active, the realm of the living, building, towns, and cities are symbolized Yang. Yin and Yang are the two opposing parts but have a complementary relationship. A good Feng Shui means that Yin

and Yang are balanced and harmonious within a space, designed to create balance in the users' life when engaging in the space (Feuchtwang, 1974).

The *Form School* relates to physical configurations of landscape design and urban planning, and the *Compass School* focus to time, space and orientation are the two main Feng Shui Schools (Xu, 2003). The most prominent approach to the built environment and building design follows the principles and practice of the Form School (Lip, 1986; Xu, 1990; and Too, 1996), which is primarily based on the verification of the physical configuration of mountains and watercourses surrounding sites and buildings (Mak and So, 2011). The Form School consists of "Five Geographical Secrets", namely dragon, sand, water, cave and direction (Lip, 1979). The combination of these five Feng Shui geographical elements and the four emblems (green dragon, white tiger, black tortoise and red phoenix as the four cardinal directions) produced the classic Feng Shui model. Figure 1 shows the Form School model that examines shapes and symbolism in the environment which can be applied to a property.

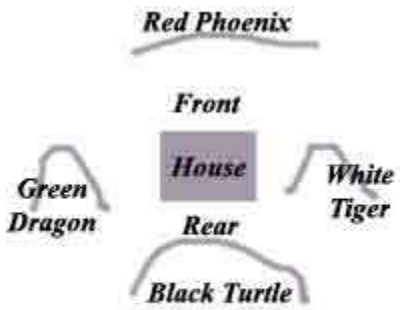

Figure 1: Form School model (Feng Shui Store, 2012)

The *Red Phoenix* is associated with the front of a property. The perfect scenario would be a meandering river to the front. The river can be replaced by a meandering road, or a circular flowerbed, or a low hedge/fence can be a replacement. The *Green Dragon* is associated to the left of the property. This feature can make up of either a building, tree or neighbours house. The *White Tiger* is associated with the right. It can be a building, a fence line or a tree. The *Black Turtle* is associated to the rear of the property. It can be a mountain behind, a row of trees, a building or a fence line to the rear.

A principle of balance between interior and exterior spaces is an important principle that describes the site conditions and the design of buildings. The location of the site, conditions that surround the site, topographical conditions and the shape of the site are called the Outer Form. The Inner Form consists of the layout of the building, elevations of the building, and elements of building (Lee, 1986). Cheng and Kong (1993) provided a further classification of space into four design modules: surrounding environment, external layout, internal layout and interior arrangement.

3. Feng Shui Design Criteria

Many scholars have developed their own design criteria based on the Feng Shui principles discussed above. Lee (1986) outlined three basic criteria for architectural design. Xu (1990)

derived four-step landscape model to deal with land formations. Han (1995) used 24 major criteria for selection of the best location. Lip (1979, 1986) listed a set of standard rules of thumb for assessment of architectural design. Choy (1999) suggested a ten-point design criteria checklist for property selection and Rossbach (1984, 1987) provided a set of interior design diagrams for furniture placement. A set of "standard rules-of-thumb" was developed by Lip (1979) in accordance with the Form School of principles. These rules-of-thumb include:

- A building should be constructed on high ground instead of in a valley.
- A house standing on the triangular lot at a "Y" junction will suffer.
- Trees on the northwest side of the site protect the house.
- A big tree planted in front of the main door is unfavourable.
- A building located at the end of a narrow street will be an "unfortunate" dwelling.
- A desirable position will be obtained if the main road is on the west side of the building.
- An open field or garden to the south of the building is ideal. Windows and doors facing the north and south sides are desirable.
- The most important area of a building should be centrally located to reduce circulation space.
- Bedrooms located next to the kitchen are polluted and unfavourable.
- A house or a building must have a back door, which is not in line with the front door.

The rule-of-thumb was expanded to the application of interior elements include location and direction of doors and windows; shape and structure of rooms; building components such as walls, ceiling, structural beams and columns, staircases, etc.; room arrangement includes the position of the bed in the master bedroom; the placing of the stove; refrigerator and sink in the kitchen; lounge seats in the living room; layout in the bathroom and similar criteria.

The principles of *Form School* Feng Shui can be applied to houses that are located in cities or suburban areas in term of surrounding environment, external layout, internal layout and interior arrangement. Table 1 shows the key elements of *Form School* Feng Shui for a building.

Table 1: Key Elements of Form School Feng Shui (Mak and So, 2011)

Surrounding Environment	External Layout	Internal Layout	Interior Arrangement
Topography	Shape of Site	Layout	Door Openings
Front of Site	Entrance	Doors	Bedroom
Rear of Site	Shape of Building	Windows	Kitchen
Sides of Site	Orientation	Shape of Rooms	Living Room
Street Location	Trees	Staircase	Bathroom
Water View	Pond	Ceiling	
Wind Direction			

4. Contemporary Design Principles

Traditional Chinese Feng Shui are well known by the western world. In recent times, the combinations of traditional Feng Shui and western approaches have become more apparent. For example, contemporary architects in New York and Washington DC have consulted Feng Shui experts for their input on architectural and interior designs (Xu, 2003). Bioclimatic design approach is the common approach applied in the Western design world. The approach applies a logical sequence of analysis and constructs appropriate strategies to minimise the external impacts and rational use of resources (Olgyay, 1963). The bioclimatic design strategies aim to take advantage of the favourable environmental aspects, while avoiding or moderating the unfavourable impacts through appropriate design decisions. Axarli and Teli (2008) implemented of bioclimatic principles in the design of urban open spaces to improve human comfort which includes thermal comfort, visual comfort, acoustic comfort and improvement of building's energy behaviour and air quality. The Comfort Triangles was an innovative concept to emphasise the periodic thermal behaviour of a space during a 24 hours interval or the average values of a series of days, rather than the conventional bioclimatic method that focus the conditions of temperature and humidity at a specific moment of time (Evens, 2007).

More recently, the concept of sustainability has brought into the design principles in the built environment contexts. The elements of sustainable design includes many areas such as waste and recycling, energy, water, building design, emission, indoor environmental quality (IEQ), alternative transport, landscaping, and about everything that do affects everything around human, aims to eliminate negative environmental impact and maintain ecologically sustainable completely through skilful and sensitive design (McLennan, 2004). Dong and Zuehl (2009) recognized that there is a set of five fundamental concepts for sustainable development. They are constructivism, circular design, energy efficiency, balance between natural and the built environment, and thinking global and buying local.

*Constructivism*is based on human interactions with their environment to enhance the environment to make the space more enjoyable for the people using it (Dong and Zuehl, 2009). The *circular design* concept is a new design paradigm of "reduce, reuse, recycle" through the intelligence of natural systems, i.e., the effectiveness of nutrient cycling, and the abundance of the sun's energy, etc. (McDonough and Braungart, 2002). *Energy efficiency* can be achieved by site planning and building design in accordance to sunlight and the use of various building materials and technology.

The concept of '*Balance*' is one of the main principles of western design which aligns with the Feng Shui concepts. Widener (2009) advised to *balance between natural and the built environment* in designed to bring natural elements (such as sunlight, plants, water features, etc.) into a person's environment that will change the behaviour of the user in the environment to a more harmonious and enjoyable space. *Thinking global and buying local* in the design principle means to reduce energy costs and wasted materials and increase the environments overall wellbeing (Dong and Zuehl, 2009).

Chinese Feng Shui and the Western design principles are similarities in term of that both systems target human wellbeing. The concept of constructivism translates well into the principles of harmony between universe, earth and human in Feng Shui. The ideal

environment for Feng Shui when is these three aspects intersect and overlap. These three circles can be found in sustainable design as social contexts, environment and human as shown in Figure 2.

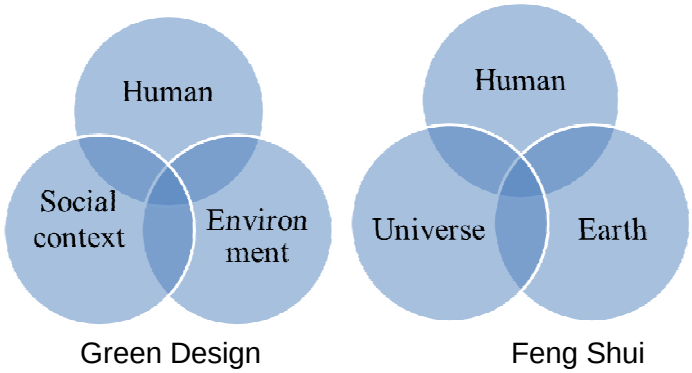

Figure 2: Comparison between Constructivism and Feng Shui concepts (Dong and Zuehl, 2009)

The principle of Feng Shui is the productive and destructive cycles of five elements, which is similar to the circular design concept. The concept is the balance and harmony between Yin and Yang, which also matches with the concept of sustainable design of balancing between natural environment and the built environment. The Feng Shui concept of balance between interior and exterior spaces focuses on the physical form and spatial arrangement of the built environment coincides with the energy efficiency and buying local concepts that explicitly emphasise on the sources and consumptions of natural resources.

The difference between Feng Shui and the Contemporary models can be identified in term of research and analysis methods, analysis structure and criteria. Xu (2003) summarized their differences presented in the Table 2.

Table 2: Comparisons of Feng Shui and the Contemporary Models (Xu, 2003)

Model	Research Methods	Analysis Methods	Analysis Structure	Analysis Criteria
Bioclimatic Model	Climatic factors: temperature, humidity, wind, etc.	Individual analysis and their correlation effects psychometric chart, and comfort zone	Frame structure	Human comfort
Sustainable Design Model	Nature process: geology, physiography, hydrology, climate, vegetation, energy efficiency etc.	Identify values for different categories and select a better fit environment and adaption	Layer structure	Fitting environment for development
Feng Shui	*Qi* and its relation with environment	Survey the mountain and water, find suitable area and arrange *Qi*	From big system to small sub-system	Living *Qi* should be abundant and harmonious with the surrounding

5. Case Study and Discussions

Two major applications of Feng Shui are site selection of buildings and sites for human settlement (Xu, 2003). Elements such as rivers, mountains, sun, soil, underground water, and the surrounding environment of the site are important factors for selecting sites though the rules and methods for selecting a housing site emerged over the years. The ancient Chinese believed that these major elements could influence the formation and circulation of *Qi.* The ultimate goal of Feng Shui is to find a place where *Qi* is abundant, so that the site can maximize its benefits for those who live there (Xu, 2003).

Three residential units are selected as case studies for analysis different views in home purchase decisions using the Fend Shui concepts and the contemporary models. The cases are located at Chatswood New South Wales Australia. Most of the information and photos provided by the real estate agents and recorded in the RP Data database contain positive perspectives of the properties. However, when each unit was investigated in details, negative elements were found in all three case studies. The key positive and negative elements of these three case studies are analysed and compared with the bioclimatic model, sustainable design model and the Feng Shui model. The addresses of the three selected units are listed in Table 3.

Table 3: Brief description of the three selected case studies in Chatswood

A three bedrooms and two bathrooms unit at 15-floor, 2A Help Street, Chatswood - Regency Tower.		The unit faces the South East and revels in breathtaking panoramic views stretching all the way to the Pacific Ocean and taking in glimpses of the city skyline. Total 178 square meters.
A two bedrooms and two bathrooms unit at level 8, 11 Railway Street, Chatswood – Altura Tower.		The unit is located on the North West corner of the building with 119 square meters including balcony, the bedrooms are separated by the living area which creates excellent space and privacy within the unit.
A three bedrooms and two bathrooms unit at 21-floor, 1 Cambridge Lane Chatswood – Cambridge Tower.		North-west facing, 3 bedrooms with ensuite with panoramic distance views, capturing the northern sunlight.

5.1 The External Environment

Chatswood is a suburb in the state of New South Wales, Australia, 10 kilometres north of the Sydney central business district. It is a major commercial and retail districts in the North Shore. In the 2011 Australian census, the total population of Chatswood was 21,194 people. There are two main shopping centres (Westfield and Chatswood Chase) and retail shops are nearby. The Chatswood railway station is on the North Shore Line and the Northern Line of the Cityrail network. The three selected units are located around 200 – 450 meters from the Chatswood railway station. The Altura Tower is located at the western side of the rail, while

Cambridge Tower and Regency Tower are located at the eastern side of the rail. The Altura Tower is near the Pacific Highway. Figure 3 depicts the relationship of these three buildings and their environment.

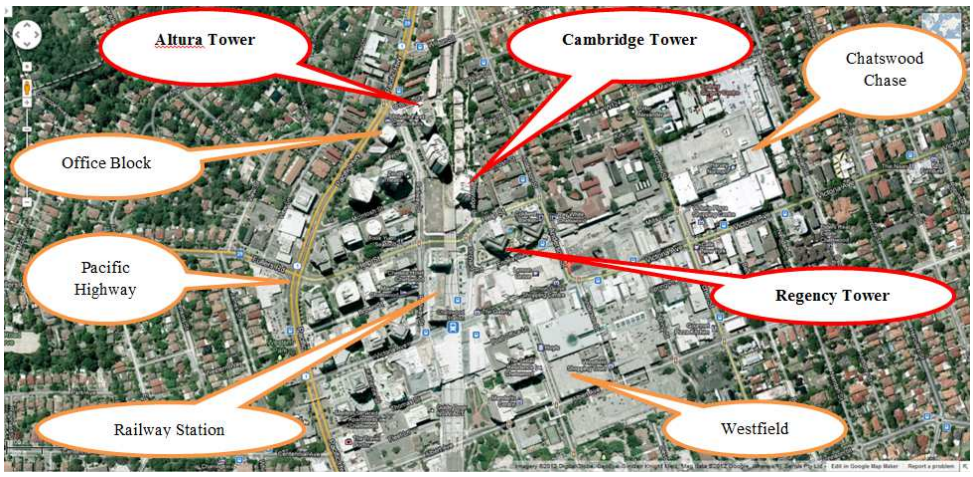

Figure 3: The Chatswood Built Environment (Google Maps, 2012)

There is a high-rise building at the southern side of the Altura Tower and low-rise units and houses are located at the northern and eastern side of the Tower. An office Tower building is located opposite. With regards to the Cambridge Tower, there are some high-rise buildings next to its northern side. A new construction is underway at its south-eastern corner. The southern side of Tower is facing the Chatswood rail station. The Regency Towers consist of Tower A and B both side by side. The water features and court yard are built between the two Towers.

5.2 The Internal Environment

All three selected units have open-plan layouts. Bedrooms are separated from the living areas to maintain a level of privacy. All rooms are bright with a lot of natural light. Positive and negative elements with three models are identified for each of the selected units.

The positive elements of the Regency unit are (Figure 4):

- Distance panoramic views to Pacific Ocean (**Bioclimatic model**) that brings positive energy (**Good Feng Shui**) and summer breeze from the ocean (**Sustainable Design model**)
- Open-plan floor layout and bright rooms with a lot of natural light (**Sustainable Design model**)



Figure 4: Positive elements of the Regency unit (RP Data, 2012)

The negative elements of the Regency unit are (Figure 5):

- South-East facing (**Bioclimatic model**) will result hot in summer morning and no Northern sunshine in winter (**Sustainable model**)
- Overlook the Tower B of Regency and distance view blocked (**Bad Feng Shui**)
- Overlook the roof of Westfield shopping centre and constant noise from cooling towers of Westfield shopping centre that brings negative energy (**Bad Feng Shui**)
- Irregular shape of bedrooms (**Bad Feng Shui**)



Figure 5: Negative elements of the Regency unit (Source: the Authors)

The positive elements of the Altura unit are (Figure 6):

- Balcony with distance views from North-East side (**Bioclimatic model**) that brings morning sun and summer breeze (**Sustainable Design model**), as well as street view (**Good Feng Shui**)
- Open-plan layout, bright kitchen and breakfast area with a lot of natural light (**Sustainable Design model**)



Figure 6: Positive elements of the Altura unit (RP Data, 2012)

The negative elements of the Altura unit are (Figure 7):

- The windows and balcony face a high-rise office building tower with large signage/logo on the opposite side thus Northern views are blocked (**Bioclimatic model**) that creates negative energy (**Bad Feng Shui**)
- Constant noise from the main road Pacific Highway (**Sustainable Design model**)
- The unit's main entrance facing the building's lift door opening (**Bad Feng Shui**) that brings negative energy (**Bad Feng Shui**)



Figure 7: Negative elements of the Altura unit (Source: the Authors)

The positive elements of the Cambridge unit are (Figure 8):

- Panoramic views to North direction (**Bioclimatic model**) that brings positive energy (**Good Feng Shui**) and large open-plan space with north facing balcony bring Northern sunshine in winter (**Sustainable Design model**)
- Separate kitchen and breakfast area (**Sustainable Design model**)
- The bedrooms are separated from the living room (**Good Feng Shui**)



Figure 8: Positive elements of the Cambridge unit (RP Data, 2012)

The negative elements of the Cambridge unit are (Figure 9):

- Construction site outside Western windows (**Bioclimatic model**)
- Direct line of sight incoming and outgoing trains to railway station from the balcony (**Sustainable Design model**) that brings negative energy (**Bad Feng Shui**)
- Mirrors on both opposite sides of wall create “ghost” effect of multiple reflections (**Bad Feng Shui**)



Figure 9: Negative elements of the Cambridge unit (Source: the Authors)

Based on the bioclimatic model, the three case studies are first compared according to the climatic factors, mainly directions and orientations in urban context. Secondary, based on the sustainable design model, three case studies are then analysed on the interaction with the natural environment, such as sunshine, wind direction, noise, etc. Finally, based on the Feng Shui model, these three case studies were analysed incorporating the holistic view of invisible energy between the built and natural environment. This process of analysis from bioclimatic model, sustainable design model to Feng Shui model is transited from tangible factors to intangible factors.

6. Conclusion

Traditional Chinese Feng Shui has been adopted, accepted and applied by the Western world in the built environment contexts. The principles of both the Feng Shui and the Contemporary models are similar in term of targeting human wellbeing and study the relationships between human and the built environment, though the analysis method, structure and criteria of the western and eastern principles are different. The distinct feature of western sustainable design has more emphasis on measurement of physical attributes such as efficiency of water and energy consumptions; whereas Feng Shui emphases are on

balance of Yin and Yang, exterior and interior, the relationship between human and surrounding environment. The interpreting Feng Shui knowledge has embraced the western concept of sustainability. The Feng Shui concept should be used more and worked together with the Contemporary models in building designing and the built environment contexts.

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Performance of Seismically Isolated Buildings at March 11, 2011, Tohoku Earthquake

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Tatsuya Azuhata[4] and Namihiko Inoue[5]

The State of the Art of Seismically Isolated Buildings in Japan

Seismic Isolation Techniques has been widely adopted in Japan since the 1995 Great Hanshin-Awaji Earthquake Disaster which caused over 6,400 deaths and 100,000 buildings totally collapsed. From the statistics until the end of 2010, in total over 2,800 buildings are seismically isolated. Also, the number of detached houses equipped with seismic isolation has reached over 4,800, so total number is around 7,000. In recent disastrous earthquakes in Japan, seismic isolation buildings have shown excellent performance and are recognized as promising techniques for sustainable buildings against earthquakes.

As one of the working commissions in CIB (International Council for Research and Innovation in Building and Construction), the Commission W114 (Earthquake Engineering and Buildings) was established in November 2006 and the JSSI (Japan Society of Seismic Isolation) became headquarter of the Commission. One of the missions of W114 is to disseminate seismic isolation technique and enhance its application to buildings.

This paper summarizes the state of the art of application of seismically isolated buildings ((hereinafter referred to as SI buildings) in Japan and its performance in recent earthquakes. Especially survey results of SI buildings after the Great East Japan (Tohoku) Earthquake on March 11, 2011 is described in detail. From the damage survey, it was found that super-structures of SI buildings suffered almost no damage even under strong shaking with JMA (Japan Metrological Agency) intensity 6 plus. It verifies the excellent performance of SI buildings. However, in some buildings, damage was observed at the expansion joints. It seems that parts of expansion joints were not well operated due to the large displacement of SI floor during earthquake. Moderate damage to seismic dampers such as lead dampers and steel dampers was observed.

Keywords: Seismically Isolated Buildings, 2011 Tohoku Earthquake, Earthquake damage

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1. Profile of Seismically Isolated Buildings in Japan

The number of seismically isolated buildings increased after the 1995 Hyogo-ken Nanbu (Kobe) earthquake. Half of the buildings are condominiums and 15% of the buildings are hospitals. Figure 1 shows the latest statistics of seismically isolated buildings except detached houses from the JSSI (Japan Society of Seismic Isolation) database. Detached houses are the seismically isolated wooden private houses increased tremendously after year 2000 as shown in Figure 2 when the new regulation was issued to approve not the individual design of houses but the manufacture of the specific type of construction to streamline the inspection process.

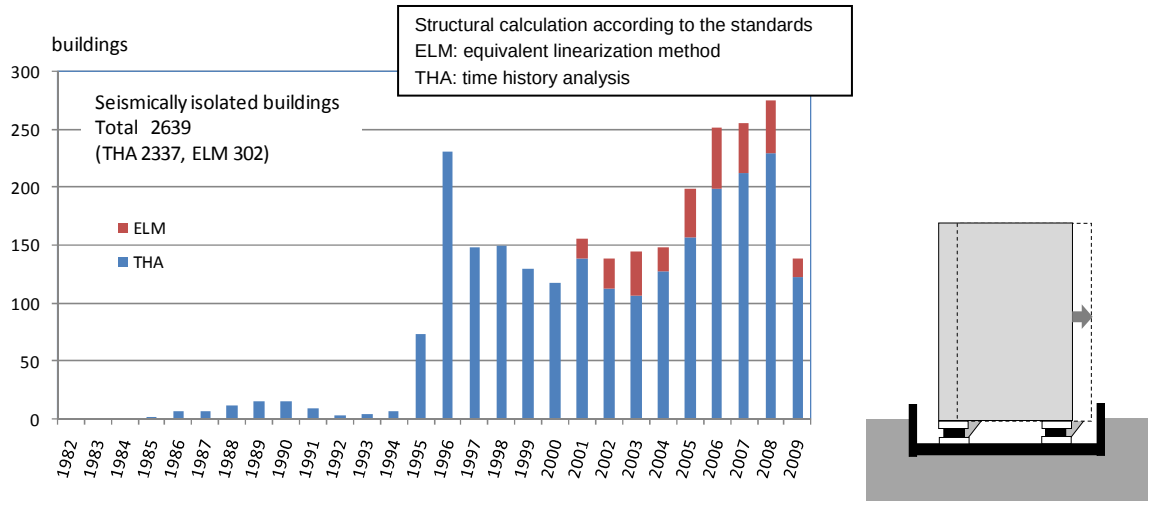

Figure 1: Statistics of seismically isolated buildings except detached houses

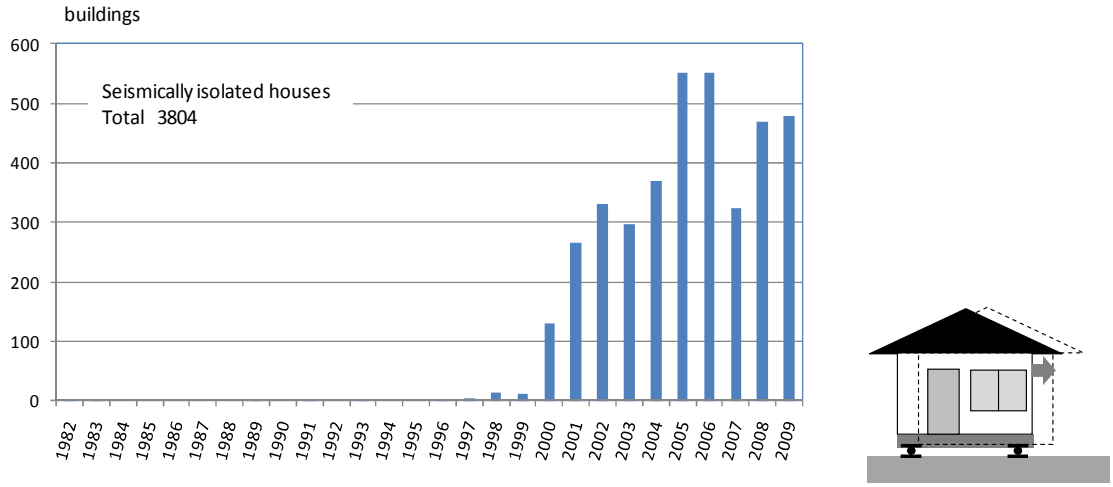

Figure 2: Statistics of seismically isolated detached houses

2. Performance of Seismically Isolated Buildings

Reflecting high consciousness of earthquake risks in Tohoku region, Japan, there are many seismically isolated buildings (hereinafter referred to as SI buildings) have been constructed in those areas. After the 2011 Tohoku Earthquake, an investigation team consisted by the members from NILIM (National Institute of Land, Infrastructure and Management) and BRI

(Building Research Institute) was dispatched to the disaster areas on June 1st and 2nd to examine performance of SI buildings and ask persons in charge of the buildings about the structural damage. In total, 17 SI buildings were investigated. Table 1 shows the list of SI buildings investigated. The list contains the JMA (Japan Meteorological Agency) seismic intensity (from 0 to 7) near the building. Most buildings in the list suffered severe ground motion with the intensity more than JMA 6 lower.

Table 1: List of SI buildings investigated on June 1st and 2nd in 2011

	Usage	Structural type and number of floors	Existence of scratch board	Existence of earthquake record	JMA Seismic Intensity at the nearest observatory
A	Office	SRC, 9F+B2F	○	○	6 lower
B	Warehouse	S, 1F	○		6 lower
C	Condominium	RC, 14F			6 lower
D	Condominium	RC, 12F			6 lower
E	Condominium	RC, 15F	○		6 lower
F	Condominium	RC, 10F			6 lower
G	Hospital	RC, 6F			6 lower
H	Office	RC, 18F +B2F	○	○	6 lower
I	Hotel	RC,12F			6 upper
J	Fire Station	S, 3F			6 upper
K	Hospital	RC, 5F			6 upper
L	Fire Station	RC, 3F	○		6 lower – 6 upper
M	Hospital	S, 6F	○		5 upper
N	Fire Station	RC, 3F	○		5 upper - 6 lower
O	Hospital	RC, 4F			6 lower
P	Hospital	RC, 10F		○	4
Q	Hospital	SRC, 4F	○		5 upper

(SRC: steel reinforced concrete, RC: reinforced concrete, S: steel)

2.1 SI building (A)

The SI building (A) is a reinforced concrete office building with 9-story super-structure and 2-story basement, located in Miyagino-ward in Sendai-city (Figure 3-(a)). The building was retrofitted by using base isolation technique putting isolation devices on the top of columns in B1F. The floor plan has the 26.4 m × 54 m rectangular shape and 44 high-damping rubber bearings (HRBs) are installed. At 2011 Tohoku Earthquake, no furniture was turned over and no structural damage was observed. However, some damage was observed at the cover-panels of fire protection and the expansion joints near the boundary between isolated and non-isolated floors (Figure 3-(b)). It seems that parts of expansion joints were not well operated due to the large displacement of SI floor during earthquake. This building has accelerometers at B2F, 1F and 9F (top floor). Also, there is an accelerometer installed by JMA in the basement of an adjacent building. The maximum acceleration values of these accelerometers at the main shock of 2011 Tohoku Earthquake are listed in Table 2.



(a) Overview of the building



(b) Damage to the cover panel

Figure 3: SI Building (A)

Table 2: Maximum acceleration values obtained at 2011 Tohoku Earthquake

Location	Direction		
	Horizontal X(EW) [cm/sec^2]	Horizontal Y(NS) [cm/sec^2]	Vertical Z [cm/sec^2]
Basement of adjacent building	317.9	409.9	251.4
B2F (below SI)	250.8	289.0	234.9
1F (above SI)	143.7	120.5	373.7
9F	169.9	141.7	523.9

2.2 SI building (B)

The SI building (B) is a one-story steel warehouse constructed in 1996, located in Miyagino-ward in Sendai-city (Figure 4-(a)). The building height is 30 m. There are 20 HRBs (with diameter 850 mm) and 4 HRBs (with diameter 800 mm) arranged in the basement with 51.6 m × 31.7 m rectangular shape. Since the building is located near the Sendai-Shiogama bay, Tsunami reached the building and the SI floor was submerged under water. Since this warehouse is a freezer, water entered in the freezer space was frozen after the earthquake. Also it took 16 days to remove the water from the SI floor. No damage to the building was observed. Also, from visual inspection, there was no harmful scratch or inflation of the rubber of HRB, however, severe rust was observed at the steel plates and bolts (Figure 4-(b)).



(a) Overview of the building



(b) Damage to the cover panel

Figure 4: SI Building (B)

2.3 SI building (C)

The SI building (C) is a 14-story reinforced concrete building used for condominium, located in Miyagino-ward in Sendai-city (Figure 5-(a)). The building has the U-shape plan and the corners of the building are separated by expansion joints. There are 24 NRBs, 8 Lead dampers, and 13 U-shape steel dampers installed in the SI floor. According to the owner of the building, no furniture was turned over and no structural damage was observed inside of rooms after the earthquake. Also no damage was found to NRBs by visual inspection; however, paint of U-shape dampers was peeled off (Figure 5-(b)) and many cracks were found on Lead dampers (Figure 5-(c)).



(a) Overview of the building



(b) U-shape steel damper



(c) Lead damper and crack on the surface

Figure 5: SI Building (C)

2.4 SI building (L)

The SI building (L) is a 3-story reinforced concrete building used for firehouse, located in Tome-city (Figure 6-(a)). The following SI devices are installed in the basement with L-shape plan; 61 m in the East-West direction and 58 m in the North-South direction: 34 lead rubber

bearings (LRB) (6 with diameter 650 mm and 28 with diameter 700 mm) , 11 elastic-sliding bearings (6 with diameter 500 mm and 5 with diameter 600 mm), and 8 U-shape steel dampers. a) According to the person in charge of the building, no furniture was turned over and no structural damage was observed. However, because of the movement of SI floor during earthquake, the bolts of steel dampers became loose and the paint on the dampers was peeled off widely. Also a large amount of residual deformation of steel was remained (Figure 6-(b)).



(a) Overview of the building



(b) Deformation of steel damper

Figure 6: SI Building (L)

2.5 SI building (M)

The SI building (M) is a 6 story steel building with one story basement used for hospital, located in Ishinomaki-city (Figure 7-(a)). Lower part of the building up to second story has the 100 m × 100 m square plan and higher part has 100 m × 25 m plan.

The following SI devices are installed in the basement: 6 natural rubber bearings (NRB) with diameter 1000 mm, 16 laminated rubber bearings with diameter 1000 mm with U shape steel dampers, 16 U shape steel dampers, 74 elastic sliding dampers (30 with 400 mm diameter, 25 with 600 mm diameter, 11 with 800 mm diameter and 8 with 900 mm diameter). According to the person in charge of the building, up-down shaking happened together with horizontal shaking during earthquake. On the 6th floor, contents inside of the rooms such as refrigerators and shelves were moved or turned over, and the fire protection steel door moved to open and hit against the ceiling by vertical shaking causing the damage to the lamp covers. From the trace on the scratch board in the SI floor, the maximum displacement was estimated around 25 cm in the West direction. This displacement was also confirmed from the trace of movement of the sliding bearing (Figure 7-(b)). The bolts of steel dampers became loose and the paint on the dampers was peeled off widely (Figure 7-(c) and (d)).



(a) Overview of the building



(b) Trace of movement of sliding damper



(c) Overview of the building



(d) Trace of movement of sliding damper

Figure 7: SI Building (M)

3. Conclusion

In Japan, construction of seismically isolated buildings is increasing rapidly. The superior performance of seismic isolation has become clear every time experiencing a large earthquake. However, since the seismic isolation techniques is still a new technology, it is necessary to consider the benefits of technology from various perspectives.

From the investigation of 17 seismically isolated buildings located in the disaster area of the 2011 Tohoku Earthquake, the following points were revealed:

1) Super-structures of all seismically isolated buildings suffered almost no damage even under strong shaking with JMA intensity 6 plus. It verifies the excellent performance of seismically isolated buildings.

2) In most cases, the maximum displacement has been estimated around 20 cm. There was one case with the maximum displacement estimated over 40 cm.

3) On the other hand there is no damage to super-structure; damage was observed at the expansion joints. It seems that parts of expansion joints were not well operated due to the large displacement of seismically isolated floor during earthquake.

4) Also damage was seen in the seismic isolation devices. Many cracks were found in lead dampers that might be increased by the aftershocks. Loose of the bolts and peeling off the paint was observed widely for U-shape steel dampers. In some cases, residual deformation of steel was remained.

From the survey results, it can be seen that the safety and function of the building was ensured after the earthquake by adopting seismic isolation technology. On the other hand, damage to non-structural members and damper devices was widely seen. It is necessary to pay more attention to these points when seismic isolation technology is employed.

Also, it was confirmed that some steel dampers experienced plastic deformation during the earthquake; however, it is unclear how much of plastic deformation capacity is left. Therefore, it is required to install a sensor in seismically isolated floor to measure the amount of deformation.

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Technical Core Competencies Assessment for the Global Construction Professional

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Abstract

The construction industry has become an international industry with firms vying for contracts across the globe. To support this globalized construction industry, university construction programs need to ensure their students have the core competencies necessary to compete in a diversified global construction environment. Future project managers are expected to adapt to a wide range of technical construction requirements, contracting methods, and managerial challenges. The focus of this research is to lay the foundation to determine the technical core competencies of a global construction professional versus focusing on the often emphasized cultural, language, and management issues. While all programs may share core competencies, there are different technical requirements in different places. Technical competencies required may vary from country to country, depending on the geological conditions, the building materials typically used, the kind of construction equipment available, and the economic development of the country, which affects the trade-off between labor and equipment.

In order to assess potential technical core competencies, a process was developed to analyze the technical requirements for design professionals in various regions throughout the world. The well-established civil engineering curricula at colleges and universities throughout the world were examined to assess regional differences and the required design competencies. Once these regional differences in design competencies are identified, then they are compared and compiled into a master list of global design competencies. Results from an initial study of regional differences are provided. In the future, this information can be used to determine the regional technical core competencies required for global construction professionals. The ultimate outcome of this research lead to a series of technical competencies required for the global construction professionals that can be included in a construction curriculum.

Keywords: Globalization, Construction Curriculum, Education

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1. Introduction

Recently, most sectors of the economy have become increasingly globalized, and this trend can be seen in all industries, including engineering and construction. One of the impacts of this globalization is that companies are becoming more global, and are undertaking projects not just in different parts of a country, but in different countries throughout the world. This globalization has an impact on the business of both civil engineering design and construction. Globalization has an impact on the skills that employees need, and subsequently on the skills that our universities must teach.

This paper examines different civil engineering curricula throughout the world in an attempt to identify common elements, as well as differences in civil engineering education. The concept and definition of global competence for students is still evolving (Deardorf 2006, Hunter 2006, Lohmann 2006), and this paper provides one framework in which to examine a process to identify technical global competence. It is important to recognize that just as scientific discovery and engineering practices evolves, so will the role of global engineering, and thus the definition of global competence in engineering.

The long standing profession of civil engineering will provide insight into the direction of technical competencies required by the construction professional. The civil engineering curricula from around the world have been well established over a much longer period than construction management programs. Many of these engineering curricula have required that students understand critical design issues important in that region. These unique technical challenges imbedded in the curriculum will shed light on what a construction professional will be required to know when working in a particular region of the world.

2. Background

Civil engineering education includes basic courses such as math, physics, statics, and dynamics as well as core competencies for civil engineering such as structural design, hydraulics, geotechnical, transportation, and materials. These core competencies are a part of most civil engineering education everywhere. In addition to these core competencies, students take classes that reflect the needs of the country or region, in this regard, engineering programs around the world are unique from country to country. The development of engineering programs has been based on many factors that include the historical educational system for the country and political influences (Lucena 2008, Kavar 1995). Even with increased standardization of engineering programs through Accreditation Board for Engineering and Technology (ABET) and other organizations, countries have maintained unique aspects of engineering curriculum that have significant value for the practicing engineer in the country. Often engineering curricula are shaped by the needs of the industry through the industry advisory boards in the U.S.A. (Warnick 2011). The participation of industry advisory boards and the resulting influence on curriculum assures that graduates have the skills necessary for employment, and are capable of addressing the needs of the region. Civil engineering curricula need to be especially focused on meeting specialized needs of the country; in some cases, these needs may be driven by geography, climate, natural resources or even politics. For example, the country of Turkey is in a very

highly active seismic region; as a result, the engineers have to be well educated in seismology and structural dynamics. One of the oldest universities in Turkey is the Istanbul Technical University and their civil engineering program has graduate degree programs focused on earthquake engineering, which is a necessity for the region.

The concept of global competence in engineering is still evolving. This is illustrated by the fact that there is little concurrence regarding what exactly this implies. One definition, as noted in Parkinson (2009), states that for engineers to be globally competent, they must "emphasize skills such as cultural empathy, foreign language ability, or the ability to practice one's profession in an international setting". While this is certainly one perspective, it does not address technical considerations. As an analogy, an attorney who practices international law certainly benefits from understanding the culture and language, however, he or she must know more than just the culture and the language. To practice internationally as an attorney requires an understanding of the local law. Similarly, to practice internationally as an engineer or constructor it takes more than an understanding of the culture and language, it requires an understanding of the technical design and construction issues of the country.

3. Research Methodology

The methodology of this research was to assess and compare the engineering curricula for a bachelor's degree in civil engineering at schools around the world. The baseline curriculum in the United States is an ABET accredited civil engineering program; Purdue University's civil engineering program was used as a typical school in the United States. The Purdue University program is among the top ten programs at a land grant university. The curriculum at Purdue is considered typical of the many civil engineering schools in the United States. Variance between civil engineering schools in the United States is reduced by the ABET criteria sponsored by the American Society of Civil Engineers (ASCE), which assure a common framework for civil engineering education.

Civil engineering curricula for other schools across the world were also assessed based on published information available on the internet. Schools in Germany, England, Hong Kong, Mexico, India, Egypt, Russia, Turkey, and Afghanistan were found that were a very close match to a bachelor's of science in civil engineering. While not all programs were an exact match on title of degree, they offered courses that would prepare an engineering professional to structurally design facilities. While this sample is not exhaustive, it does provide an indication of the range of engineering curricula around the world. The published curriculum at each school was evaluated and coverage of each topic was assessed. Comparisons were then made between the schools in different countries to evaluate the common elements and the disparities due to local considerations.

4. Results

The results of the curriculum assessment are shown in Table 1 and 2 with the name of the school and the degree title noted. The elements in Table 1 represent the subjects that were generally common to most of the engineering schools included. The common elements included an emphasis on basic engineering topics, including materials, statics and dynamics,

structural mechanics, introductory hydraulics and geotechnical (soils) engineering, concrete and steel design. Virtually all civil engineering programs had the common elements of basic civil engineering subjects as shown in Table 1. These subjects may be considered part of a global core of courses for all civil engineering curricula.

Additional required courses for degrees in civil engineering are presented in Table 2. These subjects are required for a civil engineering degree and are not considered elective courses. These topics are outside the core curriculum or they may represent advanced topics for which the basic or introductory information is part of the core curriculum included in Table 1. An example of a course that may not typically be offered at the undergraduate level is computational finite element analysis. An example of a unique course is advanced irrigation systems, which are an outgrowth of the basic hydraulics courses included in Table 1. It is likely that some of these subjects are covered to some extent in other classes, even if an entire course is not devoted to them.

As can be seen by examining Table 2, the specialty subjects vary widely, from energy and infrastructure, to computationally intensive topics such as computational finite element analysis, numerical methods, and computer aided structural design. In some cases the difference reflect differences in academic emphasis, such as a mathematically based curriculum, in other cases the differences may reflect local design practices, available resources, traditional construction methods, or environmental conditions, such as arid climate or propensity for earthquakes.

5. Discussions

Based on the results of this study into civil engineering curricula, the programs in general were very similar; however, there were some programs that had unique required coursework. These courses were sometimes related to the specific needs or characteristics of the country, such as geography, climate, natural resources or even politics. A brief review of some of the unique courses that were required is provided below.

5.1 Country Specific Coursework

5.1.1 Computational Methods and Finite Element Analysis

The curricula in Germany, Hong Kong and England included an emphasis in computational methods. The German program had a significant emphasis with three courses devoted to computational methods, numerical methods, and finite element analysis. While many civil engineering curricula have courses that include computational methods, these programs had separate courses focused on the topics. The study of advanced computational modelling at the undergraduate level puts these programs on the forefront of advanced civil engineering design using computer modelling and analysis.

5.1.2 Advanced Water and Biosciences

The civil programs in India and Egypt had advanced courses for water and biosciences, beyond the introductory civil engineering hydraulics course. This required coursework signals an emphasis on the design of water and wastewater systems. In both of these countries, potable water is a precious commodity and there is a heavy emphasis on the construction of water and wastewater systems. It is logical that the engineering curricula in these countries reflect this need.

5.1.3 Prefabrication

One of the more unique courses was in the Russian program, which included coursework in prefabrication. Prefabrication is currently a topic of increasing interest as noted by a recent corporate study by FMI (Bowman 2013). The Russian construction industry has long embraced prefabrication for large housing complexes and other structures. The centralized government system has relied heavily on the efficiencies of housing with standard design of buildings and the manufacturing of housing components. With this in mind, it is logical that their civil engineering program includes coursework to support this design and construction technique.

5.2 Case Study of Adopting Established Curriculum into the Global Environment

As international communication and travel have increased, the activities and events at one university can have a significant impact on other universities. For example, the educational methods of Europe and later, those of the United States, had a significant impact on the educational framework for engineering in Afghanistan.

The higher education system in Afghanistan started in 1932 by opening the first Medical school in the country. Other schools such as Science, Letters, Law, Islamic studies were added later. Each of these schools was located in different part of the City of Kabul. In the early 1960s, with the help of a USAID project, a central campus was initiated at the present Kabul University site.

Initially, all the colleges followed the European system of education, in which students had a yearly evaluation, and those who failed one course were required to repeat the entire year. Student evaluations were not frequent during the academic year, starting around March 20th and ending around the end of December of each year. However, there was some variation on frequency of evaluations among the schools.

In 1956, with the help of a USAID project, a joint school of Agriculture and Engineering was initiated; this introduced the U.S. system of higher education at Kabul University. In the two new schools, the semester system was introduced and the schools used the credit system whereby a student can retake a failed course instead of repeating the whole academic year. This was a big change and the two schools were given permission to follow the U.S. system without formal recognition as an accepted university alternative system.

At the College of Engineering, the curriculum of a typical U.S. university engineering curriculum was used. It started as general engineering program which included civil, electrical, and mechanical engineering courses. Later, the electrical and mechanical separated as a unit and civil engineering became a separate unit. Also, a new department of architecture was added to the school. Finally, the electrical and mechanical engineering disciplines split into different departments and thus the school became four departments, architecture, civil, electrical, and mechanical engineering. The medium of instruction was English and typical U.S. text books were used in the classes, (Baha 1976).

One of the authors was involved first hand at the Kabul program, and is able to offer the following observations regarding the U.S. adopted curriculum in the school of engineering at Kabul University.

The School of Engineering at Kabul University played a role model of excellence and accomplishments and here are a few examples that may explain the success of this adopted curriculum.

1. Those graduates who came to the U.S. for graduate work were practically all able to successfully complete graduate programs.

2. The graduates were not only very successful in technical areas, but also successful in administrative roles. Graduates reached the cabinet positions in the government system within 20 years of the establishment of the school.

3. When the five year development plan was initiated by the government of Afghanistan in 1977, the government had asked the school to expand to provide the professionals needed for the implementation of the five year development plan of the country. The normal intake of about 250 students each year was raised to about 1,100 students in 1977, an increase of more than four fold. Although there were other institutions of higher learning to train technical personnel in the country, the popularity and success of the graduates of the faculty of engineering at Kabul University made this school an obvious choice for expansion.

4. The School of Engineering at Kabul University was one of the successful programs to provide competent professionals. It could be compared with the two other very successful programs in the region. One of these programs was the American University of Beirut (AUB), Lebanon, and the other was the Asian Institute of Technology (AIT) in Bangkok, Thailand. One of the authors has been familiar with these institutions of higher learning and is acquainted with some of their graduates.

5. Using the English language as the media of instruction could have been one of the elements of success for the Kabul program. Graduates were able to access international reference resources to further develop their professional expertise throughout their careers.

6. Conclusions

This paper provides an initial study of regional differences in civil engineering curricula from various countries from around the world. These differences can arise from differences in geography, climate, natural resources, and politics. An in-depth study is provided on how an engineering program has evolved in Afghanistan. The process of examining civil engineering design curriculum from universities around the world can be further extended to review other engineering programs with a more comprehensive analysis of the programs. In the future, this information can be used to determine the technical core competencies required for global construction professionals. An outcome of this research will be a series of technical competencies that can be included in a single course for those students focused on a global construction career or can be spread through many courses in a construction curriculum. These competencies could also serve as a basis for developing a core curriculum for construction that could be implemented globally.

Table 1: Civil Engineering Curriculum Common Subjects

	Geomatics/Surveying	Materials	Structural Mechanics	Statics/Dynamics	Computer Graphics	Hydraulics	System Design	Concrete Design	Steel Design	Geotechnical	Structural Analysis
Kabul, Afghanistan	X		X	X		X		X	X	X	X
Cairo, Egypt	X	X	X	X	X	X	X	X	X	X	X
Hong Kong Univeristy of Science and Technology (Hong Kong)	X	X	X	X	X	X	X	X	X	X	X
Imperical College London (England)	X	X	X	X	X	X	X	X	X	X	X
Indian Institute of Technology, Kharagpur (India)	X	X	X	X	X	X	X	X	X	X	X
Moscow State University of Civil Engineering (Russia)	X	X	X	X	X	X		X	X	X	X
Purdue University (U.S.)	X	X	X	X	X	X	X	X	X	X	X
Technology De Monterrey (Mexico)	X	X	X	X	X	X	X	X	X	X	X
Technical University Munich (Germany)	X	X	X	X	X	X	X	X	X	X	X

Table 2: Civil Engineering Curriculum Unique Required Courses

	Computational	Finite Element Analysis	Numerical Methods	Energy	Modeling Systems	Computer Aided Structural Design	Water/Bio Sciences Courses	Plastics Engineering	Prefabrication (Concrete)
Kabul, Afghanistan							X		
Cairo, Egypt							X		
Hong Kong Univeristy of Science and Technology (Hong Kong)			X		X				
Imperical College London (England)	X			X					
Indian Institute of Technology, Kharagpur (India)							X		
Moscow State University of Civil Engineering (Russia)								X	X
Technology De Monterrey (Mexico)						X			
Technical University Munich (Germany)	X	X	X			X			

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Does sustainable housing construction provide the home owner with a greater investment return?

Chris Eves[1]

Abstract

Over the past 20 years there has been a considerable push at all three tiers of Government and private industry in Australia to improve the energy efficiency and sustainability levels of residential housing. A number of these initiatives have been voluntary, such as solar power and solar heating rebates, with other mandatory measures being incorporated into building standards and codes.

Although the importance of energy efficiency and sustainable materials have been widely conveyed both at the academic and public level, it does not always reflect in the residential house purchase decision by typical house buyers, including residential property investors. This paper will analyse a range of housing markets in Brisbane to determine the investment performance of those markets over the past 3 years to determine any significant differences between new residential suburbs and older residential suburbs where houses have not been constructed to the current energy efficiency and sustainability guidelines. The range of suburbs to be analysed will focus on middle to lower high value suburbs, with a particular focus on residential housing in Master Planned Communities to determine if socio-economic factors and development size and scope have an impact of the purchase and investment performance of sustainable houses in comparison to older housing stock. The paper confirms that the residential property market shows a higher capital return for residential property built under stricter sustainability guidelines than similar located and type of property built prior to the BCA 2004 and older style project type homes erected prior to 2000.

Keywords: Residential property, sustainable houses, investment performance.

1. Introduction

Sustainable housing design, materials and energy efficiency in housing has been a focus of Governments in Australia for many years. Although new residential construction standards have been legislated in countries such as Australia (Building Code of Australia, 2009), New Zealand (New Zealand Building Act 2004) and US **(Energy Efficiency in Housing Act of 2009)** to ensure that some levels of energy efficiency and sustainability are factored into both design and construction materials, this is not the case with existing housing stock built prior to current regulations.

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In these situations the various governments have opted for voluntary schemes to improve the energy efficiency and sustainability of older housing stock, such as the home insulation scheme and solar hot water schemes introduced by the Australian Government in 2009.

In Australia, the Commonwealth Government is also in the process of legislating mandatory disclosure of residential building energy, greenhouse and water efficiency performance at the time of sale or lease from May 2011(Council of Australian Government (COAG), 2009).

The issue of sustainability in buildings has been gaining momentum since first identified as a factor in the environmental debate in the early 1990's. Initially identified as a commercial building issue, sustainability and in particular energy usage, has now entered the vernacular of home owners/occupiers.

2. Sustainable Building and Energy Codes and Regulations

2.1 International

Since The European Parliament and The Council of the European Union issued its Directive on the energy performance of buildings in 2002, a number of member countries have set building energy usage goals and introduced supporting legislation (Official Journal of the European Communities, 2002):

- The UK has set a goal that all new houses should be net-zero emissions by 2016. The United Kingdom's Code for Sustainable Homes was established in 2007, with compulsory rating against the Code of new homes from 2008. The Code uses a star rating from 1 to 6, based on performance against 9 sustainability criteria which combined to assess the overall environmental impact. Energy usage is a key criterion, with an Energy Performance Certificate required for the sale of all new homes. (Department of Communities and Local Government (UK), 2010)

- German authorities have set a goal that by 2020 buildings should be operating without fossil fuel. Mandatory disclosure of home energy usage at the time of sale or lease came into effect on 1 July 2008. Two types of Energy Certificates are required:

  a Demand Certificate applies to the building's thermal efficiency, rating aspects of energy efficiency such as the walls, roof, windows and furnace. The Usage Certificate is based on the actual energy use of the property over the past three years. (Deutsche Energie-Agentur, 2010)

- France introduced thermal regulations in 2000 and 2005 which defined performance levels for new buildings. From 2012, all buildings are to be low-consumption (energy ratio for heating, DHW, cooling, ventilation and lighting must be less than 50kWhep/m².y). By 2020, all buildings are to be energy-positive by balancing their low consumption by the production of renewable energy. (French Environment and Energy Management Agency 2010; Lenoir, Garde, Ottenwelter, Bornarel, & Wurtz, 2010)

Following Europe's lead, legislative sustainability targets for housing, and in particular energy usage in homes, have been introduced in a number of countries around the world including USA, Canada, Malaysia, and New Zealand (Eves and Bryant, 2012).

2.3 Australia - Federal

Increases in energy efficiency regulation in Australia gained momentum in 2004 when 4-star energy efficiency was mandated in Australia for all new residential dwellings through the Building Code of Australia. In 2007 this mandate was increased to a five-star rating. All States and territories in Australia have now agreed to make all new residential dwellings six-star energy efficient by May 2011(Housing Industry Association, 2010a, 2010b). However, this regulation is specific to new residential housing and not housing stock existing prior to 2004.

At the April 2009 meeting of the Council of Australian Government (COAG), it was agreed to introduce an Australia wide mandatory disclosure scheme to provide information to home buyers or renters about the energy efficiency of dwellings (Council of Australian Government (COAG), 2009). This scheme was due to commence in May 2011 across the nation and was based on the allocation of a thermal performance star rating by an accredited assessor for all homes for sale or lease, in a similar nature to the long running ACT model. Future expansion of the scheme is to include water consumption and greenhouse gas emissions (Eves and Bryant, 2012).issue of sustainability in buildings has been gaining momentum since first identified as a factor in the environmental debate

2.4 Australia – Other States

The Australian Capital Territory (ACT) has had mandatory thermal efficiency disclosure for all homes sold since 1999. This star rating (0 to 10) must be included in all advertising material with the full certificate, including possible improvements to the property, included in contract documents. This rating system requires accredited and trained assessors to measure a home's energy efficiency based on thermal qualities only, such as building fabric, window design, orientation, air leakage and cross ventilation. It excludes energy consumption other than temperature control, such as lighting, appliances, hot water etc. New homes built since 1995 are required to meet a minimum 4 star energy rating (National Framework for Energy Efficiency, 2008).

Queensland

As stated previously, the Queensland State Government mandated disclosure of the sustainability features of dwellings for sale in Queensland from 1 January 2010. Compliance with this legislation requires specific action from each of the three parties involved in a transaction, being the seller, the sales agent, and the buyer.

The seller is required to complete a "Sustainability Declaration" checklist ("the form") prior to the property being put on the market. The form which is a declaration of the dwelling's environmental and social sustainability features in four key areas: energy, water, safety and

access. The seller is able to complete the form themselves, and the seller may leave items on the form blank if they do not know the answer. However, the seller can be liable for any losses incurred by the buyer as a result of false or misleading information contained on the form.

The sales agent is required to include information on where a copy of the Sustainability Declaration is available from on all forms of advertising, excluding newspaper and magazine advertisements. A copy of the completed form is to be on display whenever the home is open to the public for inspection and a copy must be provided to any prospective buyer on request.

The onus is on the buyer to ask for a copy of the form from the selling agent. (Queensland Government, 2009a, 2009b, 2010a, 2010b). With the election of the Liberal National Party in 2012, this legislative requirement was repealed and is no longer mandatory for residential property sales in Queensland

The Cost of Living Amendment Bill 2012 (COLA) amendments to the Building Act 1975 came into effect in June 2012 and this resulted in the elimination of the sustainability declaration. This legislative change has resulted in residential property vendors in Queensland no longer having to complete and sign a sustainability declaration, and if a declaration is available, it no longer has to be supplied to the potential buyer.

3. Residential Property: Consumer Awareness

Since 2004, there has been a greater emphasis from all levels of government, private industry and interest groups associate with the residential property sector on the benefits and importance of sustainable building practices and materials and the need for energy efficiency in housing design and appliances. The new residential construction in the MPCs has been based on the legislative requirements for sustainable and energy efficient homes, as well as the continuing public awareness of these issues

Despite these continuing legislative frameworks and general awareness raising of energy and water costs in home ownership and occupation, this is not always considered to be a major factor in the residential house purchase decision making process. A study by Reed and Mills (2007) found that the financial aspects of the house purchase decision were the most significant factor for first home buyers and not the environmental factors. A further study by Eves and Kippes (2010, 2009; Kippes & Eves, 2010) found that in the German and New Zealand residential property markets, buyers were more concerned about the price of the property, its location and number of bedrooms, than the energy efficiency or green rating of the property. These studies also showed that buyers were generally unaware of the energy efficiency schemes and measures and considered the most important environmental aspect of the residential dwelling to be the aspect of the building.

Kippes and Eves (2010) also found that although mandatory disclosure of sustainability features were required for both residential home buyers and renters, in less than 50% of

residential sales transactions it was not considered important by the purchaser and even less so by those considering leasing residential property.

A further study by Eves and Bryant (2012) found widespread disengagement with the sustainability declaration process was recorded from sellers, and even more so, from buyers. Results from this study indicated that 98% of buyers did not ask for a copy of the sustainability declaration at any time during the sales process. Despite this, sellers during this period were legislatively required to complete these forms to their best knowledge, prior to the property going to the market. Whilst agents are not required by law to provide sustainability declarations to potential buyers, many do (60%). Therefore, up to 40% of the forms completed by sellers, were never provided to any potential buyer. Of those that are used, virtually none (96%) impacted on the buyer's decision making process. Since this 2012 study, the Queensland government has removed this requirement to produce a sustainability declaration form the residential sales process.

Previous studies in the area of buyer awareness in 2009, noted that environmental issues were not a major factor in the house purchase decision. This study again confirms that a further year on, this is still the case (Eves and Kippes, 2009).

4. Research Methodology

This paper compares the change in price for residential property in Master Planned Communities (MPCs) and the immediately surrounding residential suburbs. For this study the MPC selected were the larger developments in Brisbane being Forest Lakes, Springfield and North Lakes. These MPCs were developed from the late 1990s and comprise a mix of housing constructed before the BCA 2004 and after the introduction of the BCA 2004, which incorporated a greater focus on sustainability. Although the age of housing in these newer MPCs various from those erected at the commencement of the precincts to houses recently completed, the actual lot size in these MPCs is a relatively good estimate of the age of the dwelling. Pre BCA 2004 building regulations, the minimum lot size for residential property in Brisbane was 400m2 in the outer suburbs of Brisbane and 450m2 in the inner city suburbs. Since 2004, the councils in the greater Brisbane area have allowed the lot size for new residential construction to be below the 2004 limit of 400m2 and in a number of the new estates residential lot sizes are below 280m2.

For this study sales of houses with a lot size less than 400m2 were classified as houses built since 2004 under the stricter building codes and greater consumer awareness of energy efficient housing.

All residential property sales for the period January 2010 to September 2012 were obtained from PriceFinder, a commercial database that allows residential property sales to be isolated on a land area, location and size basis. All sales for three MPCs and the immediately adjoin older developed suburbs were obtained for the period January 2010 to September 2012. These areas are predominately outer suburban areas of Brisbane and the housing covers the late 1990s though to 2012. Only the sale of freestanding residential properties was included in the analysis. In total there were 1,518 sales transactions for the properties

classified as post BCA 2004, 1,642 sales for residential property in MPCs built prior to 2004 and 1814 sales transactions for residential property in the adjoining suburbs that were built prior to BCA 2004. The relatively similar socio-economic nature of these MPCs and surrounding suburbs eliminates locational and service differences that can influence residential property prices and price movements.

5. Results and Discussion

Figure one shows the change in the average price for residential property in the three building age categories. From this figure, it can be seen that the general trend in the price for freestanding residential properties has been reasonably similar for the properties in the MPCs over the past three years. The higher average price for the pre 2004 BCA properties actually reflects the larger land size (> 400m2) rather than building size or construction.

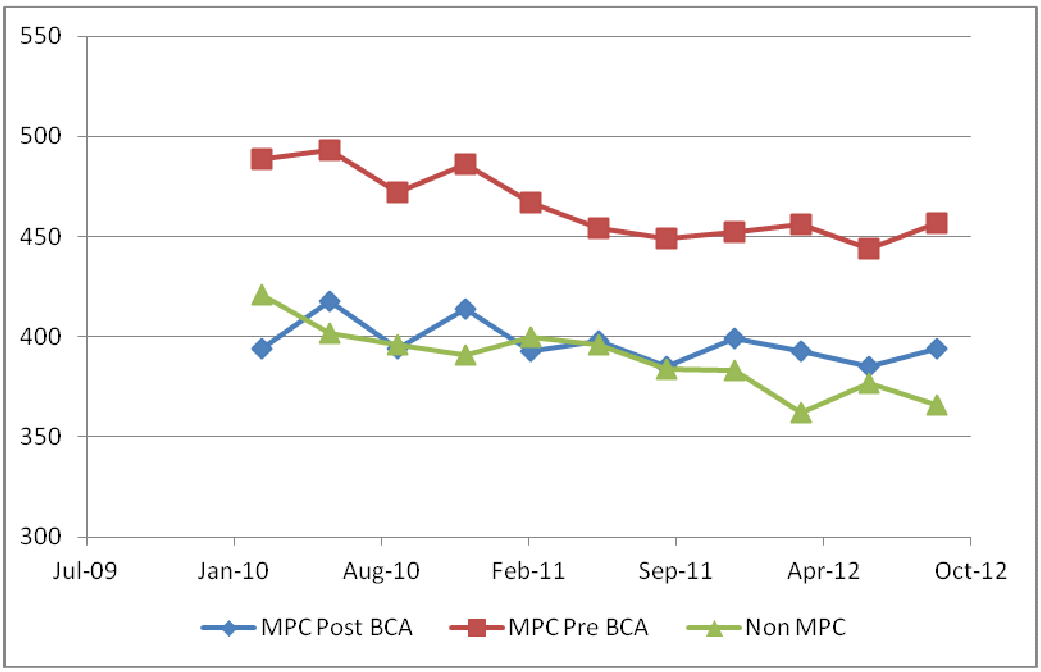

Figure 1: Average Residential Price per Quarter: 2010-2012

Although this time period covers a relatively slow residential sale and new construction period, the difference in the quarterly trend for the average sale price is significant between property sales in the Brisbane MPCs and the immediate adjoining suburbs, especially during 2102, where there was a slight recovery in the price of houses in the MPVCs but a continuing decline in house prices in the adjoining suburbs. The adjoining pre BCA 2004 constructed houses also did not show the uplift in house prices in the latter part of 2011 that was experienced by the post BCA constructed dwellings in the MPCs.

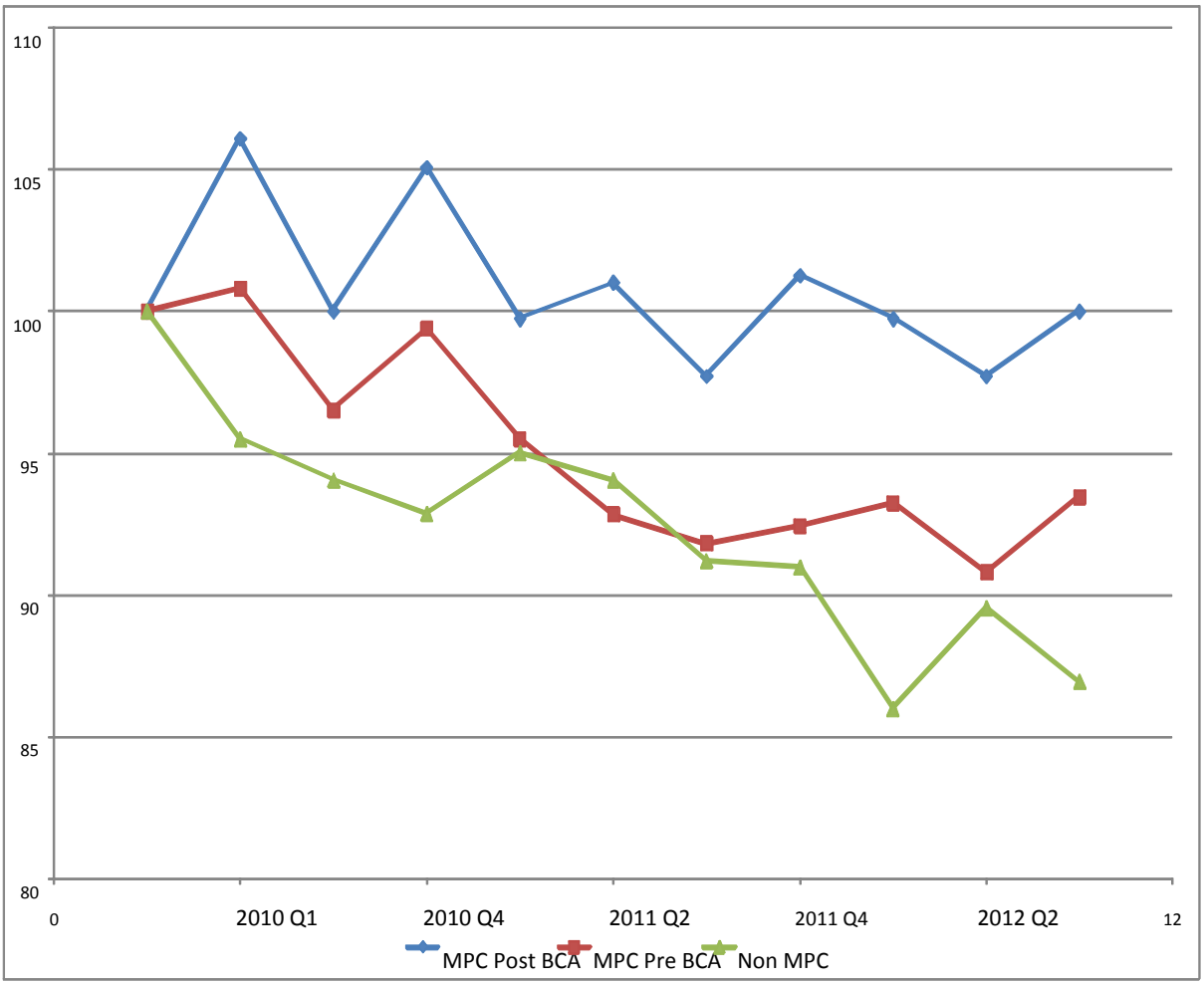

Figure 2: Capital Return Index: Sustainable Housing: 2010-2012

Figure 2 and Table 1 provides a more detailed perspective of the capital return performance of the three housing sectors, based on the index performance per quarter. From this table it can again be seen that the capital growth (loss) for residential property in the MPCs for both pre and post BCA2004, has followed a similar trend in 2010, with a series of gains and losses in the four quarters. However, in the first half of 2011, there was a considerably larger decrease in capital growth for the pre BCA 2004 constructed houses compared to the more sustainable post BCA 2004 houses in these developments. Figure 2 also shows that the overall capital return performance for the post BCA 2004 houses has been well above the capital return performance for the pre BCA 2004 houses both within and outside the MPCs. Over the study period, the houses in that have been built under the stricter sustainable building code have shown a slight increase in the index from the base of 100 to 101. During the same period the index for the pre BCA houses in the MPCs fell to 93, with the houses in the adjoining suburbs falling from an index value of 100 in quarter 1 2010 to 87 in quarter 3 2012.

Table 1

	Pre BCA 2004	Pre BCA 2004 MPC	Post BCA MPC
Jun-10	-4.51	0.82	6.09
Sep-10	-1.49	-4.26	-5.74
Dec-10	-1.26	2.97	5.08
Mar-11	2.30	-3.91	-5.07
Jun-11	-1.00	-2.78	1.27
Sep-11	-3.03	-1.10	-3.27
Dec-11	-0.26	0.67	3.64
Mar-12	-5.48	0.88	-1.50
Jun-12	4.14	-2.63	-2.04
Sep-12	-2.92	2.93	2.34
Average Quarter Capital return%	-1.35	-0.64	0.08
Volatility	2.93	2.68	4.20

This significant difference in the capital return per quarter between the houses that were constructed on a more sustainable basis and those that were constructed prior to 2004 is highlighted in Table 1. Over the period, only the residential markets in the MPCs with houses constructed in accordance with BCA 2004 showed an average positive quarterly return of 0.08%, with a high of 6.09% in quarter 2, 2010 and a lowest quarterly return of -5.74% in September 2010. During this same period, the average quarterly return for other residential property in MPCs was -0.64%, with a maximum quarterly return of 2.93% in September 2012 and a low of -4.26% in September 2010. The residential property in the suburbs adjoining the MPCs returned a negative quarterly return of -1.35%, with the highest quarter return being 4.14% in June 2012 and the lowest return being -5.48% in March 2012. During this period, the volatility for the post BCA 2004 houses was 4.2%, reflecting the higher return. However, of note is the fact that the residential market with pre BCA 2004 construction adjoining the MPCs had a volatility of 2.93%, which was higher than the same style of construction in the MPCs despite the lower capital growth. On a risk return basis, the post BCA 2004 houses were the best performing asset class.

***Table 2: Capital Return Comparison**.*

	Pre BCA 2004	Pre BCA 2004 MPC	Post BCA MPC
Capital return 2010-2012 %	-14.36	-9.66	-5.06

Table 3 compares the average price of residential property in the three sectors based on the price in March 2010 to the average price at the end of September 2012. From this table, it is again confirmed that the more sustainably built houses have shown the better investment performance over this particularly slow residential market period in Brisbane. The change in price from Quarter 1, 2010 to quarter 3, 2012 was -5.06% for the sustainable houses in MPCs, with the pre BCA 2004 houses in the adjoining suburbs actually showing a price decrease of -14.36%.

6. Conclusion

This study has provided empirical evidence that the residential property sector will pay more for an environmentally sustainable home compared to a similar located residential property that has not been constructed with the same level of environmental sustainability.

In addition, the purchaser of a home constructed according to the BCA 2004 standards can actually expect a higher investment performance compared to purchasing a house constructed prior to 2004. Over time these investment returns can be more than those other residential property sectors; however, of more importance is the fact that in a down market, the change in price for a sustainable dwelling is significantly less than the downward price movement for non sustainable residential property.

Although consumer awareness of energy efficiency and sustainable building construction has been limited in the past, this study suggests that there is an increasing trend in residential property buyers and investors placing value on more sustainable and energy efficient house designs.

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New Zealand new housing characteristics and costs

Ian Page[1]

Abstract

New Zealand housing is mainly timber framed with a variety of wall and roof cladding types. Layouts and elevations are diverse and the amount of "standardisation" is quite small. The typical building firm is small scale and the top 50 builders account for only 25% of all new houses. This paper describes how the design characteristics of new housing and the structure of the industry affect the cost of housing. Comparisons with Australian housing costs are made. The analysis is based on two surveys, first a survey of the physical characteristics of new housing, second a survey of builders on factors affecting new housing costs. The New Zealand Productivity Commission has recently examined the affordability of housing and some of their findings and recommendations are discussed.

Keywords: Housing, costs, design, firms, standardisation

1. Introduction

New Zealand housing has traditionally been made from light timber framing, usually 100 x 50 mm nominal sizes, on timber piles but more recently on concrete slab foundations. In the early days of settlement the main cladding was timber weatherboard and corrugated steel roofing, continuing through to the early 1950's. Now a wide variety of materials are used for claddings. Australian houses are similar in construction to NZ housing with timber framing in widespread use. Generally Australian builders produce a similar quality house more cheaply than in NZ. It is instructive to compare the similarities and differences in design and construction in order to better understand reasons for the cost differences between the two countries. Ownership rates are dropping from about 75% in the early 1990s to 65% now and falling. Affordability has always been a low income household issue but more recently middle income New Zealand households in some locations have found ownership unaffordable. The Productivity Commission (2012) said "it is not yet clear if this is a cyclical phenomenon or a structural trend." This paper is about the supply side of housing rather than proposing measures to assist affordability, but it provides some reasons why new housing is increasingly unaffordable for many households.

2. Main results

This section examines a number of characteristics of New Zealand new housing with some comparisons with Australia. The characteristics examined are:

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[1] Economics Section; Building Research Association of New Zealand

- New housing costs, material costs and labour rates.
- Building form, detached versus attached housing
- Average floor area sizes
- Structural types.
- Wall cladding types
- Building firm size

2.1 New house costs

The prices for a typical new house in New Zealand and Australia are shown in Table 1. This is taken from the NZ Productivity Commission report on housing affordability (NZ Productivity Commission 2012, Table 10.3). Prices were adjusted for purchasing power parity (PPP) and the Commission found Australian prices were 15% to 25% lower, depending on the cities compared. There are slight differences in specification, but generally the quality of houses is similar in all locations. Building code requirements differ (e.g. thermal insulation, double glazing, structural loading, termite protection, etc) but these do not amount to more than an extra 5% cost for NZ houses. So the conclusion is that new housing in New Zealand is at least 10% more expensive than the same house in Australia.

Part of the reason for the price difference appears to be material costs. A comparison of ten common materials (Kenly 2003) found a price premium in New Zealand of about 55% after exchange rate adjustments. The Productivity Commission (Table 10.2) identified an average price differential of about 24% for materials in place, (i.e. labour installation costs are included), see Table 2. Some items, e.g. framing hardware, have a large price difference which is believed to be due to specific building code requirements. Rawlinson (2012) has average tradesman rates at $A62/ hour in Australia compared to New Zealand rates at $NZ38 per hour, including all overheads. In PPP terms the skilled labour cost in Australia is twice that of New Zealand. Hence the lower installed costs must be due to a combination of cheaper materials and more efficient use of labour. In fact Table 3 indicates less labour is used in Australia compared to New Zealand for most housing components.

Table 1 New house building costs per sq meters

Location	Price (PPP adjusted to $NZ)	% of Auckland	% of Dunedin
Auckland	$1,650/sqm	100%	108%
Dunedin	$1,525/sqm	92%	100%
Sydney	$1,175/sqm	71%	77%
Brisbane	$1,209/sqm	73%	79%

Source: Rawlinsons Australia and Rawlinsons New Zealand. Prices are for a moderate quality standard house using the mid-points of the price ranges given in the respective Rawlinsons Cost handbooks. Prices exclude GST and consent/ approval fees.

Table 2 Material prices for a typical house in New Zealand and Australia

Material	NZ price	Australian Price (PPP adjusted to NZ$)	Australian price as a %

Bricks	4,978	4,051	81%
Framing hardware	2,428	344	14%
Pre-nailed frames	10,575	7,920	75%
Eaves/ gable materials	3,524	1,395	40%
Finishing materials	1,032	978	95%
Finishing timber	677	867	128%
Internal doors	713	526	74%
Carpenter frame	6,870	6,142	89%
Trusses	8,111	7,158	88%
Metal fascia/ spouting	2,148	2,777	129%
Metal roofing	11,567	12,226	106%
Windows	12,873	5,325	41%
Cupboards	5,442	4,758	87%
Insulation	2,227	1,699	76%
Plasterboard	12,713	8,973	71%
Total	85,878	65,139	76%

Notes:
1. Framing hardware in New Zealand houses includes metal straps, angles, bolts and weatherproof wraps at exterior openings. New Zealand windows are double-glazed while Australian houses generally have single-glazed windows.
2. These prices include labour costs for installation.

Table 3 Labour hours by component in new Zealand and Australia

Component	Unit	New Zealand	Australia	Australia as % of NZ.
Ground floor joists 200 x50	hr/m	0.21	0.185	88%
Plates and studs 100 x50	hr/m	0.13	0.155	119%
Dwangs/ nogs 100 x50	hr/m	0.17	0.155	91%
Ceiling joists 150 x50	hr/m	0.20	0.17	85%
Erect trusses 6m span	hrs each	1.5	1.25	83%
Particleboard flooring 19mm	hrs/sqm	0.36	0.21	58%
Brickwork lay standard	hr/1000 bricks	16	13	81%
Brick clean/ point	Hr/sqm	0.20	0.15	75%
Weatherboard timber	hr/sqm	0.85	0.475	56%
Roofing concrete tiles	hr/sqm	0.30	0.17	57%
Roofing sheet steel	hr/sqm	0.15	0.20	133%
Painting Walls prep + 2 coats	hr/sqm	0.20	0.13	65%
Painting Ceiling prep + 2 coats	hr/sqm	0.25	0.15	60%

Source: Rawlinsons NZ Construction Handbook 2012. Rawlinsons Australian Construction Handbook 2012.

2.2 Building form and materials

The predominant structural material in new detached housing is framing timber, typically 100 x 50 mm nominal size. In recent years it has lost market share to concrete masonry, light steel framing and a variety of minor structural systems such as solid wood, mud brick and reconstituted timber panels. In the last 5 years steel framing has gained market share, see Figure 1. Similar data is not readily available for Australia but in the late 2000s (Australian Bureau of Statistics) the main systems were timber framing (approximately 65%), double brick (15%), light steel framing (15%), and Other (5%, concrete block and panels).

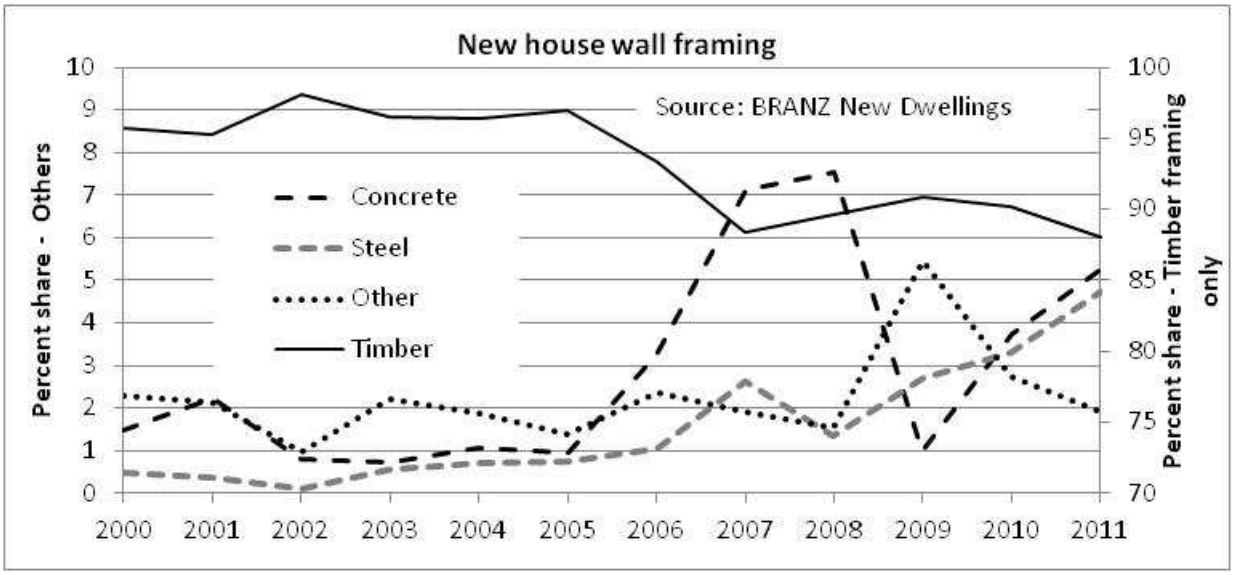

Figure 1 Framing systems in NZ housing

Wall claddings are shown in Figure 2. From the mid 1990s onward a "mediterranean" style with no eaves, flat roof and a flat wall finish became popular. Weather-tightness problems associated with these designs became apparent in the early 2000's and by the mid 2000's there was a shift back to traditional designs and materials represented by clay brick and weatherboard, and a reduction in the monolithic cladding represented by fibre cement sheet and EIFS. A feature of new NZ houses is the wide variety of cladding types as indicated on the chart. The "other" category includes plywood sheet, PVC weatherboard, and corrugated steel sheet. Furthermore many new houses have more than one cladding type, see Figure 3. Common combinations are brick and weatherboard. Owners appear to demand houses that look different to adjacent houses, both in cladding and in layout, the so-called "bespoke" housing. In contrast Australian detached houses are more limited in wall cladding types, with clay brick having well over 70% share and usually just one cladding type per house.

Roof cladding types show similar patterns with NZ housing having a variety of cladding types, with approximately equal shares in concrete tiles, pressed metal tiles and long run steel sheet, and small shares of flexible membranes and shakes. Australian new houses have mainly concrete or clay tiles. The BRANZ New Dwellings Survey referred to in the above charts is described in a report by Page and Curtis (2011).

The diversity of claddings is believed by the author to be one factor causing additional costs in New Zealand housing. Other cost factors relate to design characteristics and the size of the industry.

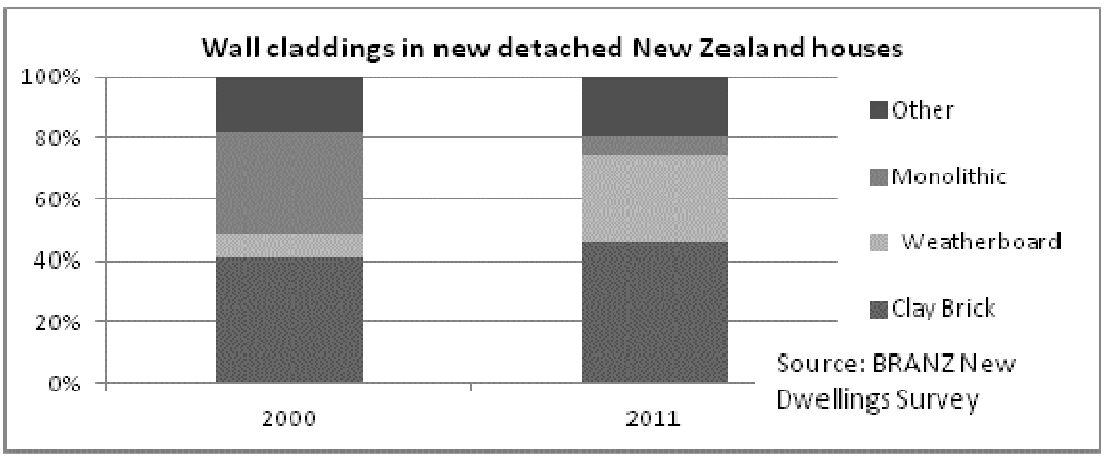

Figure 2 Wall claddings on NZ houses

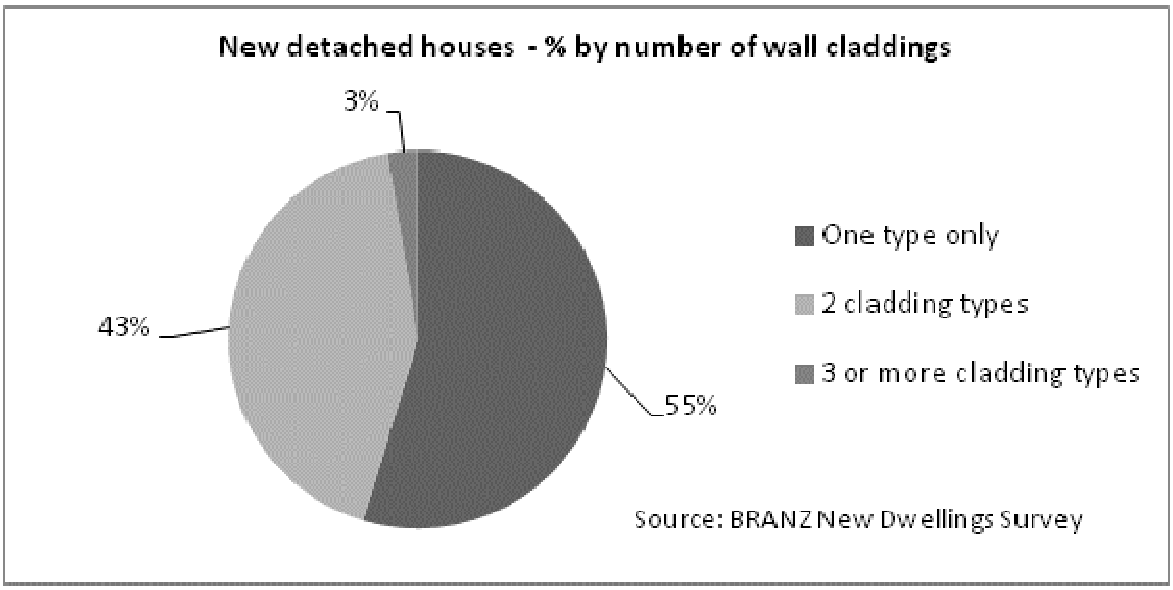

Figure 3 Numbers of cladding types on NZ houses

2.3 Detached versus attached new housing

The analysis in this paper is for detached housing because it is by far the majority of new housing in New Zealand. The proportion of multi-unit is quite low compared to Australia, see Figure 4, and most other Western countries. Average floor areas for detached houses are high by world standards, see Figure 5, with NZ houses third in size after Australia and the USA. Sizes have been rising in both countries for many years but now appear to have levelled out and may be declining.

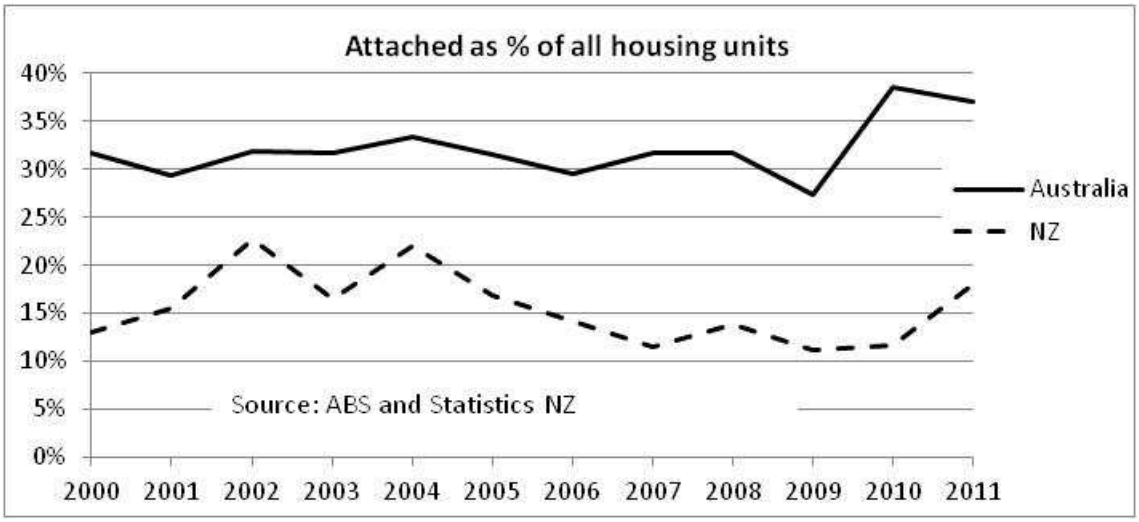

Figure 4 Attached new housing as a percentage

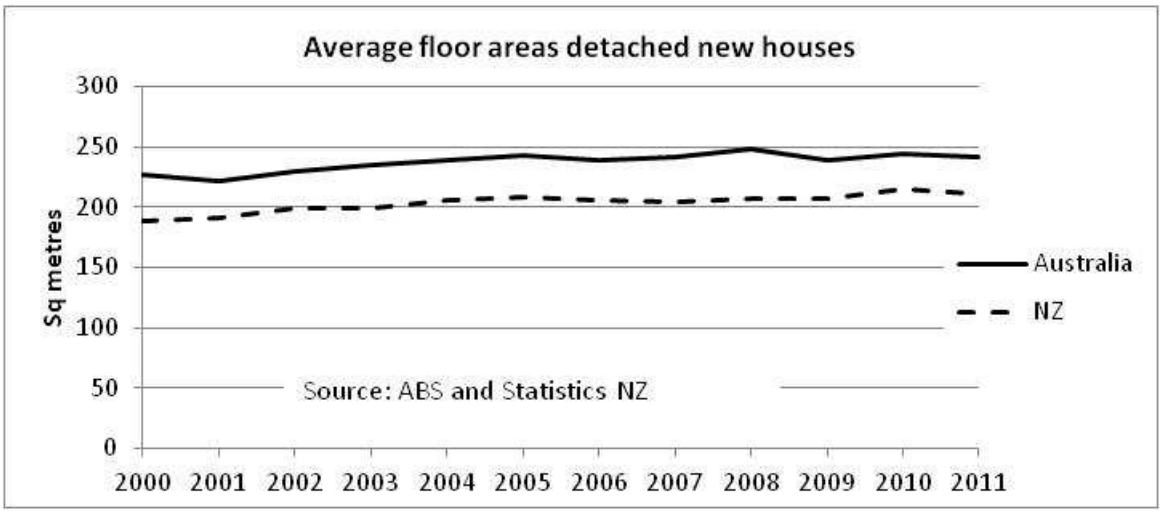

Figure 5 Average floor areas for detached new housing

Most new detached new housing is single level, see Table 4, However this is likely to change as new starts are increasingly on small lot sizes.

Table 4 Number of storeys in New Zealand new detached houses

	Percent	Average floor area sqm
One storey	78.2%	202
Two storey	20.3%	253
>Two storey	1.5%	313
	100%	
Source: BRANZ New Dwellings Survey.		

2.4 Firm size

The average size of house building firms in New Zealand is small, in common with many other countries, see Table 5. However for such a small country the NZ concentration percentage is unusually low, indicating it is very much a “cottage type” industry. This obviously affects firm market power in terms of material purchasing.

Table 5 House building firm concentration

	Percentage share			
	Australia	UK	USA	NZ
Top 10 firms	15%	28%	15%	13%
Top 50 firms	33%	66%	23%	25%
Source: Ball M (2007) Firm size and competition: A comparison of the house building industries in Australia, UK and USA. Working papers in Real Estate and Planning 02/07. Page I (2011) Cost efficiencies of standardised housing. Study Report No196, BRANZ, Wellington.				

2.5 Design factors affecting cost

A previous section mentioned the demand for "bespoke" housing in New Zealand which is manifest in varied layouts and different cladding materials for houses in the same housing development area. The large majority of new home owners have some input into the design (Curtis 2011); see Table 6. Almost half have a major input and even when standard plans are used over 40% have make some changes. This affects layout and other features such as windows, kitchens and bathrooms where common sizes of components are rare. For example, window sizes are not standardised and it is not uncommon for 6 to 8 difference sizes to be used per house. Bathroom vanities and showers are usually preformed but kitchen layouts are different in each house with custom made joinery quite common.

Builders were surveyed on design aspects and the effect on building costs (Page, Fung 2011), see Figure 6. The design features adding most to costs were an upper storey, complex roof lines, changing ceiling heights, sloping sites, and poor foundations. The latter two results from the varied NZ terrain causing issues with foundations in many locations. In the larger cities the better ground has already been claimed for housing and often new developments are forced onto more difficult sites.

Table 6 Owner input into NZ new house design

What input do owners have into the new house design?	
Select design from the builders standard plans with NO CHANGES	2%
Select design from the builder's standard plans with SOME CHANGES BY OWNER	43%
One-off design by an architect with MAJOR OWNER INPUT	48%
One-off design by an architect with MINOR OWNER INPUT	6%
Source: BRANZ New Home Owners Satisfaction Survey 2011. Sample size 481.	100%

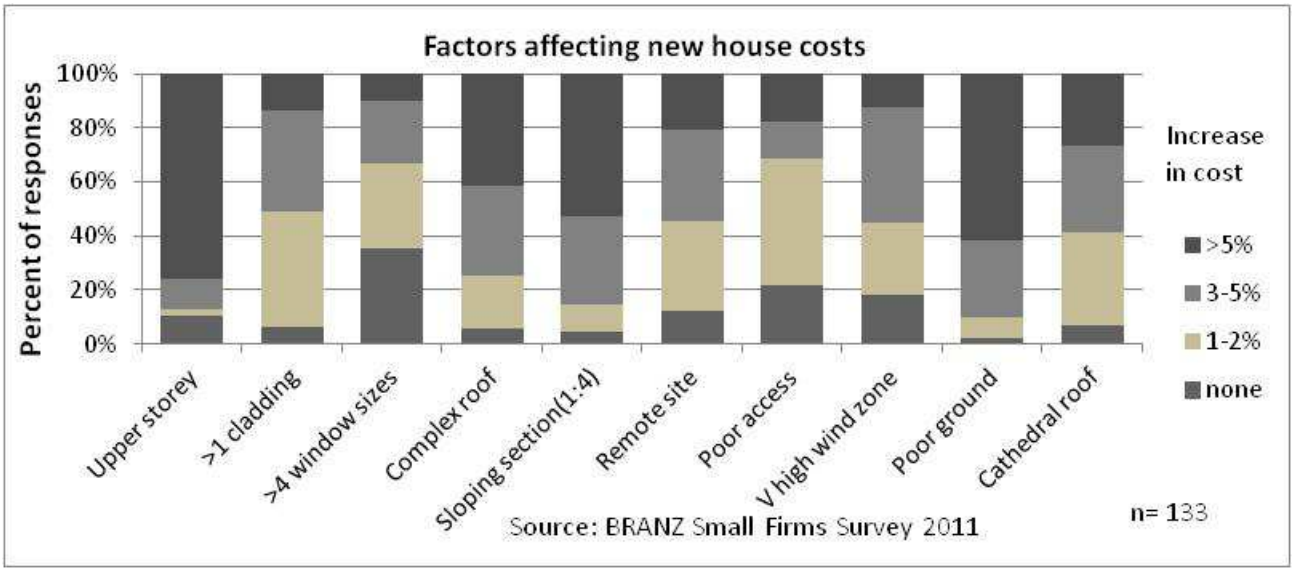

Figure 6 Factors affecting costs for new NZ detached houses

3. NZ Productivity Commission findings on housing costs

The Productivity Commission was tasked with the evaluation of the factors influencing the affordability of housing and to examine the opportunities to increase affordability. The main recommendations were:

- Increase land supply for new housing, including moderate –density development of brownfield sites and development of greenfield sites.
- Councils review regulatory processes with the aim of providing simplified, speedier and less costly consenting processes and inspections.
- Territorial authorities should develop strategies that promote competition between developers for the right to develop land.
- Treasury review the quality and robustness of the RIS process for changes to the Building Code.
- Building Consent Authorities (BCAs) adopt a customer-focused approach in their interaction with building practitioners.
- The Law Commission should consider a review of liability and the incentives faced by councils to minimise their liability.
- The Department of Building and Housing (DBH) should provide specific guidance for BCAs about what is required for an alternative solution to comply with the building code.
- The DBH should review the Multi-proof building consent process (where the same design is acceptable in all locations) to identify barriers to its application.
- Urgency should be given to Government efforts to improve BCA performance and promote greater consistency and efficiency in the building regulatory system.

Most of these relate to land zoning and other council processes. Making more land available and speeding up processes on the surface appear to be worthwhile solutions but the first conflicts with sustainability goals, and second, councils are wary of liability issues as they are often the “last man standing” in legal cases and have in the past incurred large repair costs. So while there can be improvements in land supply and council processes the right balance is needed.

The report examined the structure of the building industry and material manufacturing in some detail, but did not have many specific recommendations. The main one related to the industry Productivity Partnership (2012) work which the commission said “should develop, in consultation with the sector, practical responses to supply chain issues”. The Commission did not list these issues but they are believed by the author to include:

- Need to increase the average firm size to achieve scale efficiencies.
- Promote more standardisation in housing design.
- Better integration between owners, designers, builders, material suppliers and sub-contractors in procurement, time management and in allocating costs fairly.
- Improved processes within regulatory authorities for monitoring compliance.
- Use more prefabrication, both from a quality and time-saving viewpoint.
- Improve skills both in firm management and the on-site trades.

4. Discussion

New housing in New Zealand is characterised by a variety of housing forms with little standardisation. There are a large number of cladding types compared to Australian houses and the floor plan layout varies with almost every detached house. Average sizes of new housing are large despite average household size declining in recent years (currently the average occupancy is 2.7 persons per occupied house, down from 3.5 persons in the mid 1970s.)

Why are new house floor areas in NZ among the largest in the world? Affordability could be significantly improved with smaller houses and although home ownership rates are quite high, at 65%, they are currently declining rapidly due to affordability constraints. The reason for the large sizes appears to be the role of housing as a financial asset. For most households it is their largest single asset and new owners build with re-sale in mind for what they perceive to be the main market, i.e. 4 bedrooms, double garage and as much floor area as their budget allows. These choices are influenced by the high cost of land. In Auckland the land cost represents over 50% of the house and land package (Productivity Commission Figure 2.8). Owners do not want to under-capitalise on the house given the high land price. The average new section size is now about 450 sqm in the major cities and quite often the new house needs to be 2-storey to fit on the section. This has addition construction costs, compared to single storey construction. Poor ground conditions and lack of flat sites In many New Zealand cities is also a factor contributing to cost particularly during housing booms when the best sites are developed first.

Local councils are now zoning for more intensive housing. The Auckland Council (2012) expects about 60% of new housing over the next 30 years to be within the current urban limits and most of that will be attached housing varying from semi-detached, terraced housing and medium to high rise apartments. So house sizes are likely to decrease on average and possibly reduce or stabilise new housing price rises. Prospective owners are now becoming more aware of choices affecting energy and water use, travel times and other design factors which impact on their on-going costs. Recently developed intensive housing in greenfield and brownfield locations has been quite well designed. So possibly there will be a trend to smaller but better designed houses which cost less to run and have lower sustainability impacts.

Material costs are on average more expensive than in Australia. This is probably due to scale effects. With an average demand of 20,000 new houses per year the size of most building material manufacturers is below world scale. Also builders find it difficult to efficiently use their labour and sub-contractors as work sites are often scattered rather than being concentrated in large developments. There are only two major manufacturers of building materials and so price competition is limited for some materials. The population is well distributed across New Zealand with Auckland having at most 30% of new building work, so transport of bulky materials over the quite mountainous terrain adds to costs.

The Productivity Partnership (2012) has a programme of work to improve productivity in the building and construction industry by 20% by 2020. It is currently addressing the topics

mentioned in the NZ Productivity Commission report and it has four streams of work; Procurement, Skills, Processes and Evidence. Procurement is mainly focused on large projects and big clients (i.e. central and local government) with attempts to co-ordinate work so that boom-bust cycles are lessened. The skills stream emphases trade training but has recognised a gap in management skills in the small builder sector. The Processes group is looking at the value stream and trying to identify what processes add value and which do not and hence should be eliminated. It is considering the greater use of technology and innovation (e.g. BIM, pre-fabrication, etc) to improve overall industry performance. The Evidence stream is looking at measurement of progress toward the goals including measures of quality. One of the biggest challenges for the Partnership is to improve the performance of the small firm housing sector and make housing more affordable. Some solutions have been discussed above, including smaller houses, more standardisation, and larger firm sizes. But issues outside the industry also need to be addressed such as land and material costs, and regulation and compliance costs.

5. Conclusions

New housing in New Zealand has specific local characteristics arising out of a tradition of ownership and a wish of owners to put their mark on the new house. Due to land and consent costs most owners feel they need to build as large as possible. All this has gradually made new housing unaffordable for many households and ownership levels are dropping rapidly. Councils are zoning to contain urban sprawl and the first new house for many owners will increasingly be a multi-unit on a redevelopment site within existing urban limits rather than a detached dwelling on a green field site. It is likely in the future we will see a trend to smaller dwellings, more intensification and more standardisation. The average firm size is likely to increase to undertake this more intensive construction. This will lead to a significant change in the characteristics of new housing, possibly leading to better quality, enhanced affordability and improved sustainability.

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Appendix

BRANZ New Dwellings Survey

This is a postal survey to builders. It asks questions on types of materials by selected components (frame, roof, walls, floor, etc) for a specific building identified from building consent lists obtained from local authorities. Approximately 1,200 returns are received per year. It was originally developed to provide specific product information on market size and share for manufacturers. It has been underway since 1999 and over the years additional questions have been added as requested including efficiency measures (insulation, glazing, lighting water conservation, solar panels, etc), and questions on structural design and weather-tightness. The latter are generally requested by officials and regulators. The survey's value is that it provides data not available from official sources, and it now has wide use including time trend data. More details of the survey are available in a BRANZ Study Report (Page, Curtis, 2011).

Earthworks Planning for Road Construction Projects: A Case Study

Dr Robert Burdett, Professor Erhan Kozan

Abstract

In this paper we construct earthwork allocation plans for a linear infrastructure road project. Fuel consumption metrics and an innovative block partitioning and modelling approach are applied to reduce costs. 2D and 3D variants of the problem were compared to see what effect, if any, occurs on solution quality. 3D variants were also considered to see what additional complexities and difficulties occur. The numerical investigation shows a significant improvement and a reduction in fuel consumption as theorised. The proposed solutions differ considerably from plans that were constructed for a distance based metric as commonly used in other approaches. Under certain conditions, 3D problem instances can be solved optimally as 2D problems.

Keywords: mass-haul optimisation, earthworks allocation, fuel consumption, emissions

1. Introduction

In this paper we apply a new planning technique to a road construction case study. Road construction can be the source of very large and costly earthworks as many have significant length and pass through difficult terrain. In this type of linear infrastructure project the principal earthwork operations are: i) stripping vegetation and topsoil, ii) loosening material in cutting and borrow pits, iii) excavating material, iv) loading material from cuts and hauling to fills (or to spoil), v) spreading, shaping, watering, compacting and trimming the fill material (QTMR 1977). The main idea of earthworks is to alter an existing land surface into a desired configuration by excavating material from specific locations and using that material as fill in other locations. This earthwork problem is commonly referred to as mass-haul. A solution to this problem is an earthwork allocation plan (EAP) that describes where cut material is to be placed as fill and how much material is to be moved between each cut-fill pairing. There are two golden rules that must also be borne in mind during these projects; don't double handle material whenever possible and always load and carry material downhill (QTMR 1977).

In the last ten years much research has been performed in this field. Recent papers include Son et al. (2005), Aruga et al. (2005), Akay (2006), Karimi et al. (2007), Kim et al. (2007), Goktepe et al. (2008), Zhang (2008), Dawood and Castro (2009), Ji et al. (2010), Hola and Schabowicz (2010), Ji et al. (2011), Shah and Dawood (2011), Nassar and Hosney (2012). However, there are many limitations and inaccuracies in this work, and much of it is not comprehensive or detailed enough to be readily applicable to real life. A comprehensive review and critical analysis of this field by Burdett and Kozan (2013a) has recently shown

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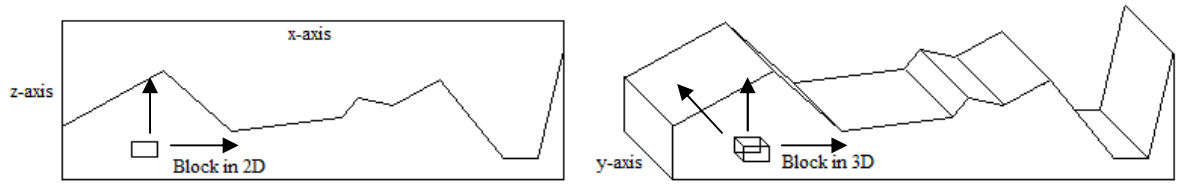
that there are many opportunities and avenues for future research, and that a variety of new approaches can be developed. Consequently in Burdett and Kozan (2013b) a number of new approaches were developed. The partitioning of the project site into blocks and the development of associated block models was the foremost approach in that paper. The block models are a superior approach to previous section based alternatives as "conceptually" they model more realistically and accurately the position of earth at different elevations. The block models are generic and are readily applicable for both 2D and 3D scenarios. Figure 1 in particular shows the difference between 2D and 3D scenarios. The path between blocks and other locations is not direct, i.e. it is the sum of separate movements over inclined planes of different angles. This approach is superior to those taken in other papers and models more realistically the movement of material through the terrain as it is altered.



a) Movements of earth across x and z axis ***b) Movements across x, y and z axis***

Figure 1. Comparison of 2D and 3D earthwork scenarios

In Burdett and Kozan (2013b) the physics concept "work" has also been used as a proxy for fuel consumption. It is a generic and robust metric for the movement of earth over inclined planes of different angles and surfaces. That approach is necessary as it is impractical to measure and quantify the exact fuel consumption of every construction vehicle and for every associated factor. Fuel consumption was used as a metric instead of haul distance or haul time for several reasons. Foremost is that distance travelled is not an accurate measure of cost as the gradient of travel (among other important factors) is not included. The gradient of travel significantly affects the ease or difficulty of moving material and greatly effects fuel consumption. Recently the environmental impact of construction activities has become an important topic due to the pollution that is created. In order to quantify emissions, the fuel consumption of vehicles performing hauls must be quantified. The reduction of fuel consumption though is important in its own right, as recent site visits to the Bruce Highway upgrade at Gympie (Queensland) has revealed that there is often hundreds of thousands of dollars worth of fuel sitting in vehicles on project sites.

2. A Review of Block Optimisation Models

This approach is based upon the partitioning of the problem domain into rectangular prisms (i.e. 3D blocks). Our previous paper Burdett and Kozan (2013b) should be consulted for extended details. The following is a review of the most pertinent features:

The set of blocks requiring excavation and fill respectively are denoted by (B^-, B^+). Borrow and waste site blocks are regarded as auxiliary blocks. They are members of set AUX. Borrow site blocks are however included in B^- as they involve excavations and are sources of earth for filling activities. Similarly waste site blocks are included in B^+ as they are

locations for fill. The size of each block *b* is specified by $(\Delta x, \Delta y, \Delta z)$ and its position in three dimensional space is given by the grid location, (x_b, y_b, z_b). Its middle point is similarly, $m_b = \big((x_b - 0.5)\Delta x, (y_b - 0.5)\Delta y, (z_b - 0.5)\Delta z\big)$. The volume of each block is denoted as v_b and the predominant soil type in each block is denoted as ω_b. However the volume of each type required (i.e. as cut and fill) is denoted by $cut_{b,s}$ and $fill_{b,s}$ respectively. A binary parameter that equals one if material of type *s* is acceptable in block *b*, and zero if material is not acceptable, is defined as $\kappa_{b,s}$. The fuel consumption of vehicles making hauls between block *b* and *b*' is denoted by $f_{b,b'}$. A binary decision variable denoted by $H_{b,b'}$ is defined to signify whether material is hauled from block *b* to b'. The volume to be cut from block *b* and moved to block b' of soil type *s* is also denoted as $Q_{b,b',s}$. Two competing block optimisation models utilise these decision variables. They are shown below.

Block Model BLM-1 (Mixed Integer Programming (MIP)):

Minimise $\sum_{b\in B^-}\sum_{b'\in B^+}\big(f_{b,b'} \times H_{b,b'} \times v_b/\hat{Q}_{b,b'}\big)$ [Total fuel consumption]
Subject to:

$\sum_{b'\in B^+}\big(H_{b,b'}\big) = 1 \quad \forall b \in B^- | b \notin AUX$ [Blocks moved to one destination]
$\sum_{b'\in B^-}\big(H_{b',b}\big) = 1 \quad \forall b \in B^+ | b \notin AUX$ [Blocks filled from one source]
$\sum_{b'\in B^+}\big(H_{b,b'}\big) \leq 1 \quad \forall b \in B^- | b \in AUX$ [Borrow site utilisation]
$\sum_{b'\in B^-}\big(H_{b',b}\big) \leq 1 \quad \forall b \in B^+ | b \in AUX$ [Waste site utilisation]
$H_{b,b'} = 0 \quad \forall b \in B^-, \forall b' \in B^+ | \omega_b \neq \omega_{b'}$ [Haulage restriction]
$H_{b,b'} \leq \kappa_{b',\omega_b} \quad \forall b \in B^-, \forall b' \in B^+$ [Haulage restriction]
$H_{b,b'} = 0 \quad \forall b \in B^- | b \in AUX, \forall b' \in B^+ | b' \in AUX$ [Borrow to waste site restriction]
$H_{b,b'} \in \{0,1\} \quad \forall b \in B^-, \forall b' \in B^+$ [Binary constraint]

Block Model BLM-2 (Linear Programming (LP)):

Minimise $\sum_{b\in B^-}\sum_{b'\in B^+}\sum_s\big(f_{b,b'} \times Q_{b,b',s}/\hat{Q}_{b,b',s}\big)$ [Total fuel consumption]
Subject to:

$\sum_{b'\in(B^+)}\big(Q_{b,b',s}\big) = cut_{b,s} \quad \forall b \in B^- | b \notin AUX, \forall s$ [Cutting constraint]
$\sum_{b'\in(B^-)}\big(Q_{b',b,s}\big) = fill_{b,s} \quad \forall b \in B^+ | b \notin AUX, \forall s$ [Filling constraint]
$\sum_{b'\in(B^+)}\big(Q_{b,b',s}\big) \leq cut_{b,s} \quad \forall b \in B^- | b \in AUX, \forall s$ [Borrow site utilisation]
$\sum_{b'\in(B^-)}\big(Q_{b',b,s}\big) \leq fill_{b,s} \quad \forall b \in B^+ | b \in AUX, \forall s$ [Waste site utilisation]
$Q_{b,b',s} \geq 0 \quad \forall s, \forall b \in B^-, \forall b' \in B^+$ [Positivity restriction]
$Q_{b,b',s} = 0 \quad \forall s, \forall b \in B^-, \forall b' \in B^+ | b, b' \in AUX$ [Borrow to waste site restriction]
$Q_{b,b',s} = 0 \quad \forall s, \forall b \in B^- | cut_{b,s} = 0, \forall b' \in B^+ | fill_{b',s} = 0$ [Haulage restriction]

These models differ quite considerably from previous approaches that only model the movement of material between sections in a horizontal fashion. Hence they are conceptually superior and somewhat novel. The two models are slightly different and it is a matter of conjecture (at present) which is most applicable to industry. The first model considers where blocks are to be moved to as fill. It is assumed that soil type within each block is uniform and blocks are whole. That is each cut block is initially full of material and each fill block has no material. Therefore "whole" blocks are cut, moved, and placed as fill and a blocks material is not divided; it goes to one location. This is not an unrealistic assumption in many situations. From a practical perspective it is perhaps more realistic to dig up a discrete block of earth and to shift it to one specified place as opposed to trying to accurately break it up into many

smaller parts and to send them to many specific locations. The second model is a relaxation of the first. Therefore block material can be divided and hauled as fill to many different locations. Conceptually the second model is superior, but practically it may not be possible to implement a solution as exactly specified by this model. It should be noted that $\hat{Q}_{b,b}$ and $\hat{Q}_{b,b'_s}$ denote the capacity of the vehicle making hauls between blocks. Dividing by these values, in the objective function, computes the number of hauls to be made. Details concerning the calculation of fuel consumption and other parameters can be found in Burdett and Kozan (2013b).

3. Case Study

The case study is a road construction project from Northern Queensland (Australia). Its length is approximately 7 km. The terrain and planned road profiles are shown in Figure 2.

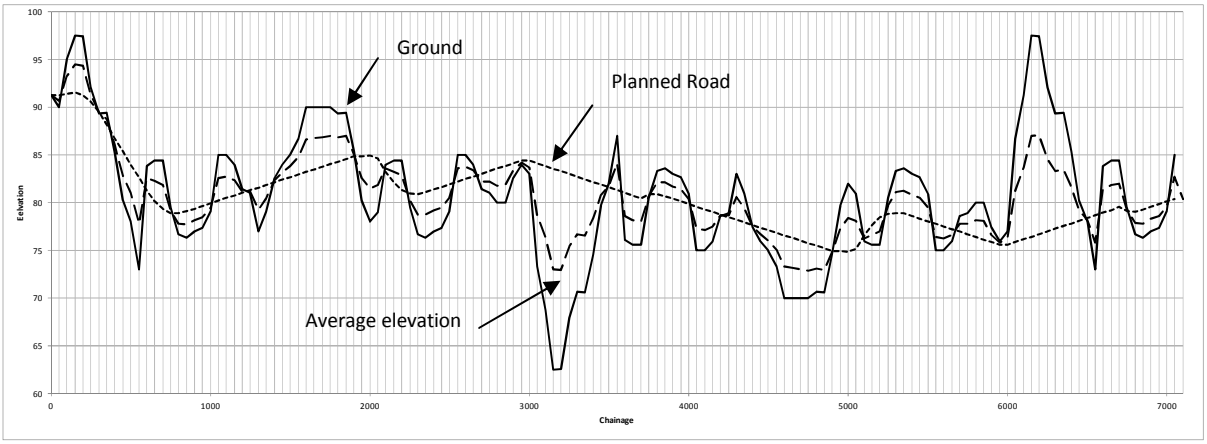


Figure 2. Longitudinal profiles of ground and planned road surface x-axis (chainage): 0-7 km; y-axis: 60 – 100 m (elevation)

The land is assumed to follow the line connecting adjacent elevations. Data occurs every 50 metres and the road width is 20 metres. A significant amount of cutting and filling are required and these “raw” amounts are fairly well balanced. The earthwork volumes are based purely on the longitudinal profiles, i.e. as the difference between the blue and red lines in Figure 2. The net cut and fill required is 304231.85 and 299246.81 cubic metres respectively; a difference of 4985 cubic metres. For this case study, one soil type has been considered and the cost of fuel is $1.50 per litre. Waste sites are placed at either end of the project (i.e. one for each cross section) and one borrow site occurs 30km to the right of the project site.

This case study has already been partially considered in Burdett and Kozan (2013b) but only 2D variants were solved in that paper and multiple soil types were addressed. A section based approach was also applied in that paper. It was found to be inferior, and therefore has not been reconsidered in this paper. As most construction projects are 3 dimensional, this paper provides an important link between theory and practice.

4. Numerical Investigations

This numerical investigation concentrates on solving 3D variants of the case study described in the preceding section. This is done as many road projects are solved as 2D problems. However some 2D variants are also solved for comparative purposes. A 3D problem is simply one that partitions the domain in each axis. Previous 2D variants of the problem did not partition the project site across the y-axis (i.e. only in x-z axis). In other words there was only a single cross section containing blocks.

Various blocks sizes have been investigated. This size directly affects the total number of blocks and is limited by the available memory on a computer. As blocks get smaller, more are required, and more decisions need to be made. From a theoretical viewpoint, the solution of earthwork problems with greater number of blocks is highly significant and very challenging from a computational point of view. However from a purely practical viewpoint, block sizes below a certain size are of limited value (at least in the near future) to contractors who perform the earthworks.

In this paper the OPL Studio software (also known as CPLEX) has been used to solve the mathematical "block" models. A quad core, Dell PC with a 2.5 GHz processor and 4GB memory has been used. The model parameters were computed in C++.

4.1. Cross Section Replication

Provided that elevations are constant across the y-axis, it is theorised that an optimal solution to the full 3D problem could be obtained by replicating the answer for a single 2D slice. In other words there is no movement of material between cross sections. This approach significantly reduces the size of the problem that must be solved. It also means that smaller blocks can be used and more blocks can be used within a single cross section. Otherwise, blocks have to be distributed across all three dimensions and fewer blocks can be used per cross section. This idea is shown in Figure 3.

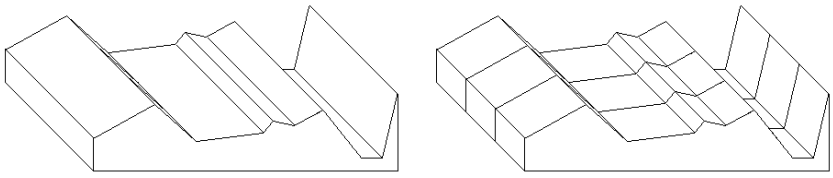


Figure 3. Single cross section versus multiple (i.e. three)

For this approach, the blocks models were applied and the results are shown Table 1 and 2.

Table 1. BLM-1 results for cross section replication approach

Variant	Block Size (sx, sy, sz)	#Block	#Cross Section	Metric	Distance (km)	Work (J)	Fuel Cons (litres)	Cost ($)	Cost Diff. ($)
2D	(100, 20, 1)	582	× 1	Work	31,115	9.5581E+10	95,581	143,372	79,243
				Distance	29,467	1.4841E+11	148,410	222,615	
2D	(100, 10, 1)	582	× 2	Work	15,557	4.7791E+10	47,791	71,686	79,244
				Distance	14,734	7.4205E+10	74,205	111,308	
2D	(100, 5, 1)	582	× 4	Work	7,779	2.3895E+10	23,895	35,843	79,244
				Distance	7,367	3.7102E+10	37,102	55,654	
2D	(50, 20, 1)	953	× 1	Work	21,071	6.6134E+10	66,134	99,201	34,575
				Distance	19,509	8.9184E+10	89,184	133,776	

2D	(50, 10, 1)	953	× 2	Work	10,535	3.3067E+10	33,067	49,600	34,576
				Distance	9,755	4.4592E+10	44,592	66,888	
2D	(50, 5, 1)	953	× 4	Work	5,268	1.6533E+10	16,533	24,800	34,576
				Distance	4,877	2.2296E+10	22,296	33,444	

Table 2. BLM-2 results for cross section replication approach

Variant	Block Size (sx, sy, sz)	#Block	#Cross Section	Metric	Distance (km)	Work (J)	Fuel Cons (litres)	Cost ($)	Cost Diff. ($)
2D	(100, 20, 1)	582	× 1	Work	13,776	4.9518E+10	49,518	74,277	15,934
				Distance	12,621	6.0141E+10	60,141	90,211	
2D	(100, 10, 1)	582	× 2	Work	6,888	2.4759E+10	24,759	37,138	15,936
				Distance	6,311	3.0070E+10	30,070	45,106	
2D	(100, 5, 1)	582	× 4	Work	3,444	1.238E+10	12,379	18,569	15,936
				Distance	3,155	1.5035E+10	15,035	22,553	
2D	(50, 20, 1)	582	× 1	Work	13,856	5.4556E+10	54,556	81,834	10,475
				Distance	12,651	6.1540E+10	61,540	92,309	
2D	(50, 10, 1)	953	× 2	Work	6,928	2.7278E+10	27,278	40,917	10,476
				Distance	6,326	3.0770E+10	30,770	46,155	
2D	(50, 5, 1)	953	× 4	Work	3,464	1.3639E+10	13,639	20,459	10,472
				Distance	3,163	1.5385E+10	15,385	23,077	

The distance metric used was Euclidean distance. The cross section column reports the number of cross sections and that the solution to the full 3D problem is the specified number of times larger. Table 1 and 2 shows that the work metric provides a reasonable improvement over those solutions obtained with the distance metric. The solutions obtained for a given (sx, sz) are all the same and different sy values had no effect on the final solution. The cost difference between BLM-1 is greater than BLM-2. This occurs because BLM-1 has less flexibility in how earth is to be divided. For example, a blocks worth of earth can only be moved to one destination. BLM-2 is given the opportunity to divide the earth as it sees fit.

4.2. 3D Instances

In this section, the y-axis is fully partitioned into blocks, and movement between cross sections is not limited. The results are shown in Table 3 and 4.

Table 3. BLM – 1 results for standard 3D problems

Variant	Block Size (sx, sy, sz)	#Blocks	Metric	Distance (km)	Work (J)	Fuel Cons (litres)	Cost ($)	Cost Diff. ($)
3D	(100, 10, 1)	1164	Work	31,115	9.5581E+10	95,581	143,372	79,243
			Distance	29,467	1.4841E+11	148,410	222,615	
3D	(100, 5, 1)	2328	Work	31,115	9.558E+10	95,581	143,372	79,243
			Distance	29,467	1.484E+11	148,410	222,615	
3D	(50, 10, 1)	1906	Work	21,071	6.6134E+10	66,134	99,201	34,575
			Distance	19,509	8.9184E+10	89,184	133,776	
3D	(50, 5, 1)	3812	Work	-	-	-	-	
			Distance	-	-	-	-	

Table 4. BLM – 2 results for standard 3D problems

Variant	Block Size (sx, sy, sz)	#Blocks	Metric	Distance (km)	Work (J)	Fuel Cons (litres)	Cost ($)	Cost Diff. ($)
3D	(100, 10, 1)	1164	Work	13,776	4.9518E+10	49,518	74,277	15,934
			Distance	12,621	6.0141E+10	60,141	90,211	
3D	(100, 5, 1)	2328	Work	13,776	4.9518E+10	49,518	74,277	15,934

3D	(50, 10, 1)	1906	Distance Work Distance	12,621 13,856 12,651	6.0141E+10 5.4556E+10 6.1540E+10	60,141 54,555 61,544	90,211 81,832 92,317	10,485
3D	(50, 5, 1)	3812	Work Distance	- -	- -	- -	- -	-

The time to solve the models was no more than several minutes in the majority of cases. On one of the largest problem instances (i.e. for the binary decision model BLM-1), the CPU time was in the vicinity of fifteen minutes. The last test problem in Tables 3 and 4 could not be solved as insufficient memory was available to generate the model. These tables show partitioning across the y-axis had no effect on the solution. The results are also the same as those obtained in Table 1 and 2. Therefore when elevations are constant across the y-axis, we can conclude that a 3D problem is optimally solved as a 2D problem. Upon closer investigation the reason for this is that distance is a significant component of fuel consumption and the distance between two blocks is shorter if the blocks are in the same cross section. This is similarly true as the elevations are the same across the y-axis. Graphically this is shown in Figure 4. For example it is less costly to move material from (1,1) to (2,1) as the distance is shorter. As the elevation at (2,2) and (2,3) are the same as (2,1), then there is no change in gradient.

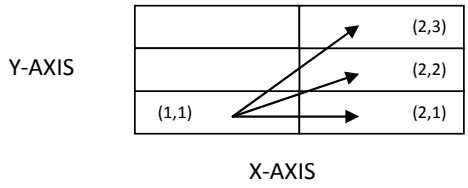


Figure 4. Increased distance when hauling between block (1,1) and (2,2) or (2,3).

Even though obtained solutions are the same in terms of cost and fuel consumption, we should point out that the solutions (i.e. the allocations) are all different. Therefore the numerical investigations as reported in these tables are still beneficial and required. These tables also show that each instance is actually solvable - something we would not otherwise know.

4.3. Revised 3D Instances

Because of the results of the preceding sub section, larger problems can be simplified and solved by cross section replication. If any of the aforementioned conditions are violated then we believe it is possible to improve the solution by partitioning in 3D. To test this hypothesis we have altered the position of waste (Wa) and borrow (Bo) sites and have resolved the optimisation models. The new position of waste and borrow sites is shown in Figure 5.

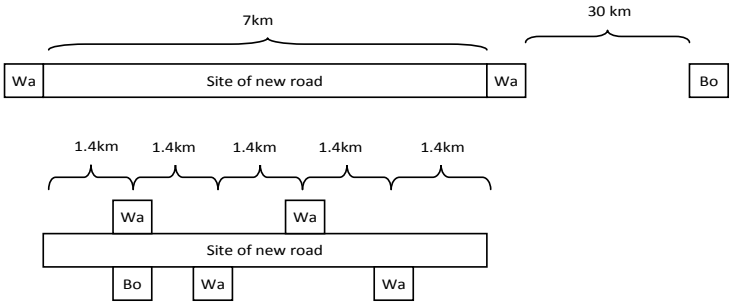


Figure 5. Original layout and the altered layout

The borrow site is now positioned closer to the road and is a more viable source of earth. Other material must therefore be disposed of in waste sites which are placed equidistantly along the length of the new road. The new results are shown in Table 5 and 6. These results show that the solution differs when the problem is partitioned into two or four cross sections. Hence the results of the previous section are in fact caused by constant elevations across the y-axis and certain symmetries in the position of borrow and waste sites. The total work required was negative in some solutions, and this means that the net effect of earth movements is downhill travel. This result in a rarity and is only obtainable because borrow and waste sites are very close to the project site, i.e. they are equidistantly placed on either side. This result is useful as it demonstrates that such an arrangement is highly beneficial and ensures that fuel consumption is minimal.

Given the different results obtained in Table 5 and 6, an interesting question that comes to mind is, how good is the cross section replication approach for solving the revised 3D problems? In other words, how close to optimal are the solutions? To answer this question the cross section replication approach was applied to the revised case study. The results are shown in Table 7 and 8. The values within brackets are for the whole problem and not for a single cross section.

Table 5. BLM – 1 results for revised 3D problems

Variant	Block Size (sx, sy, sz)	#Blocks	Metric	Distance (km)	Work (J)
3D	(100, 10, 1)	1164	Work	18,994	-1.6559E+10
			Distance	17,811	3.4148E+10
3D	(100, 5, 1)	2328	Work	19,630	-1.1172E+10
			Distance	18,147	3.7988E+10
3D	(50, 10, 1)	1906	Work	17,152	2.9940E+10
			Distance	15,772	5.5725E+10

Table 6. BLM – 2 results for revised 3D problems

Variant	Block Size (sx, sy, sz)	#Blocks	Metric	Distance (km)	Work (J)
3D	(100, 10, 1)	1164	Work	12,927	4.0608E+10
			Distance	12,031	5.2135E+10
3D	(100, 5, 1)	2328	Work	12,856	3.9993E+10
			Distance	11,959	5.1522E+10
3D	(50, 10, 1)	1906	Work	12,906	4.5116E+10
			Distance	12,019	5.4058E+10

Table 7. BLM – 1 results for cross section replication approach (revised 3D problems)

Variant	Block Size (sx, sy, sz)	#Blocks	#Cross Section	Metric	Distance (km)	Work (J)
2D	(100, 20, 1)	582	×1	Work	18,660	-2.2945E+10
				Distance	17,407	2.5685E+10
2D	(100, 10, 1)	582	×2	Work	9,328 (18,656)	-1.1491E+10 (-2.2982E+10)
				Distance	8,701 (17,402)	1.2823E+10 (2.5645E+10)
2D	(100, 5, 1)	582	×4	Work	4,664 (18,654)	-5.7490E+09 (-2.2996E+10)
				Distance	4,350 (17,400)	6.4075E+09 (2.5630E+10)

Table 8. BLM – 2 results for cross section replication approach (revised 3D problems)

Variant	Block Size (sx, sy, sz)	#Blocks	#Cross Section	Metric	Distance (km)	Work (J)
2D	(100, 20, 1)	582	×1	Work	12,928	4.0613E+10
				Distance	12,032	5.2150E+10
2D	(100, 10, 1)	582	×2	Work	6,432 (12,864)	1.9016E+10 (3.8032E+10)
				Distance	5,962 (11,923)	2.4695E+10 (4.9389E+10)
2D	(100, 5, 1)	582	×4	Work	3,216 (12,863)	9.5070E+09 (3.8028E+10)
				Distance	2,981 (11, 923)	1.2346E+10 (4.9385E+10)

These results are quite interesting as they show that the solution is steadily improving as the width of each cross section gets smaller and the number of cross sections increases. In relation to the results presented in Table 5 and 6, the above results are difficult to interpret. In an attempt to make more sense of the results, Table 9 and 10 have been provided. All that can really be concluded however is that the results are comparable. It is unclear why the cross section replication approach has returned slightly better solutions on a number of occasions.

Table 9. BLM-1 result comparisons

Variant	Block Size	Work	Fuel Cons	Cost
3D	(100,10,1)	-1.655900E+10	-16,559	-24,838
3D	(100,5,1	-1.117200E+10	-11,172	-16,758
2D×1	(100,20,1	-2.294500E+10	-22,945	-34,417
2D×2	(100,10,1	-2.298200E+10	-22,982	-34,473
2D×4	(100,5,1)	-2.299600E+10	-22,996	-34,494

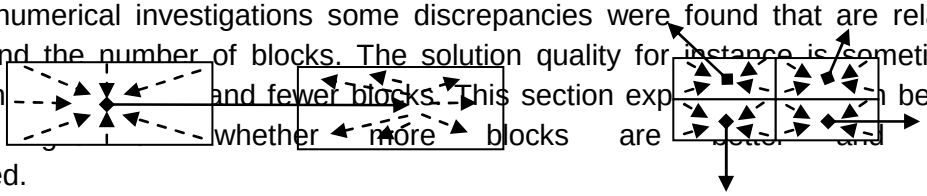
Table 10. BLM-2 result comparisons

Variant	Block Size	Work	Fuel Cons	Cost
3D	(100,10,1)	4.060800E+10	40,608	60,912
3D	(100,5,1)	3.999300E+10	39,993	59,989
2D×1	(100,20,1)	4.061300E+10	40,613	60,919
2D×2	(100,10,1)	3.803200E+10	38,032	57,048
2D×4	(100,5,1)	3.802800E+10	38,028	57,042

We conclude that the cross section replication approach is a viable approach to solving many problems. This approach is particularly useful for large problems that cannot be generated conventionally. If the cut and fill amounts are quite different across the y-axis then replicating the solution for a single cross section will not be useful. In this situation, each cross section can be solved separately. In this way the whole problem can be considered and a reasonable solution (but not optimal) can be obtained.

5. Block Size Benefits and Anomalies

In the numerical investigations some discrepancies were found that are related to block sizes and the number of blocks. The solution quality for instance is sometimes superior when th and fewer blocks. This section exp n behind this and sheds whether more blocks are and should be modelled.



a) Haulage between large blocks b) Division into smaller sub blocks

Figure 6. Effect of block size on earth movements

It has been assumed that all hauls occur from the middle point of one block to the middle point of another (see Figure 6a). This is a common practice and has been used in previous section based modelling approaches. All the movements required to haul material to the blocks central position (i.e. dotted red arrow in Figure 6) are however ignored in the current calculations. When the block sizes are decreased (see Figure 6b), then less material must be moved to the blocks centre (i.e. as they are smaller). In comparison to larger blocks, more of the earth movements are then taken into account and are modelled explicitly in the block optimisation models. Because more movements are modelled, the solution can be worse than the solution produced for larger block sizes. Though they have inferior key performance indicators (kpi), they are really better.

To prove this analytically, we define the effort of moving material to the centre of each block as follows:

$$\mathbf{TKM}(vol, dx, dy, nx, ny) = amt \times \sum_{i=1}^{nx} \sum_{j=1}^{ny} \sqrt{\left(x_i^{\mathrm{mid}} - x^{\mathrm{mid}}\right)^2 + \left(y_j^{\mathrm{mid}} - y^{\mathrm{mid}}\right)^2}$$

$$amt = \frac{vol}{nx \times ny}, \quad sx = dx/nx, \; sy = dy/ny,$$

$$x^{\mathrm{mid}} = 0.5dx, \quad y^{\mathrm{mid}} = 0.5dy,$$

$$x_i^{\mathrm{mid}} = (i - 0.5) \times sx, \quad y_j^{\mathrm{mid}} = (j - 0.5) \times sy$$

In the above equations TKM stands for tonne-kilometres. It is the sum of the product of the amount hauled by the haul distance. The equation for computing this amount is based upon dividing the block (which is of size (dx, dy)) into a number of sub blocks. The number of these in each axis is specified by *nx* and *ny* respectively. Hence the size of each sub block is given by (sx, sy). The movement from the middle of each sub block to the blocks middle point is then aggregated. The Euclidean distance is utilised. The amount of material within each sub block is equal, and given by *amt*. This equation can also be easily extended for 3D situations.

As the number of sub blocks increases the TKM value becomes more accurate and includes more and more of the internal movements. This is shown in Table 11 for a square block. It should be noted that nx and ny can be different. For any two values, it does not matter which is defined as nx or ny provided that the original block is a square (see Table 12). If the block is not square then the choice of nx and ny have a different effect (see Table

13 and Table 14). The value of TKM also does not necessarily increase with the number blocks. These differences all affect the solution of an earthwork allocation plan.

Table 11. TKM values for a 100x100 block with 500 tonnes of material

nx	ny	#blk	TKM	nx	ny	#blk	TKM
2	2	4	17677.7	8	8	64	19021.5
3	3	9	17883.1	9	9	81	19023.4
4	4	16	18721	10	10	100	19059.7
5	5	25	18743.6	20	20	400	19111.9
6	6	36	18940.9	100	100	10000	19129.2
7	7	49	18946.4	1000	1000	1000000	19129.9

Table 12. More TKM values for a 100x100 block with 500 tonnes of material

nx	ny	#blk	TKM	nx	ny	#blk	TKM
2	1	2	12500	7	1	7	12244.9
1	2	2	12500	1	7	7	12244.9
4	1	4	12500	3	2	6	18055.6
1	4	4	12500	2	3	6	18055.6

Table 13. TKM values for a 100x20 block with 500 tonnes of material

nx	ny	#blk	TKM	nx	ny	#blk	TKM
2	2	4	12747.5	8	8	64	12974.4
3	3	9	11998.5	9	9	81	12944.2
4	4	16	12893.9	10	10	100	12989.3
5	5	25	12714.3	20	20	400	13013.3
6	6	36	12947.9	100	100	10000	13022.7
7	7	49	12882.4	1000	1000	1000000	13023.1

Table 14. More TKM values for a 100x20 block with 500 tonnes of material

nx	ny	#blk	TKM	nx	ny	#blk	TKM
2	1	2	12500	7	1	7	12244.9
1	2	2	2500	1	7	7	2448.98
4	1	4	12500	3	2	6	12068.7
1	4	4	2500	2	3	6	12791.2

Given the effect of moving earth within blocks, this aspect should be included in all earthwork allocation models. Therefore all fuel consumption costs $f_{b,b'}$ should also include the fuel consumption of moving earth to the centre of block b and moving material away from the centre of block b'. The following example demonstrates the effectiveness of dividing the domain into smaller blocks, the possible improvement, and the additional calculations required.

Example: Consider a 100x20 metre block with 500 tonnes of earth to be moved to an adjacent block. Also consider a partitioning of the block into 50x10 sub-blocks (see Figure 7).

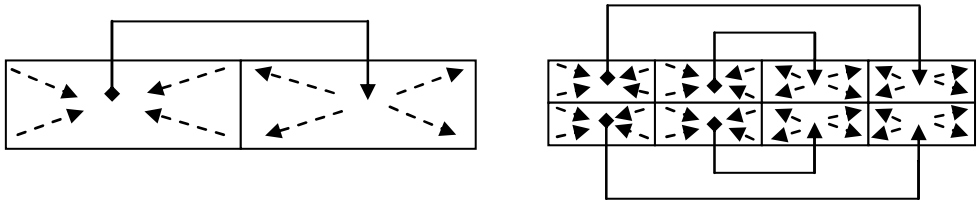


Figure 7. Graphical description of example

For *nx* = 1000 and *ny* =1000 the calculations are as follows:

Case 100x20: TKM_1 = 100 V + 2 ***TKM**(V,100,20,nx,ny)= 50000+ 2*13023.1 = 76046.2

Case 50x10: TKM_2 = 2*[150*(V/4) + 2***TKM**(V/4,50,10,nx,ny)]
+ 2*[50*(V/4) + 2***TKM**(V/4,50,10,nx,ny)]
= 2*[18750+2*1627.89] + 2*[6250+2*1627.89] = 63023.12

The results differ quite considerably in favour of the 50x10 partitioning.

6. Conclusions

The earthworks in a road construction case study were considered in this application paper. The main focus was to construct an earthwork allocation plan of least cost (or with least emissions), where cost is a direct measure of fuel consumption. The project site was partitioned into blocks and two block models were applied. 2D and 3D versions of the problem were compared to explore the effect of past simplifications. The computational burden of solving the block models (in 3D) was also investigated. In certain situations we have found that a 3D problem can be solved as a 2D one. When project domains (i.e. sites) are rectangular then it is most efficient to haul material along an axis rather than across it. In these situations, a 2D variant of the problem can be solved and replicated to obtain the optimal for the whole 3D problem. However in other scenarios this produces inferior solutions. As the number of blocks increases, the computational burden increases. This is particularly noticeable when considering 3D problems. In this paper we were unable to solve 3D problems with more than 2500 blocks, and a block size of less than 50 metres in length on a 7 km road project. More advanced solution techniques (such as graph theoretic, constructive algorithms, meta-heuristics) are hence necessary and/or the use of more powerful computers.

Reducing the block size and modelling more blocks is a superior approach as i) more earth movements are included and ii) earth can be moved to more destinations (i.e. improved decision making flexibility). Given the theory in Section 5, it is not possible to

directly compare the solutions for different block sizes as the block size also affects the amount of “internal movements-haulages” that are included in modelling activities.

Acknowledgements

This work was performed as part of an ARC linkage grant (LP110200314) in conjunction with Queensland University of Technology, Swinburne University and the Sustainable Built Environment National Research Centre (SBENRC).

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A new first-order decision-making model for the procurement of public sector infrastructure: Procedures and Testing

Poh Lian Teo[1], Adrian J. Bridge[2] and Jason Gray[3]

Given global demand for new infrastructure, governments face substantial challenges in funding new infrastructure and delivering Value for Money (VfM). As part of the background to this challenge, a critique is given of current practice in the selection of the approach to procure major public sector infrastructure in Australia and which is akin to the Multi-Attribute Utility Approach (MAUA). To contribute towards addressing the key weaknesses of MAUA, a new first-order procurement decision-making model is presented. The model addresses the make-or-buy decision (risk allocation); the bundling decision (property rights incentives), as well as the exchange relationship decision (relational to arms-length exchange) in its novel approach to articulating a procurement strategy designed to yield superior VfM across the whole life of the asset. The aim of this paper is report on the development of this decision-making model in terms of the procedural tasks to be followed and the method being used to test the model. The planned approach to testing the model uses a sample of 87 Australian major infrastructure projects in the sum of AUD32 billion and deploys a key proxy for VfM comprising expressions of interest, as an indicator of competition.

Keywords: decision-making model, infrastructure, procurement, value-for-money

1. Introduction

1.1 VfM challenge and weaknesses in MAUA approach to procurement

The global demand for infrastructure is increasing dramatically and governments are facing substantial challenges to fund public infrastructure and achieve value-for-money (VfM). OECD (2006) estimated USD3 trillion is required globally 2007-30 and in Australia there is an estimated pipeline of infrastructure projects amounting to more than AUD 770 billion (Infrastructure Partnerships Australia 2010). As such, leveraging private finance through Public-Private Partnerships (PPP) is considered to be a key mode of delivering new infrastructure in many countries (KPMG 2010). However, recent concerns have been raised in UK regarding uncertainties of PPP delivering VfM and criteria for early identification of projects suitable for PPP (House of Lords 2010). At the same time, PPPs have become largely a business as usual consideration in Australia, comprising separate contracts of design and construct; and operations and maintenance (Infrastructure Australia 2012).

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Procurement options analysis (POA) in the National PPP Policy Framework in Australia provides an approach for selecting a suitable procurement mode including PPP, and tends toward using semi-quantitative measures (use of rankings/perceptual scales and non-monetary) of costs/benefits of alternative procurement modes. In other words, client requirements (project outcomes) are systematically matched with the relative merits of alternative procurement modes in order to select the preferred procurement mode. This approach is also known as the Multi-Attribute Utility Approach (MAUA). MAUA is supported by a large body of work with around 900 studies related to MAUA and procurement systems, and has been regarded as "the foremost technique and approach for examining the criteria of clients and the preferences of experts' weights for each method in the most objective way" (Love et al. 1998). However, MAUA has inherent problems of implementation, that is, a lack of generally agreed and accepted set of criteria among the experts and difficulty in reaching consensus in the set of utility scores for each procurement method (Skitmore and Marsden 1988; and Love et al. 1998). Additionally, the range of procurement methods in research may not be comprehensive; the scores produced may differ by narrow margins which results in limited differentiation and less reliable selection; and the analyses may be carried out on limited range of trial projects (Sweeney 2009). These issues arise from MAUA's fundamental weakness associated with its tautological nature. That is, matching project outcomes with the relative merits of alternative procurement modes to select the preferred procurement mode (Chang and Ive 2002; Teo, Bridge and Jefferies 2010). The preferred procurement mode is defined as a subset, or effectively in the same terms, as the desired outcomes of the project and is therefore tautological, that is, the relationship is circular and considered a truism that is not falsifiable (Popper 1959). In summary, MAUA lacks scientific maturity and can be decoupled from the risk management plan given a justifiable rationale and which may not be economic. The top three boxes in Figure 1 indicate the direction of the current approach where procurement selection is based on matching project outcomes with alternative procurement modes (right to left). In other words, rather than deriving the procurement mode from project attributes (bottom three boxes left to right), other factors such as time is driving the selection of the procurement mode. Hence, the current approach is susceptible to non-economic influences and undermines risk analysis being carried out. This creates a narrow approach to VfM, where VfM is determined by whether or not the selected procurement mode delivers the key performance outcome. Furthermore, the current procurement approach also requires risk analysis to be carried out at early stages of the project where information is lacking, and requires guessing the nature and extent of potential risk events occurring, and subsequently second guessing the value and extent of these risks.

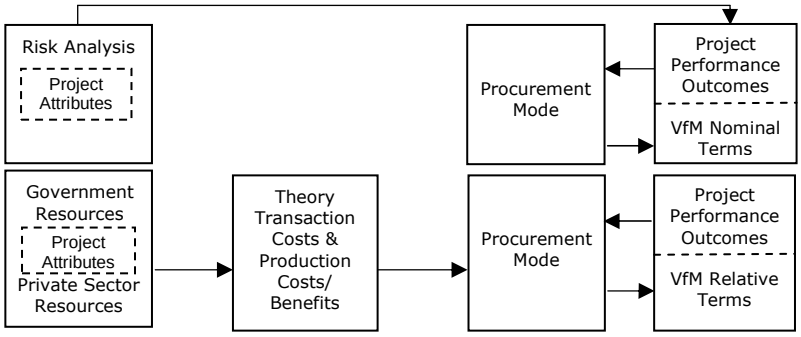

Figure 1 New model versus current approach

Hence from the above critique of MAUA, current research and practice appears to lack a sound basis to procure VfM across whole-of-life of the asset, and research in the construction literature is only beginning to show some signs that the dominant and Nobel prize winning theory from the New Institutional Economics field, that is, Transaction Cost Economics (TCE) and the dominant strategic management theory, that is, Resource-Based Theory (RBT), are being deployed in construction related sectors, for example, Chang and Ive (2002), Bridge and Tisdell (2004), Jin and Doloi (2008) and Sweeney (2009).

1.2 Compensating virtues of new first-order decision-making model

Given the weaknesses of MAUA, a new first-order procurement decision-making model (shown in Figure 2) has been developed and described elsewhere (Teo, Bridge, Gray and Rowlinson 2012; Teo, Bridge, Gray and Jefferies 2011; Teo, Bridge and Jefferies 2010). The new model deploys both TCE and RBT, to measure the technological and physical attributes of the project, as well as the relative capabilities and competencies of government versus the private sector with respect to the project, to identify a procurement strategy that is more likely to deliver a better ratio of production benefits to production costs and transaction costs across the whole-of-life of the asset, than procurement modes associated with the outcome of deploying MAUA. The key departure of the new model from MAUA is the model's analysis of make-or-buy decisions within the project at the individual activity level. That is, the focus is on production activities of design, construct, operations and maintenance of a first-order level, and not the organisation or management across activities which are considered second-order level. The project is divided into key activities. With knowledge of the key activities, the model measures the relative technical and/or organisational capabilities and competence of each activity across government and private sector, in terms of who is better placed to manage the activity. As such, the new model avoids issues arising from information gaps surrounding the new project during its early stages, and indirectly performs risk allocation at the activity level without having to guess with information missing at schematic stages and later second guessing when the buyer, for example, government or its agents, attempt to assess the nature and value of risks which are better understood by suppliers. In other words, the new model is more reliable and an appropriate level of analysis in terms of accessing who is better at dealing with inherent risks that might occur within the activity.

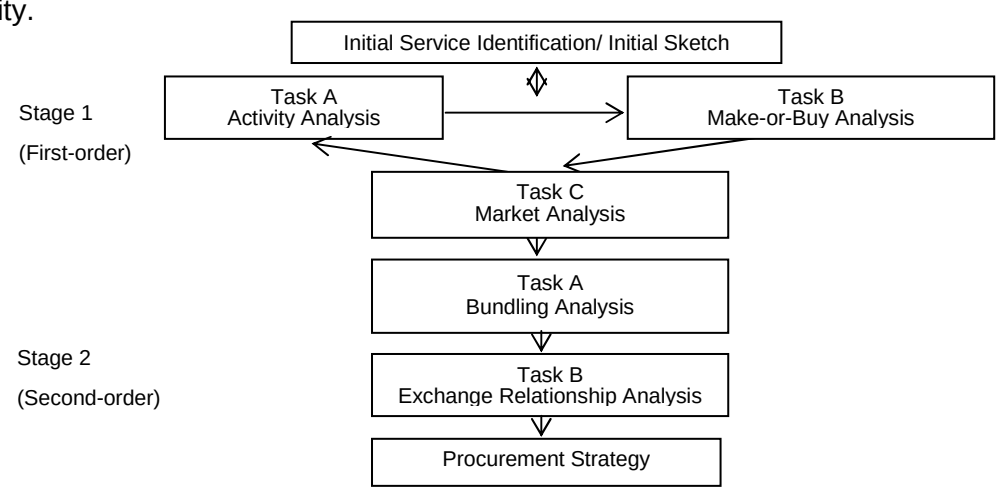

Figure 2 Schematic of new first-order procurement decision-making model

The model also provides a direct and clear connection between data gathering, including risk analysis, and the approach to procuring the project. As such, the procurement strategy is informed based on economical factors and not influenced by political goals, hence more likely to deliver superior VfM, or a better ratio of production benefits to production costs and transaction costs across the whole-of-life of the asset, than procurement modes associated with deploying MAUA. The paper aims to provide a step-by-step description of the new model and the approach of testing using competition as a dependent variable.

2. Procedures

2.1 Stage 1 Task A Activity analysis

The main purpose of Task A is to identify key first-order activities in the project. The distinction between key activities lies in the discrete technological boundaries, distinct knowledge base or skill sets, associated with design; construction; operations and maintenance (D,C,O,M) as the dominant source of adding value. Table 1 illustrates key activities of a typical road project. The key activity should be non-trivial in terms of significant cost relative to the capital cost of the project. The following are not a key activity: a milestone on the program, such as schematic design which covers many consultant disciplines; a building element which covers many trades; and organisational and/or management activity which includes planning/programming and supply chain management including procurement, as the main source of adding value. The scope of activity analysis is delimited to activities starting from and including schematic design (hence excludes upstream activities like planning and surveying site); to and including maintenance of built asset and operation to but excluding core/front-line activities (hence excludes downstream activities, such as clinical services in hospitals). This approach starts with focus on key production activities of D,C,O,M and is therefore first-order analysis, unlike current practice that starts at an organisational or second-order level, say managing contractor. Corresponding to the critique of inappropriate risk analysis, this approach avoids being too focused on individual risks and does not require guessing and second guessing of risks with information gaps. Furthermore, it provides a transparent framework based on economic principles, unlike MAUA where risk analysis can be overshadowed by the main concern of matching key opening day outcomes to procurement mode.

Design	Construction	Operations	Maintenance
Design of construction 1. Road civil engineering design 2. Traffic engineering design *Design of performance specification of maintenance* 3. Plan for routine maintenance, programmed maintenance and rehabilitation of road pavement, road furniture, drainage maintenance & ITS	4. Earthworks 5. Traffic management 6. Drainage and culverts 7. Retaining walls 8. Plant-mixed stabilised pavements 9. Sprayed bituminous surfacing and cover aggregate 10. Asphalt, including preparation, surfacing and grading 11. Roadside structures 12. Noise barrier 13. Line markings; markers 14. Electrical pits, conduits, fittings, including road lightings, ITS ducts and pits 15. Landscaping	16. Intelligent Transport Systems and traffic operations	17. Inspections & data collection, including reactive and programmed maintenance 18. Reactive maintenance 19. Rehabilitation

Table 1: List of typical key activities in a road project

2.2 Stage 1 Task B Make-or-buy analysis (on each activity)

This task involves measuring TCE and RBT attributes using a questionnaire instrument and then assigning an activity level for each key activity. The conventional approach in TCE views transaction costs which occurs across technological boundaries as the unit of analysis, and is mediated by governance structures (markets, hybrids and hierarchies) which lends itself to make-or-buy analysis (Chang 2013). Correspondingly, the first-order approach also leads into a make-or-buy analysis around the key activities/ transactions in Stage 1 Task B and which is effectively risk analysis using an indirect approach, by deploying RBT and TCE. RBT deals with technical/production risks, that is who is better at the key activity, either technologically or organizationally, and therefore better able to manage risks arising out of the key activity. TCE deals with external exchange risks arising out of hold-up as function of specific investment by one party to the key activity that creates a dependency of this party on the other party and which makes the less vulnerable party more powerful and able to behave in negative opportunistic ways on the occurrence of a change/variation. For example, changes in technology (high asset specificity), and demand and demographic changes (uncertainty beyond control), resulting in variations which causes potential for hold-up. Hence asset specificity and uncertainty are the more influential TCE variables in determining the possibility of hold-up in a key activity. Specifically, RBT measurements are concerned with relative capability and competence of government versus private sector and TCE deals with physical, technological or human asset attributes and addresses the issue of potential hold-up to the government by private sector. From applying the measurements, a pattern for each activity is matched with the closest theoretical/predicted pattern shown in Table 2. In doing so, the activity is suggested as internalised or externalised to achieve greatest efficiency, including the most efficient allocation of risks. Activities are internalised when the government uses its own resources to carry out the activity or when it owns more than fifty percent of the subsidiary firm, and externalised when contracted out to an external firm by the government directly or subsidiary indirectly. This approach of identifying the party best able to manage risks associated with an activity is a significant departure from current practice. Instead of identifying and assessing risks at the early stages of the project where information is missing, the emphasis is on resources owned by government versus private sector relative to each project activity. Hence, this approach is able to more reliably anticipate which party is better at managing the risks associated with each activity.

Level	Logic	Asset Specific (TCE)	Uncertainty (TCE)	Frequency (TCE)	Value (RBT)	Rare (RBT)	Costly To Imitate (RBT)	Mode of Govern'
1	Capability	+ / + + +	0 / + + +	+ / + + +	+ + +	+ / + + +	+ / + + +	Internal
2	Capability	0 / + + +	0 / +	+ / + + +	+ +	+ / + +	0	Internal
3	Transaction Costs/ Capability	0 / + + +	0	+ / + + +	+	0	0	Internal
4a	TCE	+ / + + +	+ / + + +	+ / + + +	0	0	0	Internal
4b	TCE	+ / + + +	+ / + + +	0	0	0	0	External
5	Transaction Costs/ Capability	0	0	0	-	0	0	External
6	Capability	0 / + + +	0 / + + +	0 / +	- -	+ / + +	0	External
7	Capability	0 / + + +	0 / + + +	0 / +	- - -	+ / + + +	+ / + + +	External

Table 2: Integrative framework of vertical integration (from Bridge and Tisdell 2004; Bridge 2008)

2.3 Stage 1 Task C Market analysis

From here on, the focus is the procurement of externalized activities. SCP analysis is used to corroborate the levels of activities identified, and consider any Level 7 activities arising out of large scale of this activity's work. If any of these activities are found, the model suggests attempting to break down into two or more smaller/sub-activities to reach the next tier of firms specialising in these activities. This avoids lack of competition due to size or possibly more powerful sub-market firm (for example, subcontractor) as part of supply chain by main-market firm (main contractor).

2.4 Stage 2 Task A Bundling analysis

The model then considers any potential troublesome activities that will lead to government becoming dependent/vulnerable and market firms becoming more powerful, that is, Level 4b activities that can potentially cause hold-up *ex post* arising out of high asset specificity and high uncertainty, or any residual Level 7 activities that cannot be further broken down because of physical/proximity issues or Level 7 activities arising out of rare technology leading to a lack of competition, and market power to set prices *ex ante*/pre-contract and which again can cause hold-up problems *ex post*/post-contract. Next, the model determines if any of the potential opportunistic behaviour by market firms associated in these troublesome activities be checked by the firm engaged at the head of supply that includes these activities, for example main contractor at the head of the supply chain that is coordinating/subcontracting these troublesome activities using threat of future work to attenuate any potential negative opportunistic behaviour. If not, then considering either 1) a special relationship with the firms providing these troublesome activities through the firm being engaged at the head of the supply chain that includes these troublesome activities (for example, use of PC Sum and a nominated subcontractor/supplier arrangement) which then drops down into an exchange relationship consideration; or 2) a separate contract between the firm/government and the firm providing the troublesome activity, that is, excluding the troublesome activities from any subsequent bundle.

This task refers to Property rights theory whereby creating greater ownership, such as bundling operations and/or maintenance (O&/M) together with design and construct contracts (D&C), the firm is likely to invest more to gain greater returns in investments in the long term. Conversely, less bundling means lower incentives to provide better quality or design. By bundling O&/M into the contract, such as DCM, DCOM or PPP, there is greater ownership which makes the contractor responsible for operations & maintenance of the asset, and so greater likelihood of investments in production and non-production related investments. In addition, Hart (2003) indicated that if a service delivery provision is not clearly specified, contractor has the flexibility to modify the nature/quality of the facility without violating the contract. In contrast, in D&C, the contractor does not internalise any operating costs and there is little incentive for investment, where they perform minimum production and non-production related investment. If there is a lack of specification of production quality and more focus on the service provision, contractors may have the flexibility to choose lower productive investments, that is providing a cheaper and lower quality solution for the client. Hence, property rights do not favour D&C contracts and where

contracts that cannot be specified clearly, favours conventional provision (or unbundling), for example, construct only instead of PPP (Hart 2003).

The next step is to bundle remaining key activities into main activities of D,C,O,M, and undertake second-order analysis (assess the activities of organizing/managing each of these main activities, such as, main contractor on construction). And similarly break down each activity if size and/or complexity of main activity leads to Level 7 (again, leading to lack of competition and market power to set prices ex ante and hold-up problems *ex post*). Next, the model identifies any potential viable major activities, that is, bundle(s) of either DCO main activities or DCM main activities or DCOM main activities as PPP(s), or otherwise via contract(s) and remainder as separate D/C/O&M main activities with each main activity organized by government (either directly and/or using market firm, such as, PM/consultant). In sum, there are three levels of activities; namely 1) key activities (about highest level of market specialization); 2) main activities (set of D or C or O or M key activities); and 3) major activities (set of DCO or DCM or DCOM main activities). Organisation and management of activities includes, planning and coordination of timing of tasks within activities; and across key activities in main activities; and across main activities in major activities.

2.5 Stage 2 Task B Exchange relationship analysis

This task involves re-measuring TCE variables at the exchange between government and the market firm that can provide each major activity (bundle) and/or each main activity and/or each key activity to determine the most efficient exchange ranging from 1) efficient relational exchange, such as, Alliancing or pain/gain share regime to 2) efficient discrete exchange (such as, arms-length exchange, or standard neo-classical contracting such as, lump-sum/fixed-price contracts with mechanisms to resolve dispute by third parties and 3) short-term inefficient discrete exchange, such as, non-standard contracts written with bespoke credible threats for non-performance (See Figure 3 for summary). This measurement now includes the task of planning and coordination *across* key activities and so this measure of main and major activities may produce a different result on the TCE variables than that recorded across the TCE results measured in the constituent key activities.

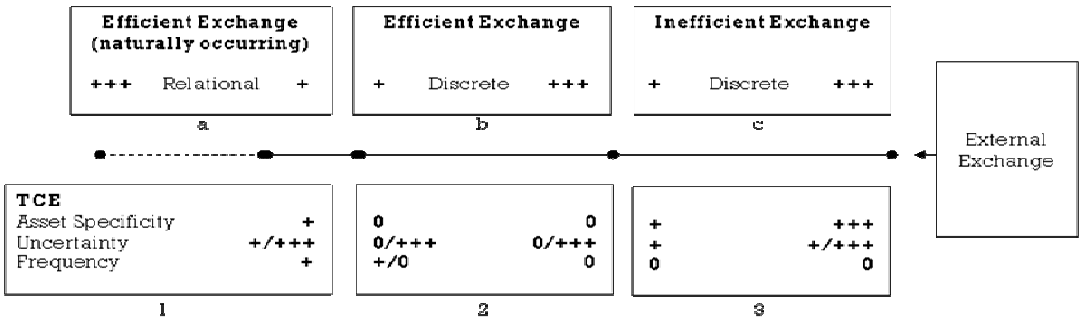

Figure 3: Exchange relationship analysis (Bridge 2008)

In Box 1, activities have a very high potential for hold-up due to high asset specificity and high uncertainty, that is Level 4b, and government can more efficiently seek to control these activities using more relational exchange, such as collaborative approaches or share risks in an alliance fashion. Main or major activities dominated by Level 5 and 6 activities are

reflected in Box 2 which can yield an efficient transfer of risk and control to the contractor. Standard neo-classical contracts can be deployed to obtain a fixed price for construct only and/or DC and/or DCOM package. If DCOM with private finance is being used in Pattern 5 and 6 activities, then a conventional PPP arrangement is appropriate. Box 3 reflects activities with a very high potential for hold-up (Level 7), but unlike Level 4b, government lacks in-house capability and access to agents to effectively collaborate with the contractor in terms of D,C,O,M. In transferring control to the contractor, government can seek assurances through writing contracts with credible threats concerning compliance with contracted performance, and hence a very arms-length and discrete exchange with the contractor/consortium.

3. Approach to testing the new first-order decision-making model

3.1 Developing competition as a dependent variable/proxy for VfM

The preferred method of demonstrating VfM is through estimation of costs and benefits associated with alternative procurement modes of a project over the whole life of the asset. However, a lack of quantitative and comparable data in operations and maintenance creates difficulties in measuring VfM using an absolute monetary value. In cases where the concept is not able to be measured directly, Remler and Van Ryzin (2011) recommended developing a proxy, that is a “measure that substitutes for another unavailable measure”. Competition has been widely recognised and accepted to be the determinant of value. Surveys regarding critical success factors for PPP have been conducted in many countries, including Australia, United Kingdom and Hongkong; and results have identified competition as one of the key VfM drivers (Andersen 2000; Cheung et al. 2009; Dixon et al. 2005). In economic terms, competition drives down marginal costs and creates downward pressure on prices. Not only does absolute level of competitive tension create downward pressure on prices but it also facilitates the crystallisation of innovations in the design that impinges on time, cost and quality and which will influence the overall performance of the project across its life-cycle. Studies have shown empirically that greater number of bidders have the effect of reducing value of lowest bid (McCaffer 1979; Skitmore 2002; Domberger and Rimmer 1994). Auction theory scholars have empirically demonstrated that in a sealed tender auction, perfect or intense competition leads to convergence of the true value of the object even when bidders have incomplete information about the value (Brannman et al. 1987). Gupta (2002) examined 1,937 highway construction projects over five year period, and results show that absolute level of competition creates downward pressure on price, that is the value of winning bids decreases as number of bidder increases and the effect on value becomes insignificant when the absolute number of bidders reaches a maximum, that is, competitive threshold. Gupta derived competitive threshold to be 6-8 bidders in an open tender, subject to factors, such as size of project and market conditions. Gupta (2002) made the important contribution of an optimal level of competition that is dependent on size and bundling of the project and market at the time of tender.

For the purposes of this study, actual competition is measured by the attractiveness of the project using the number of firms demonstrating their willingness to bid either through open tendering (OT) or Expressions of Interest (EoI). This avoids measuring competition based on

selective tendering, which does not reflect the level of interest in the market. The next section discusses competition and market failure before or *ex ante* and after or *ex post* a transaction/contract, and how the model is able to address potential market failure.

3.2 Market failure *ex ante*

In neoclassical economics, one major driver for market failure is lack of competition, resulting an inequilibrium in allocation of goods and services or Pareto inefficiency in a free market. In TCE terms, transaction costs in general impede the formation of the market (Arrow 1969). For example, in a monopoly or duopoly where there are only one or two competitors in the market, market equilibrium will not be considered Pareto efficient and indicates the potential for market failure due to a lack of competition or imperfect competition. There is lack of incentives for contractors to be innovative in order to be price competitive, and that can impinge on performance across the whole life cycle. The new model deals with lack of competition by dividing up the project/activity into bundles of activities mindful of the market or supply. For example, empirical results show limited numbers of contractors capable of AUD800 million and above in Australian major infrastructure market (Teo, Bridge, Gray and Rowlinson 2012).

3.3 Market failure *ex post*

A study of major infrastructure market in Australia shows that current contracting practice may have resulted in market failure *ex post* (Sweeney 2009). Market failure is not an absolute theory (Arrow 1969), and in addition to lack of competition, TCE envisages market failure occurring *ex post* due to post-contractual opportunistic behaviour. Opportunistic behaviour is not uncommon in the construction industry especially for complex projects associated with high uncertainty, and the market may perceive the project to be lucrative in terms of a potential for variation claims, and the opportunity to make superior profits post contract. Sweeney (2009) examined the Australian market and observed that contractors may use low bid tendering strategies to win contracts in an extremely competitive market (that is high EoI), and adopt a claim strategy resulting in high variation claims *ex post*. The new model deals with opportunistic behaviour in transactions susceptible to changes, when the environment is too complex or uncertain to be fully specified (Level 4 activity), or when the market is limited to a small number of players (Level 7 activity). Main contractors/ subcontractors can hold-up clients/main contractor, when the activity is on the critical path and susceptible to time and cost delays. In summary, as high EoI (over 6-8 EoI) have been shown to yield little production benefits in terms of lower prices and lower incentives for design innovations and at same time may indicate the prospect of *ex post* market failure, then 6-8 is derived as an optimal level of competition and consistent with VfM for purposes of this study.

3.4 Testing new first-order decision-making model

The new first-order decision-making model is tested using competition as the dependent variable as illustrated in Figure 3, and the corresponding hypothesis is given as:

- *In cases in which actual procurement matches the theoretical procurement (informed by new first-order decision-making model), then actual competition is expected to be closer to optimum competition (6 to 8 EoI), than in cases of an appreciable mismatch between actual procurement and theoretical procurement.*

Data has been collected on actual procurement (Box A), actual competition (Box D) in both road and health projects in Australia via questionnaire survey of government road and health departments; and also optimum competition (Box C) via nationwide contractor survey. Based on results Box A and Box D (a representative sample of 87 road and health projects worth AUD32 billion), Teo, Bridge, Gray and Rowlinson (2012) has already shown the general relationship between procurement and competition. That is, a significant relationship between EoI and size/value, bundling and payment terms.

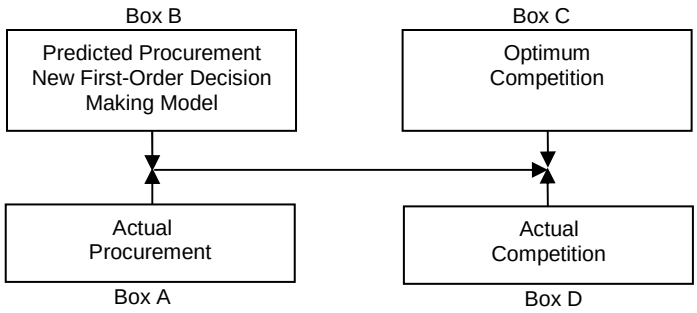

Figure 3: Procurement-tendering-competition hypothesis

In the final step of testing the hypothesis, case studies are selected from the sample of 87 projects. Multiple case studies are preferred as this approach can test theory in different sectors and attest reliability in different projects. If two or more cases have been shown to support the theory, then replication has been achieved. Based on theoretical replication and the spread of EoI in the sample (largely low levels of EOIs to around optimum levels), an approach is taken in which low/high EoI and optimum EoI are replicated, and based on literal replication, the same results will be duplicated, that is low/high EoI and optimum EoI are repeated for road and health sectors. The case study design is illustrated in the 2x2 matrix in Figure 4. The model is expected to predict a different procurement approach from practice at low/high level EoI and similar procurement approach at optimum level EoI.

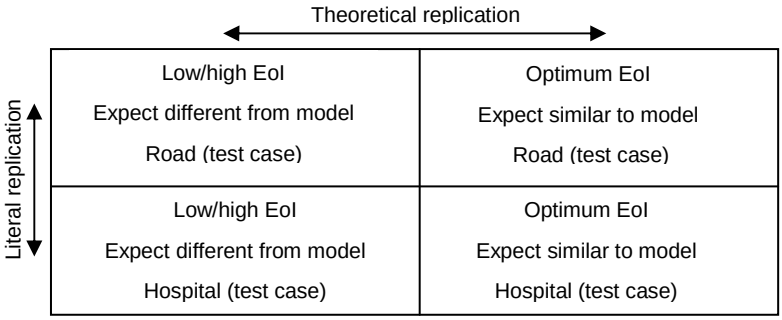

Figure 4: Multiple case studies replication design

4. Conclusion

In summary, the new first-order procurement decision-making model addresses the weaknesses of MAUA and provides a more reliable method of risk allocation which is based

on Nobel Prize winning economic theory. The new procurement model is not predisposed to any particular procurement mode, and identifies an efficient procurement approach, including size, bundling, and exchange relationship (including payment terms); by deploying TCE and RBT at a first-order level of the project. The model may uncover projects/bundles of activities within projects that may be investigated as potential PPP, and able to cope with changing market conditions and resources of government relative to private sector at the time of project and in any location.

5. Acknowledgement

This research was supported under Australian Research Council's Linkage Projects funding scheme (project number LP0989743).

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Corporate real estate management: More than clients' and users' procurement

Christopher Heywood[1], Russell Kenley[2]

Abstract

This paper draws on the emerging property discipline – Corporate Real Estate Management (CREM) – to more completely conceptualise the entity that is meant by 'clients' and 'users'. With CREM's focus on meeting CRE organisations' business objectives this theory provides a stronger definition of clients and users as it displays more of their multi-dimensional nature that can manifest in procurement relationships.

Six theoretical CREM models are presented, reviewed and integrated into a single, coherent model. These models are that: 1) Real estate is more than buildings; 2) CREM is the demand-side to the real estate economy; 3) The five roles of corporate real estate must be addressed and balanced; 4) CREM evolves in its strategic capacity; 5) CRE's levels of strategic-ness; and 6) CREM encompasses multiple domains of practice across strategic, tactical and operational levels. This reveals that, while there is much importance in procurement relationships, CREM is much more than procurement.

The paper provides cross-over theory applicable to both real estate and construction management theory and practice. There are potential implications for those researching how the demand-side (corporate real estate and facilities management) and supply-side (construction management) engage with each other but this requires further research. This model provides a basis for doing so.

Keywords: Clients, Construction management, Corporate real estate projects, Theory, Users

1. Introduction

The real estate economy – collectively the real estate, design, and construction industries – has many diverse entities and relationships. Broadly, these are its demand and supply sides where the former (conceptualised here as Corporate Real Estate Management (CREM)) consumes real estate and services and the latter provides them.

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This paper argues that corporate real estate (CRE) organisations are, essentially, the same entities as 'clients' and 'users'. The CRE literature provides a stronger, though still emerging theoretical basis for the entity as it displays more of CREM's multi-dimensional and evolving nature. This is useful when thinking about clients and users as it better displays the entity's internal dynamics that manifest in procurement and it also suggests contrasting perspectives on, and power dynamics in, that procurement.

Corporate real estate is a major part of the real estate economy's demand-side[3] and houses the productive or business activities of an organisation that owns or leases real estate incidental to its business objectives, where the primary business is not real estate (after: Brown et al. (1993), and Kenley et al. (2000)). This CRE organisation is the entity that acts as clients and contains many users. Consequentially, managing CRE is conceived as aligning real estate and its services with the core business to maximise the contribution to the core business rather than to maximise the real estate value, and to contribute in an optimal way to the overall business performance (from Dewulf et al. (2000: 14)).

CREM has emerged over the last 20 to 30 years as a distinct real estate discipline. In understanding CREM in relation to being clients and users distinction needs to be made between CREM as necessary organisational function and CREM as an organisational unit. The former is required by all organisations because they occupy space for business purposes. The latter is one or more personnel responsible for managing the CRE. These may be real estate people but this is not always the case with instances of clerical personnel being solely responsible for carrying out CREM. The distinction between the two forms of CREM recognises that while CRE decisions are always necessary they are not always supported by dedicated organisational resourcing.

2. The research problem

The construction management discipline has expressed an interest in 'clients' and 'users' to build better bridges within the real estate economy, as evidenced by the creation of the CIB Working Commission W118. Concerns about clients are longstanding around the world, as exemplified by the UK's Latham and Egan Reports of 1994 and 1998 respectively, and similarly in Australia (Purchasing Australia, c1995). There are also numerous publications directed at construction and design industries to understand and help their clients. Boyd and Chinyio's (2006) reference lists contain useful examples. CREM's take on procurement in recent years has been framed in terms of outsourcing both the real estate through leasing, the partial or total outsourcing of the management function, or integrated into a single contract (Dixon and Pottinger, 2006). It is rare, though, for CREM to reflect on 'client-ness' and users has most recently been focussed on in considering workplace styles (Appel-Meulenbroek et al., 2011; Oseland, 2009).

[3] The other major part is residential real estate and even here some is CRE for accommodation businesses. This paper focuses on CRE.

The use of ‘clients’ in the real estate economy conceptualises a relationship formed around procurement of construction products and services during construction, and occupation and use. The ‘client’ perspective is that of the supply-side, that is, the supply-side has clients. ‘Clients’ also contains connotations of an expert provider and inexpert consumer with commensurate power dynamics.

‘Users’ represents a supply-side relationship with the demand-side post-procurement and also a concern with the demand-side’s relationship to the constructed product. ‘Users’ can be differentiated into:

- The occupying (CRE) organisations;
- Their sub-entities or business units (if any);
- The individuals within those organisations; and
- Members of the general public that interact with the CRE.

Therefore, the question that this paper addresses is, how can the entities described as ‘clients’ and ‘users’ be better conceptualised to represent their multi-dimensional and evolving nature in the demand and supply relationships of the real estate economy, and what are some the implications of that.

3. Method

The paper’s contribution to knowledge is based on the authors’ decade-long deep immersion in CREM theory through research and teaching. This provides insights into what it means to be the demand-side to the supply-side’s real estate, design, and construction products and services. The deep immersion allows the synthesis of six theoretical models into a more complete conceptualisation of the real estate economy’s demand side and discussion of its value in understanding CREM and its procurement.

4. The demand-side models

Six models are presented here as a basis of forming a coherent theoretical basis to the demand-side. They are:

1. (Corporate) Real Estate is more than buildings;
2. CREM is the demand-side for supply chains for products and services when real estate and construction exists for consumption by clients and users;
3. CREM encompasses five roles in CRE organisations’ economies that must be addressed and balanced in managing CRE;
4. CREM has evolved through levels of strategic development;
5. CRE has varying levels of ‘strategic-ness’ with implications for its management; and
6. CREM comprises multiple, inter-connected domains of practice.

4.1 Model 1: (Corporate) Real Estate is more than buildings

Real estate theory, to which CRE and CREM theories belong, is founded on real estate's heterogeneity with its uniqueness derived from a conflation of location, site and the improvements (commonly called buildings). This emphasises the physical artefact.[4] Location can be further disaggregated to the site's surrounding physical, economic and social contexts. The building can be disaggregated into (from a real estate perspective) its constituent sub-assets. These are very similar to the constituent building elements used in construction. Real estate value is often construed in terms of wealth founded on economic rents derived from occupation. For CREM, value is largely, though not exclusively, derived from functionality and utility afforded by the location and its improvements.

Called the real estate artefact here as the most complete conceptualisation it is clearly evident that various real estate economy entities fundamentally conceive the artefact differently. This gives rise to differences in semantics and cognitive concepts that need to be addressed if a common understanding is to be achieved. Construction sees the artefact as a 'building' (as consistently used by Boyd and Chinyio (2006)). This can be slightly expanded to include its site but only in so far as it impacts on the construction process, for example, ground conditions. For real estate generally, there are more dimensions as a 'property' tangibly consists of the site (land), its context (usually taken as location) and the building (improvements to the land), and the consequential non-tangible property rights. For CREM, these concerns are further enlarged to include the property's impact on the business and what the business requires of the property. The end result of this is that CREM brings with it multiple meanings when acting as a client or user and interacting with the supply side in a project, but may encounter a smaller set of meanings on the supply-side.

4.2 Model 2: CREM is the demand-side

A consumption-based perspective on real estate, implicit in 'clients' and 'users,' defines two forms of real estate – CRE, that is the real estate for some 'business' purpose, and residential real estate. This perspective emphasises the real estate economy's demand-side characteristics as the driver in that economy and the economy's purpose in meeting that demand (Heywood and Kenley, 2010). This suggests a different dynamic from that frequently met in real estate and construction theory which is supply-side dominated. With a consumption perspective it can be argued that every other activity in the real estate economy exists to meet the demand-side's needs (Figure 1).[5] Three types of real estate products and services are identifiable. One is procuring new CRE requirements that can be met from the existing property stock. Two, is procuring new CRE requirements that needs new stock, and three, CREM requirements that need services to operate the property and the business. The services could be both management services and technical, operational

[4] Another foundational real estate concept is that real estate is a bundle of rights where abstract, non-tangible concepts such as the legal foundation of rights, rights of use, rights of entry, and the like are emphasised (Reed, 2007).

[5] This is clearly contestable given that every participant in the real estate economy has a different stake in that economy's products and outcomes.

services. Furthermore, the demand-side has become complex with more extensive CREM outsourcing to replace or to augment the demand-side CREM capacity. Initially on the supply side, post-contract these service provider(s) move to create a hybrid demand-side entity. Such relationships raise issues in the service providers' agency capacity to represent or act for the CRE organisation (Gibler and Black, 2004). We note them but discussing these issues is beyond the scope of this paper.

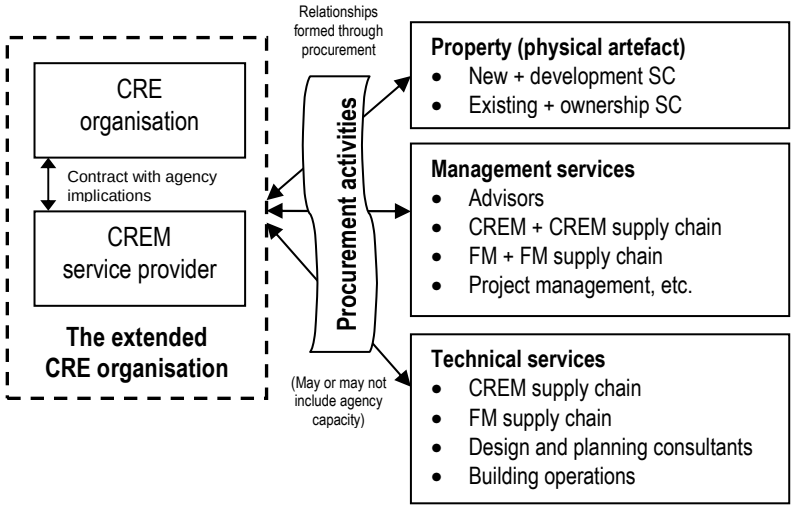

Figure: A framework for demand-supply entities and relationships (After: (Heywood and Kenley, 2010, Figure 1))

At present, power tends to reside with the supply-side for several reasons. These include: 1) The semantics of 'client' and also 'customer' as supply-side concepts with expertise held by the provider; 2) The low weight of numbers in CREM research (Heywood and Kenley, 2013) compared to supply-side research in real estate and construction, 3) Real estate theorisation is most focussed on the supply-side's wealth in investment real estate; and 4) Consequently, there is a dominance of 'client' in the discourse about procurement. Recognising the importance of clients and users does shift power to the demand-side and it also opens up the conceptual space for 'customership' (Kuronen et al., 2011) to represent this changed power dynamic, customership being what the demand-side bestows on the supply-side as a result of being their customer.

4.3 Model 3: CREM encompasses five roles in CRE organisations' economies

One of the complexities of CREM is recognising that real estate plays five roles in CRE organisations' economies, and that these roles need to be balanced in any CRE action, including those that result in procurement. The five roles are:

1. A factor of production;
2. A corporate asset;
3. An investment;
4. A commodity; and
5. As public infrastructure (Heywood and Kenley, 2013).

The CRE as a factor of production is one of the most important CREM roles when clients and users are considered in procuring, producing and using real estate. Self-evidently, achieving property that functions well in production is a key outcome of any procurement. However, internal to the CRE organisation all the other roles do need to be considered in moving to procurement.

4.4 Model 4: CREM's evolution through levels of strategic development

As an emerging real estate management discipline CREM is developing its capacity to meet the strategic needs of its organisation. Joroff et al. (1993) conceived this in five-steps:

1. Taskmaster:
2. Cost controller;
3. Dealmaker;
4. Intrapreneur; and
5. Business strategist.

Each step can be defined in terms of the information used, personnel involved in management, decision criteria, treatment of capital costs and internal pricing mechanisms. Each evolutionary step above that exhibits greater strategic capacity as each step subsumes the strategic capacities of the lower levels. Individual organisations will be at one of the levels and (hopefully) will move to higher levels over time. The Taskmaster level is basic real estate competence with regard to technical requirements and specifications. CREM at this level can be very expert and may well adequately be able to write functional briefs and manage projects.

The consequence of this model in the real estate economy demand-supply model is that over time the supply-side will meet different levels of strategic sophistication, depending on CREM's evolution. The sophistication will be found in the demand-side's understanding of the strategic intent of procurement, and can play out in the procurement of the CREM function and its mix of internal and external staff and their skill sets (Joroff et al., 1993). In projects it is possible that a more strategic orientation to procurement methods will be evident, as will, in project initiation, the information used to create briefs – for instance, aspirational or performance briefs are more likely parts of that initiation at higher levels, though this is yet to be emprically tested

4.5 Model 5: CRE's levels of 'strategic-ness'

It is largely self-evident but not every project or real estate activity has the same strategic value to the CRE organisation (Kaya et al., 2004), and as a consequence, may not receive the same attention from CREM. To represent this value several CREM classification systems have been proposed though none of these are consistent or conceived on the same basis. For instance, Kaya et al. (2004) used the European Quality Management Framework, Adendorff and Nkado (1996) used need and redundancy, and Park and Glascock (2010) used a strict interpretation of the resource-based view of firms. This suggests that additional theorisation is necessary to resolve such inconsistencies (Heywood and Kenley, 2013).

4.6 Model 6: CREM comprises multiple domains of practice

CREM is responsible for providing new CRE and managing existing CRE requirements, though the latter is often called Facility (or Facilities) Management (FM). CREM deploys multiple domains of practice organised into strategic, tactical (Management and Control here) and operational levels (Figure 2). Procurement intersects most with operational levels such as FM, project management, and CRE transactions in managing tenure in leases and purchase for ownership.

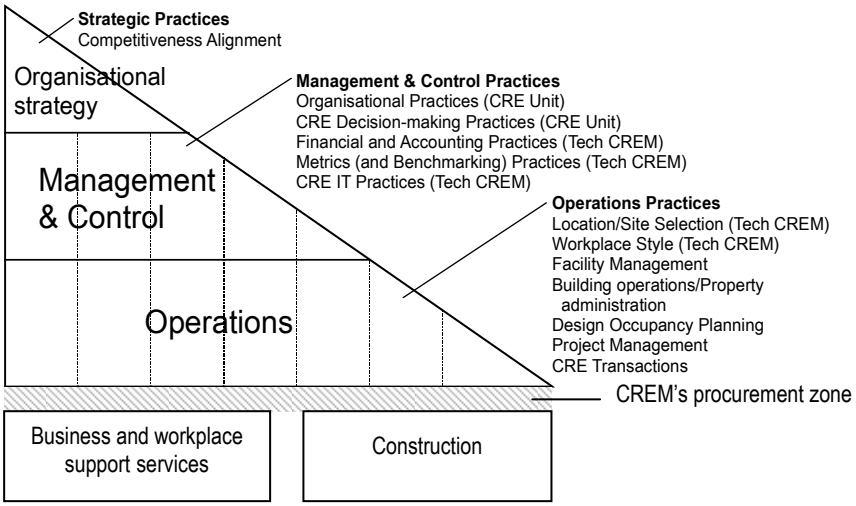

Figure 2: The strategic CREM Framework (After:Heywood and Kenley (2008, Figure 4) and Varcoe (2000, Figure 2))

This model subsumes FM as a CREM domain of practice. An alternative, FM-centric view sees FM as the main activity and CREM's location and tenure aspects are peripheral to the FM (Jensen et al., 2012). We prefer the first model on two grounds. One is the criticality of location and tenure to the strategic management of business premises. The second is that it better accords with set theory's conceptualisation of relationships applicable to providing and managing business premises where CREM is the superset to FM's activities.

In this modelling of CREM 162 practices are categorised into the multiple domains of practice (Heywood and Kenley, 2008).[6] Within CREM many aspects across these domains of practice need to be resolved in any project. Changes within a domain, for example strategic management or transactions (lease expiries) can often trigger the need for supply-side delivered projects. Then location, tenure method, financial practices and workplace styles all need to be resolved in a demand-side statement of requirements.

[6] Varcoe's (2000) model is similar though it omits the allocation of specific practices and specifically includes construction and detailed workplace support practices as integrated in this Figure 2.

5. Synthesising the models

The six models presented above can be integrated into a coherent model of the demand-side entity, its constituent parts, and relationships with the supply-side (Figure 3). This coherent picture tells us more about the demand-side than 'just' describing them as clients and users but does point towards how the demand-side functions in coming to be clients and users.

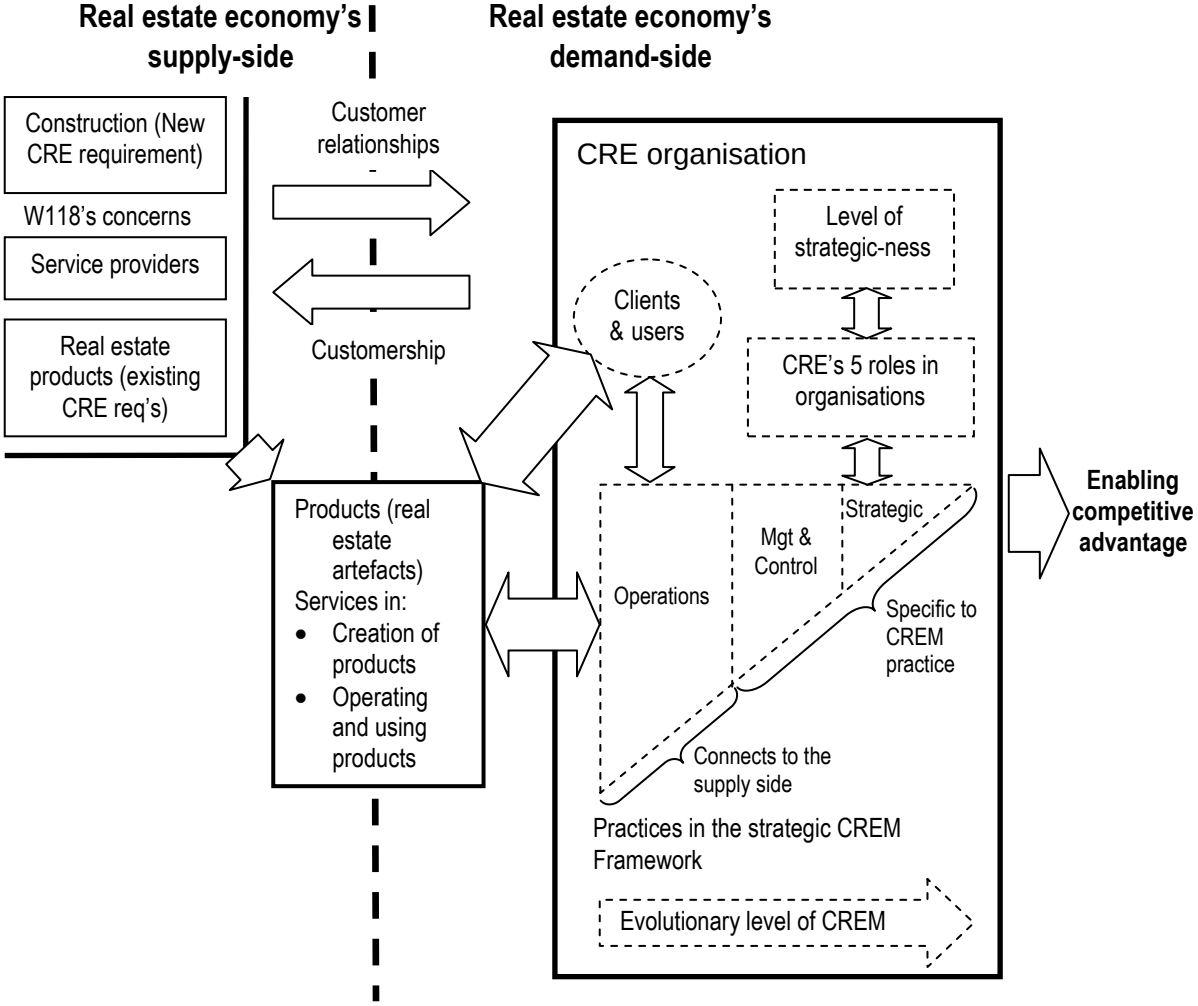

Figure 3: The coherent demand-side model in relation to procurement and the supply-side

A key purpose of the CRE organisation is to achieve competitive advantage for its business with CREM an important enabler of that advantage (Heywood and Kenley, 2008). The CREM practices in the strategic CREM Framework, the evolutionary level of the CREM, the five roles played by CRE, and the criticality of the CRE (level of strategic-ness) all contribute to enabling competitive advantage. This model shows that though an emergent property of the CRE organisation connected to operational practices being a client or user, from CREM's perspective, is a by-product of core CREM activities.

The real estate economy's demand and supply-sides meet in the products and services required by the demand-side CRE organisation and provided by the supply-side. The products and services in the model are: 1) Constructed products new to the CRE organisation, either new or altered, where the relationship with construction supply is strongest; 2) Existing real estate products where the relationship is with investment in real estate; and 3) Service providers for management and technical CREM services. This meeting does give a substantial rationale for the demand-supply relationship to be conceived in procurement terms. Within that relationship CREM becomes a customer to the supply side and wanting to better understand clients and users is part of managing customer relationships. An inference of customer relationships or management is that they are related to or managed for the benefit of those doing the managing – the supply-side. The *quid pro quo* to the supply-side's customer relationships is the demand-side's customership bestowed on its suppliers. Customership inverts the usual client-provider dynamic shifting more power to the demand-side on the premise that the supply-side exists to meet its requirements.

6. Discussion

A concern about clients and users of real estate products and services opens up an opportunity to consider what are the entities represented by clients and users. This paper draws on CREM theory to identify the entity as being a CRE organisation and in doing so invokes a cross-over between demand and supply-side theories. Each side has associated professional disciplines, perspectives on the real estate artefact, and perspectives on the entities and their relationships in the real estate economy. These differences need to be resolved or at least accommodated in the cross-over modelling of relationships such as those of client or user.

CREM theory provides a basis for this cross-over though there are some issues with it as theory. CREM remains an emerging body of knowledge and it is far from accepted that CREM is the best term with which to label the demand-side's management. There is not yet a universally accepted definition of what CRE is, with some theorists separating ownership and use aspects (where leasehold may suffice), for example Dewulf et al. (2000). Others are more interested in corporate ownership of real estate which may be for use and/or investment, for example Yu and Liow (2009). There is also not yet widespread acceptance of what CRE's roles are in organisations with several models existing (Heywood and Kenley, 2013). It is debatable whether adding value to organisations (Dewulf et al., 2000; Haynes, 2012), or enabling competitiveness (Heywood and Kenley, 2008; O'Mara, 1999) is the core contribution that CREM makes. Nevertheless, the CREM body of knowledge has sufficiently matured to provide a basis for the required demand and supply-side cross-over theory.

The value of the model synthesised here is several-fold:

1. For CREM, the model shows its complexity and more comprehensively defines itself as is necessary for an emerging property discipline;

2. More relevant here, the model shows which internal factors are involved as precursors to procurement and explicitly shows their relationship to the internal client

and user dimensions of procurement. Though CREM has long been involved in procurement of real estate for use, and increasingly in externally sourcing the CREM function, what it means to be a client or user is rarely explicitly considered within CREM theory;

3. The mechanisms in internal CREM are more explicitly revealed. Specifically, the internal management practices that interact and the level of application based on strategic evolution are evident; as are the roles real estate plays and their strategic importance. These factors' dynamics prior to and during procurement provide uniqueness to every interaction regardless of existing demand and supply-side relationships. The model, potentially, provides dimensions to those circumstances;

4. The model shows the full extent of products and services procured by the demand-side; and

5. The customer-customership dipole that is the basis of procurement is shown. There is a dominant theoretical paradigm of the supply-side's customers, customer relationships and their management, and by extension clients and users. Customership provides the demand-side's reciprocal and provides a theoretical counter-balance to the prevailing conceptualisation of the relationship.

What the model does not show is CREM's treatment of innovation, and risk and reward. Other models for CREM competitive advantage include innovation as the key basis to sustainable competitive advantage (Heywood and Kenley, 2008). The internal CREM dynamics provide potential for innovation but innovation, *per se*, is rarely explicitly addressed in CREM theory. Risk and reward in general real estate theory is often considered on an investment basis, perhaps through selecting a discount rate for analysis, or the effect on corporate beta (an investment risk measure). There is some evidence of risk being attended to in CREM outsourcing practice (Heywood and Mottley, 2011), but, again, this is rarely found in CREM theorisation. These limits are a partial consequence of CREM's emergent nature, the scarcity of CREM researchers, and the diversity of domains of practice within which to theorise. In the models presented here, risk management would probably be a tactical (Management and Control) level domain of practice in the strategic CREM Framework. Its absence is indicative of the state of the CREM literature and clearly points towards areas for future research.

7. Conclusion

The integrated model presented here was motivated by a desire to provide a clearer picture of what constitutes the client and user entity that is a focus of current concerns. Arguably this model is better because it uses the demand-side's own theory to describe that entity. What this shows is that the CRE organisation is an entity with multiple interacting CREM factors, represented in the constituent models, and which contains clients and users as properties of that entity. These factors play out within the entity at strategic and tactical levels and emerge into operational requirements that the supply-side encounters in procurement.

In conclusion, using CREM theory, the entity that is clients and users is shown to be much more complex theoretically than just being clients and users. Nevertheless, there are benefits in this model in building bridges within the real estate economy because it shows both the internal CREM dynamics and the relationships between the demand and supply-sides of that economy. This, potentially, provides a stronger theoretical base on which to move forward in building bridges within that economy.

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Corporate Culture in Construction Companies

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Abstract

Since the 1980's, research interests in the subject of corporate culture has increased as an important driver for organizational success (Kim 2008). Many corporations have begun to recognize the significance of having a corporate culture in order to increase productivity, growth, efficiency and to reduce employee turnover and other counterproductive behaviour. Nevertheless, there has been no previous research in regards to corporate culture in the construction industry. The purpose of this paper is to identify variables and components that categorize corporate cultures in the construction industry. A thorough literature review was performed first in order to identify the definitions and components of corporate culture in construction. The variables and types of corporate culture were then defined based on a literature review and interviews with industry managers. Finally, a structured survey was conducted with the top 30 Korean general contractors in order to validate the proposed model. Survey results clearly represented four distinct types of corporate culture, and provided a basis for future research in corporate culture for the construction industry.

Keywords: Corporate Culture, Components, Variables, Competing Value Model (CVM), and **Construction Industry**.

1. Introduction

Every single organization has a unique culture. The inherited and learned culture within a company is a way to represent the distinct characteristics of the corporation. Recently, corporate culture is recognized as the fifth managerial resource in addition to human, capital, materials, and information (Kim 2006). Corporate culture combines in-house members, determines their behavior, and influences management patterns. Corporate cultures also have a remarkable effect on corporation performance and provide tacit directions for decision-making (Lee 2006).

Therefore, corporations recognize the importance of corporate culture that has a significant impact on enterprise-wide operations. Corporations also systematically try to promote and develop existing corporate culture under ever-changing business environments (Cho 2007). Recently, the effects of corporate culture as a source of competition has increased in the growth and development of a corporation, according to the difference between companies which have a similar scale, type of business, and environment. It is noteworthy that

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flourishing corporations have a strong corporate culture. For these reasons, the issue of corporate culture is of great concern for researchers and practitioners. However most of the previous studies on corporate culture were only implemented from the academic aspect of management science and business administration. In this context, the purpose of this paper is to develop and analyze different patterns in corporate culture for the construction industry.

2. Background and Research Objectives

Despite growing interest in corporate culture, there has been no previous research on the construction industry. Moreover, corporate culture regards as only aspect of human relationship or welfare rather than enterprise-wide aspect in Korea. Research on corporate culture in the construction industry would facilitate to understand the patterns of construction business management. These researches can also provide companies with valuable implications for increasing managerial effectiveness through formulating clear objectives. The purpose of this paper is 1) to define the meaning of the corporate culture for the construction industry, 2) to identify its variables and components, and 3) to classify the types of corporate culture in the construction industry.

In this study, an extensive literature review was performed first in order to identify the variables and components of corporate culture in construction. A definition and types of corporate culture were then defined based on the literature review and interviews with industry managers. Finally, a structured survey was conducted with the top 30 Korean general contractors in order to validate the proposed model. The survey results clearly revealed distinct types of corporate culture for the Korean general contractors.

3. Corporate Culture in the Construction

In order to understand corporate culture in the construction industry, it is necessary to explore the fundamental meanings and components of corporate culture by reviewing the literature from the aspect of business administration and corporate management. Based on a thorough literature review, this paper defines four different categories of corporate culture for the construction industry including *'advanced technology', 'forced-growth', 'internal stability', and 'specialization'* as depicted in Figure 1. Five consequential components of corporate culture, including *'corporate culture', 'organizational structure', 'shared value', 'management pattern', and 'informal network'* are also identified in order to quantify the four patterns of corporate culture (Table 1).

3.1 Definition of Corporate Culture in Construction

Corporate culture differs from organizational climate or atmosphere; it is more complex and creative (Park 2004). The meaning of corporate culture can vary depending on different analytical perspectives or researcher's academic backgrounds. Based on the literature review with a strong emphasis on the distinct characteristics of the construction industry, corporate culture in construction is defined in this study as "*the shared values and beliefs among in-house members those affect the distinctions between other corporations in terms*

of corporate strategy, organizational structure, and management patterns of entire enterprise.

The components of corporate culture are also vary widely according to the different views of researchers; it has been formed over a long time by combining several relevant components rather than abruptly formed into single component (Lee 2006).

3.2 Pattern of Corporate Culture in Business Administration

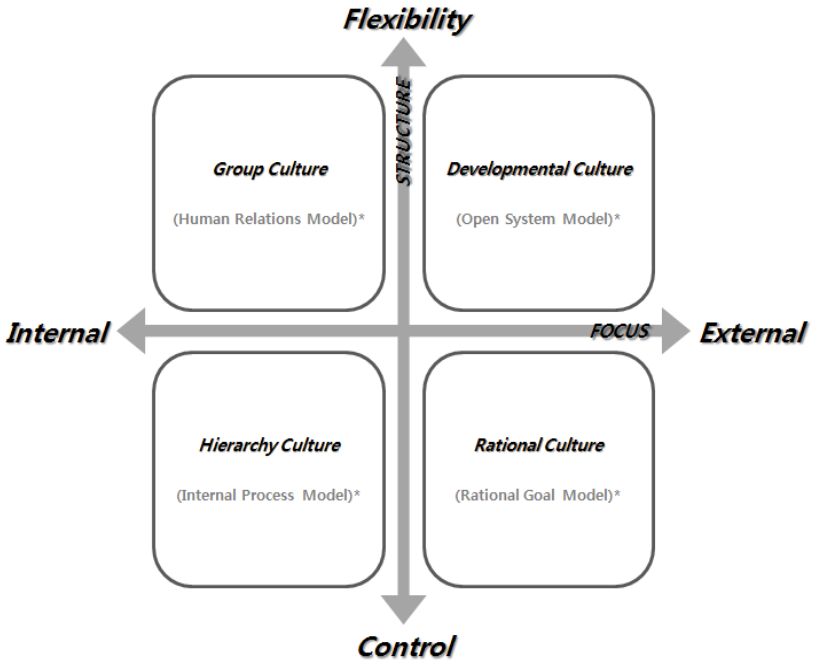
Categorizing corporate culture requires comprehensiveness in order to encompass the overall characteristics of culture (Park 2004). The competing value model (CVM) is recently utilized to analyze the corporate culture, to classify the variables of organizational effectiveness (Quinn & Rohrbaugh 1981), and to apply the leadership and total quality management (TQM) concept (Kim 2002). Corporate culture based on the CVM is composed of the four different types along with two dimensions; “group culture, developmental culture, hierarchy culture, rational culture”. The four types of corporate culture vary widely according to the different views of researchers. However each type of corporate culture have similar attribute. The first dimension (the horizontal axis in Fig 1a) is related to organizational focus, from an emphasis on internal to an emphasis on external. One end of this dimension represents a focus on integration and buffering to sustain the existing organization, while the other represents a focus on competition and interaction with the environment (Denison 1991). The second dimension (the vertical axis) is related to organizational structure, from an emphasis on stability to an emphasis on flexibility.

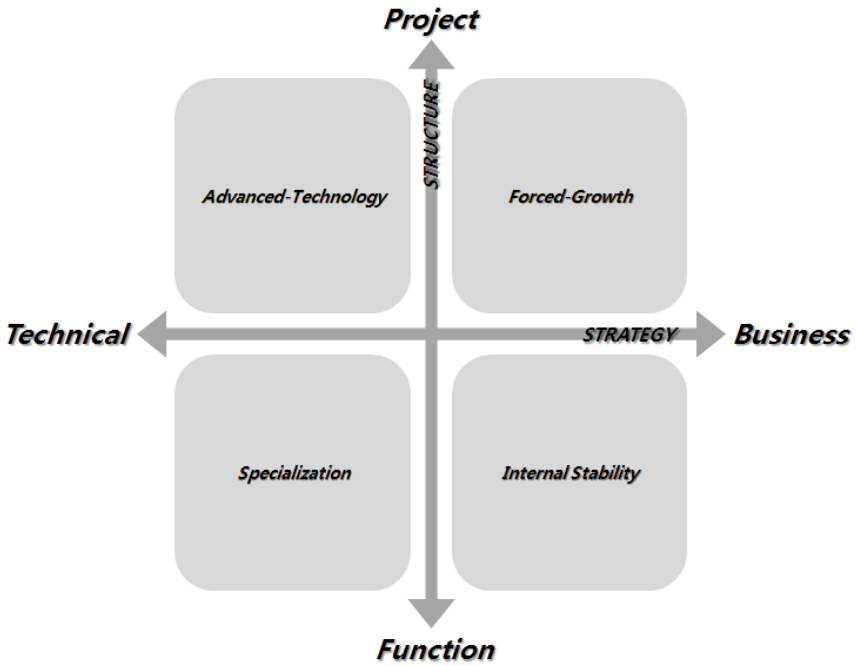
In the most often cited study by Quinn and Kimberly (1984), “group culture” in the upper left section places a great deal of emphasis on flexibility and internal focus. This culture concerns human relations and emphasizes cohesiveness and interaction through teamwork. The “developmental culture” in the upper right section places much emphasis on flexibility and external focus. This culture emphasizes growth, creativity, and adaptation to the external environment. The “hierarchy culture” in the lower left section places a lot of emphasis on control and internal focus. This culture emphasizes internal efficiency, uniformity, order, rules, and regulations. The “rational culture” in the lower right section places a great deal of emphasis on control and external focus. This culture emphasizes productivity, goal fulfillment, efficiency, and achievement (Quinn and Kimberly 1984).

3.3 Pattern of Corporate Culture in Construction

The fundamental objective in studies on corporate culture is to enhance long-term performance. These performances can be increased through active adaptation to the changing business environment and through continuous development of advisable corporate culture. These two processes should be closely linked in between strategy and structure (Shin 2008). Corporate culture in construction involves the existing types and means of corporate culture. Based on this rationale, this paper proposes four categories of corporate culture classified the by two dimensions for the construction industry; and include four categories, which are ‘advanced technology’, ‘forced-growth’, ‘internal stability’, and ‘specialization’ as depicted in Fig 1. The two dimensions are ‘corporate strategy’ and

(a) *Quinn & Kimberly (1984)	(b) This Study





* Summary of Quinn & Kimberly (1984)

Figure 1: Categories of Corporate Culture for the Construction Industry

Table 1. Components of Corporate Culture for the Construction Industry

	Component	Definition	Remarks
Tangible	Corporate strategy	Determination of directions for projects and enterprise-wide operations	Business-oriented Technical-oriented
	Organizational structure	Foundation for established strategy and interrelation of members	Project-oriented Function-oriented
Intangible	Shared value	Shared goals, beliefs of the in-house members	-
	Management pattern	Management skills by business functions of an organization	-
	Informal network	Informal means or processes of communication within an organization	-

Table 2. Variables and Measures of Corporate Culture for the Construction Industry

Component	Variables	Measures
Corporate strategy	Technical capability (Organizational)	Number of techniques (e.g. patent, officially listed new technology)
	Technical capability (Individual)	Number of professional qualifications / Number of entire staff
	Ratio of engineering staffs	Number of engineers / Number of entire staff
	Expenses for technical training	Training expenses per capita
Organizational structure	Sales per capita	Total revenue / Number of the entire staffs
	Distribution of Employees (HQ vs. Site)	Number of site employees / Number of entire staff
	Specialization of product	Deviation of specialization distribution

‘organizational structure’, which are selected from among five candidates for corporate culture components as listed in Table 1. The two dimensions are tangible and measurable in comparison with other corporate culture components.

The first dimension (the horizontal axis) is related to corporate strategy, from an emphasis on technical-oriented to an emphasis on business-oriented. This is not simply limited to strategy; it involves the meaning of “maintenance or competition” by Quinn & Kimberly (1984). The second dimension (the vertical axis) is related to organizational structure, from an emphasis on function-oriented (e.g. design, estimating, scheduling, etc.) to an emphasis on project-oriented. Again, this dimension is not simply limited to the distinction of the organization; it also implies the “control or flexibility” of the actual organizational structure by Quinn & Kimberly (1984).

The culture of ‘advanced technology’ in the upper left section places a great deal of emphasis on project-oriented and technical-oriented. The ‘forced-growth’ in the upper right section places much emphasis on project-oriented and business-oriented. The ‘specialization’, in the lower left section places a lot of emphasis on function-oriented and technical-oriented. Finally, the ‘internal stability’ in the lower right section places a great deal of emphasis on function-oriented and business-oriented.

3.4 Variables for Categorizing Corporate Culture in Construction

As four categories with two dimensions of corporate culture for the construction industry were classified, variables for each dimension were then identified and elaborated. The ‘Corporate strategy’ dimension (the horizontal axis) consists of organizational ‘technical capability of organization’, ‘technical capability of individuals’, ‘ratio of engineering staff’, and ‘expenses for technical training’. As the scores for these variables were higher, corporate strategy is closed as technical-oriented rather than business-oriented. The variables of organizational structure (the vertical axis) include three factors; it consists of sales per capita, distribution of employees, and specialization of product. As the scores of sales per capita and number of site employees are higher and the scores of specialization of product is lower, organizational structure is closed project-oriented rather than function-oriented. The variables and measures to evaluate these two dimensions for categorizing corporate culture are defined in Table 2.

4. Case Study with Korean General Contractors

A structured survey was conducted with the top 30 Korean general contractors in order to validate the proposed model. More than 30% (10 corporations) of the questionnaires were returned. The scores of variables were normalized first; where 100 is the exact median and average. Fig 2 shows the distributions of ‘corporate strategy’ and ‘organizational structure’ scores from the responding corporations. As the score in graph is higher, corporate strategy (Fig 2a) is close to technical-oriented and organizational structure is close to project-oriented (Fig 2b). By combining these two dimensions, the types of corporate culture for the Korean contractors are clearly categorized as shown in Fig 3.

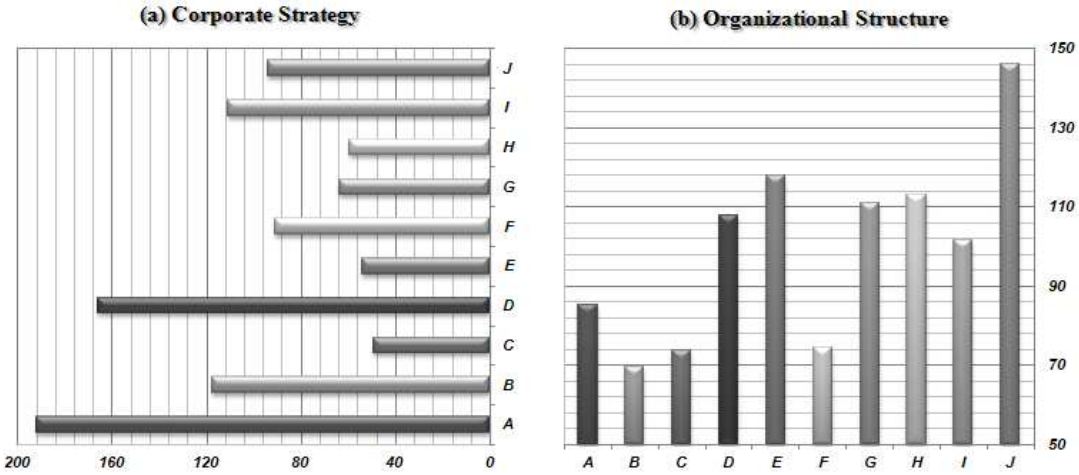


Fig 2. Survey Results from 10 Responding Companies

For classifying the 'corporate strategy' in corporate culture, the most influencing item among the four variables in Table 2 were 'organizational technical capability' and 'expenses for technical training'. For classifying the 'organizational structure', influencing variables among the three variables were the 'specialization of product' and 'distribution of employees'. As results from the survey show, companies with a similar pattern can be categorized into four groups as depicted in Fig. 3. As for D company belonging to '*advanced technology*' group, the score for 'specialization of product' and 'distribution of employees' are both higher than other companies. This means that the companies positioned in the upper-left quadrant (advanced technology group) in Fig 3 are flexible and project-oriented in terms of 'organizational structure'. The company also has higher scores for the 'technical capability' and 'expenses for technical training'.

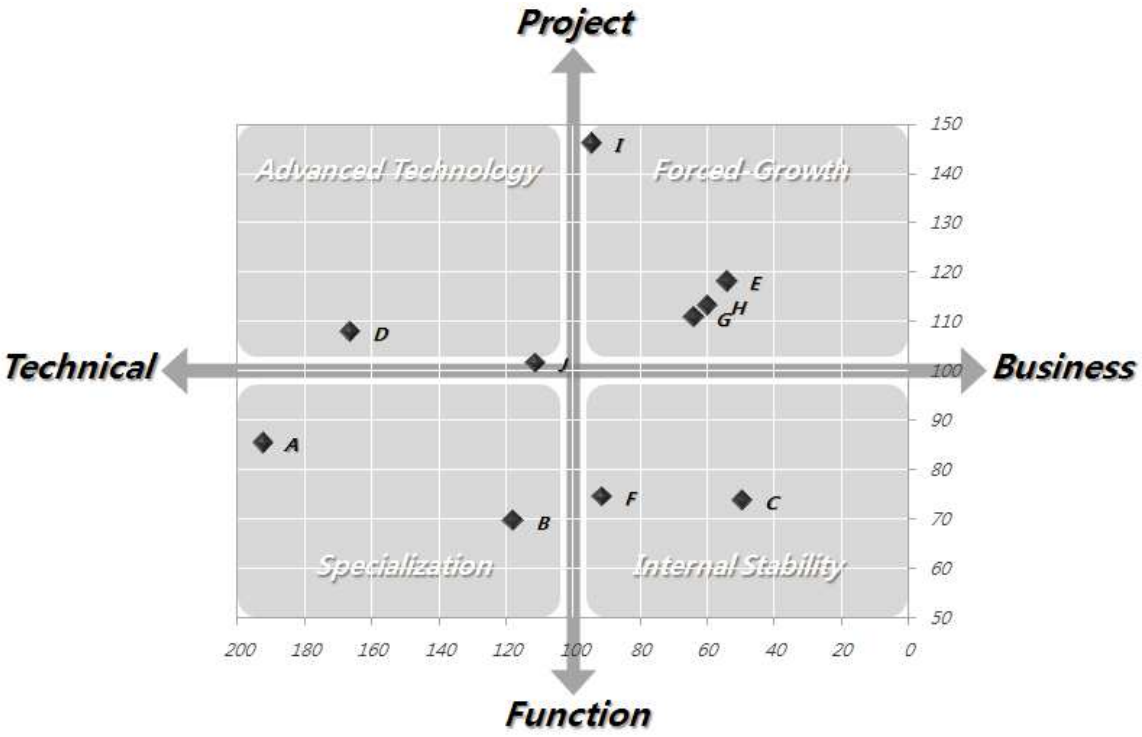


Fig 3. Categorizing Corporate Culture of General Contractors

Companies in the '*specialization*' group have relatively larger functional organization in their head offices in order to be a specialized firm. It is found that companies in this quadrant also ranked high scores in technical variables. In other words, specialized companies have more patents, in-house developed new technologies, and higher expenditures for technical training. Companies in the upper-left quadrant (forced-growth) are focusing diversified portfolio encompassing housing, buildings, industrial plant, and infrastructure civil construction. A higher ratio of site engineers is a distinct characteristic of this group. Finally, the lower-left quadrant (internal stability) is the group where rationality is emphasized in both organizational structure and corporate strategy.

5. Conclusion

Each construction corporation has unique and easily recognizable culture; these cultures have a direct impact on the project and affect the performance of the corporation. Despite growing interest in corporate culture, no previous research was performed for the construction industry. In this context, the definitions and components of corporate culture were identified in this study in order to vitalize the corporate culture for the construction industry. This paper defines the five components of corporate culture as that of 'corporate strategy, organizational structure, shared values, management pattern, and informal network'.

The types of corporate culture for the construction industry are classified by two dimensions; the first dimension (the horizontal axis) is related to corporate strategy, the second dimension (the vertical axis) is related to organizational structure. This paper developed four different types of corporate culture for the construction industry that included '*advanced technology', 'forced-growth', 'internal stability', and 'specialization'*. The variables effectively illustrate different categories of corporate culture in construction companies.

The survey results provide distinct groups of corporate cultures for the Korean general contractors. The most influencing variables are found to be the 'organizational technical capability' and 'expenses for technical training' in corporate strategy and the 'specialization of product' in organizational structure.

The authors of this paper believe that categorizing the types of corporate culture needs to be strongly encouraged in order to accelerate future practical corporate culture studies for the construction industry. Additional variables such as types of the CEO and sister companies were also studied and are now under evaluation. These findings would facilitate to understand the patterns of construction engineering and business management.

6. Acknowledgements

This study was supported by the Korean Ministry of Education, Science, and Technology (MEST) under Grant No. 2009-0074881 and by Ministry of Land, Transport and Maritime Affairs of Korean Government Grant No. 10 R&D B01. Their supports are gratefully acknowledged.

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The Next Generation of Performance-Based Fire Safety Engineering in New Zealand

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Abstract

The introduction of a new Building Act in New Zealand in 2004 prompted a comprehensive review of the Building Code to ensure that its provisions were both consistent with the new Act, and contained sufficient quantification of performance requirements. The review resulted in new Protection from Fire code clauses, Acceptable Solutions (prescriptive, non-mandatory deemed-to-satisfy provisions), and a Verification Method (based on the structural design process where design loads and performance criteria are specified) being introduced in 2012. This new generation of fire safety regulation is expected to substantially reduce the level of inconsistency and inefficiency that previously existed. The next paradigm shift in the New Zealand building regulatory environment is expected to introduce a risk-informed regime, where probabilistic provisions will be incorporated to address the inherent risk and uncertainty associated with performance-based fire safety engineering design. With this scenario in mind, a collaborative research project involving BRANZ Ltd and the University of Canterbury has recently developed a new fire safety engineering design tool called B-RISK, with the project forming part of the essential underlying research necessary to underpin any such future code change. This paper describes the development of the B-RISK tool and its application to the practice of performance-based fire safety engineering design. Instead of doing calculations in the traditional deterministic manner, B-RISK improves the designer's risk-informed decision-making by using a physics-based model in conjunction with the probabilistic functionality of iterative Monte-Carlo sampling techniques. A design fire generator that populates a room with items and predicts item-to-item fire spread produces probabilistic families of fire growth curves as modelling input. User-defined distributions for key input parameters are included, as well as distributions for the reliability of fire protection systems, from which B-RISK samples for each iteration. The resulting model results are presented in the form of cumulative density functions of probability, whereby a risk-informed design decision can be made.

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Keywords: performance-based design, fire safety engineering, quantitative risk assessment, systems reliability, design fires.

1. Introduction

1.1 Building controls framework

There are essentially three hierarchical levels to the performance-based building controls framework in New Zealand. The overarching legislation is the Building Act (NZ Govt., 2004), which contains the provisions for regulating building work, and which must be adhered to when buildings are designed and constructed. The purpose of the Building Act is to ensure that people can safely use buildings without endangering their health, they can escape from the building in the event of fire breaking out, the building provides amenity for users, the building promotes principles of sustainable development, and Fire Service personnel can undertake fire fighting and rescue functions without undue risk (DBH, 2011a). The second tier of the overall building controls framework consists of a number of sets of building regulations which provide more specific details relating to administration of the building regulatory system. The third level of this hierarchy is the New Zealand Building Code (NZBC) which is an annex to one of the sets of building regulations, namely the Building Regulations 1992 (NZ Govt., 1992), which provides the minimum legal requirements for building works. The NZBC contains the mandatory provisions for new building work by stating the required level of building performance but not prescriptively describing how the level of performance should be achieved. The NZBC contains 35 technical clauses that set out the different performance criteria that must be met including structural stability, fire safety, access, moisture control, durability, services and facilities, and energy efficiency.

Each clause of the NZBC stipulates, in a descending hierarchy: (a) Objectives (statements of social objectives in terms of health, safety, amenity and sustainability); (b) Functional Requirements (how a building in general terms could be expected to satisfy the relevant Objectives); and (c) Performance Criteria (qualitative or quantitative criteria to meet the Functional Requirements and Objectives). There are three possible pathways for demonstrating compliance with the NZBC: (1) Acceptable Solutions (deemed-to-satisfy instructions) that are contained in the Compliance Documents (prescriptive methods to meet Performance Criteria); (2) Verification Methods (calculation or test methods) also contained in the Compliance Documents; or (3), Alternative Solutions (alternative methods, other than those contained in Compliance Documents, to meet Performance Criteria) (DBH, 2011a).

1.2 Fire safety engineering

Performance-based fire safety engineering makes use of calculations and modelling. For example, demonstrating that building occupants can safely evacuate in the event of a fire breaking out is generally done by conducting an ASET/RSET analysis. In this context the available safe egress time (ASET) is the time for conditions to become untenable, while the required safe egress time (RSET) is the time taken to reach a place of safety (Gwynne, 2012). Focussing on ASET, the starting point for the calculations are design fire scenarios (qualitative descriptions that characterize the key events of a potential fire), which include

such aspects as the location of the fire, building characteristics, fire loads, fire protection systems, etc. A design fire scenario also includes a design fire (quantitative description of fire characteristics within the design fire scenario) which is typically defined as a heat release rate (HRR) time history, but will also often include species production rates and the effective heat of combustion (ISO, 2006). In order to demonstrate that the ASET exceeds the RSET, generally with an appropriate safety factor, widespread usage is made of computer models to simulate both compartment fires (ASET) and occupant escape (RSET). Generally, models can be classified as being either deterministic (single values for calculation parameters) or probabilistic (range of possible values for calculation parameters), with the former being the most commonly used in performance-based fire safety engineering. With only a few specific scenarios being considered and single-point values for key design parameters incorporated into the calculation procedures, this approach makes no allowance for the probability of these scenarios occurring or the variability of input parameters (Fleischmann, 2011).

1.3 New safety from fire provisions

During the two decade period in which performance-based fire safety engineering has been carried out in New Zealand, a number of issues have become apparent. One major issue that has hampered the full benefits of a performance-based regime being achieved has been a lack of quantification of performance criteria in the NZBC. This lack of quantified performance criteria has resulted in the unsatisfactory situation of fire designers both proposing and applying their own criteria. In addition, a lack of suitable verification methods has resulted in a general design approach that is not standardised and sensitivity analysis, to address uncertainty, is rarely done. The current process of design and regulatory approval appears to involve a high degree of subjective judgement and has resulted in inconsistency in fire engineering and disputes about fire safety (Wade et al., 2007). Until recently, the Compliance Document for the fire safety clauses of the NZBC (DBH, 2011b) did not provide quantified guidance for specific performance-based fire safety engineering. In 2006 a project was initiated by the building regulator which in part had the objective of providing more specific guidance to practitioners – this culminated in the publication in 2012 of a new Verification Method (C/VM2) (DBH, 2012) which quantifies design fire scenarios, design fires, pre-travel activity time and acceptance criteria.

1.4 Collaborative research project

The inability to deal in a rational manner with the risk and uncertainty inherent in performance-based fire safety engineering was the catalyst for a collaborative research project that started in 2007. The research project has developed a quantitative risk assessment (QRA) tool called B-RISK, which incorporates deterministic calculations, probabilistic sampling from input parameter distributions, and Monte-Carlo iterative functionality. At the same time, the building regulator has indicated a desire to move towards more risk-informed building regulations at some point in the future. One possible manifestation of this intent could be probabilistic statements of building performance (PSBP) in future revisions of the NZBC. Notarianni (2000) notes that PSBPs contain a minimum of four elements: probability; time; a performance criterion; and a threshold value. In the context of the new Verification Method, C/VM2, an example of a PSBP could be:

The fractional effective dose (FED) of carbon monoxide (CO) shall have a 90% probability of not exceeding 0.3 at a time of 400 seconds after a fire starts.

The B-RISK model has been developed for use by fire safety engineering practitioners and regulatory authorities to be able to demonstrate compliance with the requirements of such statements of performance.

2. B-RISK model development

Extensive use is made of computer models in performance-based fire safety engineering. Olenick and Carpenter (2003) classify such models into six types; zone, field, detector response, egress, fire endurance, and miscellaneous. These six classes of models can then be further differentiated as being either deterministic or probabilistic/stochastic (Beard, 1992; Ramachandran, 2008). Compartment fires are generally modelled using either zone (Walton et al., 2008) or field (McGrattan and Miles, 2008) models.

Structurally, B-RISK consists of a User Input Module, a Sampling Module, a Deterministic Calculation Module, an Output Data Module, and an Output Distribution Module. The Deterministic Calculation Module incorporates a Design Fire Generator (DFG) Sub Module and a Systems Effectiveness Sub Module. Figure 1 shows schematically the high-level conceptual structure of B-RISK.

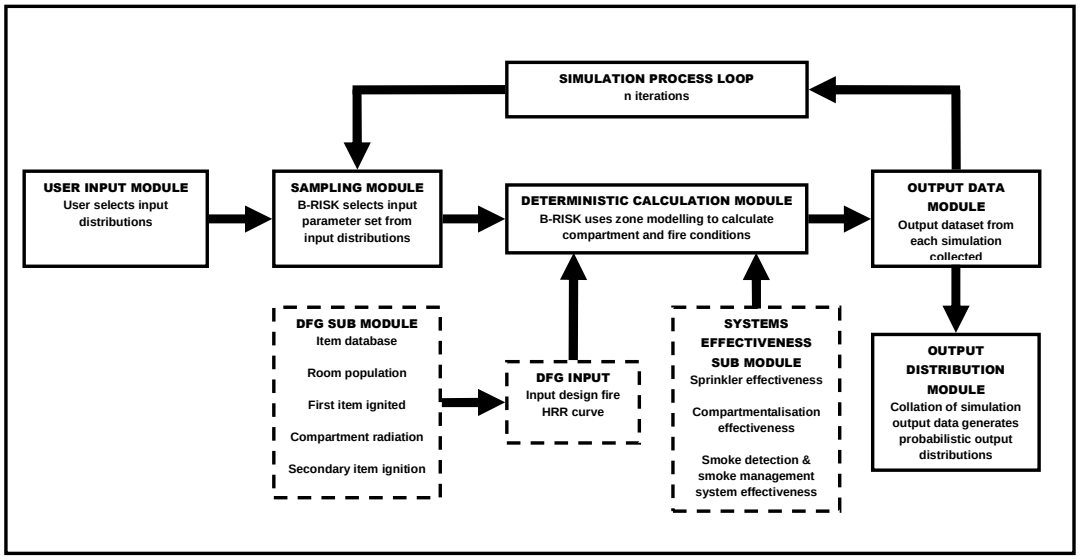


Figure 1: Schematic structure of B-RISK modules.

The User Input Module deals with the variability and uncertainty associated with the modelling inputs by assigning probability distributions to key input parameters. Next, the Sampling Module uses iterative Monte-Carlo sampling techniques to select a set of input values from the user-defined input distributions.

The Deterministic Calculation Module uses zone modelling principles to determine the fire environment. Two important sub modules contribute to the Deterministic Calculation Module

- the Design Fire Generator Sub Module provides an input HRR curve for each simulation loop, while the Systems Effectiveness Sub Module provides the ability to incorporate fire safety systems reliability and efficacy into the B-RISK modelling predictions.

Each of the *n* iterations of the Simulation Process Loop provides a set of output data to the Output Data Module and then the Output Distribution Module collates these datasets into output distributions, which take the form of cumulative density functions of probability. The fire safety engineering practitioner is then able to compare these outputs to the applicable PSBP.

2.1 Design Fire Generator

The starting point for any performance-based fire safety engineering design is to characterise the severity of the fire that may occur in the building. For traditional deterministic modelling, the model user manually inputs a HRR curve for a theoretical design fire. The HRR curve is a plot of heat output vs. time, and generally will have growth, fully-developed and decay phases. The growth phase is typically represented in a parabolic “t-squared” form (Karlsson and Quintiere, 2000).

In order to be able to efficiently input hundreds, or even thousands, of unique HRR curves for each individual iteration of the B-RISK calculation process, a sub model was developed within B-RISK for this purpose, termed a “design fire generator” (DFG).

2.1.1 Room population functionality

The starting point for the DFG is a database of combustible items. The items represent typical objects that are likely to be found in the occupancy under consideration, such as chairs, desks, armchairs, sofas, televisions, bookcases, etc. As shown in Figure 2(a), each item has various geometric, chemical, ignition and HRR properties assigned to it.

Once the physical dimensions of the compartment of fire origin have been defined in B-RISK, the DFG randomly selects items from the item database and populates the space with combustible objects. The total number of objects is governed by one, or a combination, of the following:

1. The physical space available in the compartment, i.e. once an area is occupied by one item, another object cannot overlap the first item,

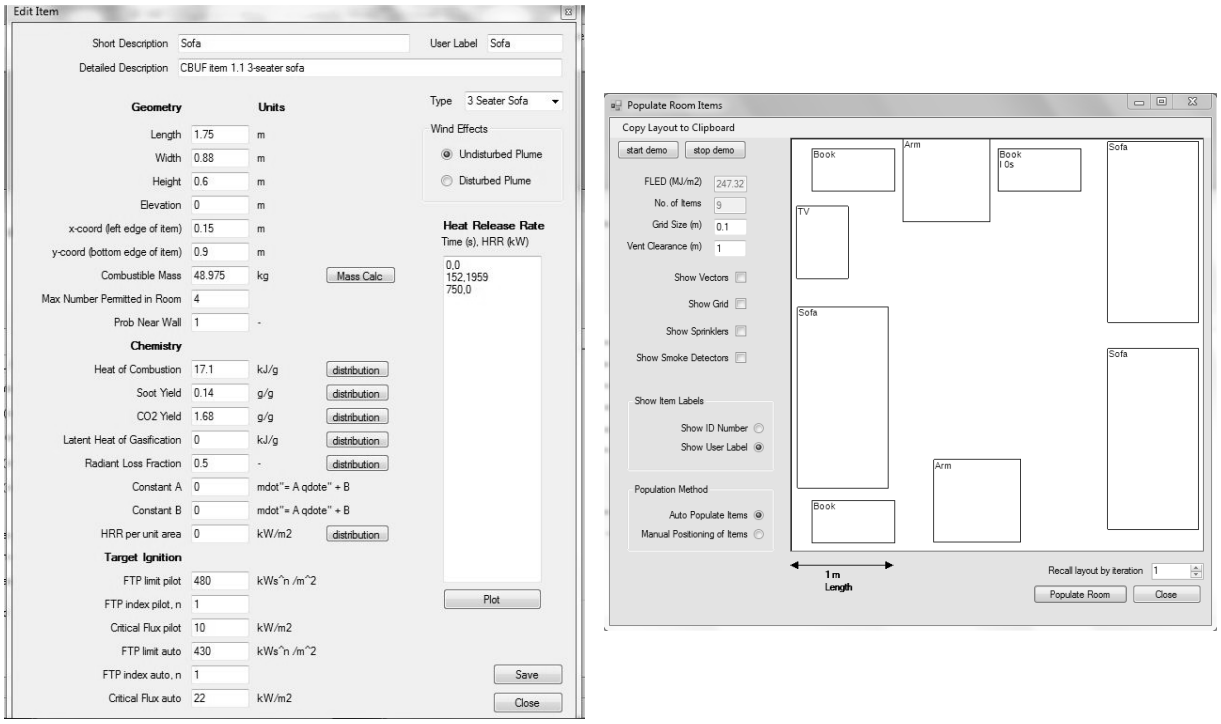
2. The maximum number of that type of object permitted,

3. The fire load density, which can be either a distribution, or a single value.

With regard to item 2, the B-RISK user may want to limit the number of items – an example may be televisions, where there is likely to be only a single item of that type in any one room.

With regard to item 3, when the distribution option is used for the fire load density, a value will be randomly sampled for each iteration, and hence the number of items in the space could vary from iteration to iteration.

Having populated the enclosure with items, the DFG randomly assigns an object to be the first item ignited in the scenario being modelled, as illustrated by the notation “I (ignition) 0s” in Figure 2(b).



(a) (b)

Figure 2: Room population: (a) Typical item from B-RISK item database; (b) random population with items.

As well as the stochastic populate room functionality, the DFG also has the option to locate items in a pre-determined location, so that validation comparisons are possible.

2.1.2 Compartment radiation and secondary item ignition

The ignition of the secondary items in the compartment of fire origin is modelled on the basis of the radiation received from other burning objects in the compartment. The radiation is either directly from the flames of burning items, or from the underside of the hot upper layer that forms during the pre-flashover stage of the growing fire.

Based on work conducted by Fleury (Fleury et al., 2011), the flame radiation is modelled as emanating from a point at the centre of a sphere, the so-called “point source model” (Modak, 1977).

The underside of the hot upper layer is modelled in the DFG as a uniform, isothermal surface that emits diffuse (directionally-uniform) and gray (wavelength-independent) radiation (Tien et al., 2008), while the emissivity is based on the soot and gases in the upper layer.

To calculate the point at which secondary items will ignite, the Flux-Time Product (FTP) methodology (Baker et al., 2011) is utilised by the DFG sub model. When the incident radiation exceeds a critical value, radiation is assumed to accumulate at the surface of an object until a threshold value is exceeded, at which point ignition is deemed to have occurred - Figure 2(a) shows an example of the FTP parameters that are assigned to an item in the DFG item database.

2.2 Systems effectiveness

Once potential fires have been characterised for a building, measures to mitigate the risk may be required. The primary tools available for fire safety engineering practitioners to manage fire risk are fire safety systems such as automatic suppression (sprinklers), compartmentalisation, and smoke management systems. However, it has been observed in New Zealand and elsewhere that the lack of ability to account for the reliability and efficacy of fire safety systems has been a major limiting factor in performance-based fire safety engineering solutions (DBH, 2005). The ability to include system reliability and efficacy is integrated with the B-RISK modules for sprinkler systems, detection systems, compartmentalisation, and smoke management.

2.2.1 Sprinkler effectiveness

B-RISK includes the capability to consider the effectiveness of sprinkler systems on fire development in three stages: the first assumes the sprinkler system has no effect on the fire development; the second assumes the HRR is constant after the sprinkler system activates; and the third assumes the HRR is suppressed once the sprinkler system activates using an exponential decay model developed by NIST (Evans, 1993). Probability distributions can be entered for the first and second stages, with the remaining fires included in the third stage. An additional distribution can be added for the number of sprinklers activated before the HRR rate is affected by the sprinkler system.

The physics-based Systems Effectiveness Sub Module within the Deterministic Calculation Module (refer to Figure 1) is used to determine when sprinklers activate. Distributions for the sprinkler thermal response parameters allow uncertainty in sprinkler response to be included. Due to the nature of the DFG which allows the fire to be located at random in the fire room, all of the sprinklers in the fire room can be included in the simulation. The activation of multiple sprinklers can be simulated (Frank et al., 2012).

A question that often arises with zone fire physics models is whether they provide a close enough representation to realistic fire behaviour. A study using B-RISK to compare model uncertainty and natural scenario variability uncertainty in sprinkler activation time showed that the zone approach was sufficient to provide a “consistent level of crudeness” with the

uncertainty in input parameters for the scenarios considered, particularly in design conditions where more uncertainty is present compared with a reconstruction scenario (Frank et al., 2011).

2.2.2 Compartmentalisation

B-RISK can include compartmentalisation effectiveness using vents in the compartment boundary. Probability distributions can be entered for the probability that a vent is open when the simulation starts (a propped open door, for example) and also for the width and height of vents to include the potential effects of compartment leakage. A study has been undertaken to collect data on the probability for fire and smoke doors being open in shared means of escape routes.

2.2.3 Smoke detection and smoke management system effectiveness

Both passive and active smoke management strategies can be included probabilistically in B-RISK. Detectors can be used to activate vents or fans. A distribution for smoke detector reliability can be used, as well as distributions for optical density at alarm and the detector characteristic length. The ability to enter a distribution for optical density at activation can be used to account for the uncertainty in photoelectric or ionisation detector detection time due to the discrepancy between the physics of the response of these types of detectors and light obscuration (Milke, 2012). Distributions can also be used to include uncertainty in fan reliability and flow characteristics.

3. Discussion

3.1 Design fire generator output

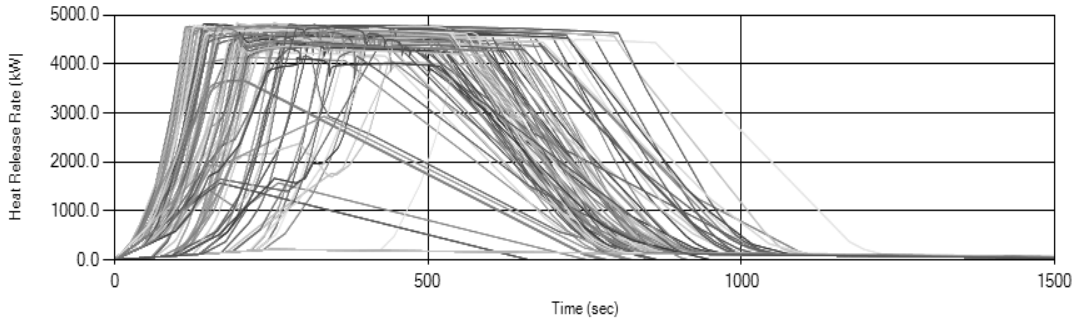
With reference to Figure 2(a), each item in the DFG item database is assigned a free-burning HRR curve. At the start of each DFG iteration, the HRR for the entire compartment consists of the individual HRR curve for the first item ignited. As subsequent items are deemed to have ignited, the individual HRR curves for the secondary items are added in a cumulative fashion to the HRR curve for the entire compartment. As the fire spreads from item to item, and the fire growth starts to accelerate, the total combined HRR curve will go through a transition from a growing fire to a fully-developed fire, akin to flashover (Karlsson and Quintiere, 2000). While initially the growing fire is fuel-controlled in the pre-flashover phase, the fire will quickly become ventilation-controlled as it transitions into the post-flashover, fully-developed, phase. The HRR curves that are the output from the DFG sub model simulations constitute the design fire input for B-RISK calculations, with Figure 3(a) illustrating the subsequent HRR curve output from B-RISK, in this case for 100 iterations. Of these 100 iterations, the fire did not spread beyond the first item ignited in 7 of the 100 iterations. The remaining 93 iterations all reached flashover (deemed to be when the average upper layer temperature reached 500 ^{o}C).

3.2 Comparison to experimental and parametric data

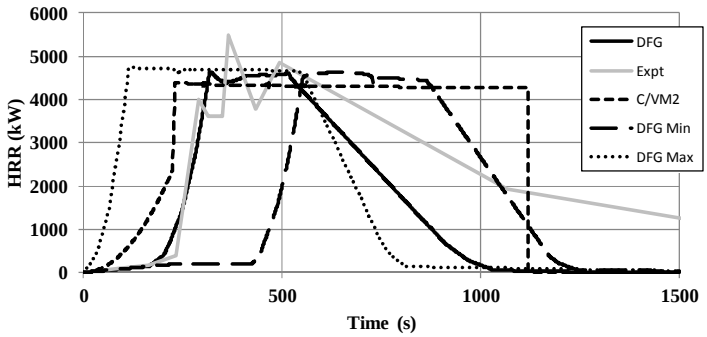
In order to compare the HRR curve predictions of the DFG, B-RISK was used to simulate some existing residential-scale experiments (Blomqvist et al., 2004) in an “a posteriori” manner. The combustible object layout and ignition source scenario were replicated in the DFG – the resulting comparison is shown in Figure 3(b), labelled as “DFG” and “Expt”.

It should be noted that the actual experiment conducted by Blomqvist and colleagues, shown in Figure 3(b), had a long (≈ 750 s) incipient phase. The start of the growth phase is set at the same time between the “DFG” and “Expt” datasets, so the resulting comparison shown in Figure 3(b) is a comparison of the growth, fully-developed, and decay phases only. The experimental data also include post-flashover flaming out through the room doorway, which would give HRR values higher than the compartment-only values generated by B-RISK.

Figure 3(b) also includes the design fire curve (labelled “C/VM2”) that would be required by the new C/VM2 verification method in New Zealand, noting that this HRR curve is based on a “fast t-squared” fire growth (DBH, 2012). For further comparative purposes, the curves with both the fastest and slowest growth rates for the 93 flashover iterations illustrated in Figure 3(a) are also plotted in Figure 3(b), labelled as “DFG Max” and “DFG Min” respectively. The “C/VM2” curve equates to the lower 23 percentile of the 93 flashover iterations.



(a)



(b)

Figure 3: HRR output curves: (a) 100 DFG iterations; (b) comparative.

Further validation experiments are in progress in which two multiple item fire spread scenarios are being set up in an ISO room. Each scenario will be replicated three times and the results compared to B-RISK simulations. The flammability properties of the materials used to construct the combustible items has been determined from cone calorimeter tests and the free burn HRR of each item has been measured under the furniture calorimeter. For the ISO room experiments the item to item ignition sequence and total HRR will be monitored. In addition, it is intended that the response of sprinklers and smoke detectors will be recorded.

3.3 Influence of fire load density

The B-RISK HRR curves shown in Figure 3(b) are each individually based on a unique value sampled from an assigned fire load density distribution. Although it is not immediately obvious from the cluster of overlapping HRR curves shown in Figure 3(a), the extracted curves in Figure 3(b) (labelled “DFG Min” and “DFG Max”) demonstrate different fire load density values (in the form of different durations for the ventilation-controlled peak HRR plateau) when compared to the HRR curve labelled “DFG”, which has a lower fire load density value.

4. Conclusion

This paper has described the development of new fire modelling software called B-RISK. B-RISK combines probabilistic/deterministic functionality with stochastic Monte-Carlo sampling algorithms so as to deal with the risk and uncertainty inherent in performance-based fire safety engineering in a rational manner.

B-RISK includes a design fire generator (DFG) sub model in its calculation module that can generate a unique design fire HRR input for each calculation cycle (iteration) that the model performs. On this basis, B-RISK produces HRR data that compare favourably with experimental and parametric design fire curves.

B-RISK also incorporates functionality that quantifies systems effectiveness, which until now has hampered the robustness of performance-based fire safety engineering, by including metrics for sprinkler, compartmentalisation, and smoke detection and smoke management system efficacy.

Instead of the traditional single point outputs that deterministic models produce, B-RISK produces tenability outputs in the form of cumulative density functions of probability, which quantify the likelihood of values occurring over the range of the output domain.

In conjunction with recent regulatory changes to the Protection from Fire clauses of the New Zealand Building Code, it is expected that B-RISK will help to minimise the subjectivity and inconsistency that has affected the full benefits of performance-based fire safety engineering being realised in the New Zealand building and construction industry.

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Are Project Managers Ready for Green Construction?
- Challenges, Knowledge Areas, and Skills –

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Abstract

Global concerns over climate change and sustainability have spurred the need for green construction. With the rising number of green construction projects, it is necessary to ensure that such projects are delivered successfully. Considering that a competent project manager is vital to project success, it is therefore essential to identify the critical knowledge and skills that a project manager needs to effectively execute a green construction project. As a result, the objectives of this study are: (1) to discover the challenges that project managers encounter in managing green construction projects; and (2) to determine critical knowledge areas and skills that can respond to the challenges. Through literature review, surveys with 30 project managers, and interviews with three project managers, "the longer time required during the pre-construction process", "difficulty in the selection of subcontractors who provide green construction services", "uncertainty with green materials and equipment", "the high cost of green materials and equipment", and "increased meetings and coordination required with green consultants and engineers" were identified as the top-five ranked challenges. Furthermore, the most important knowledge areas that will respond to the challenges were "schedule management and planning", "stakeholder management", "communication management", "cost management", and "human resources management". In addition, the most important skills that are required to mitigate the challenges were "analytical", "decision-making", "team working", "delegation", and "problem-solving skills". The findings from this study will help establish a knowledge base for project managers to be competitive and to effectively execute sustainable projects.

Keywords: Project Manager, Project Management, Knowledge Areas, Skills, Green Construction, Singapore

1. Introduction

Having a competent project manager is vital to project success. Several studies (Avots, 1969; Sayles and Chandler, 1971; Belassi and Tukel, 1996; Crawford, 2000) highlighted critical roles of project managers for project success, and especially Frank (2002) reported that project managers have direct influence over 34% to 47% of project success. To manage a project professionally, a project manager needs to possess the required skills and knowledge. However, given the fast changing environment of the construction industry with

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challenges such as skills shortages, the rapid advancement of information and communication technologies, and the increasing prioritization of issues such as sustainability, environmental protection and climate change, the role of the project manager needs to be adapted.

According to Perez-Lombard et al. (2008), commercial and residential buildings combined comprise 20% to 40% of the world's energy consumption, while In Singapore, buildings account for 16% of the nation's total energy consumption. With the mounting global concern for the environment, many industries are steering towards sustainable development and implementing green measures. In line with this trend, building construction companies from various regions around the world have integrated green features into their construction plans (Hwang and Tan, 2012), and Singapore has made sustainable development a key national priority as well (Singapore Green Building Council, 2009).

As the green building construction phenomenon continues to grow and gain popularity, there is a need to better understand the pivotal attributes that project managers should possess to manage green construction projects. Despite numerous studies on a project manager's competency, few have specifically examined what skills the project manager will need to successfully deliver a project requiring sustainable construction. As a result, with the intent to enhance sustainability efforts without compromising the competitiveness of project managers, this study aims: (1) to discover the challenges that project managers encounter in managing green construction projects; and (2) to determine critical knowledge areas and skills that can respond to the challenges.

2. Literature Review

2.1 Challenges of Green Construction Projects

Based on the comprehensive literature review carried out for this study, the major challenges that project managers face in managing green construction projects were identified and are discussed in the following sub-sections.

Higher Costs for Green Construction Practices and Materials: As compared to conventional projects, green projects tend to cost more to construct. According to an estimate by Tagaza and Wilson, (2004) capital costs for green projects range from 1 to 25% higher. The higher costs are due to design complexity and the modeling costs needed to integrate green practices into projects (Zhang et al., 2011). Higher costs are also associated with green materials and using green construction technologies (Hwang and Tan, 2012). Zhang (2011) calculated that using green materials costs from 3 to 4% more than conventional construction materials. Some green materials cost significantly more than their conventional counterparts, compressed wheat board costs about ten times more than ordinary plywood (Hwang and Tan, 2012). The higher costs of green construction directly affect the project manager, because they are responsible for managing and delivering their projects within an allocated budget (Ling, 2003).

Technical Difficulty during the Construction Process: A project manager implements a project plan by authorizing the execution of activities to produce project deliverables (Ling, 2003). Often, green technologies require complicated techniques and construction processes (Zhang et al., 2011). If complexities are not addressed well then it may affect the project manager's performance. Tagaza and Wilson (2004) suggested that one of the main challenges in green building is the technical difficulties experienced during the construction process. Similarly, design can be more complicated than that of a conventional building due to the evaluation of alternative materials and systems (Hwang and Tan, 2012).

Risk Due to Different Contract Forms of Project Delivery: Tagaza and Wilson reported that the success of developing and implementing a green design depended greatly on the type of contract selected for the delivery of the project (2004). The type of contract used in green projects must incorporate the details of a fully integrated green design. This creates a problem if the design is locked before being developed fully (Tagaza and Wilson, 2004). Multiple changes of significant scale are likely if green features are incorporated at a later stage, resulting in a greater overall project cost (Hwang and Tan, 2012).

Lengthy Approval Process for New Green Technologies and Recycled Materials: The market environment suggests that the planning process can be protracted as the process of approving the use of new green technologies and recycled materials can be lengthy (Tagaza and Wilson, 2004). Similarly, surveys conducted by Zhang et al. (2011) and Eisenberg et al. (2002) show that additional time is expected in order to gain approval. A lengthy approval process presents a challenge to project managers as they must develop the schedule and approve progress payments to vendors and suppliers (Ling, 2003).

Unfamiliarity with Green Technologies: Many studies have verified that green technologies pose certain obstacles for developers, clients and contractors. Two reasons suggested by Eisenberg et al. (2002) are insufficient knowledge or technical expertise and unfamiliarity with the products, materials, system, or design. The main challenge is that green technologies are usually more complicated and are different from conventional technologies (Tagaza and Wilson, 2004). This was confirmed by Zhang et al. (2011). A project manager has to deliver the project with the required performance specified by the client (Ling, 2003), and unfamiliarity with the performance of green technologies may affect the performance outcome.

Greater Communication and Interest Required amongst Project Team members: To be successful, the project manager must manage a large number of suppliers, subcontractors and team members. Communication is especially critical for the green project in order to convey the sustainable practices expected from the team members. Interest amongst team members is important, Tagaza and Wilson (2004) found that the initial enthusiasm for separating waste materials amongst sub-contractors dissipated as the projects progressed and the recycling skips were found to contain a mix of materials.

More Time Required to Implement Green Construction Practices on Site: Random checks and on-site visits by project managers are usually required to ensure that sustainable practices are implemented on-site (Tagaza and Wilson, 2004). This is essential because

workers may tend to forego time-consuming sustainable practices when there are time pressures to complete a project.

2.2 Knowledge Areas & Skills of Project Manager

Project Management Institute (PMI) first documented its nine knowledge areas (Integration, Time, Cost, Procurement, Quality, Communication, Human Resource, Scope and Risk) in the Guide to the Project Management Body of Knowledge (PMBOK Guide) in 1987 in an attempt to document and standardize generally accepted project management information and practices (PMI, 2008). Each of the nine knowledge areas contains processes that need to be accomplished within its discipline in order to achieve an effective project management program. Dogbegah (2009) identified eighteen project management competency areas and the argument in the finding is that project management must be conceptualized beyond the commonly emphasized project administration expertise. In addition, Edum and McCaffer (2000) stated that acquiring the knowledge inputs for a particular type of project enables the project manager to develop two types of skills. These are specific skills, which relate directly and only to construction projects, and in particular, the areas that reflect their specialty; and general skills, which are transferable from the construction arena to other fields, but more importantly from one type of construction to another. The general skills provide much of the foundation for developing project management skills. They are often essential for the project manager to function effectively with knowledge specialists. Table 1 lists the knowledge areas and essential skills required for an effective project manager, based on previous studies.

Table 1: Knowledge Areas & Skills

Knowledge Areas	References	Skills	References
Schedule management and planning Cost management Quality management Human resources management Risk management Supply chain management Claims management Knowledge management Health and safety management Conflict and dispute management Ethical management Stakeholder management Information technology management Communication management Materials resources management Financial management Plant and equipment resources management	Project Management Institute (2008); Dogbegah (2009); Odusami (2002); Gushgar et al. (1997); Kerzner (1989); Ling (2004)	Basic technical skill Site layout and mobilization Estimating and tendering Design activities and background Reading &understanding drawings Technical writing Leadership Decision making Problem solving Negotiation Human behavior Delegation Team working Stress handling IT skills Drafting contracts Presentation Report writing Public speaking Marketing and sales Chairing meetings Public relation	Edum-Fotwe & McCaffer (2000); Odusami (2002); Gushgar et al. (1997); Fraser (1999); Tett et al. (2000)

3. Methodology

A pre-survey questionnaire was developed to validate 39 knowledge and skill areas that had been identified through the literature review. A total of 52 completed pre-survey questionnaires were returned and analysed with the use of the mean value ranking method. As the result of the analysis, the top 20 knowledge and skill areas were selected and eventually adopted for the main survey. In addition, interviews with three project managers were conducted to fine-tune the list of challenges that project managers face in managing green construction projects. The results from the pre-survey and interviews served as a platform in developing the main survey questionnaire.

The purpose of the main survey was: (1) to discover the challenges that project managers encounter in green construction; and (2) to identify critical attributes that project managers need to possess in managing green construction projects. The first section of the survey questionnaire captured the respondent's profile. The second section listed the challenges and the respondents were asked to rate the extent to which each of the challenges affected them using a five-point Likert scale (1 = not relevant at all; 5 = most relevant). The last section asked the respondents to rate the importance of project manager attributes in responding to the different challenges (1 = not important at all; 5 = most important).

Out of the 500 questionnaires sent out, 30 sets of completed survey questionnaires were received and analyzed. All the respondents had more than 4 years of experience in managing traditional projects and had some experience with green construction projects (Up to 1 year – 7%; 1 to 2 years – 17%; 2 to 3 years – 23%; 3 to 4 years – 23%; more than 4 years – 30%).

4. Data Analysis and Discussions

4.1 Top 5 Challenges faced in Green Construction Projects

Table 2 summarizes the analysis results with 36 specific challenges categorized into seven areas, their mean scores and ranks across the categories. Due to the page limit, only top five challenges are discussed in this section.

Table 2: Overall ranking of the Challenges

Category	Challenge	Mean	Rank
Planning-related	Adoption of different contract forms of project delivery	3.20	28
	The design, orientation and structure of the building	3.33	27
	Planning of different construction sequence	**4.20**	**8**
	Planning of different construction technique	**4.13**	**10**
	Lengthy approval process for new green technologies within the organization	2.43	36
	Longer time required during the pre-construction process	**4.57**	**1**
	Difficulty in comprehending the green specifications in the contract	**4.27**	**7**

Project-related	Difficulty in approving payment disbursement to suppliers and subcontractors	3.07	33
	Difficulty in assessing the progress of completion in green construction	2.97	34
	Difficulty in the selection of subcontractors in providing green construction service	**4.50**	**2**
	More time is required to implement green construction practices onsite	3.97	15
	More alteration and variation with the design during the construction process	**4.37**	**6**
Client-related	Specific budget specification of the green project	3.77	20
	Objective of the building project	4.01	14
	Required date of completion	3.67	21
	Level of risk the client is willing to take in green technologies	3.97	16
	Client uses a lot of time in making decision	3.63	22
	Special request from client pertaining to specified green technologies to be used	3.93	18
Project team-related	Conflict with the architect over the type of material to be used	3.17	29
	Lack of communication and interest among project team members	4.10	11
	Frequent meetings with green specialists	**4.37**	**5**
	Green consultant delay in providing information	3.13	30
	Conflict of interest between consultant and project manager	3.53	24
	Specific performance required for green building projects	2.53	35
Material & equipment-related	**High cost in green material and equipment**	**4.43**	**4**
	Uncertainty with green material and equipment	**4.50**	**3**
	Availability of green material and equipment	4.01	13
	Decision on different green material and equipment	4.07	12
	Imported green material or equipment	3.97	17
Labor-related	Resistance to change from their traditional practices	3.60	23
	Lack of the technical skill regarding green technologies and techniques	3.37	26
	Workers' unaware of the correct methods and procedures	3.50	25
External	Government policy	3.87	19
	Lengthy BCA approval process for new technologies	3.10	31
	More time required for TOP due to green mark certification process by BCA	3.07	32
	Unforeseen circumstances in green project	**4.20**	**8**

"**Longer time required during the pre-construction process: planning-related**" yielded the highest mean score of 4.57, indicating that it is the most frequently encountered challenge. The interviewees from this study verified that the pre-construction period of a green construction project usually requires more time as compared to traditional construction projects. The reason is due to the need for a more detailed and comprehensive design plan which incorporates all the green features required by the construction project. This often means more involvement and interaction with different stakeholder groups, which may also slow down the pre-construction process. The interviewees emphasized the importance that during the design development stage, the design team needs more time to study the design system performance against the stated green building goals. Most green technologies are

relatively new to the construction industry and their system performance is not well-known. Furthermore, greater efforts are needed to ensure that the green features that are incorporated into the design consider sources for cheaper, but still efficient green options.

Next, "**Difficulty in the selection of subcontractors in providing green construction service: project-related"** had the second highest mean of 4.50. Selection of subcontractors for traditional construction projects may be less difficult for experienced project managers who are familiar with the performance of subcontractors with whom they have worked in the past. It is also likely that there is insufficient performance information for subcontractors who are involved in green construction projects. As a result, the selection process becomes tougher and may take more time.

In terms of material and equipment-related challenges, the respondents cited **"Uncertainties with green material and equipment: Material & equipment-related"** as the third relevant challenge that they faced. All interviewees expressed concern over the reliability of green materials and equipment as most of these new technologies do not have a proven track record. Also, the fourth highest challenge was cited as "**High cost in green material and equipment: Material & equipment-related"**. Research done by Zhang et al. (2011) argued that using green materials would cost from 3 to 4% more than conventional construction materials. Selection of the green materials has to be cost-conscious in order to prevent budget overruns. Unlike conventional construction materials, the availability of many green materials may not be available locally. Problems arising from imported material may include understanding the legal regulations of the various countries. Furthermore, to ensure that an imported material will be compatible for local use, extensive testing may be required.

Lastly, the analysis revealed that **"Frequent meetings with green specialists: Project team-related"** is the fifth most critical challenges faced by project managers. An interviewee confirmed that there are an increased number of meetings required for a green construction project because an intense alliance with green specialists is necessary to fine-tune emergent issues.

4.2 Knowledge Areas & Skills Responding to the Challenges

Based on the analysis results summarized in Table 3, this section discusses knowledge and skill areas that project managers need in order to effectively deal with the challenges of green construction.

Knowledge Areas and Skills for the Planning-Related Challenges

As shown in Table 3, the survey responses revealed that the top three knowledge areas critical to project planning-related challenges are: (1) schedule management and planning; (2) communication management; and (3) risk management. As discussed, more time is usually required during the pre-project planning process for green projects. Therefore, project managers must be effective at schedule and planning management to ensure that the project will be completed in time.

Table 3: Knowledge Areas & Skills Responding to the Challenges

Knowledge Areas / Skills		Category of Challenges													
		Planning-related		Project-related		Client-related		Project team-related		Material & equipment-related		Labor-related		External	
		Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank
Knowledge Areas	Schedule management & planning	4.37	1	4.53	1	4.17	5	3.17	9	3.00	9	3.53	3	4.00	1
	Health and safety management	3.93	5	4.07	4	3.60	7	3.23	8	3.50	6	2.80	7	2.70	7
	Human resources management	3.60	8	3.60	9	3.53	9	3.53	5	3.37	8	4.40	1	3.07	5
	Stakeholder management	3.80	7	3.87	7	4.37	1	4.03	3	3.83	4	3.23	6	3.23	4
	Cost management	3.83	6	4.30	3	4.23	2	3.43	6	4.67	1	2.67	8	2.60	8
	Communication management	4.27	2	3.87	6	4.20	3	4.30	1	3.53	5	4.00	2	3.63	2
	Conflict and dispute management	4.03	4	3.93	5	3.73	6	4.17	2	3.43	7	3.53	4	2.83	6
	Risk management	4.17	3	4.33	2	4.20	4	4.03	4	4.03	3	3.50	5	3.50	3
	Materials resources management	3.57	9	3.70	8	3.57	8	3.23	7	4.40	2	2.43	10	2.47	10
	Claims management	3.13	10	3.23	10	3.27	10	2.90	10	2.87	10	2.67	9	2.60	9
Skills	Delegation	4.37	2	4.47	2	3.93	5	3.60	8	3.73	5	4.40	1	2.83	8
	Leadership	3.67	8	3.77	7	4.23	2	3.93	3	3.40	6	4.07	2	3.07	5
	Decision making	4.33	5	4.53	1	3.83	6	3.83	6	4.30	1	3.07	7	3.30	3
	Problem solving	4.37	4	4.33	3	4.17	3	3.73	7	3.83	3	3.17	6	4.10	1
	Team working	4.20	6	4.10	6	3.77	8	4.27	1	2.87	7	3.47	3	2.87	7
	Analytical	4.50	1	4.33	4	4.50	1	3.53	9	4.07	2	3.00	8	3.50	2
	Presentation	3.50	9	3.07	10	3.17	10	3.23	10	2.30	9	2.23	10	2.10	10
	Human behavior	3.33	10	3.57	8	3.80	7	3.87	4	2.50	8	3.33	4	3.03	6
	Negotiation	4.37	3	4.20	5	4.17	4	4.10	2	3.77	4	3.23	5	3.20	4
	Chairing meetings	3.70	7	3.47	9	3.27	9	3.83	5	2.30	10	2.37	9	2.27	9

Communication management is also important as project managers have to ensure that information is communicated effectively to all the various parties involved in the pre-project process including green specialists and architects. Analytical skill was found to be the most important skill required to address pre-project related challenges, as shown in Table 3. An interviewee mentioned that it is crucial for the project managers to analyze the whole situation and come up with an integrated project schedule that is achievable and manageable.

Knowledge Areas and Skills for the Project-Related Challenges

For project-related challenges, the respondents ranked schedule management and planning as the most important knowledge area, followed by risk management. Project managers have to be aware of the risks involved in selection of a new subcontractor. As a longer risk assessment and decision-making process as well as additions and alterations to the construction scope may also affect the planned project schedule, project managers need to be equipped with good schedule and planning knowledge to cope with these challenges. The most important skill to manage the challenges was found to be decision-making, which implies that there is the need for project managers to make the best possible decision on the selection of specific technologies, systems and subcontractors required for green projects.

Knowledge Areas and Skills for the Project-Team Related Challenges

Knowledge of communication management was ranked first with a mean of 4.30. Since green projects require a more holistic and integrated approach, the design process is more complex and the design phases often overlap with construction (Glavinich, 2008). Some of the interviewees reported the need for everyone in the project team to be well-informed with the project's goals and objectives in order to prevent errors. Conflict and dispute management was ranked second, as shown in Table 5. Conflict with other project team members may be unavoidable and project managers must be equipped to effectively manage conflict without affecting the progress of the project.

The survey results identified team work as the most important skill in this category (Table 6). Since challenges in this category are related to the project team, it is reasonable that project managers who are equipped with good team building skills could enhance team cohesiveness, improving the overall team performance.

Knowledge Areas and Skills for the Material and Equipment-Related Challenges

Based on Table 3, knowledge of cost management, (Mean = 4.67), was ranked first for dealing with material and equipment-related challenges, followed by material resources management, (Mean = 4.40), and risk management, (Mean = 4.03). It is crucial for project managers to have a good understanding of cost management in order to effectively manage costly green materials and to prevent cost overruns. One of the interviewees pointed out that to ensure that costs stay within budget, cost estimates should be as close to the actual sum as possible during the project planning stage. Project managers have to quantify the costs and benefits of using green materials, despite market uncertainties, and assess the risk

involved in their acquisition. One interviewee reported an example of this cost versus risk decision. The employment of an innovative product could yield a high Green Mark score, but at the same time posed a high risk of product failure because it lacked a proven track record. In fact, Table 3 shows that the decision-making skill is the most critical to effectively mitigate material and equipment-related challenges. Effective decision making also implies making the right choice within the shortest time to prevent delays.

5. Conclusions and Recommendations

This study aimed: (1) to discover the challenges that project managers encounter in managing green construction projects; and (2) to determine critical knowledge areas and skills that can respond to the challenges. The analysis of the responses from the survey and the interviews revealed the top five challenges which are critical to project managers in managing green construction projects, include: (1) the longer time required during the pre-construction process; (2) difficulty in the selection of subcontractors who provide green construction services; (3) uncertainty with green materials and equipment; (4) the high cost of green materials and equipment; and (5) frequent meetings with green consultants and engineers. Critical knowledge areas and skills that are essential to respond to the challenges were also identified. The most important knowledge areas were schedule management and planning, stakeholder management, communication management, cost management, and human resources management. In addition, the most important skills that are required to mitigate the challenges were analytical, decision-making, team working, delegation, and problem-solving skills.

Through the findings from this study, the construction industry may gain an understanding of the attributes of a competent project manager in relation to green construction projects. In addition, the importance level of the attributes could serve as a guide to companies and learning institutions for developing training syllabi that target and focus on the more critical attributes. For future studies, it would be of interest to identify attributes that are required for a project manager from the perspective of other stakeholders such as clients, developers, government associations and construction contractors. With different perspectives, future studies could develop a competency framework. Also, it is recommended to carry out further studies on how to improve and strengthen the critical knowledge areas and skills identified in this study. By doing so, project managers can improve their competency in managing green construction projects, increasing the probability of producing successful green construction projects.

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Normative Technical Parameters of Low Energy Buildings

Josifas Parasonis[1]

Abstract

The consumption of fossil fuel is a global problem and the solution of this problem could be the increase of energy efficiency and renewable energy consumption. However, the pace and methods to solve this global problem in general and particularly in construction are insufficient. In different countries, there are energy efficient buildings (passive, environmental, green, smart, sustainable etc.), although generally accepted normative evaluation parameters of energy efficiency of buildings and their impact on the environment are not available yet. The building assessment systems cover a very wide range of parameters. This makes it difficult to assess and analyse the energy efficiency of buildings objectively.

The paper proposes to introduce and regulate the coefficient of energy stock ratio, which will promote the use of renewable resources. Motion made searching for technical regulatory parameters to describe low energy buildings. According to the analysis of global energy situation, experimental buildings designing and calculations are proposed with normative values of the parameters (energy stock ratio - $\mathbf{e}_r$, final annual energy consumption - $\mathbf{Q}_a$) for low energy buildings at the use stage. The principal of the proposed methodology (energy stock ratio coefficient) is suitable not only for the construction, but for every technological process to assess the use of energy resources regarding the consumption of efficient and renewable energy and environmental impact.

Keywords: stock energy ratio, low energy building, regulation, normative parameter, environment

1. Introduction

Our society has come into such a stage, when consumption of fossil fuel has become a

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global problem. The solution of this problem could be the increase of total possible effective consumption of energy resources, search for new ones, increase of the consumption of already known renewable energy resources. The society cannot exist to unlimited extent using finite energy resources.
Since buildings represent about 40% of all energy use and they are the largest source of emissions in Europe, the EU has addressed the problem by introducing minimum requirements for the energy performance of buildings. In 2002 the EU adopted Directive 2002/91/EC of the European Parliament and of the Council dated 16 December 2002 on the energy performance of buildings, which committed the Member States to apply minimum requirements regarding the energy performance of new and existing buildings, ensure the certification of their energy performance and require regular inspection of boilers and air conditioning systems in buildings. By its Second Strategic Energy Review the European Parliament approved on the Council of 19 May 2010 the EU new Directive 2010/31/EU on the energy performance of buildings (recast)[1].
In order to protect environment from the surplus of emissions and saving energy resources clean, green, energy efficient, passive, zero energy sustainable buildings are being used increasingly. Usually, the definitions of these buildings are similar, still their characteristic parameters are quite different, and for example, eco or green buildings may not necessarily be energy-efficient. Apparently, one of the reasons for this situation is that building assessment systems cover a very wide range of parameters. Two of these certification systems are widely used in the world. One of them is American, called LEED (leadership in energy and environmental design)[2]. It is the most common so that it already has more than 5000 internationally certified projects. It was founded in 1998 and based on the U.S. Green Building Council. LEED is the only system, which is used in South America and in Africa, Europe and Asia. The oldest and most extensive in Europe is the British system BREEAM [3]. It is the second system that functions internationally in North America, Africa, Europe and Australia. All other systems until 2009 are only working at national level: DGNB (German)[4], HQE (French)[5], CASBEE (Japan)[6], Green Star9 (Australia)[7] and other.
These certification systems are analysed in the Longlife*) project reports [8, 9].
Today the situation is such that all types of buildings in generally have not approved definitions [8-10]. Also there are no low energy buildings in Europe with standardized parameters. In connection with the new Directive 2010/31/EU increased emphasis in the last period on the Zero Energy Buildings [10-16]. The Zero Energy Building definition in the Directive includes the use stage.
Regulations of energy efficient building for energy demands in various countries differ a lot. In this research the proposed technical parameters of the energy efficient buildings, which would help to standardize the identification of low energy buildings, are described.

2. Global situation of overall consumption of energy resources

The structure of energy production and consumption necessitates transformation. There are lots of scenarios of consumption development, where decrease of fossil fuel (non-renewable) consumption and increase of renewable energy sources are mentioned. Fig. 1 presented by Shell and International Agency of Energy (IAE) [17] shows energy production development of different fuel sources in overall fuel balance.

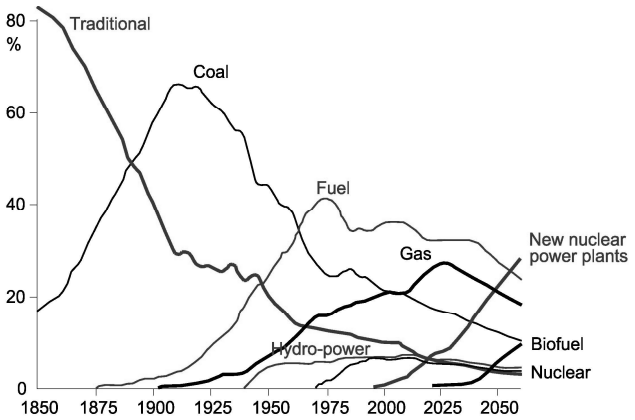

Figure 1. Development Energy production of different fuel sources

According to chart lines shown in Fig. 1, there was decrease of carbon consumption in the beginning of the 20th c., when oil and gas were discovered. In 1980s there was decrease of oil extraction and in short time the decrease of gas extraction is expected. That is why increase of renewable energy resources development is expected and in overall it will make up to 30 % of all global fuel in 2050. In this respect there are more optimistic scenarios [18]. Fig. 2 shows highly aspirated, but more realistic, the so called- AIP (Advanced International Policy) scenario.

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*)*The Longlife project is carried out under the Baltic Sea Region 2007-2013 programme: "Sustainable, energy efficient and resource saving, residential buildings in consideration of unified procedures and new and adopted technologies".*

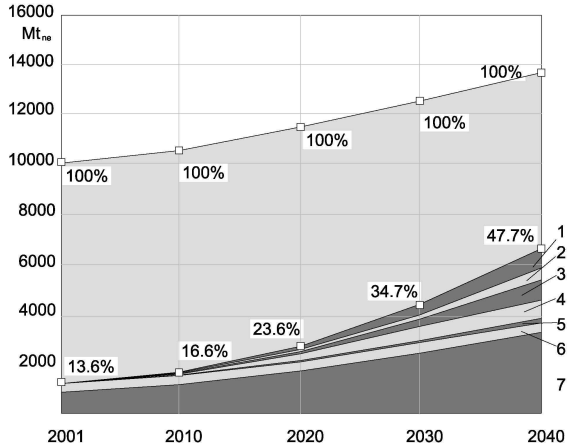

Figure 2. Global energy production scenario by EREC (European Renewable Energy Council)

Fig. 2 (*1 – geothermal; 2 – solar heat; 3 - solar electricity; 4 – wind power; 5 – small HE; 6 – large HE; 7 – biomass power*) reveals that it can be achieved in 2040, that 50% of all served energy could be renewable energy.

On the other hand, global experience of fossil fuel consumption reveals its very low effectiveness. There is estimation [19], that primary energy (the energy of renewable and non-renewable energy resources that was not converted or transported in any way) in overall is consumed only in 30% (Fig. 3).

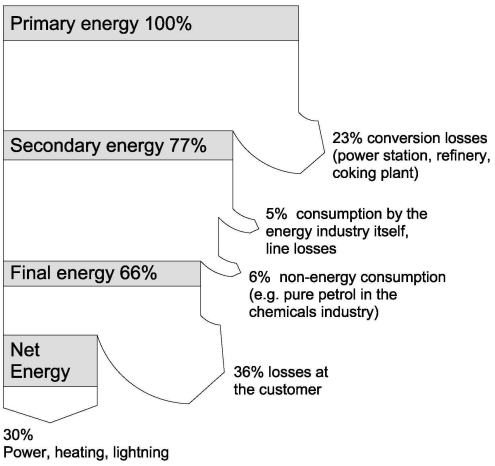

Figure 3. Energy consumption efficiency of non-renewable energy resources.

Considering the above mentioned, not only in the construction industry, but the use of energy resources in technological processes in general state of the world can be described as follows:

- Effectiveness of energy consumption must be increased in all possible ways;
- Energy production should be transformed with increase of renewable energy resources consumption.

3. Standardization of energy effectiveness in building construction industry technological processes

Sustainable development [8, 9, 20,21] plans environmental protection, every possible pollution reduction, and efficient use of natural resources.
Over the past decade European Parliament and the Council, adopted a number of important resolutions and directives on energy efficiency. All of this is important in case of building construction industry. As for intentions of the construction industry as a whole, this would mean that its energetic efficiency of the renewable and non-renewable energy resources should be compared throughout its product life cycle [8, 9, 16, 21, 22]:

- raw materials production;
- production of elements, structures;
- transportation of materials, elements, structures;
- technological process of construction period;
- building use period (heating, air conditioning, hot water production, other domestic needs);
- building demolition; recycling of its materials, elements, structures.

A change of energetic resources in favour of renewable energy resources makes better ecological parameters and better impact on environment. To promote this change, the new energy efficiency parameter of technological processes to be introduced is proposed: energy stock ratio $\mathbf{e_r}$ (the ratio of fossil fuel (non-renewable) and renewable sources of energy, necessary for a technological process). Apparently, it would be helpful not only in construction industry, but in general for all, and especially in the technology industry, pursuing sustainable development and significant environment protection results.
Considering all this, low energy building during its life cycle could be defined by two technical parameters of energy [9]:

- normative annually final energy consumption (kWh/m^{2}a);

- coefficient $\mathbf{e_r}$ (energy stock ratio) of energy consumption (ratio of fossil fuel and renewable energy resources needed for normative functioning of building).

If the energy stock ratio $\mathbf{e_r}$ value for energy efficient building, for example, could be equal to 2, renewable sources will supply the building in one-third of the total energy demand. It is clear that the regulatory energy factor value must be based on the special research for each technological process and technical possibilities.

Of the above, to describe the needed energy efficiency of the building life cycle, not only of the building use period we have to identify and normalize the energy stock ratio $\mathbf{e_r}$ regulatory values for total building life cycle [9]. Today we have the biggest amount of the needed data to find out at least the energy stock ratio $\mathbf{e_r}$ value on the period of the building use.

4. The overall annual energy demand of low energy building

It should be decided of the amount of normative annual energy consumption, after analysis of normative regulations of different countries and experimental designs of low energy building are done [8, 23, 24]. Analysis of normative regulations of European countries reveals that, there are only 7 countries where there are normative regulations of low energy buildings: Austria, Czech Republic, Denmark, Finland, France, Germany and United Kingdom. Normative regulations of these countries are shown in Table 1.

Table 1. Normative annual energy consumption regulations of low energy buildings

Country	Normative annual energy consumption kWh/m^{2}a (heating, air conditioning, hot water production, other domestic devices)	Notes
Austria	60 - 40	Bigger value is in private residential sector
Czech Republic	51 - 97	C class
Denmark	35	Without consumption for lightening and domestic devices. Project of normative regulation
Finland		At the moment energy consumption is normalized
France	40 -45	Depending on climate (location). With lightening needs, without needs for domestic devices.
Germany	40 - 60	
United Kingdom	Planned value from 2013- close to passive building value	At the moment building regulations are not compulsory

It should be mentioned, that European Community has common methodology of evaluating [25], and still there are difficulties of result comparison, because of national specificity. The reasons of differences are:

- internal or external measures evaluating heated area;
- variations of inner heat additions;
- differences in parameters of comfort conditions;
- inclusion of unheated areas in the calculations;
- differences of climate conditions.

Influence of climate conditions based on passive building built in Lithuania is shown in Table

2 [26].

Table 2. Energy consumption for heating of passive building in different climate conditions

Country	City	Yearly energy consumption for heating, kWh/m^{2}a
Germany	Hanover	11.2
Austria	Salzburg	7.4
Switzerland	Bern	8.4
Denmark	Copenhagen	10.4
Ireland	Dublin	3.9
Poland	Warsaw	14.5
Finland	Helsinki	24.3
Lithuania	Vilnius	15

Passive one household residential house, in Vilnius (Lithuania) climate conditions, was designed evaluating that annual energy consumption for heating is 15 kWh/m^2. Other data: building gross area- 194.9 m^2, heat transfer coefficient – walls- 0.1 W/m^2 K, roof – 0,07 W/m^2 K; windows –from 0.73 to 0.83 W/m^{2}K; annual energy consumption – 107 kWh/m^2; tightness, if there is 50 Pa pressure difference, – 0.4 h^{-1}.

Table 2 data reveals that climate conditions influence is big and differences in energy consumption for heating are radical: varieties from 3.9 to 24.3 kWh/m^2 per year. It means that, if energy consumption of low energy buildings will be regulated, in different European countries these buildings will be designed using different thermodynamically parameters or different engineering solutions will be used to compensate the heat loss difference because of climate conditions.

Evaluation of low energy residential building made by Lithuanian partners of Longlife project [9, 10] is based on pilot design proposal. Building has 4 floors, two staircases, oriented by diametrically opposite angles in North- South direction. There are in total 26 flats: 8 flats have 1 room (38,1m^2); 10 flats have 2 rooms (57,3 m^2); 4 flats have 3 rooms (82,6 m^2); 4 flats have 4 rooms (111,1m^2). External dimensions of the building 33.2*16.2*14 m. Total heated area- 1980 m^2, area of the windows on different sides of the building: SE - 320 m^2, NW – 160 m^2, NE – 0, SW – 50 m^2. Heat conduction coefficient of external surfaces: U_{wall} = 0,20 W/m^{2}K, U_{roof} =0,15 W/m^{2}K, U_{window}= 1,3 W/m^{2}K, U_{floov} = 0,25 W/m^{2}K. All flats are equipped with individual heat recovery air handling units, mechanical ventilation air change rate N_{mech} = 0,5 h^{-1}, infiltration air change rate n^{inf} =0,2 h^{-1}. Internal height of the flat is 2.9 m. Amount of building occupants is 58 persons. Area of solar collector for water heating is 85 m^2. Energy consumption data of the building is shown in Table 3. Heat demand is calculated in accordance with Lithuanian Building Technical Regulations (STR 2.09.04:2008 Power of heating system; STR 2.02.09:2005 Heating, ventilation and air conditioning). The Regulations are based on EN 12831:2003, EN 832:1998/AC:2002 and EN ISO 13790:2004, EN ISO 13370:2007.

Results shown in the Table 3 do not include energy consumed by internal lightening and domestic devices. This result correlates well with regulatory values of the low energy building in European countries shown in Table 1 and is close to the aspirations of the Longlife project [9].

It seems, that the two suggested normative regulatory values for the design of low energy buildings must be enough, as far as of the building use phase. Longlife project partners agreed with this proposal [9]. Socio cultural, functional and other technical parameters are already assured now through Basic building requirements: stability, longevity, safety, hygienic, acoustics, and impact on environment, fire protection. If we mast

Table 3. Energy consumption data of the low energy residential building (Longlife LT partners pilot project)

Parameters	Annual energy consumption, kwh/m^{2}a
Thermal demand for heating (heat pump COP 4,00) and ventilation (heat recovery 80%)	77,16
Thermal demand for hot water	36,39
Solar gains	**22,61**
Internal gains	**4,67**
Electricity energy demand (pumps, recuperates, elevators)	12,6
Energy produced by solar collectors and 4x3kW vertical axis wind turbines	**16,71**
Finally energy demand 31, 44	

to certificate a low energy building, the most important parameters are the energy requirements.

For energy saving over the building life cycle it would be valuable to find relations between the two suggested parameters at all stages. The result of such our attempt is shown in Figure 4, which depicts a hypothetical link between these parameters of the building use phase.

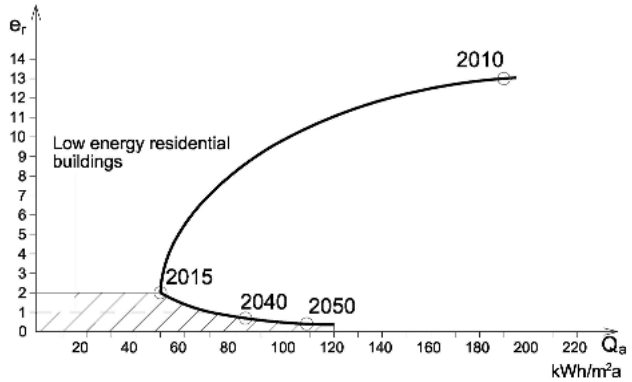

Figure 4. Hypothetic curve representing energy stock ratio e_r and annual finally energy consumption of residential buildings Q_a

Year 2010 reflect the current average situation of European Union countries in the residential sector [8]. For the proposed energy efficient building design in 2015 the regulatory factor for energy stock ratio $\mathbf{e_r}$ = 2 and the overall annual energy demand 40-50 kWh/m^2 a value is suggested.

Fig. 4 reveals that there is a field (Fig. 4., drawn in lines) where in the intersection of the two parameters the building falls into the category of low energy. Extension of the curve after the year 2015 in the growth direction of annual energy consumption is disputable.

It is clear, that effective consumption of energy resources will be topical issue, though total energy saving in the context of increasing renewable energy resources consumption will not be so important. On the other hand societal development reveals in the further the bigger energy consumption. That is why hypothetical draft lines of suggested parameters shown in Fig. 4 are yet to be researched.

5. Conclusions

Energy situation in the world forces to increase consumption of renewable energy resources. To assess this, normative $\mathbf{e_r}$ (energy stock ratio) coefficient value of fossil fuel (non-renewable) and renewable energy resources ratio should be used and normative regulations of this coefficient should be made for the stimulation of the use in technology processes renewable energy resources. The energy stock ratio coefficient is appropriate to use not only in the construction sector. It is appropriate to normalize the $\mathbf{e_r}$ for all industrial technological processes. This would significantly improve the ecological situation in the world.
Life cycle energy efficiency of the building should be valued by $\mathbf{e_r}$ coefficient value of fossil fuel and renewable energy stock ratio (taking into account periods of raw materials, elements and structures production, construction, operational (use) period, demolition and recycling).
For the design of low energy buildings, normative $\mathbf{e_r}$ coefficient value of fossil fuel and renewable (energy stock) ratio should be used and normative regulations of this coefficient should be made. Requirements of the Directive 2010/31/EU, that in 2020 the buildings could be nearly zero energy, requires to this period to achieve the energy stock ratio value $\mathbf{e_r} < 1$.
The normative value of 40-50 kWh/m2 of the gross area for the annual final energy demand (for the building use period) mast be no later than in 2015.

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Post-occupancy evaluation of university student hostel facilities: a case study in Hong Kong

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Abstract

With the new 4-year university curriculum of Hong Kong implemented in 2012, the volume of university students has continued to expand, leading to the increasing development of student hostels. In order to assess if the facilities in the hostels have performed to the satisfaction of their end users, it is necessary to carry out post-occupancy evaluations (POEs). A search from the open literature, however, could hardly find any recent POE studies on university hostel facilities in Hong Kong. Therefore, a two-stage POE study targeting a typical hostel was conducted. In the first stage, a research model was formed based on a review of relevant literature and past studies. On this basis and referring to the findings of a focus group discussion among the hostel's end users, a questionnaire was designed for use in a survey. By way of face-to-face interviews in the second stage, the survey solicited the end users' expected performance levels and perceived satisfaction levels of six main aspects of facilities, namely lighting, air-conditioning, fire safety, acoustic, internet, and hygiene. The largest gap between the expectation and satisfaction levels was found with the air-conditioning aspect. Gender was not a factor affecting the orders of perceived satisfaction with the facilities. The importance levels of the various aspects were determined using the analytic hierarchy process (AHP) but the respondents' judgments based on which the AHP weights were computed were not of good consistency. Further work is needed to overcome this deficiency and study if there are factors other than gender that would affect the end users' expected and perceived performances of the hostel facilities.

Keywords: expectation, importance, post-occupancy evaluation, satisfaction, university hostel facilities.

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1. Introduction

Post-occupancy evaluation (POE) is the process of evaluating buildings in a systematic and rigorous manner after they have been built and occupied for some time (Preiser, 1989). In order to evaluate the performance of existing facilities in a building, a POE is usually needed. Results obtained from a POE will inform how well the building matches its user needs, and reveals ways for improving any design, construction and performance of its built facilities.

POE studies, particularly those on student hostels, have been growing across the world. For instance, Hassanain (2008) conducted a POE study to investigate the major technical and functional elements of performance of the facilities in a student housing in Saudi Arabia. Adewunmi et al. (2011) carried out a POE study on the facilities of a postgraduate hostel in Nigeria. In Malaysia, Najib et al. (2011) completed a POE study which identified the level of student satisfaction with campus student housing facilities.

In Hong Kong, the new 4-year university curriculum, which supersedes the original 3-year curriculum, has been implemented since September 2012. This change has led to an increasing number of university students and hence a rising demand of hostel facilities for the higher education institutes. The Hong Kong Polytechnic University serves as an example. In addition to the existing Halls of Residence (i.e. the Hunghom Halls), a new Halls of Residence (Homantin Halls) has been completed for occupation in 2012. Yet a search from the open literature could hardly find any recent research findings on university hostel facilities in Hong Kong. Therefore, it is not known whether the performance of the facilities in the existing hostels is satisfactory.

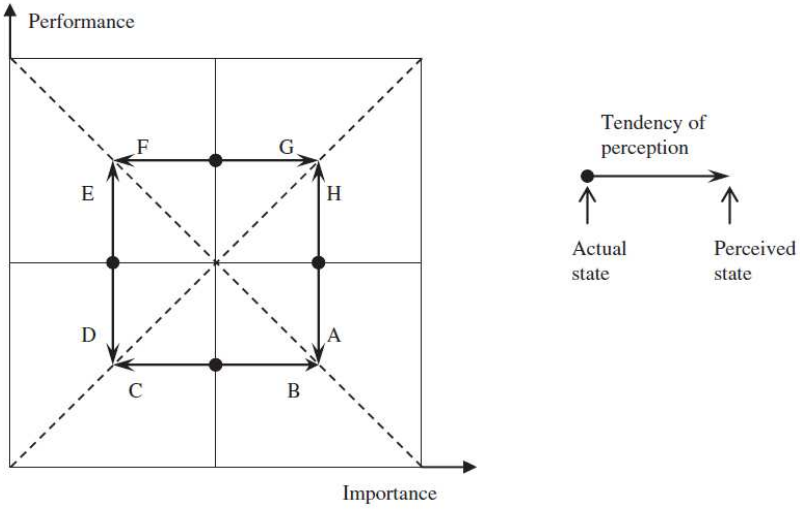
In order to investigate the performance of the facilities in the hostels, a POE study was conducted on a typical university student hostel. In the following, a review of some previous POE research models is given and the formation of a research model for the present study is outlined. The major characteristics of the hostel and the design of the questionnaire used for collecting data from the hostel's end users are described in the next section. Then the data analyses, including those made on the demography of the interviewed end users, the levels of their expectation of and satisfaction with the hostel facilities, as well as their perceived levels of importance of the facilities, are reported. The final section covers the conclusions drawn from the findings and the future work required.

2. Research model

The model based on which a POE should be performed may vary from one case to another, depending on the circumstances. As reviewed before (Carpenter et al., 1995), there are various POE models, e.g. the Merri Model (Merri Inc.,1993), the Performance-Based POE Model (Preiser, 1989), the System of Building and People (Markus, 1972), and so on. According to the life-cycle facility evaluation (LiFE) continuum (Carpenter et al., 1995), there are four facility performance categories in relation to occupancy: (1) physical system; (2) environmental quality; (3) functional system; and (4) behavior factors. Under each of these categories, there are multiple elements of performance.

Generally, the quality of a service involves a comparison of expected performance of the service and its actual performance (Gronroos, 1978). Parasuraman et al. (1988) developed the SERVQUAL model to enable evaluation of customers' expectation of the quality of a service and their perception of the service's actual performance. Along this line, the performance of facilities in a hostel can be assessed by detecting any gap between the end users' expected level of performance of the facilities and their level of satisfaction with the facilities' performance.

In an earlier study (Lai and Yik, 2007), it was found that factors such as gender and duration of stay of building end users affect their perceived importance of various indoor environmental qualities of commercial buildings. Similarly, this kind of findings was observed in another study (Lai and Yik, 2009) which, based on a conceptual framework of tendencies of perceptions (Figure 1), investigated the users' perceptions of importance and performance of the environmental qualities of residential buildings. These studies illustrated that by using the analytic hierarchy process (AHP) of Saaty (1980) to analyze the users' perceived relative importance between pairs of environmental quality attributes, their orders of importance and performance can be determined. According to the evaluation framework of Lai (2010), the importance and performance of facilities in buildings can be further analyzed using the matrix in Figure 2 to determine which aspect of facilities should be monitored, maintained, improved or capitalized.



A: Perceived low performance due to high expectation commensurate with perceived high importance
B: Perceived high importance due to dissatisfaction with poor performance
C: Perceived low importance due to adaptation to poor performance
D: Perceived low performance due to lack of attention given rise by perceived low importance
E: Perceived high performance due to low expectation commensurate with perceived low importance
F: Perceived low importance with good performance taken for granted
G: Perceived high importance due to fear of poor performance (despite the already good performance perceived)
H: Perceived high performance relative to low performance experienced in other situations (while understanding the importance of the attribute)

Figure 1: Tendencies of perception and perceptions of importance and performance

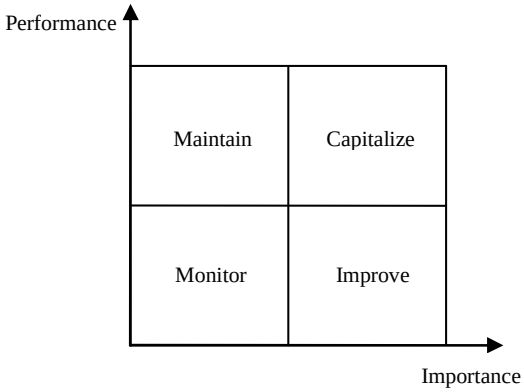


Figure 2: Importance-performance evaluation matrix

Based on the above, information about the studied hostel was gathered and a questionnaire was designed to collect data from its end users.

3. The hostel and data collection

Housing over 3,000 boarders, the hostel has been occupied for 9 years. It is 22-storey high, with its majority (3-20/F) being student accommodations, and the remaining floors include: 21-22/F for warden suites and staff quarters; 2/F for function rooms; 1/F for dining hall; and G/F for reception and lobbies. There are three types of rooms for the boarders, namely A: double room in a conventional 4-person-suite; B: double room in a 5-person-suite, and C: triple room in a 5-person-suite. An example floor plan of room type A is shown in Figure 3.

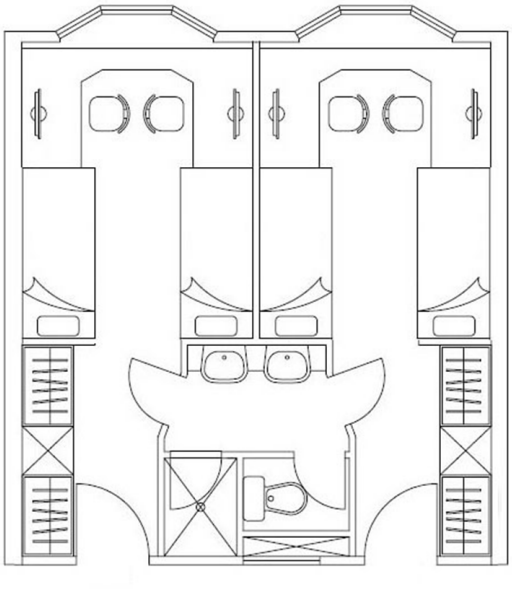
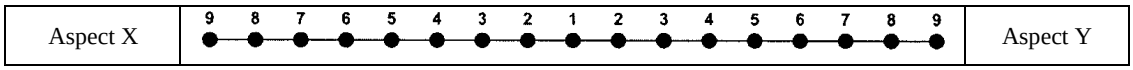


Figure 3: Typical layout plan of a 4-person-suite

A walk-through visit was paid to the hostel to obtain an overview of the facilities there. A focus group consisting of five users of the hostel was then formed to discuss on the facilities affecting their living and activities in the hostel. The main aspects of such facilities were found to be: lighting, air-conditioning, fire safety, acoustic, internet, and hygiene.

A questionnaire comprising three sections was designed to collect data from the hostel's end users. The first section enquired into the demographic information of the respondents. The second section asked the respondents to indicate, based on a 7-point scale (1: lowest to 7: highest), their expectation and satisfaction levels of performance of the six facilities aspects in their accommodations. In the final section, the respondents were requested to make a series of comparisons between pairs of the aspects based on the same 9-point scale (Figure 4) adopted in an earlier study on residential buildings (Lai, 2012).



Point	Description
1	Equally important
2	Intermediate level between the two adjacent levels
3	Moderately more important
4	Intermediate level between the two adjacent levels
5	Strongly more important
6	Intermediate level between the two adjacent levels
7	Very strongly more important
8	Intermediate level between the two adjacent levels
9	Most important; no compromise acceptable

Figure 4: The 9-point scale for pair-wise comparisons

The questionnaire was used in face-to-face interviews with the end users, who were invited to participate in the study on a voluntary basis. In total, 204 interviews were completed and the collected data were analyzed.

4. Analysis and discussion of findings

4.1 The interviewees

There were 101 female and 103 male among the interviewees. The vast majority (94.6%) of them were regular residents of the hostel although their residence durations varied from 1 to 12 months, with the majority having lived there for 5 months (Figure 5). The proportions of the interviewees staying in room types A, B and C were 47.5%, 31.4% and 21.1%, respectively.

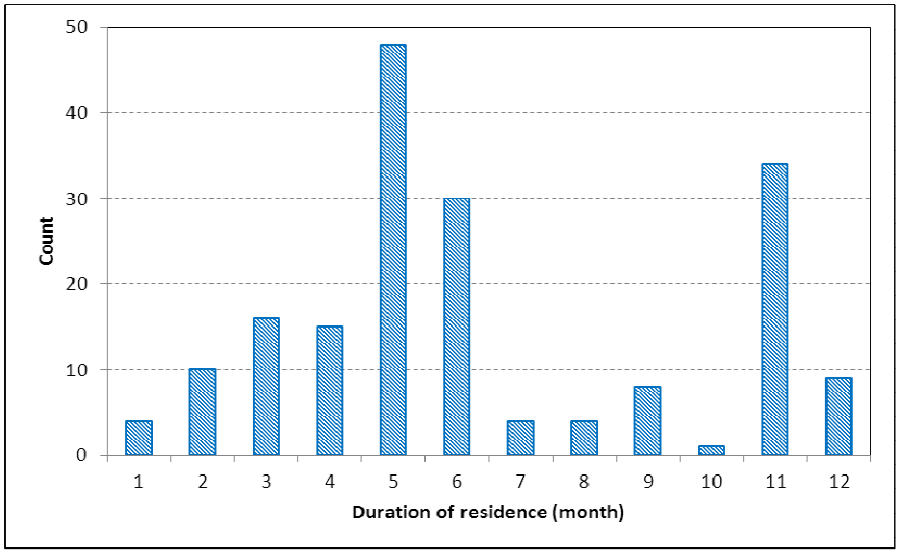


Figure 5: Residence durations of the interviewees

4.2 Expectation of and satisfaction with the facilities

The responses given by the interviewees to the second section of the questionnaire were taken to figure out the key statistical values - minimum, maximum, mean, and standard deviation (S.D.) (Table 1). Among the six main facilities aspects, air-conditioning was given the highest mean level of expectation (4.99), showing that the end users desired this aspect to outperform the remaining aspects. The aspect with a lower level of expectation was internet (4.65), followed by lighting (4.47), acoustic (4.17), hygiene (3.95), and fire safety (3.79).

Table 1: Levels of expectation and satisfaction

Aspect	Expectation				Satisfaction				Gap
	Min.	Max.	Mean	S.D.	Min.	Max.	Mean	S.D.	
Lighting	1	7	4.47	1.25	2	7	5.13	1.24	+0.66
Air-conditioning	1	7	4.99	1.14	1	7	3.56	1.40	-1.43
Fire safety	1	7	3.79	1.48	1	7	4.80	1.40	+1.01
Acoustic	1	7	4.17	1.46	1	7	3.30	1.32	-0.87
Internet	1	7	4.65	1.46	1	7	3.04	1.37	-1.61
Hygiene	1	7	3.95	1.27	1	7	3.86	1.39	-0.09

The lighting aspect, the mean expectation level of which being 4.47, was most satisfied by the end users. While fire safety was given the lowest level of expectation, its level of satisfaction (4.80) was only second to that of the lighting aspect. The hygiene aspect, with a satisfaction level of 3.86, ranked third. Apart from this aspect which was perceived by the end users as lower than the neutral satisfaction level (rating being 4), the remaining aspects falling within this category, in descending order of satisfaction levels, were: air-conditioning (3.56), acoustic (3.30), and internet (3.04).

Analyzing only the expectation levels or satisfaction levels of the facilities aspects, however, could not inform whether or not their actual performance were able to meet with the end users' expectations. The differences between the calculated mean satisfaction levels and mean expectation levels of the various aspects revealed that the lighting and fire safety aspects, both with a positive gap value, were able to satisfy the end users' expectation. Nevertheless, the gap values of the remaining four aspects were all negative, meaning that their performance levels failed to meet the levels that the end users expected.

The mean levels of expectation of the various aspects of facilities drawn from the female and male respondents were computed. Similarly, the counterparts of the satisfaction levels were obtained. Based on such mean expectation and satisfaction ratings (Table 2), the corresponding rank orders were determined, which show that the air-conditioning aspect recorded the highest order of expectation from both the female and male subgroups. While the hygiene aspect ranked bottom according to the male respondents, the female subgroup expected its performance to be higher than that of the acoustic and fire safety aspects.

Table 2: Mean expectation and satisfaction ratings of the female and male subgroups

Aspect	Expectation		Satisfaction	
	Male	Female	Male	Female
Lighting	4.544 (3)	4.396 (3)	5.243 (1)	5.010 (1)
Air-conditioning	4.961 (1)	5.020 (1)	3.476 (4)	3.653 (4)
Fire safety	3.816 (5)	3.762 (6)	4.709 (2)	4.901 (2)
Acoustic	4.252 (4)	4.089 (5)	3.320 (5)	3.277 (5)
Internet	4.835 (2)	4.465 (2)	2.893 (6)	3.198 (6)
Hygiene	3.786 (6)	4.119 (4)	3.951 (3)	3.772 (3)

Note: Rank orders are in parentheses.

Referring to the results pertaining to perceived satisfaction levels, it was found that the rank orders across all the rated aspects were identical between the female and male subgroups. This indicates the existence of perfect positive correlation between the subgroups of satisfaction ranks. On the other hand, the rank orders of expectation of the two subgroups were not identical. The Spearman rank correlation coefficient (range: -1 to +1) calculated based on these rank orders was found to be 0.829, indicating the existence of a strong but imperfect positive correlation.

4.3 Importance of the facilities aspects

Under the final section of the questionnaire, the interviewees were asked to make comparisons on the importance they perceived between each pair of the facilities aspects. Given that there were six such aspects, each interviewee had to make ${}_6C_2$ (i.e. 15) pairwise comparisons. The response given by each interviewee was processed by the AHP method to give the importance levels they perceived for each of the six aspects. Statistics of the calculated AHP weights, including the minimum, maximum, S.D. and mean values, are shown in Table 3. Also listed in the same table are the importance ranks of the aspects, which were determined with respect to their mean importance weights.

Table 3: Statistics of importance (AHP) weights

	Min.	Max.	S.D.	Mean	Rank
Lighting	0.029	0.414	0.068	0.180	2
Air-conditioning	0.053	0.457	0.076	0.231	1
Fire safety	0.030	0.377	0.055	0.145	5
Acoustic	0.026	0.321	0.060	0.160	3
Internet	0.029	0.274	0.061	0.129	6
Hygiene	0.042	0.316	0.052	0.154	4

Inspections across the minimum values of the importance weights found that they were of the same order of magnitude, and a similar observation was noted from the maximum values. Among the standard deviation values, the one pertaining to the air-conditioning aspect (0.076) was the highest, indicating the widest spread of its importance weight values. On the other hand, the spread of the importance weight values of the hygiene aspect was the smallest given that its standard deviation was the least (0.052).

As the total AHP weight of all the rated aspects is unity (1.000), the nominal weight of each of the six aspects is 1/6, or 0.167. The calculated mean importance weights show that the perceived importance levels of the air-conditioning and lighting aspects were higher than the nominal level. The greatest importance weight of the air-conditioning aspect reflects that the air-conditioning facilities were dominant elements affecting the end users' perceptions. The importance levels of the remaining four aspects, ranging between 0.129 and 0.160, were lower than the nominal importance level.

Whereas the above results have informed the levels of importance of the various aspects of facilities, the credibility of these findings depends on whether or not the pairwise comparisons made by the interviewees were made from consistent judgments. In order to determine such consistency, the consistency ratio of each interviewee's response was computed following the same process used in the study of Lai and Yik (2009). The distribution of the calculated consistency ratios is displayed in Figure 6.

The majority of the consistency ratios lied in the range of 0.22-0.34 and the mean value was 0.4494. According to Saaty (1995), the consistency ratio of responses made from consistent judgments should not exceed 10%. But the smallest consistency ratio was found to be 0.1202, meaning that none of the responses was made from consistent judgments. Although the analysis thus far is unable to explain the cause for this finding, the fact that the interviewees had to make 15 pairwise comparisons on the importance levels of the six facilities aspects is a factor that probably contributed to the inconsistent judgments. In the study of Lai and Yik (2009) where six pairwise comparisons were made for four attributes under study, 33% of the responses were made from consistent judgments. A lower proportion (31%) of consistent judgments was obtained in another study (Lai, 2011) where the respondents had to make 10 pairwise comparisons for five attributes.

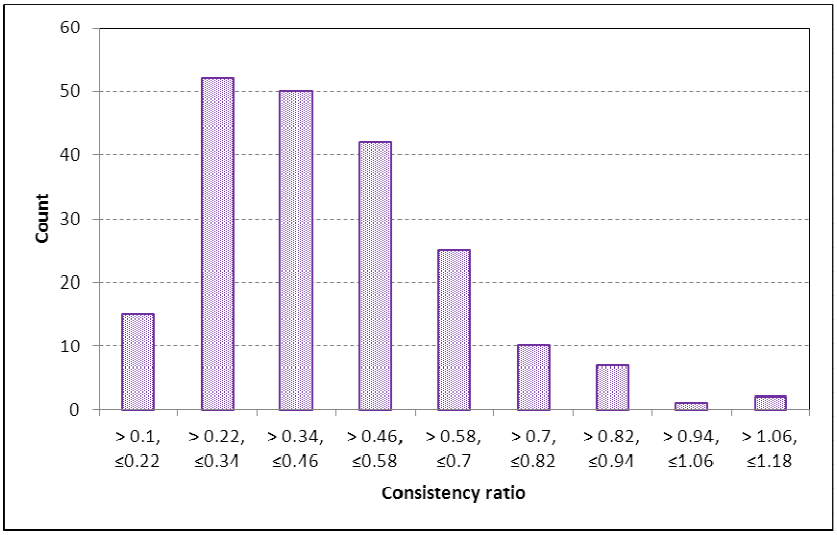


Figure 6: Distribution of consistency ratios

5. Conclusions

The POE study, focusing on a typical university student hostel in Hong Kong, was carried out based on a research model incorporating the SERVQUAL model of Parasuraman et al. (1988) and the performance-importance model of Lai and Yik (2007; 2009). The six main aspects of facilities affecting the living and enjoyment of the boarders, as identified from the focus group discussion, were: lighting, air-conditioning, fire safety, acoustic, internet, and hygiene. By interviewing the end users of the hostel, their perceived expectation of, satisfaction with and importance of these aspects of facilities were solicited.

While air-conditioning recorded the highest mean level of expectation, the end users indicated their lowest satisfaction with this aspect of facilities. The evaluation so far, however, was not able to inform the root cause of this finding. The users' qualitative comments on the performance of the air-conditioning facilities need to be analysed in future in order to identify what improvements are required for such facilities.

Lighting and fire safety were the only two aspects which were given a satisfaction level higher than the respective expectation level. In other words, the performances of the other four aspects of facilities have yet to be improved in order to meet with the expectation of the end users. Although the analysis of the responses given by the male and female users revealed that gender was not a significant factor affecting the rank orders of satisfaction with the facilities, whether other factors such as residence duration, room capacity, level and orientation, etc. would have influence on the end users' perception of the facilities' performance should warrant further investigation.

Using the AHP method, the importance levels of the six aspects of facilities were determined, with air-conditioning bearing the highest importance. In contrast, internet facilities were perceived as the least important. Examination of the consistency ratios of the responses unveiled that the judgments given by the interviewees for the pairwise comparisons between the various facilities aspects were not of good consistency. While it

may be ascribed to the large number of comparisons the interviewees had to make, further work is needed to find ways to tackle this problem.

Acknowledgement

The study reported above was supported by a research grant (No. G-YL16) of The Hong Kong Polytechnic University.

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Mandatory Reporting of Greenhouse Gas Emissions from Buildings: A Survey of the Stakeholders in Hong Kong

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Abstract

Recognising the need of mitigating global warming, mandatory reporting of greenhouse gas (GHG) emissions from buildings has been increasingly implemented across the globe. For buildings in Hong Kong, however, GHG reporting remains as entirely voluntary although the government has issued in recent years a guidance document to facilitate building owners and managers to quantify GHG emissions from commercial, residential and institutional buildings. Aimed at investigating the views of the building stakeholders on whether, and to what extent, the GHG reporting should be made mandatory, a self-administered survey was carried out. Analysis of the response given by 200 stakeholders revealed that the majority supported making the reporting mandatory, mainly for office, industrial, and hotel/hostel buildings. Their agreement on requiring mandatory reporting for activities in scopes 1 and 2 of the GHG Protocol was stronger than that on the scope 3 activities. The common reasons for those who did not support the mandatory reporting policy were also identified. While these findings are useful information to policy makers, further work is needed to investigate whether the vested interests of the stakeholders are influential in determining their support to the policy; what kinds of building areas should be covered by the mandatory reporting; and what factors would affect the views of the stakeholders on the extent to which the mandatory reporting should cover.

Keywords: building, greenhouse gas, mandatory reporting, public policy, stakeholder survey.

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1. Introduction

Climate change is a growing problem that stems from the increasing greenhouse gas (GHG) emissions across the globe. Man-made activities that give rise to such emissions include combustion of fossil fuel for energy generation, release of refrigerants from mechanical equipment, and so on. While most of the emissions are inevitable by-products of economic activities nowadays, more and more stakeholders have started to find ways to reduce their generation. This is not only a social responsibility but also a critical element in achieving sustainable development.

Quantification of the GHG emissions associated with business activities, operations in buildings, etc. is essential to understanding the impacts they impose on the environment. Proper documentation of the quantified amounts of GHG emissions, also known as GHG reporting, has been increasingly implemented by local governments as well as large organisations since the late 1990s (Kauffmann et al., 2012). For instance, over 80 company GHG reporting methods and initiatives were identified as being in use around the world, among them some are prescribed by the law and the others are taken on a voluntary basis (EC, 2010).

In Hong Kong, the public have become aware of the need of mitigating GHG emissions. A few years ago, the government issued a set of guidelines to facilitate building owners and managers to quantify and report the GHGs emitted/removed from their buildings. So far, the guidelines remain as a voluntary initiative and it is entirely up to the individuals to decide whether to adopt the guidelines. Whereas official statistics on such adoption rate are not available, the nascent implementation of GHG reporting was revealed by an earlier empirical audit (Lai et al., 2012) where the necessary record data of the audited building were found incomplete. With an aim to understanding whether the building stakeholders agree making the initiative mandatory and, if so, the extent to which it should cover, a survey was carried out.

The ensuing section shows an abridged review of the major overseas GHG reporting schemes and the current reporting guidelines in Hong Kong. Then the design of the questionnaire used in the stakeholder survey and the demographic information of the respondents are reported. The collected responses, including the support of various stakeholder groups to making GHG reporting mandatory for buildings and the extents they considered the reporting should cover, are analysed and discussed. Based on the analysed findings, the conclusions drawn as well as the further works needed are given at the end.

2. GHG reporting schemes

2.1 Overseas schemes

According to the 2009 RICS Global Zero Carbon Capacity Index (RICS, 2010), Australia and the UK were the top two performing countries in terms of developing policy frameworks for making progress towards the goal of a zero-carbon built environment. Earlier Lai et al.

(2012) conducted a review, which included making comparisons between the key features of the GHG reporting schemes of the two countries. The major findings are shown in Table 1.

***Table 1: GHG reporting schemes in Australia and the UK** (Lai et al., 2012)*

Feature	Australia	UK
Reporting of carbon emissions	Mandatory (governed by National Greenhouse and Energy Reporting Act)	Will become mandatory (governed by Climate Change Act; Companies Act)
Standards that the guidelines are based on	AS ISO 14064, ISO 14040, GHG Protocol, NGER Act 2007	GHG Protocol (also aligns with ISO 14064-1 and Carbon Trust Standard; complements PAS 2050 and ISO 14040)
GHGs quantified	All six Kyoto Protocol recognized gases	All six Kyoto Protocol recognized gases
Emissions classified into scopes 1, 2 and 3 of the GHG Protocol	Yes	Yes
Optional reporting for scope 3	No	Yes
Separate guidelines for emission factors	National Greenhouse Account Factors	Guidelines to DEFRA/DECC's GHG Conversion Factors for Company Reporting

Meanwhile, a stocktaking of government schemes on corporate GHG reporting was prepared (Kauffmann et al., 2012), which showed that a number of governments had established voluntary or mandatory GHG measurement and reporting schemes in the past decade. Such mandatory schemes include those listed in Table 2.

Table 2: Examples of mandatory GHG reporting schemes

Country	Reporting schemes	Year
Canada	GHG Emission Reporting Scheme (mandatory)	2004
Japan	Mandatory GHG Accounting and Reporting System	2006
Australia	NGER Mandatory Reporting	2009
US	Mandatory Reporting GHG Rule	2010
France	*Bilan des Emissions de gaz à effet de serre (BEGES)* (mandatory reporting)	2012

Lately, the UK government announced on 20 June 2012 the introduction of a statute requiring reporting of GHG emissions by the quoted companies, which follows a public consultation in 2011 where the majority supported making the reporting mandatory. At the time of this writing, a consultation (set to end on 17 October 2012) was launched to seek views on the regulations drafted (DEFRA, 2012).

2.2 The Hong Kong situation

The total volume of GHG emissions in Hong Kong, according to the latest available statistics of the Environmental Protection Department (EPD, 2012), was 42,900 kilotonnes of CO_2-e in 2009, representing a 28.8% increase from the total emissions in 1999. As shown in Figure 1,

the majority of GHG emissions were due to electricity generation, followed by transport, other end use of fuel, waste, and others.

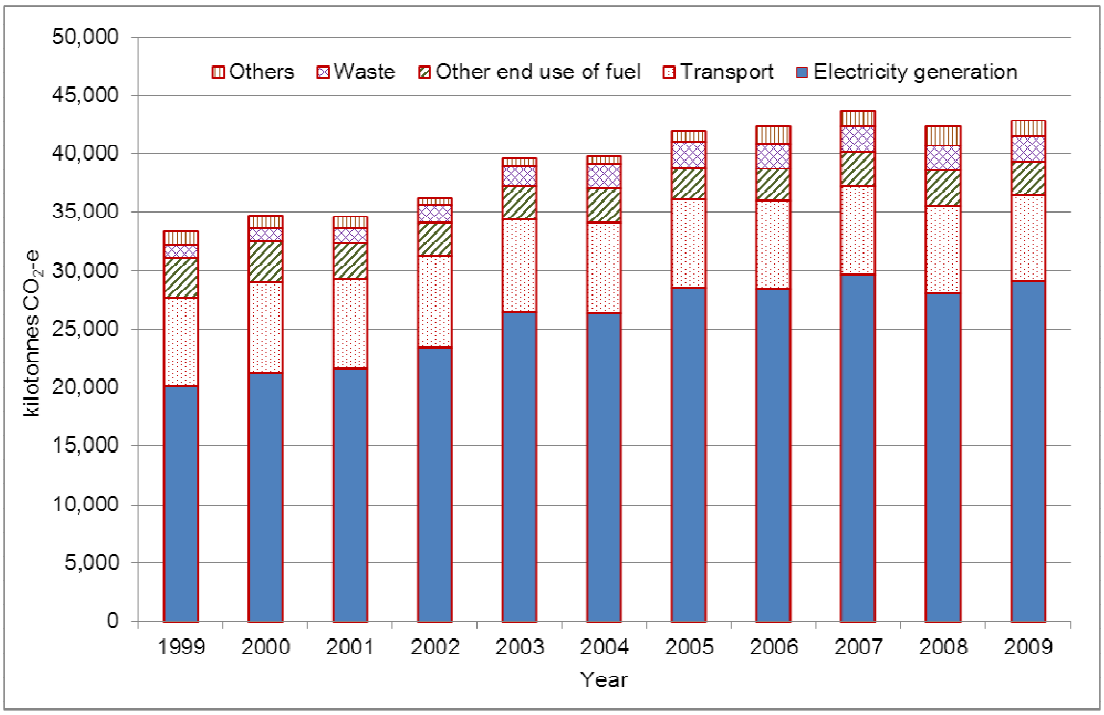

Figure 1: Greenhouse gas emissions in Hong Kong

Being a member economy of the Asia-Pacific Economic Co-operation (APEC), Hong Kong has committed to achieving a reduction in energy intensity of at least 25% by 2030 (with 2005 as the base year) as set out in the APEC Leaders' Declaration on Climate Change, Energy Security and Clean Development (APEC, 2007). Without energy-intensive industries, Hong Kong is a service economy where electricity generation is the major source of GHG emissions. Since buildings account for 89% of the end uses of electricity, reducing electricity consumption for building operations is crucial to mitigating GHG emissions.

To raise the awareness of building owners and managers about GHG emissions and assisting them to measure the emissions from buildings, the Environmental Protection Department and the Electrical and Mechanical Services Department jointly issued in 2008 the "Guidelines to Account for and Report on Greenhouse Gas Emissions and Removals for Buildings (Commercial, Residential or Institutional Purposes)". This guidance document was revised in 2010 to become the current guidelines (EPD-EMSD, 2010). Defined in accordance with the reporting framework of the Greenhouse Gas Protocol (WRI-WBCSD, 2004) and the International Standard on Greenhouse Gases (ISO, 2006), the scopes of emissions and removals covered by the guidelines are summarized in Table 3.

Intended primarily for use on buildings which are used for commercial (including offices, retails, restaurants, hostels and hotels) and/or residential purposes, the guidelines can also be applied to institutional buildings such as schools, universities, community centres, sports complexes, etc. Basically the guidelines are designed for self-assessment and self-reporting

by the buildings' reporting entities, but third parties may also be employed to assess the GHG emissions/removals from the buildings. While Hong Kong is a community governed by the rule of law and thus a variety of statutory controls on buildings have been in place (Lai et al., 2011), adoption of the above guidelines for GHG reporting remains as entirely voluntary.

Table 3: Scopes of GHG emissions

Scope 1	Scope 2	Scope 3
• Combustion of fuels in stationary sources excluding electrical equipment to generate electricity, heat or steam • Combustion of fuels in mobile sources • Intentional or unintentional GHGs release from equipment and systems • Assimilation of CO_2 into biomass • Any other physical and chemical processing	• Consumption of purchased electricity • Consumption of purchased town gas	• Methane gas generation at landfill in Hong Kong due to disposal of paper waste • Electricity used for fresh water processing • Electricity used for sewage processing • Others

3. Stakeholders survey

3.1 Questionnaire design and data collection

In order to solicit the opinions of building stakeholders on whether, and to what extent, the GHG reporting for buildings in Hong Kong should be made mandatory, a survey was conducted. For this purpose, a questionnaire comprising four sections was designed. Under section 1, the respondents were asked to provide their personal particulars, including years of work, company types, work natures, building/premises types they worked on, and professional and academic qualifications. Section 2 asked for their opinions on the scope of physical boundary of buildings to be included for mandatory GHG reporting. Opinions of the respondents on the extent of mandatory reporting of GHG emissions/removals (under scopes 1, 2 and 3 of the GHG Protocol) were collected by the questions in Section 3. An open-end question was included in Section 4 to allow the respondents to express any additional views or opinions not covered by the preceding sections of the questionnaire.

The survey was conducted in a self-administered manner on two occasions - a seminar and a forum. The participants of the two events were requested to take part in the survey voluntarily, and totally 200 questionnaires completed with useful data were collected.

3.2 Demography of the respondents

The majority (42.5%) of the respondents were highly experienced, having worked for 15 years or more. Respondents with the least work experience (five years or less) amounted to one-fourth of the sample. When classified by company types, the vast majority (78.5%) of the respondents were employed by the private sector. 14.5% worked for non-government public organizations and the rest were government employees.

The respondents were asked to indicate the main nature of their work and the latest types of building/premises they worked on at the time of the survey. The proportion distributions of such responses are shown in Table 4. The proportions of those working in the building/facility management, construction/contracting and design/consulting fields were comparable and they collectively represented the majority (67.5%) of the respondents. The proportion of those working for property developers or project management companies was smaller, and even fewer respondents were from the academic/research sector.

Table 4: Work natures and building/premises types

Main work nature		Building/premises type*	
Property development / project management	12.5%	Office	67.5%
Design / consulting	21.5%	Retail	24.5%
Construction / contracting	22.5%	Residential	31.5%
Building / facility management	23.5%	Industrial	18.0%
Academic / research	3.0%	Hotel / hostel	22.5%
Others	8.5%	Restaurant	9.0%
More than one of the above natures	8.5%	School / university	15.0%
		Leisure / cultural	11.0%
		Others	12.5%

*Note: The aggregate proportions exceeded 100% because some respondents worked on multiple types of buildings/premises.

Office was the dominant type of building/premises the respondents worked on. The proportions of the remaining building/premises, in descending order, were: residential, retail, hotel/hostel, industrial, school/university, leisure/cultural, and restaurant. Additionally, 12.5% of the respondents indicated that they worked on other types of building/premises which are beyond those listed in the answer options.

Generally the respondents belonged to those who were well educated. 96.0% possessed a bachelor degree; 30.0% had their highest qualification up to the master degree level. As regards their professional qualifications, 23.5% were professional engineers registered under the Engineers Registration Ordinance (Cap. 409), 6.0% were energy assessors registered under the Buildings Energy Efficiency Ordinance (Cap. 610), and 5.5% were carbon auditors meeting the requirements for registration as a qualified service provider to certify energy-cum-carbon audit projects under the Environment and Conservation Fund of Hong Kong.

4. Analysis and discussions

4.1 Overall agreement

Of all the respondents, 72.0% agreed imposing mandatory GHG reporting on buildings. Those with a neutral stance and those who did not indicate their views amounted to 22.5%. Only a small proportion (5.5%) expressed their disagreement. Projecting on the basis of

these findings, it is likely to obtain strong support from the stakeholders in Hong Kong if a consultation for making the reporting mandatory is launched.

This part of the responses was further scrutinized to reveal the proportions of agreements and disagreements given by different subgroups of the respondents. As Table 5 shows, the majority across the subgroups were generally supportive of regulating GHG reporting for buildings. In particular, the supports among those working for non-government public organisations were much common than the counterpart among the government subgroup.

Table 5: Subdivided groups of response

Group	Subgroup	n	Disagree	Neutral/Nil	Agree
Work experience	≤ 5	50	8.0%	22.0%	70.0%
	>5 , ≤ 15	58	5.2%	24.1%	70.7%
	>15	85	4.7%	21.2%	74.1%
Company	Government	13	7.7%	23.1%	69.2%
	Non-government public	29	10.3%	6.9%	82.8%
	Private	157	3.8%	25.5%	70.7%
Main work nature	Property development / project management	25	12.0%	40.0%	48.0%
	Design / consulting	43	4.7%	20.9%	74.4%
	Construction / contracting	45	4.4%	22.2%	73.3%
	Building / facility management	47	6.4%	19.1%	74.5%
	Academic / research	6	0.0%	0.0%	100.0%
Professional qualification	Carbon auditor	11	9.1%	18.2%	72.7%
	Registered energy assessor	12	0.0%	16.7%	83.3%
	Registered professional engineer	47	4.3%	31.9%	63.8%
Academic qualification	Sub-degree	6	16.7%	33.3%	50.0%
	Bachelor degree	60	8.3%	20.0%	71.7%
	Master degree	126	3.2%	21.4%	75.4%
	Doctorate degree	6	0.0%	50.0%	50.0%

When grouped by the respondents' work natures, less than half of those in the property development/project management sector supported requiring buildings to have mandatory reporting of their GHG emissions/removals. In fact, this subgroup of respondents mainly worked on new building projects but the framework of GHG reporting under the current guidelines (EPD-EMSD, 2010) targets on the operation of existing buildings. This may be a reason for the relatively low support rate among them. On the other hand, all those in the academic/research field considered that GHG reporting for buildings should be made mandatory. Note, however, should be taken that the number of samples of this subgroup

was small. A larger sample of this subgroup is needed before their views can be generalized.

The professional qualifications that the respondents were allowed to select were not mutually exclusive to each other. In general, carbon auditors include registered professional engineers (RPEs) having attended relevant training for carrying out carbon audits, and registered energy assessors include RPEs possessing the required experience and qualifications as defined under the Buildings Energy Efficiency Ordinance (Cap. 610). Those who were carbon auditors commonly agreed requiring mandatory GHG reporting for buildings. This kind of agreement was even more commonly found among the registered energy assessor subgroup.

Most of the respondents with their highest academic qualifications up to the bachelor or master degree level agreed to making the reporting mandatory. But only half of those with a lower academic qualification (sub-degree) indicated their support to this arrangement, and an identical proportion of response was found with the doctorate degree subgroup. Common to both of these subgroups, the small sample size limits the representativeness of the respective observations.

4.2 Types of building/premises

As shown in Table 6, six in every 10 respondents agreed imposing mandatory GHG reporting on office building/premises but obviously less (42.5%) of the respondents indicated their agreement on requiring retail building/premises to be bound by the same mandatory reporting. Whereas both types of these building/premises are occupied by commercial users whose energy consumption significantly outweighs other groups of energy end use, the reasons for the significant difference between the agreements are yet to be identified.

Table 6: Responses on building/premises types to be covered

Building type	No.	Proportion
Office	120	60.0%
Retail	85	42.5%
Residential	51	25.5%
Industrial	106	53.0%
Hotel / hostel	109	54.5%
Restaurant	63	31.5%
School / university	62	31.0%
Leisure / cultural	47	23.5%

Unlike commercial buildings which are mainly used by business organizations and customers, residential building/premises are occupied by all people in society and their operation period extends to cover the night time during which most commercial premises are left idle. However, only about one-forth of the respondents indicated their agreement on implementing mandatory GHG reporting for the residential building/premises. Possible

reasons for this level of response may include the following perceptions of the respondents: i) residential activities are basic necessities for daily life and so reporting of the GHG emissions associated with such activities should not be regulated; and ii) residential activities are much less GHG-intensive and so the mitigation effect that can be achieved through regulating the reporting of their emissions is minimal.

Hotels and hostels are similar to residential buildings in that they have round-the-clock operations. Over half of the respondents expressed their agreement on including these two types of accommodations in the list of buildings for which GHG reporting should be made mandatory. A comparable proportion of the respondents supported that mandatory GHG reporting should also be imposed on industrial buildings. Even though the volume of this kind of buildings in Hong Kong has substantially gone down as a result of the progressive move of industrial organizations to the mainland China over the past few decades, the high intensity of GHG emissions generated from industrial activities is probably a key consideration for those who supported the mandatory policy.

Commercial premises used for operating restaurants, as compared with those used for office and retail purposes, are even more energy-intensive and the intensity of their GHG is thus even higher. But only a weak support (31.5%) was given to having mandatory GHG reporting for this type of premises. While the reasons for this finding are not known from the analysis so far, an almost equal proportion of response was found with the same question on school/university buildings, whose nature and hence operations are distinct from those of restaurants.

The group of buildings recording the lowest rate of support for having mandatory GHG reporting was leisure/cultural. In fact, most of such buildings in Hong Kong are managed by the Leisure and Cultural Services Department (LCSD) of the government. It is likely that LCSD has already practiced regular GHG reporting for the buildings they managed. Yet, whether this is the reason for those who considered it not necessary to regulate GHG reporting for leisure/cultural buildings is worth-investigating.

4.3 Extent of GHG emissions/removals

Scope 1 emissions cover those due to stationery combustion sources, mobile combustion sources and fugitive GHGs release from equipment and systems. Within this group, emissions due to mobile combustion sources received the lowest level of support for inclusion in the list of GHG emissions that should be reported mandatorily (Table 7). Among those who opposed to this arrangement, 14 considered it hard to gather the required data for reporting, echoing with the difficulty encountered in an earlier carbon audit study (Lai et al., 2012). An equal proportion of the respondents indicated that they agreed requiring mandatory reporting of CO_2 removals. The reason given by 13 respondents who were against this arrangement was it is time-consuming to do so.

Emissions due to consumptions of electricity and town gas, which were both under scope 2, were supported by most of the respondents to be included in the mandatory GHG reporting coverage. Essentially quantification of these emissions, in annual term, entails identification

of the corresponding monthly electricity and town gas consumptions, as well as the emission factors pertaining to productions of electricity and town gas. The fact that such emission factors for a particular year are given in the annual reports of the respective electricity and gas supply companies in the subsequent year typically leads to delay in the quantification. This concern may be a consideration for those who expressed their disagreement to the mandatory reporting policy.

Table 7: Opinions on extent of emissions/removals

Emission/removal	Disagree	Neutral/Nil	Agree
Stationary combustion sources	5.5%	20.5%	74.0%
Mobile combustion sources	12.5%	26.0%	61.5%
Fugitive emissions	11.5%	23.5%	65.0%
CO_2 removals	13.5%	25.0%	61.5%
Consumption of electricity	9.0%	16.0%	75.0%
Consumption of town gas	13.0%	16.0%	71.0%
Disposal of paper waste	17.5%	23.5%	59.0%
Consumption of fresh water	12.5%	17.5%	70.0%
Treatment of waste water discharged	12.5%	17.0%	70.5%
Transportation of purchased materials or goods	12.0%	18.5%	69.5%
Business travel by employees	12.0%	17.5%	70.5%
Outsourced activities	13.0%	17.5%	69.5%

The remaining items in Table 7 belong to scope 3 GHG emissions, among them disposal of paper waste attracted the largest proportion of respondents who disagreed to making the GHG reporting for such activity mandatory. 18 respondents of this group considered that gathering the required data for reporting GHG emissions due to disposal of paper waste is difficult. In fact, the same difficulty was experienced in a hotel's carbon audit where the record on the amounts of paper consumed and paper collected for recycling was incomplete (Lai et al., 2012).

5. Conclusions

The global trend of enforcing mandatory requirement on GHG reporting is on the rise. The guidelines on GHG reporting for buildings in Hong Kong, first issued by the government in 2008 and subsequently revised in 2010, remain as a voluntary initiative. A questionnaire, which was designed with consideration of the coverage of the guidelines, was distributed to collect the views of 200 building stakeholders on imposing mandatory GHG reporting on buildings. Overall, the majority were supportive of this policy but the rate of agreement among those in the property development/project management fields was below half. Only office, industrial, and hotel/hostel buildings were considered by over half of the respondents to be the types of buildings on which the mandatory policy should be imposed. Among the

activities to be covered by the mandatory reporting, disposal of paper waste received the least proportion of support among the respondents.

In order to obtain a more comprehensive and detailed understanding of the views of the building stakeholders, the collected response needs to be analyzed further to reveal whether the backgrounds and hence the vested interests of the stakeholders affect their views on the building types to be covered by mandatory GHG reporting; and what areas (e.g. communal area, tenant area) of different types of buildings should be covered. Future work is also needed to identify the factors that influence the views of the stakeholders on the extent to which the GHG emissions from buildings should be reported on a mandatory basis.

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How Can Facilities Management Add Value To Organisations As Well As To Society?

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Christian Coenen[4]

Abstract

The purpose of this paper is to present lessons learnt from a 3 year collaborative research project on the added value of Facilities Management (FM) involving institutions in five European countries. The starting point was the so-called FM Value Map developed earlier by the leader of the research group. The project applied three basic theoretical perspectives: FM, Corporate Real Estate Management (CREM) and Business to Business (B2B) marketing and started with a major literature review on added value based on each of these perspectives. The collaboration included a series of workshops and preparation of research papers covering theoretical, methodological and empirical aspects. The results were published as an anthology in May 2012. The three basic perspectives of FM, CREM and B2B marketing provide both overlapping and complementary focus areas in relation to adding value. Four conceptual models are presented and compared. They include parameters and strategies for how FM can add value with many similarities and a trend towards convergence. Stakeholder relationships and relationship management are seen as crucial in adding value, which for instance is expressed in the concepts FM Value Network and Value Adding Management. Besides adding value for the core business of organisations it is becoming increasingly important for FM to add value for society, for instance in terms of sustainability and corporate social responsibility. The advancement in knowledge and understanding presented in the paper offers a new state of the art, which can give inspiration and guidance for cutting edge FM organisations and professionals as well as for advanced teaching and future research.

Keywords: Facilities Management, Corporate Real Estate Management, B2B Marketing, Added Value, State of the Art.

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1. Introduction

This paper is based on the work of a EuroFM research group on “The Added Value of FM” established in 2009. The group included researchers from Denmark, Finland, Switzerland, The Netherlands and the UK. The background for the collaborative research is that the perception and application of Facilities Management (FM) during the last few decades have seen a gradual shift from a focus on cost reduction towards managing of facilities as a strategic resource to add value to the organisation and its stakeholders and to contribute to its overall performance. The main results of the work so far are presented in the anthology “The Added Value of Facilities Management – Concepts, Findings and Perspectives” (Jensen et al., 2012), which was launched during the European Facility Management Conference (EFMC) in Copenhagen, May 2012.

The book shows why and how this shift occurred and how the supply of facilities and services can or should be aligned to the different interests and needs of various stakeholders. It connects concepts, theoretical frameworks, research data and measurement tools from different countries and different disciplines, including Facilities Management (FM), Corporate Real Estate Management (CREM), and Business to Business Marketing (B2B Marketing). The empirical studies explored different sectors such as offices, higher education, industry and health care.

This paper presents some of the main results of this collaborative research with a focus on how FM can add value to organisations as well as society. The three basic theoretical perspectives of FM, CREM and B2B marketing will be outlined and four models of how FM and real estate can add value will be presented and compared. Furthermore, some important lessons learnt and new insights concerning relationship management and sustainability are presented.

2. The Three Basic Theoretical Perspectives

It was clear from the outset, that the researchers in the group had different academic and theoretical backgrounds. Even though they all did research in relation to FM, some of the researchers were more engaged in the related field of CREM. There were also differences with some researchers from architectural and engineering backgrounds and others from B2B marketing and similar marketing related backgrounds. These different backgrounds were seen as fruitful in providing different types of insights into frameworks and challenges in reaching common understanding of the benefits and shortcoming of the different theoretical frameworks.

2.1 Facilities Management (FM)

The activities that today are regarded as part of FM have existed in organizations for a long time before the term FM was used and the profession of FM was established starting in the 1980’s. The development of FM as a new management discipline in many countries during the 1980’s and 1990’s has very much been driven by an aim to control and reduce cost by new ways of organizing and managing a number of disparate activities, which formerly had

been without much management attention. With the introduction of centralisation, internal markets, benchmarking, outsourcing, Service Level Agreements (SLAs) and Key Performance Indicators (KPIs), a new management regime has been introduced and in many cases resulting in tremendous cost savings. Around the change of the millennium the role of FM has changed in many corporations. Controlling cost is no longer sufficient. In periods of expansion and with strong demand for new generations of a limited number of highly skilled professionals from the creative class, it is for many companies more important to attract and retain employees. Providing attractive workplaces with excellent services has become increasingly important as a primary requirement for FM. This forces FM to focus on how facilities can be managed to add value to the core business. The same applies to the changes in society towards an experience economy. The financial crisis which started in 2008 may, for a period, change the focus back towards cost reduction, but the underlying change to knowledge and experience economy has not changed. The new focus on sustainability and corporate social responsibility are other trends that, drives FM towards a focus on added value.

One of the first manifestations of the new focus on added value in FM was the establishment of a NordicFM work group in 2006 to 'Highlight the added values for the core business provided by Facilities Management'. The members were mostly practitioners. The only researcher participating in meetings in the work group was Per Anker Jensen, Technical University Denmark, who alongside participating in the NordicFM work group was leading a research project at the Technical University of Denmark on FM Best Practice in the Nordic Countries. The project included 36 case studies. One of the general conclusions was that there had been a change in FM from mainly focusing on cost reductions towards a higher degree of focus on adding value. By analysing 21 cases from the first phase of the research project he developed the so-called FM Value Map, which was partly inspired by strategic mapping from the Balanced Scorecard (BSC) methodology (Kaplan and Norton, 2000). The FM Value Map was published together with the 36 cases in books in English and Danish (Jensen et al., 2008) and as a research paper in the scientific journal Facilities (Jensen, 2010).

2.2 Corporate Real Estate Management (CREM)

During the last few decades there has been a shift going on from perceiving real estate as a necessary burden, toward a rising awareness of the possible contributions of real estate to corporate performance. Contrary to the transaction-oriented focus of real estate management from an investors' point of view, aiming to get the best possible return on investment in the short and long run, CREM focuses on alignment of real estate to corporate needs and objectives, incorporating the needs and wishes of shareholders and different stakeholders at strategic, tactical and operational levels. While real estate resources and capabilities were initially controlled and managed by the individual corporations, activities and responsibilities are nowadays delegated more and more unto professional parties outside the corporation. In the field of public real estate, i.e. real estate owned or rented by ministries, municipalities and other governmental agencies, a shift is going on from decentralised real estate management with a focus on facilitating primary processes towards integration of FM and CREM in centralised shared services.

As a consequence of this changing context and the changing scope of corporate and public real estate, real estate managers working in or for public or private companies are in urgent need for clear conceptual frameworks, data and tools for “evidence based” decision making on linking real estate decisions to corporate strategy and adding value by real estate. Nourse and Roulac (1993) were the pioneers who started to investigate how alternative real estate strategies can contribute to business objectives. They found that too often the dominant emphasis is on the financial goal of cost minimization. In order to effectively support a range of corporate objectives, multiple rather than single real estate strategies are required. They linked eight types of real estate strategies to a number of possible aims of a firm. This research has been followed up by Anna-Liisa Lindholm (Lindholm et al., 2006), who developed a model based on strategic mapping from Balanced Scorecard (BSC) methodology (Kaplan and Norton, 2000) to show how real estate strategies can lead to profitability growth and/or revenue growth and thereby maximize the wealth of shareholders. Jackie de Vries investigated the impact of real estate interventions on organisational performance through a survey among Institutes of Higher Professional Education in the Netherlands (De Vries et al., 2008). The empirical study was based on a theoretical model that takes its starting point in the thinking of Joroff et al. (1993), that real estate is the fifth resource after human resources, technology, information and capital. A recent dissertation by Alexandra den Heijer on *Managing the University Campus* (Den Heijer, 2011) further explored how policymakers and real estate managers incorporate ways to add value to the core business in campus management and how they balance the needs of different stakeholders such as the daily users, controllers and society.

2.3 Business to Business Marketing (B2B Marketing)

Marketing - in the sense of development of new products or pricing decisions - has been playing a role in market transactions for several centuries already. The early phase of marketing’s development was characterized by the idea of selling products. In the 1950s and 1960s, the so-called marketing-mix was defined (McCarthy, 1964), which integrated the existing concept of marketing as advertising and sales into a broader system of classifying marketing activities. In recent years the discipline has witnessed a shift to issues addressing marketing implementation, which called for a more multi-disciplinary viewpoint combining marketing with other business disciplines such as organizational behaviour, psychology or finance (Workman et al., 1998). A new approach addressed the question of to what extend a company should be managed as a market-oriented organization (Jaworski and Kohli, 1993). Parallel to the emphasis on market-oriented management, customer relationships increasingly gained more importance and attention from both marketing practice and theory (Homburg et al., 2009). The basis of this perspective is the awareness that the establishment and sustainability of profitable long-term customer relationships pose a central challenge to business in general and marketing in particular. The concept of relationship marketing implies that the individual transaction with customers is replaced by a focus on long-term business relationships (Berry, 1983; Grönroos, 1990).

In the 1980s a string of research evolved around the difference between marketing of goods and services (Parasuraman et al., 1985). Basically, service marketing was established as a research and management discipline, because services needed different marketing

approaches than physical goods. Services are mostly intangible and the customer takes part in the delivery process (Zeithaml et al., 2006). Because of this the customer and his/her perception of the service process plays an even more significant role than in evaluating physical goods. Based on the original idea of the value chain (Porter, 1998), the Service Value Chain structures value creating processes of service firms (Bruhn and Georgi, 2006). In addition, the concept of the Service Profit Chain (Heskett et al., 1994) by Harvard Business School structures the impacts of service provider's activities on the customer's perceptions and behaviours. At the same time it shows how customer value is created. Services marketing activities are evaluated by the customer and will lead to certain customer's behaviours, e.g. loyalty and repurchasing. This positive behaviour will ultimately lead to increased firm value. It can be stated that the Service Value Chain encompasses value activities by organizations; the Service Profit Chain encompasses the value effects of these activities (Bruhn and Georgi, 2006).

2.4 Comparison of the three perspectives

The difference in scope between FM and CREM is that CREM has its focus on real estate as physical and economical assets utilized by an organization, while FM has a wider service focus including demands related to space and infrastructure as well as people and organization (CEN, 2006). As professions, FM and CREM can be overlapping with different traditions in different countries and organizations. The difference in scope between FM and CREM on one side and B2B marketing on the other as professions is that FM and CREM are related to organizations' use of built facilities and the input side of business processes, while B2B marketing can concern the sale of any product or service and is related to the output side of business processes. B2B marketing as a discipline is mostly based on social science with research and teaching at business schools, while FM and CREM have a more multi-disciplinary character with a knowledge base from social science, architecture and engineering. FM and CREM are strongly related to the resource based view in strategic management thinking. Marketing in general has a longer tradition as a profession than FM and CREM.

Table 1 presents a comparison of the different aspects included in the scope of the three basic disciplines. FM and CREM both have a strong focus on the physical assets of an organisation in terms of facilities, real estate, property and buildings. FM has a much stronger focus on services and service management than CREM, whereas B2B marketing also can have a strong focus on services, particular when applied to the FM domain. B2B marketing naturally has a strong focus on marketing, which is not the case for FM and CREM. Relationships are also very much in focus for B2B marketing, but that is increasingly the case for both FM and CREM too, particularly in terms of stakeholder relationships and management and regarding partnerships between providers and customer organisations. Economy is important for all perspectives, but with major differences in focus. FM has a strong focus on operational cost and CREM has a strong focus on investments and life cycle costs, while price and income generation is the main economical focus of B2B marketing.

Table 1: Comparison of the three basic perspectives

Aspect / Perspective	Physical assets	Services	Marketing	Stakeholders	Economy
FM	X	XX		X	X
CREM	XX	X	X	X	X
B2B marketing		X	XX	X	X

3. Four Conceptual Models

When the collaborative research started there were three main conceptual models of mapping added value – The FM Value Map by Per Anker Jensen and two models from CREM by Anna-Liisa Lindholm (now Sarasoja) and Jackie de Vries. The model of Jackie de Vries is shown in Figure 1. The FM Value Map is shown in the generic version in Figure 2. An updated version of the model by Anna-Liisa Sarasoja is shown in Figure 3. It includes "Supporting environmental sustainability" as an additional real estate strategy and also shows possible Green FM influences for the other real estate strategies. Alexandra den Heijer developed a fourth model shown in Figure 4 as part of her PhD-study at Delft University of Technology (Den Heijer, 2011). It is partly based on the model by Jackie de Vries, but it rephrased and added new values and as such is seen as a new model.

A comparison of the added value parameters in the four conceptual models is shown in Table 2 structured according to the four headings: People, Process, Economy and Surroundings. The parameters related to People are quite similar in model A and D. All models include (employee) satisfaction. Model B defines "Culture" as including "Image", which are separated as different parameters in model A and D. Model C only includes "Increase employee satisfaction" under People, but this model as the only model includes "Promote marketing and sale" under Economy, which can be seen as an economical expression of "Image", similar to brand. All four models include at least three parameters for Process with many overlaps; the differences can partly be seen as different degrees of sub-dividing. In relation to Economy, model B (the FM Value Map) only includes the parameter "Cost", while the three other more CREM based models include parameters for "Value of real estate", "Value of assets" or "Possibility to finance". The parameter "Controlling risk" in model D is defined as related to financial goals, but it is also strongly related to the Process parameter "Reliability" in model B. In model A "Risk control" is included as well, partly related to reducing financial risks, but also to improving health and safety. Model B was the first model to include parameters related to Surroundings, including the "Environmental" parameter, but the other more recent CREM based models C and D also include a parameter for "Environmental sustainability".

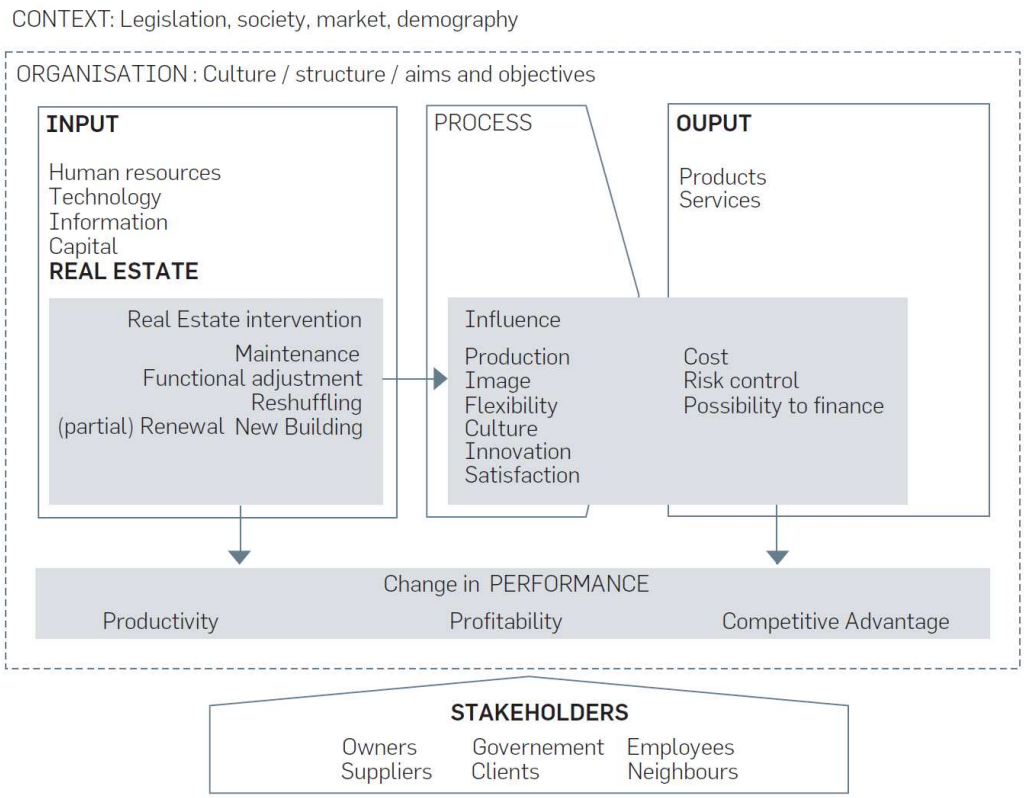

Figure 1: Model 1 by Jackie de Vries (De Vries et al., 2008)

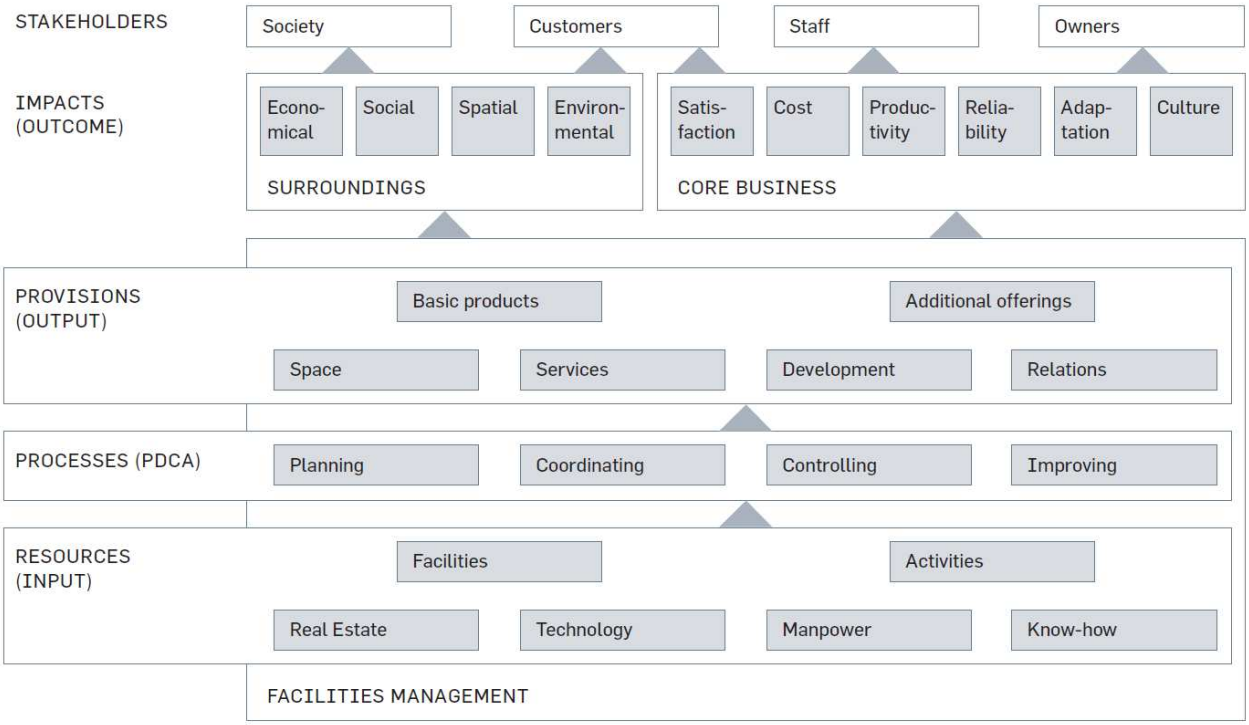

Figure 2: Model 2 by Per Anker Jensen (Jensen et al., 2008)

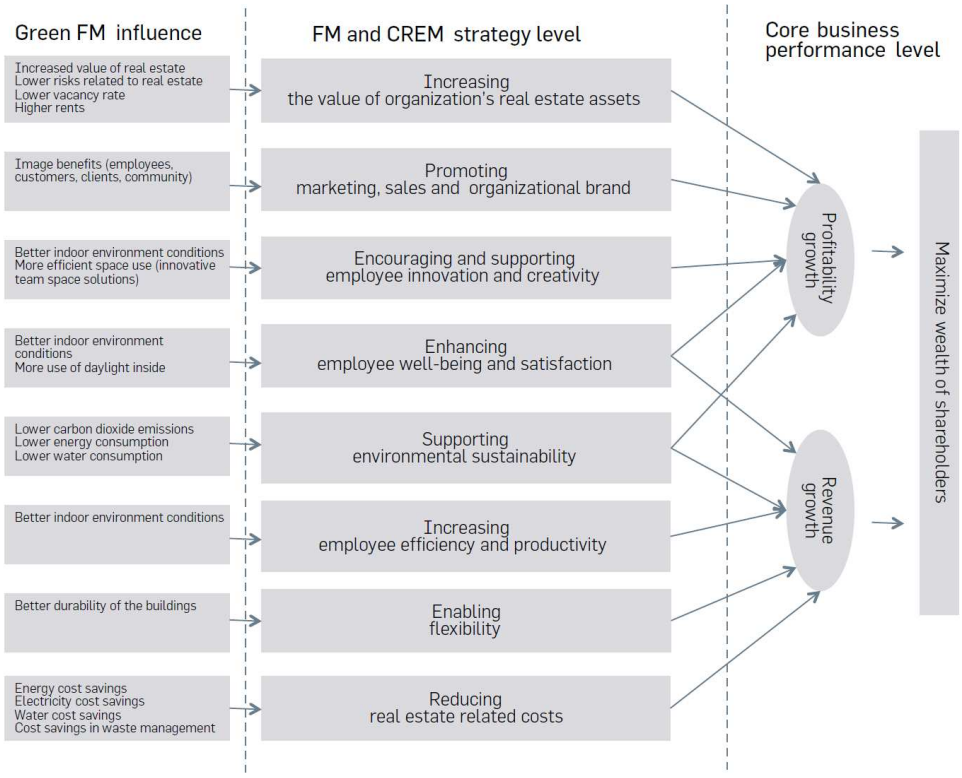

Figure 3: Model 3 by Anna-Liisa Sarasoja (Jensen et al., 2012)

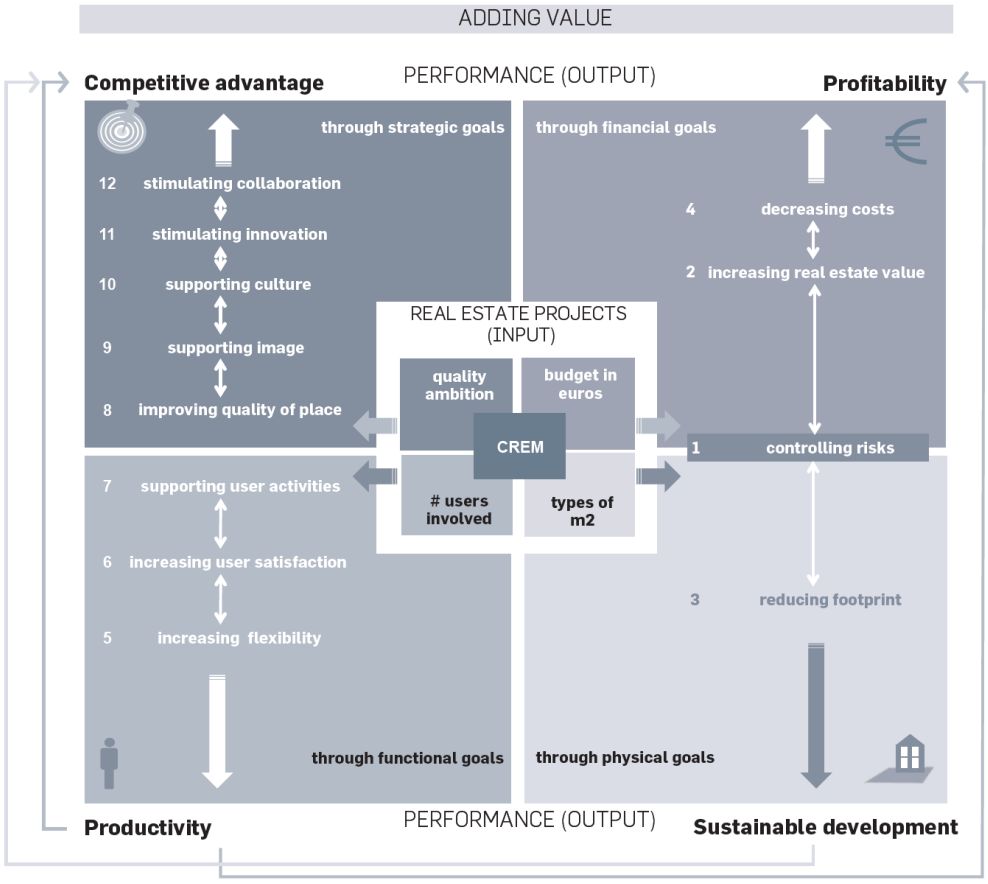

Figure 4: Model 4 by Alexandra den Heijer (Den Heijer, 2011)

Table 2: Comparison of added value parameters in the four models

	A. **Jackie de Vries**	**B.** **Per Anker Jensen**	**C.** **Anna-Liisa Sarasoja**	**D.** **Alexandra den Heijer**
Core business				
People	Image Culture Satisfaction	Satisfaction Culture	Increase employee satisfaction	Increasing user satisfaction Supporting image Supporting culture
Process	Production Flexibility Innovation	Productivity Reliability Adaptability	Increase innovation Increase productivity Increase flexibility	Increasing flexibility Supporting user activities Improving quality of place Stimulating innovation Stimulating collaboration
Economy	Cost Possibility to finance Risk control	Cost	Increase value of assets Promote marketing and sale Reduce cost	Controlling risk Increasing real estate value Decreasing cost
Surroundings		Economical Social Spatial Environmental	Supporting environmental sustainability	Reducing the footprint

The structure of the FM Value Map (B) differs basically from the three CREM based models (A, C, D) by including a clear separation between FM and core business and inclusion of FM processes. The distinction between FM as a support function to a core business is a fundamental part of much theory on FM – although not undisputed. The CREM based models A and D also include a process view with input and output. However, the process in question is obviously the core business process with no distinction of a separate CREM process. Model C does not include a process view but focuses on different real estate strategies and their impact on revenue growth and productivity. Model C is also different by a focus on maximizing shareholder value, while the two other CREM based models include multiple stakeholders like the FM Value Map. The distinction in the structure of the FM Value Map and the CREM based models can be related to the basic theoretical understanding in FM and CREM. CREM is a resource based management discipline and connects building science with business administration and business economics, while FM is a service and process oriented discipline.

4. Lessons Learnt and New Insights

Several chapters in the book discuss relationship management and the subjective nature of value, making clear that added value of FM cannot be created without cooperation and by understanding the different value perspectives. Coenen et al. (2012a) presents FM as a “Value Network” and propose to consider FM as a network of relationships, which create perceived value amongst key stakeholders i.e. clients, customers and end users. Furthermore, they claim that perceived value can only exist and be produced within this specific network of relationships. They extend the idea of the FM Value Map by taking up a demand-driven, co-creating, and subjective perspective of value and differentiating between various dimensions or perceived value in FM. Coenen et al. (2012b) goes a step further to

find a way to capture relationship value in FM. Various value dimensions and relevant drivers of FM relationship value are described and analysed, including trust, reliability and adaptability. The key learning point is that the success of a collaborative relationship leads to the success of value delivering to the stakeholders. Jensen and Katchamart (2012) present the concept of “Value Adding Management”, which focuses on the relationships between FM and the core business at strategic, tactical and operational levels and argues that the relationships with the stakeholders should be managed differently at each level. At the strategic level FM should have a business orientation, where considerations for the whole corporation are in focus. This calls for joint decision making involving all main stakeholders at management level, which can take the form of a coalition. At the tactical level FM should have a customer orientation, where the specific needs of each business unit are in focus. This calls for a bilateral negotiation and decision making. At the operational level FM should have a service orientation, where the individual users’ needs are in focus and the services are either provided based on price per order or based on a service charge.

Just like everywhere else, sustainability is discussed more and more - also in connection to FM. It is already a widely known fact that at present, buildings contribute as much as one third of total global greenhouse gas emissions and that the building sector has the most potential for delivering significant and cost-effective green house gas emission reductions in western economies (UNEP, 2009). However, less recognized is that over 80% of greenhouse gas emissions take place during the operational phase of buildings (Junilla et al., 2006) and is (or should be) under the control of FM. Sarasoja and Aaltonen (2012) studied environmental sustainability from the occupier organisation perspective and identified in a case study the ways to create added value through greener FM processes. This case study shows that improving the environmental performance of facilities and services does not only decrease the energy consumption and greenhouse gas emissions, but also contributes to the organisation in other ways. Greener FM services have a potential to affect employee wellbeing and productivity, improve image of the occupier organisation, and last but not least decrease costs at the same time. These kinds of studies are good examples also on the strategic nature of FM and how FM had a potential to contribute at the strategic level to the client organisation. With proven and commercially available technologies, the energy consumption in both new and existing buildings can be cut by an estimated 30 to 80% with potential net profit during the building life-span. Consequently, it is not overstating to say that FM has a potential to influence the world more than ever before.

5. Conclusion

The comparison of the three basic perspectives of FM, CREM and B2B marketing show that they provide both overlapping and complementary focus areas. FM and CREM has a strong focus on the physical assets. FM and B2B marketing both have a strong focus on services, which is not so much a focus area in CREM. All three perspectives share a focus on stakeholders and relationship management. Comparisons of the added value parameters of four conceptual models from FM and CREM show many similarities and a trend towards convergence. It is particularly noticeable that the recent models from CREM like the FM Value Map include “Environmental sustainability” as a parameter. However, the basic

structures of the models are different, which can be related to CREM being transaction and project oriented, while FM is more service and process oriented.

One of the important lessons learnt is that relationship management is an essential aspect of FM and a careful management of stakeholders and relations is a prerequisite for FM to add value. The different conceptual models are important tools to analyse and demonstrate how FM and real estate can add value, but there is a need to further develop management concepts, which can guide facilities managers to develop strategies and relationships that enhances the implementation of value adding activities. The concept of FM Value Network and Value Adding Management are attempts to develop such concept. Another lesson learnt is that sustainability is a crucial aspect of FM in relation to adding value to both organisation and society and is particular attractive as it can at the same time increase staff satisfaction and corporate image and result in cost savings, particularly in relation to reduction in energy consumption. But the wider aspects of sustainability in relation to social aspects needs to be developed much further and Corporate Social Responsibility is another area, which is expected to be essential for FM to create value in the future.

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Construction Mediation Training: A Case of Pedagogical Principle-based E-learning

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Abstract Title

Mediation is becoming popular as a means to settle dispute in Hong Kong. There is a cogent need for mediation training to support its wider use. This paper reports the use of network technology to deliver training is the latest trend in the training and development industry and has been heralded as the 'e-learning revolution'. Many institutions are resorting to e-Learning as an important tool in teaching and learning. One of the most crucial prerequisites for successful implementation of e-Learning is the need for careful consideration of the underlying pedagogy, or how learning takes place. In practice, however, this is often the most neglected aspect in any effort to implement e-Learning. The purpose of this paper is first to identify the pedagogical principles underlying the teaching and learning activities that constitute effective e-Learning. Application of the principles and ideas is by way of an online user-interface mediation training system. The primary aim of the online mediation training course is to explore the logrolling methods and strategies for achieving "win-win" settlement in mediation. On completion of the course, students shall be able to demonstrate that i) they have acquired knowledge on the key concepts of logrolling in mediation, namely reality test and preference identification; ii) they have the ability of putting the theories they learnt into practice, i.e. generating an optimal bargaining range and reach a "win-win" agreement; iii) they have acquired knowledge on the evaluation of their e-learning performance. The online learning program provides 3 teaching and learning activities (reality test, preference identification and logrolling) together with 3 learning progress reports to achieve the intended learning outcomes. Finally the logrolling-difference degree (L-DD) is used to evaluate students' learning performance by comparing their logrolling outcomes with the system's logrolling suggestions. The learning assessment report also includes the peers' L-DD results for the reflection by the participating student.

Keywords: Mediation, bargaining range, reality test, preference identification and Logrolling

1. Introduction

During the past two decades, serious disputes have become increasingly common on construction projects in Hong Kong. Mediation has gained wide acceptance as an effective

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informal means of resolution. It has become an integral part of the dispute settlement provisions in most of the standard forms of construction contract in Hong Kong (Cheung, 2010). In addition to this contractual use, voluntary mediation has been introduced in the civil procedures of the High Court as part of the Civil Justice Reform that came into force on 2nd April 2009. Under Practice Direction 6.1, adverse cost order is used to discourage 'refusal to mediate' and 'failing to attempt to mediate'. The Hong Kong Department of Justice in 2010 published a draft report giving recommendations on how to promote and develop mediation services in Hong Kong. One of the key recommendations is to provide mediation training widely in order to arouse public awareness. There is a cogent need for mediation training to support its wider use.

In recent years, the knowledge-based economy has exhibited a pervasive and ever-increasing demand for innovative ways of delivering education, which has led to dramatic changes in learning technology and organizations. As the new economy requires more and more people to learn new knowledge and skills in a timely and effective manner, the advancement of computer and networking technologies are providing a diverse means to support learning in a more personalized, flexible, portable, and on-demand manner (Zhang et al. 2004). With the advance in information technology, the use of network technology to deliver training is the latest trend in the training and development industry and has been heralded as the 'e-learning revolution'. One of the most crucial prerequisites for successful implementation of e-Learning is the need for careful consideration of the underlying pedagogy, or how learning takes place (Govindasamy, 2002). In practice, however, this is often the most neglected aspect in any effort to implement e-Learning (Bixler & Spotts, 2000). Most e-learning providers perceive themselves as mere providers of technology. For example they can only provide tools for e-Learning, but cannot tell educators how to use these tools to teach (Govindasamy, 2002). E-Learning cannot continue to exist without incorporation and consideration of pedagogical principles. This paper firstly identifies the pedagogical principles underlying the teaching and learning activities that constitute effective e-Learning. These principles are then applied and illustrated by an online user-interface mediation training system.

2. Guidelines for development of e-learning programs

Guidelines have been developed to help assure the quality of e-learning programs and courses (Hirumi, 2009). Notable examples include: (1) The Council of Regional Accrediting Commissions (2000), statement of the regional accrediting commissions on the evaluation of electronically offered degree and certificate programs. The Best Practices generated by C-RAC (2000) seek to address concern that regional accreditation standards. Based on the Principles of Good Practice, initially drafted by the Western Cooperative for Educational Telecommunications (WCET, 1997), the Best Practices are meant to assist institutions in planning electronic e-learning activities and provide a framework for self-assessment. (2) The Institute for Higher Education Policy (2000), Quality on the line: Benchmarks for success in Internet-based distance education. The National Education Association (NEA) and Blackboard Inc. jointly commissioned The Institute for Higher Education Policy (IHEP) to examine existing guidelines for distributed learning. An initial list of 45 benchmarks was then analyzed by faculty, administrators, and students from six colleges and universities. The final

outcome of 24 benchmarks for success in Internet-based distance education was published by IHEP in 2000. Subsequently, 16 higher education leaders reviewed the IHEP benchmarks for a symposia sponsored by The Pew Learning and Technology Program, providing further insights into e-learning and quality assurance from a provider and consumer perspective (Hirumi, 2009). (3) The American Council on Education (ACE, 1997), Guiding Principles for Distance Learning in Learning Society. A national task force created by the American Council on Education and The Alliance: An Association for Alternative Programs for Adults generated The Guiding Principles for Distance Learning in a Learning Society (ACE, 1997) that focused on the changing nature of education and training, not on specific delivery systems or methods. The purpose of the guidelines is to "help learners, educators, trainers, technologists, and accreditors/state regulators to develop, deliver, and assess formal learning opportunities" (Sullivan & Rocco, 1997). (4) The American Federation of Teachers (2000), Distance Education: Guidelines for Good Practice. The Guidelines for Good Practice, published by the American Federation of Teachers (2000), is based on a 1999 survey of 200 members. The guidelines are to be applicable to all types of distance education, including job and skill training "because they are simply about good teaching" (AFT, 2000, p. 6). The guidelines are designed to help faculty negotiate distance education issues with management, as well as to help administrators and public officers who want to put quality at the centre of their initiatives. (5) Open and Distance Learning Quality Council (ODLQC, 2001), Standards in open and distance education. Set up by the British government in 1968, the Open and Distance Learning Quality Council (ODL QC) operates as a voluntary distance learning registration system. Course providers must meet the Standards in Open and Distance Education published by ODLQC (2001) to register courses.

E-learning courses and guidelines do not include underlying pedagogical principles. E-learning program and courses focus on the interoperability and reusability of learning objects. The published guidelines do address important instructional variables, such as objectives, content, assessment, feedback, and media use. However, the pedagogical and instructional design principles are seldom deliberated. For example, the following design principles are not addressed by published guidelines. (1) The alignment of objectives and assessments: Alignment between explicit objectives and criteria is fundamental to high-quality instruction (Berge, 2002; Welsh, et al., 2003). High-quality learning environments present learners with explicit and congruent learning objectives and assessment criteria. (2) The alignment of objectives and instructional events: Research suggests that how to teach should be based on the contents to be delivered. The methods to be used to teach verbal information should be different from the methods to be used to teach a procedure that, in turn, should differ from the methods to teach complex problem solving, and so forth (Hirumi, 2009). (3) The nature of feedback: Feedback is vital to e-learning (Yacci, 2000). Feedback may also (a) increase response rates or accuracy, (b) reinforce correct responses to prior stimuli, and (c) change erroneous responses (Jonassen, 1995; Rosenberg, 2001). (4) The design and sequencing of e-learning interactions: In traditional classroom settings, key interactions that affect learner attitudes and performance often occur spontaneously (Zhang, et al., 2004). During e-learning, opportunities to interact in "real-time" are relatively confined (Alexander, 2001; Mason, 2001). (5) Motivational design: Educators recognize that motivation is essential to student learning. Students must be presented with the appropriate

skills and knowledge and they must be motivated to learn and use them (Hirumi, 2009; Reisetter and Boris, 2009).

3. Pedagogical Principles for E-learning

Pedagogical principles are theories that govern the good education practice. The “Seven Principles for Good Practice in Undergraduate Education” were first published in 1987 by the American Association for Higher Education. The “Seven Principles” form a sound model for quality collegiate instruction. While these principles have formed a foundation for traditional classroom instruction, it is important to consider them when developing and designing instruction in technology-based environments (Sorensen and Baylen 2009). The “Seven Principles” can also be adapted to many learning environments (Chickering and Gamson 1987). They support the notion that good teaching is good teaching. They describe some essential components that are important in effective learning environments. The “Seven Principles of Good Practice” (Winona State University, 2003) includes (1) encourage student-faculty contact; (2) encourage cooperation among students; (3) encourage active learning; (4) give prompt feedback; (5) emphasize time on task; (6) communicate high expectations, and (7) respect diverse talents and ways of learning. Based on Jonassen (1995), Ruokamo and Pohjolainen (1998) summarised “Seven Qualities of Learning”. (1) Active - Learners' role in learning process is active; they are engaged in mindful processing of information and they are responsible for the result. (2) Constructive - Learners construct new knowledge on the basis of their previous knowledge. (3) Collaborative - Learners work together in building new knowledge in co-operation with each other and exploiting each other's skills. (4) Intentional - Learners try actively and willingly to achieve a cognitive objective. (5) Contextual - Learning tasks are situated in a meaningful real world tasks or they are introduced through case-based or problem-based real life examples. (6) Transfer - Learners are able to transfer learning from the situations and contexts, where learning has taken place and use their knowledge in other situations. (7) Reflective - Learners articulate what they have learned and reflect on the processes and decisions entailed by the process. All these qualities are interactive, interrelated, and interdependent with each other. Govindasamy (2002) further proposed 5 pedagogical attributes for successful e-learning as developing content, storing and managing content, packaging content, student support, and assessment. The pedagogical principle-based e-learning attributes are summarised in Table 1.

4. Pedagogical Principle-based E-learning Exploration: Case of Construction Mediation Training

Student-cantered approach is a major feature of the change in universities, which sets an orientation to the responsibility of teaching. There has been a concern with anchoring performance in student learning outcomes, teaching according to how students learn as well as evaluating how well students learn (Biggs and Tang, 2011). Outcome-based Teaching and Learning (OBTL) is a student-centred approach for the delivery of educational programs. OBTL includes three items: Course Intended Learning Outcomes (CILOs), Teaching and Learning Activities (TLAs) and Assessment Tasks (ATs). The curriculum topics in a program

and courses are expressed clearly as the intended learning outcomes. Teaching and learning activities are then designed to directly facilitate students to achieve those outcomes.

Table 1: Pedagogical Principle-based E-learning Attributes

Phrase	Reference	Learning Activates	Pedagogical E-learning Attributes Deliverable
Design	Berge (2002)	Determine learning objectives	Intended Learning Outcomes (ILOs)
Teaching and Learning	Jonassen (1995); Ruokamo and Pohjolainen (1998); Govindasamy (2002); Hirumi (2009);	Instructional events; online organization and design; Instructional design and delivery; Teaching based on the contents to be delivered; instructional methods; Instructional media; E-learning and instructional system design; Differentiate Teaching; Construct new knowledge on the basis of their previous knowledge; Learning tasks are situated in a meaningful real world tasks or introduced through case-based or problem-based real life examples; Innovative teaching with technology	Learning Contents Development (LCD)
	Chickering and Gamson (1987); Jonassen (1995); Yacci (2000) Rosenberg (2001); Winona State University (2003)	Students feedback; Response; Encourage student-faculty contact; Engaged in active learning process;	Learning Progress Report (LPR); Learning Interaction and Students Support (LISS)
	Jonassen (1995); Ruokamo and Pohjolainen (1998); Zhang et al. (2004); Alexander (2001); Mason (2001); Govindasamy (2002); Winona State University (2003)	Design and sequencing of learning interaction; Encourage cooperation among students; Student's support	
Assessment	Govindasamy (2002); Welsh et al. (2003);	Assessment is to test whether the learning performances achieve the learning objective or not; Assessment and evaluation of student learning and performance outcomes	Learning Assessment Report (LAR)

Assessment tasks address what students are supposed to learn and achieve as well. As stated earlier, in order for any e-Learning implementation exercise to be successful, it must be rooted in strong pedagogical foundations. The followings illustrate the ideas underpinning in this paper. The online mediation training system is used here as an example. The online mediation training course is designed to assist negotiators and mediators to achieve "win-win" settlement. Reaching "win-win" settlement is the desired outcome of mediation. A "win-win" settlement can be seen as one that encourages parties to uphold their contracts when one party achieve its profits and the other party would still be better off. However, this desired outcome is not always achieved. The course includes 3 processes: reality test,

preference identification and logrolling. Reality Test is used to establish the concession rate of the disputing parties and assist them to get ready for “win-win” settlement. Preference identification assists parties to identify their preferences among the issues, through assigning weightings to the issues. Logrolling is to provide user-friendly strategies for parties to make efficient trade-off that involves (1) when to concede (2) on which issue (3) for which party and (4) how much should be conceded. The following pedagogical attributes will be discussed along five parameters: Intended Learning Outcomes (ILOs), Contents Development (LCD), Learning Progress Report (LPR), Learning Assessment Report (LAR), Learning, Learning Interaction and Student Support (LISS).

4.1 Intended Learning Outcomes (ILOs)

The intended learning outcomes (ILOs) are the core of the whole e-learning materials and all e-learning contents must meet and achieve the ILOs that are established. The primary aim of this experiment is to explore the logrolling methods and strategies for achieving “win-win” settlement in mediation. On completion of this experiment, students shall be able to demonstrate that: a) they have acquired knowledge on the key concepts of logrolling in mediation, namely reality test and preference identification; b) they have the ability of putting the theories they learnt into practice, i.e. making use of the logrolling system to generate an optimal bargaining range and reach a “win-win” agreement; c) they have acquired knowledge on the evaluation of their logrolling performance through the devise of “logrolling-difference degree” (L-DD). The OBTL based learning structure is shown in Figure 1.

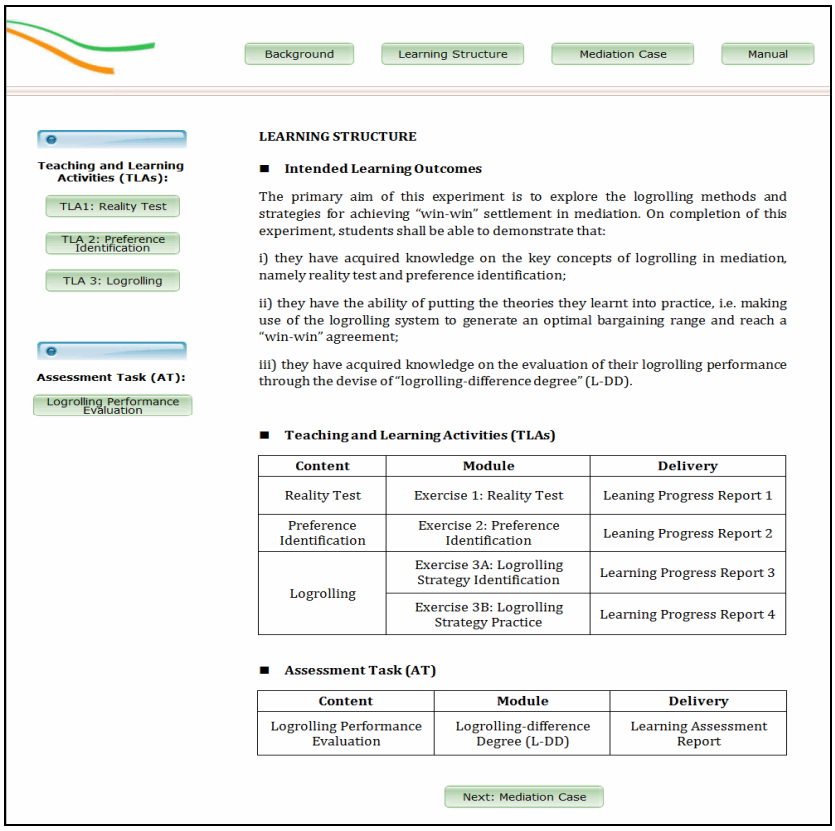

Figure 1: Online Mediation Training Course-OBTL Learning Structure

4.2 Learning Contents Development (LCD)

The effective e-learning program is not only a mere instructor, but also is assumed as role of content experts, instructional designers, graphic artists, media player, et al. From functional perspective, the learning contents include introduction for course background, learning structure, learning and teaching activities (TLAs), and Assessment Task (AT), as well as some complementary materials like mediation case which is a hypothetical construction case "ABC property Management Limited vs. Peter & Bothers Gardening & Landscaping Limited" used in the course, and manuals to illustrate how to use the online course system. These functional contents are also shown in Figure 1. To achieve the ILOs, the TLAs in this course include three learning units: Reality Test, Preference Identification and Logrolling. Each learning unit has a corresponding exercise to help students better understand the learning contents and increase the learning performance. A learning progress report will also be delivered when students finished each unit. Assessment task is designed to evaluate the learning outcome; also a learning assessment report will be delivered to students finally. Learning contents development shall take the effective learning route for students in account. Constructivism is an essential theory for the research of technology-based learning environments. Constructivism learning is seen as a building process in which learners have an active role and learning is based on their cognitive functioning. The learners obtain new knowledge by constructing it on the basis of their earlier knowledge. The mediation course is designed a clear learning route for students to follow. The students are proposed to have acquired knowledge on the key concepts of logrolling in mediation--reality test and preference identification, by finishing Exercise 1and Exercise 2. Through Exercise 3A and 3B, the students are proposed to have the ability of making use of the logrolling system to generate an optimal bargaining range and reach a "win-win" agreement. Finally evaluation of their logrolling performance will be conducted through the devise of "logrolling-difference degree" (L-DD).

4.3 Learning Progress Report (LPR)

The real value of e-Learning lies not in its ability to train just anyone, anytime, anywhere, but in our ability to deploy this attribute to train the right people to gain the right skills or knowledge at the right time (Govindasamy, 2002). Thus it is important for e-learning program to track learner activities whether or not the appropriate learner is learning the right information at the right time. In mediation course, shown in Figure 2, the Exercise 3B "Logrolling Strategy Practice" is to assist students to reach win-win agreement. In each of the bargaining round, the students will be provided with a suggestion, through which each party concedes at minimum loss to himself while accordingly maximum benefit to the other party. The students need to confirm whether they accept the suggestion or not. If yes, click "Accept" button. If they click "Reject" button, the system will provide some alternative choices to choose. The figure 3 shows the logrolling progress report as the students logrolling record.

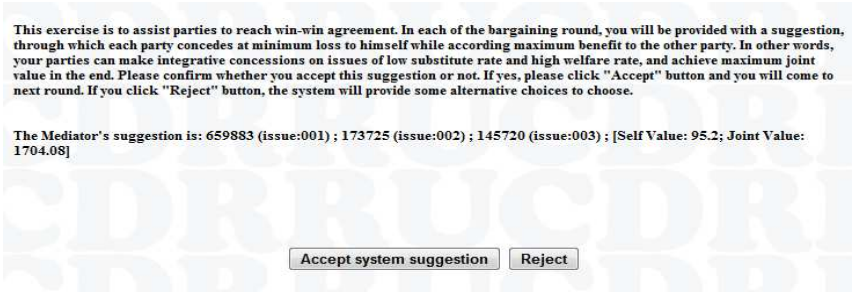

Figure 2: Online Mediation Training Course--Exercise 3B: Learning Strategy Practice

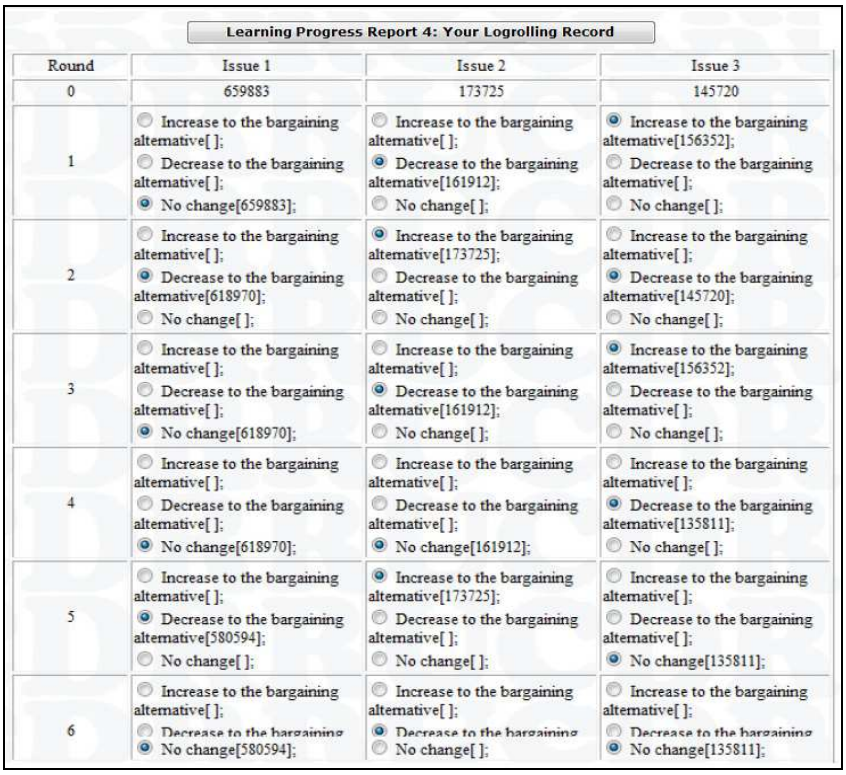

Figure 3: Online Mediation Training Course--Exercise 3B: Learning Progress Report

4.4 Learning Assessment Report (LAR)

Assessment is an indispensable part of e-learning program. Essentially, it is assessment that reinforces the learning approach a student adopts. Assessment is typically divided into two types, the summative assessment and the formative assessment. Summative assessment is used to grade students to demonstrate students' achievement and it involves making a final judgment of the students' achievement. Formative assessment is used as a diagnostic tool for students and teachers to identify and improve areas of weakness (Govindasamy, 2002). In mediation course, the logrolling-difference degree (L-DD) is defined to evaluate parties' logrolling performance by comparison of the difference between system's logrolling suggestions and the parties' logrolling outcomes. The smaller the L-DD, the closer are the actual outcomes to the optimal bargaining that each party concedes at minimum loss to himself while according maximum benefit to other parties. Here is an example. The L-DD

between Subjects' actual logrolling outcomes and Mediator's expected logrolling outcomes of group *i* is 5%. The average L-DD of all experiment groups is 5.5%. Thus the group *i*'s logrolling performance is better than the average level. Seen from Figure 4 below, the system's logrolling suggestions are marked in red and parties' logrolling outcomes are marked in blue. M represents to system and H is for party. The parties are proposed to begin with their most preferred position. Client begins with point H1 and Contractor begins with point H16 (seen the arrow direction). Parties are proposed to concede at minimum loss in exchange for maximum benefit to the other party, and get convergence at point M9 which is marked as "■".

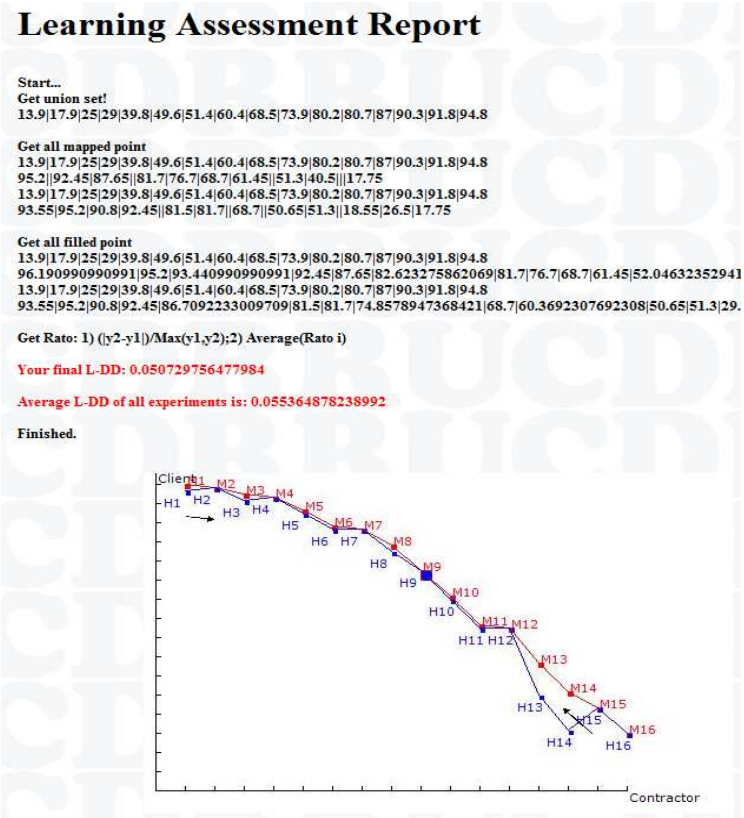

Figure 4: Online Mediation Training Course—Learning Assessment Report

4.5 Learning Interaction and Students Support (LISS)

Learning interaction and student support is one area of e-Learning that is markedly different from the traditional classroom delivery method. In traditional classroom instruction, student support can be addressed on a supply-and-demand basis. In e-Learning settings, where students learn as a result of interaction with programmed instructional systems, all possible types of problems student are likely to face have to be foreseen in advance in order to introduce features for performance support. One way of doing this is by using a framework based on Laurillard's Conversational Theory. This theory advocates a teaching strategy based on interaction between teacher and student; not on the actions required of the student by the teacher (Govindasamy, 2002). Role play is applied in the online mediation course to help students understand the mediation process. In this mediation training course, the

students were randomly assigned to the roles of Mediator, Contractor and Client in Exercise 1 “Reality Test”. Contractor is inputting the concession rate first. Mediator and Client receive the Contractor’s information. Client then responses a corresponding concession rate, after which Mediator has a record of both parties’ concession rate and make a judgment whether the concession rate are within the potential win-win agreement zone. The judgement will deliver to parties as well. If no, the Mediator would suggest adjustments. If yes, parties can continue after confirmation.

5. Conclusion

Disputes are common in construction projects in Hong Kong, and mediation has gained wide acceptance as an effective informal means of dispute resolution. One of the key recommendations is to provide mediation training widely in order to arouse public awareness. With the advance in information technology in the last few decades, the use of network technology to deliver training is the latest trend in the training and development industry and has been heralded as the ‘e-learning revolution’. One of the most crucial prerequisites for successful implementation of e-Learning is the need for careful consideration of the underlying pedagogy, or how learning takes place (Govindasamy, 2002). In practice, however, this is often the most neglected aspect in any effort to implement e-Learning (Bixler and Spotts, 2000). Most e-learning providers perceive themselves as mere providers of technology. In fact e-Learning cannot continue to exist without incorporation and consideration of pedagogical principles. This paper identifies the pedagogical principles underlying the teaching and learning activities that constitute effective e-Learning. These principles are then applied and illustrated by an online user-interface mediation training course. The following pedagogical attributes are discussed along five parameters: Intended Learning Outcomes (ILOs), Contents Development (LCD), Learning Progress Report (LPR), Learning Assessment Report (LAR), Learning, Learning Interaction and Student Support (LISS). The primary aim of the online mediation training course is to explore the logrolling method and strategies for achieving “win-win” settlement in mediation. On completion of the course, students shall be able to demonstrate that i) they have acquired knowledge on the key concepts of logrolling in mediation, namely reality test and preference identification; ii) they have the ability of putting the theories they learnt into practice, i.e. generating an optimal bargaining range and reach a “win-win” agreement; iii) they have acquired knowledge on the evaluation of their e-learning performance. The online learning program provides 3 teaching and learning activities (reality test, preference identification and logrolling) together with 3 learning progress reports to achieve the intended learning outcomes. Finally the logrolling-difference degree (L-DD) is used to evaluate students’ learning performance by comparing their logrolling outcomes with the system’s logrolling suggestions. The learning assessment report also includes the peers’ L-DD results for the reflection by the participating student.

Acknowledgements

The work described in this paper is fully supported by a City University of Hong Kong Teaching Development Grant (project number 6000372).

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Value Triangles in the Management of Building Projects

Per Anker Jensen[1]

Abstract

The purpose of this paper is to investigate value triangles and their implementation in the management of building projects. The paper is based on results from a research project on space strategies and building values, which included a major case study of the development of facilities for Danish Broadcasting Corporation (DR) over time. The conventional iron triangle of quality, cost and schedule for project management is the theoretical starting point, but this is seen as mainly being related to process integrity in the construction stage. It is supplemented by a similar value triangle of cultural value, use value and quality of realization for product integrity, mainly for the design stage. Based on this framework an evaluation is made of the value management in six of DR's building projects from the first around 1930 to the most recent – the new headquarters DR Byen finalised in 2009. The conclusion is that DR's buildings have a strong focus on value and fulfilment of intentions. This is not surprising as DR is a public service broadcasting corporation. This means that the buildings on one side have to be high-tech production facilities and on the other side shall represent a cultural institution of national importance. The study indicates that the value triangles provide a useful framework to evaluate project management and discuss the characteristics of building projects. All together project management aims at reaching the project goals and optimizing performance by developing and maintaining project integrity with the right balance between value management and resource management throughout the project.

Keywords: Value triangle, project management, building project, product integrity, process integrity

1. Introduction

The focus of this paper is the implementation of value triangles in the management of building projects. The aim is to develop a framework for characterizing and evaluating the project management of different building projects and test the framework on a number of buildings from different periods. The paper is mostly theoretical but also presents the results from a case study, where the theoretical framework has been implemented and tested.

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The conventional iron triangle or value triangle of quality, cost and schedule for project management is the starting point, but this is seen as mainly being related to process integrity in the construction stage. It is supplemented by a similar value triangle of cultural value, use value and quality of realisation for product integrity, mainly for the design stage. Based on this framework an evaluation is made of the value management in six of the building projects of Danish Broadcasting Corporation (DR) from the first around 1930 to the most recent – the new headquarters DR Byen finalised in 2009.

The research was part of a project on space strategies and building values, which involved a major case study of the development of facilities for DR. The paper starts with a description of research method. The theoretical part includes an introduction and discussion of the conventional value triangle and a framework with supplementary value triangles for product integrity and process integrity is developed. The empirical part presents the results of the evaluation of the six buildings. Finally the results are discussed and conclusions are drawn.

The research aims to contribute to the development of a theoretical and empirical understanding of the management of building projects and the use of the concept of value in this context.

2. Research Methodology

The theoretical part is based on a literature study and framework development in relation to project management both in general and in relation to building projects. The empirical case study is based on literature studies, archive research and an interview survey. The empirical literature studies have mostly concerned publications related to DR's history from 1925 and onwards. The archive research has supplemented the empirical literature studies and has included studies of archives at DR's internal library and archive as well as archives on some of DR's major building projects at the Danish National Archive (Rigsarkivet). The interview survey has involved 12 interviews with former managers in DR and former consultants for DR.

The research is based on a huge amount of empirical material about the case study (Jensen, 2006 and 2007). This paper only includes a brief summary of the results of the evaluation of six building projects from different time periods.

3. Theory on Value Triangles in Project Management

3.1 The concept of value triangles

In the literature on project management it is common to see the objective as optimizing the outcome in relation to cost and time. The relationship between these three factors is sometimes described as the iron triangle (Atkinson, 1999**)**, the project management triangle (Wikipedia, 2012), the triple constraints or the value equation (Verzuh, 2003). The outcome is described in terms like scope (Wikipedia, 2012), quality (Atkinson, 1999), benefit (Verzuh, 2003), and function, specification and performance (Engwall, 1995).

In the following the term “value” will be used for the outcome and the term “value triangle” for the relationships. This term is preferred because “value is the only fundamental metric which makes a positive contribution to all the other bottom-line metrics” (Cook, 1997). The term “value” has been used for a long time in industrial management as “Value Management” and “Value Engineering”, but these terms have also become common in Quantity Surveying (Kelly and Male, 1993). Furthermore, the term “value” has in general been used increasingly in construction management research over the last decade; see for instance Spencer and Winch (2002), McMillan (2006) and Thyssen et al. (2009).

A project that keeps within budget and schedule and results in a product of high value is typically regarded as a success. The challenge in the planning of a project is to create the equilibrium between the three factors. The value of the product depends on how much time and money one is willing to invest. When this balance has been fixed, a change in one factor will influence the other two factors.

According to Engwall (1995) the relationship between the three factors can be illustrated as an equilateral triangle stretched between value, cost and schedule in each corner as shown in Figure 1.

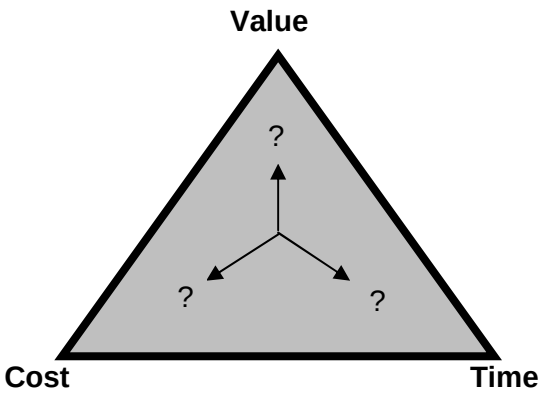


Figure 1: The conventional value triangle (Briner et al, 1991 and Engwall, 1995)

The triangle could be seen as having three axes, which can be used to indicate the priority of each factor. This is illustrated in Figure 2. The sum of the priorities necessarily has to be 100%. If all factors are given equal priority, then the centre of gravity will be one third on each axis, i.e. a priority of each by 33.3%.

Different projects will have different centres of gravity in the triangle. This is illustrated in Figure 3 with the three extreme situations, where value, cost or time is the dominant factor, respectively. Concert halls and nuclear power plants can be mentioned as examples of projects, where value is the critical factor, because the functional aspects are dominant. Production buildings and social housing projects are often very cost critical, while the schedule is extremely critical for facilities for sports events like the Olympic Games with a clear deadline.

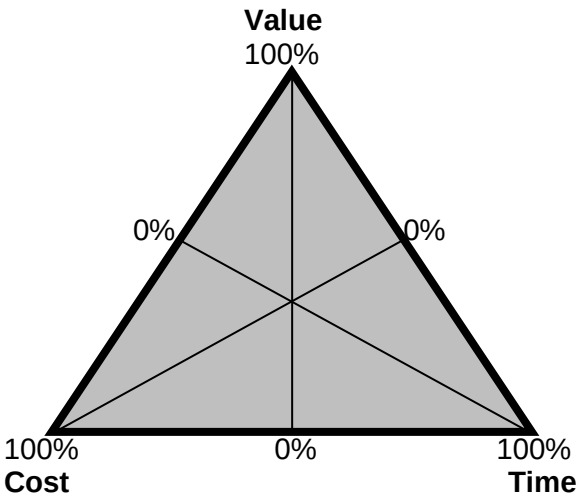


Figure 2: The value triangle with axes of priority

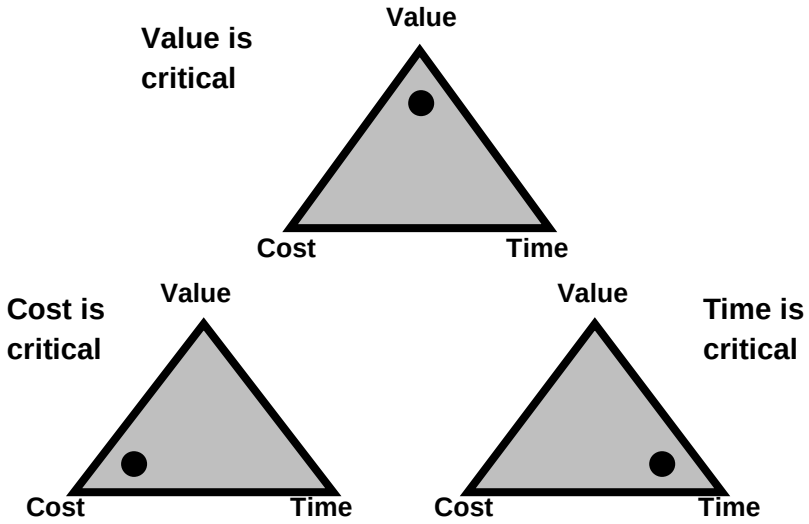


Figure 3: Value triangles for projects with extremely different priorities

The total value of a project consists of the resources (cost and time), that are used in the project, and the value that is created as a result of a successful project. When the project goal is set one must define the value that the project should result in and the resources available for the project. An implicit part of the goal normally is an expectation that the value should be optimized in relations to the use of resources and therefore the value creation should be maximized. Thus, a primary task for the project management is to secure an effective value management and an efficient resource management.

3.2 Implementation and innovation projects

Verzuh (2003) emphasizes, that the priority between the three factors in the value triangle should take place in the project definition phase, before the decision to start a project.

According to this view the priority should not be made by the project organisation but by the client or sponsor, who make the decision to start the project. Engwall (2002) distinguish between implementation projects and innovation projects as described in Table 1.

Table 1: Implementation and innovation projects (Engwall, 2002 – translated)

	Implementation project	Innovation project
Pre-knowledge	Complete	Incomplete
Project goal	Exogenous to the project work	Endogenous to the project work
Knowledge development	During preparation	During preparation and during the project development
Result	Final product	Final product and knowledge about the project goal and the process to reach it
Rationality	Efficient delivery of the result	The right knowledge about the result

In implementation projects the project goal is exogenous to the project organisation and this is equivalent to the view of Verzuh (2003) with project goals defined by the sponsor. In contrast, the definition of the project goal is endogenous for innovation project, i.e. it is a part of the work in the project organisation to define the project goal and set the priorities.

Building projects can be either an implementation or an innovation project or a combination of both. A small, standardized building project can be regarded as an implementation project, while large and complex building projects can be seen as innovation projects. That is particularly the case in the early stages with briefing and conceptual design. Construction based on a detailed design can contrarily be regarded as an implementation project.

3.3 Changes in priorities

During a project the focus and therefore also the priorities between the three factors in the value triangle will often change over time. In the beginning the definition and fulfilment of the value will be the primary focus area. As the project develops the budgetary strains will become more present and this will change the focus towards keeping the budget and perhaps make savings to avoid overrun. Towards the end the deadline comes closer and keeping the schedule becomes the main priority. This typical development in the priority is illustrated in Figure 4.

When the priority between the three factors in the value triangle has been made, it can be useful to change the axes to have the starting point in the centre of the triangle as shown in Figure 5. By this illustration it becomes clearer, how changes in the priority to the benefit of one factor will influence one or both of the other factors negatively.

Some of these relationships can be problematic. By extending the schedule it might be possible to improve the value – particularly if the project is delayed - but it is doubtful whether it gives possibilities to save cost. For building projects the cost of running the building site will for instance usually increase if the schedule is extended. Contrarily, it often

increases cost if the schedule is forced to be shortened. Therefore, the value triangle should not be regarded as an expression of some kind of absolute law, but only as a general illustration of principles for the relationships and priorities between the three factors.

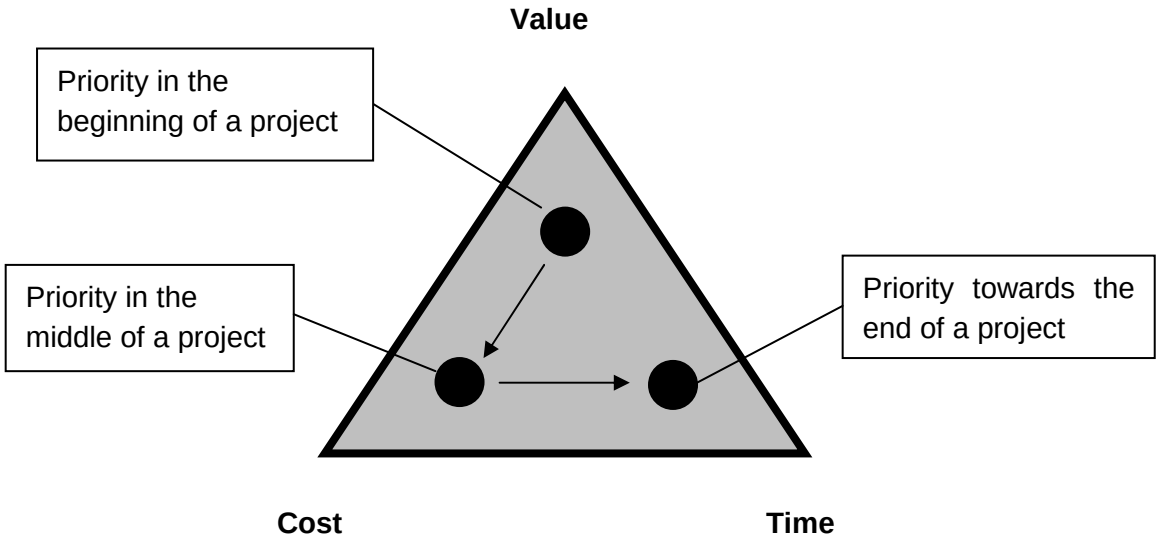


Figure 4: Typical development in the priorities in a project over time

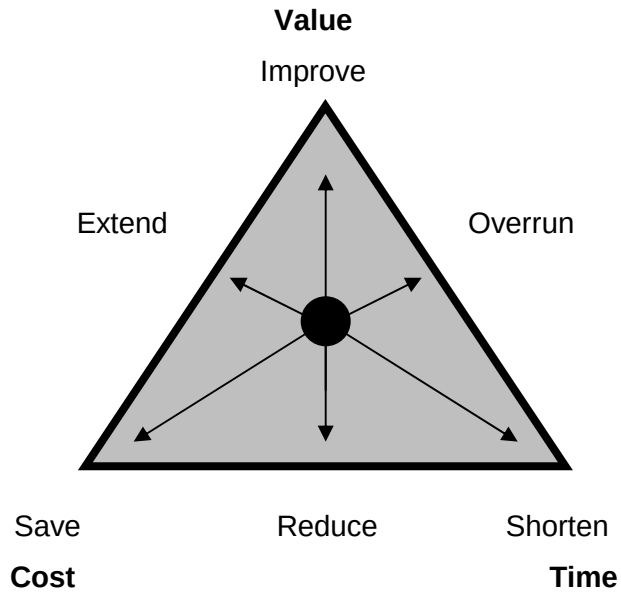


Figure 5: The value triangle with priority fixed in the centre

3.4 Example of DR Byen

The use of the value triangle can be illustrated by the example of DR Byen. When the project was started in 1999 it was decided by DR's board, that it should be built within a budget of maximum € 400 million (DKK 3.0 billion) in the price level of 1999. A deadline for the project was stipulated as well. With these preconditions two of the three factors in the value triangle were fixed in one direction as shown in Figure 6.

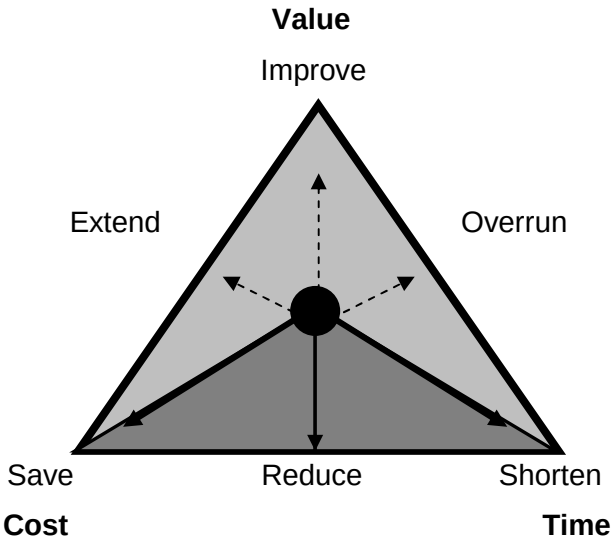


Figure 6: The value triangle for DR Byen

The room for changing priorities during the project is reduced to the third part of the triangle marked by the dark grey colour. This means that there in principle only are the possibilities to reduce value, save cost and/or to shorten the schedule. A building project like DR Byen is very much an innovation project. Even though the budget and deadline was defined exogenously by DR's board, the value definition was at that stage only defined rather vaguely, and an important part of the project was to define the value more specifically and develop knowledge about the project.

One of the great challenges in the project management is that most external parties involved in the project has an economical interest in increasing value and thereby the cost of the part of the project, that they are involved with – even though that might be on the expense of the total budget or other parts of the project. Therefore, it is a crucial part of the management task to continuously prioritize the solutions in each of the different parts of the project and make sure that they stay within budget.

Fixing the budget and the deadline can be seen as a strait-jacket for the project management, but it can also have the advantage that it gives a clear objective and thereby a clear focus for the management – to optimize value within a set budget and deadline. It can be regarded as contradictory to define clear objectives for cost and time without a specific definition of the value. On the other hand, the typical development of building projects is suitable for a gradual detailing of the specification of the value objectives.

For the project management it can be an advantage to have a well defined budget and deadline. It increases the legitimacy, when a request to increase the value is refused. If it was possible to increase the budget or the value, the project management may have to accept to use time and energy to investigate various suggestions to increase the value and prepare decisions proposals to change the project, which can disturb the smooth running of the project. Therefore, it should never be too easy to change the project goals and objectives – and it should be more difficult the later in the project period it occurs.

It is of course a problem, if the cost and time limitations do not allow the value objectives to be fulfilled in spite of all possibilities for adjustments are made. In such a case the objectives for the three factors in the value triangle have been defined unrealistically without the necessary balance and they will have to be redefined. That is what happened in DR Byen and it meant that the budget had to be increased and the deadline postponed.

3.5 Product and process integrity

The English construction management researcher Graham Winch (2010) has by inspiration from the product development in the car industry created a model for product integrity or the quality of intention as shown in Figure 7. The quality of conception expresses the symbolic aspects in terms of elegance of form, spatial articulation and contribution to the urban culture. The quality of specification expresses the functional aspects in terms of the fit and finish desired, and the fitness for purpose of the completed facility. The quality of realisation expresses the resource and process aspects in terms of budget, schedule and the service delivery experience.



Figure 7: Model for product integrity – quality of intention (Winch, 2010)

Winch connects the model for product integrity with a model for process integrity, which is near enough identical with the value triangle presented earlier. The product integrity concerns an appropriate intention while the process integrity concerns a predictable realisation. This is shown in Figure 8. The terms “Quality of conception” and “Quality of specification” has been replaced by “Cultural value” and “Use value” in accordance with the arguments explained in section 3.1 about value as focus of this research.

According to the models for product and process integrity there are two main factors in the value management: Cultural value and use value. Similarly, there are two main factors in the resource management: Cost and time. Value creation in project management includes both value management and resource management.

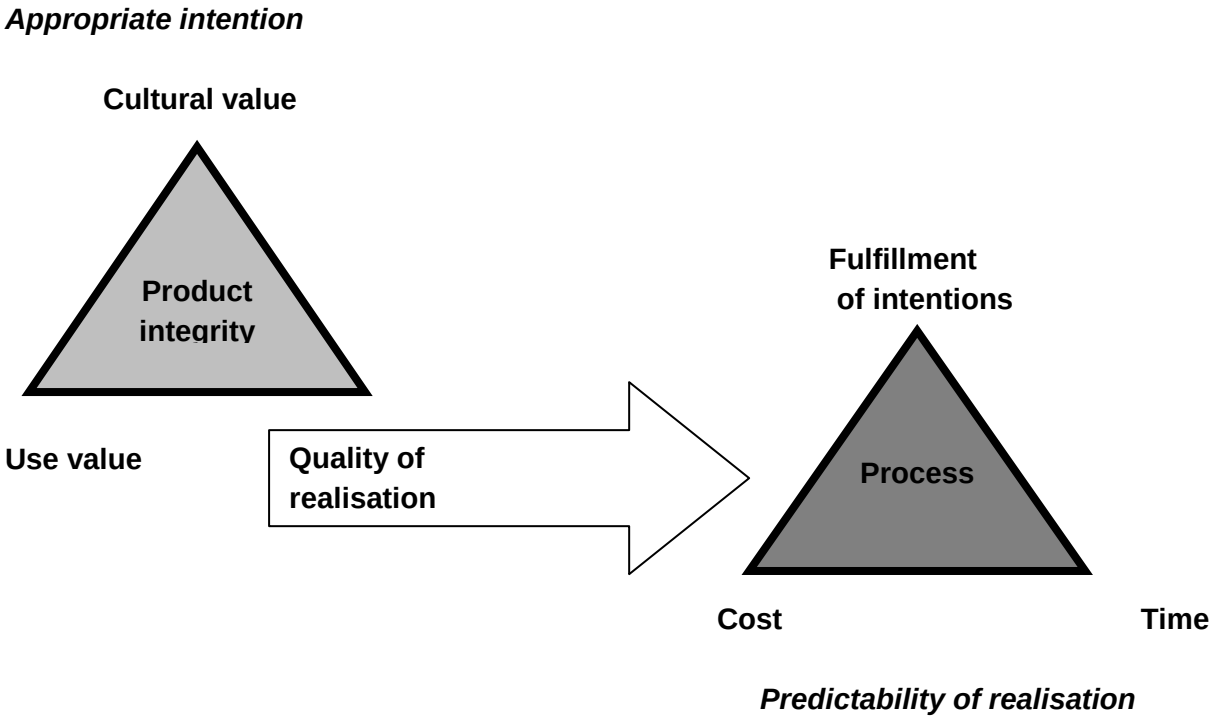


Figure 8: Models for product integrity and process integrity (based on Winch, 2010)

4. Empirical Results

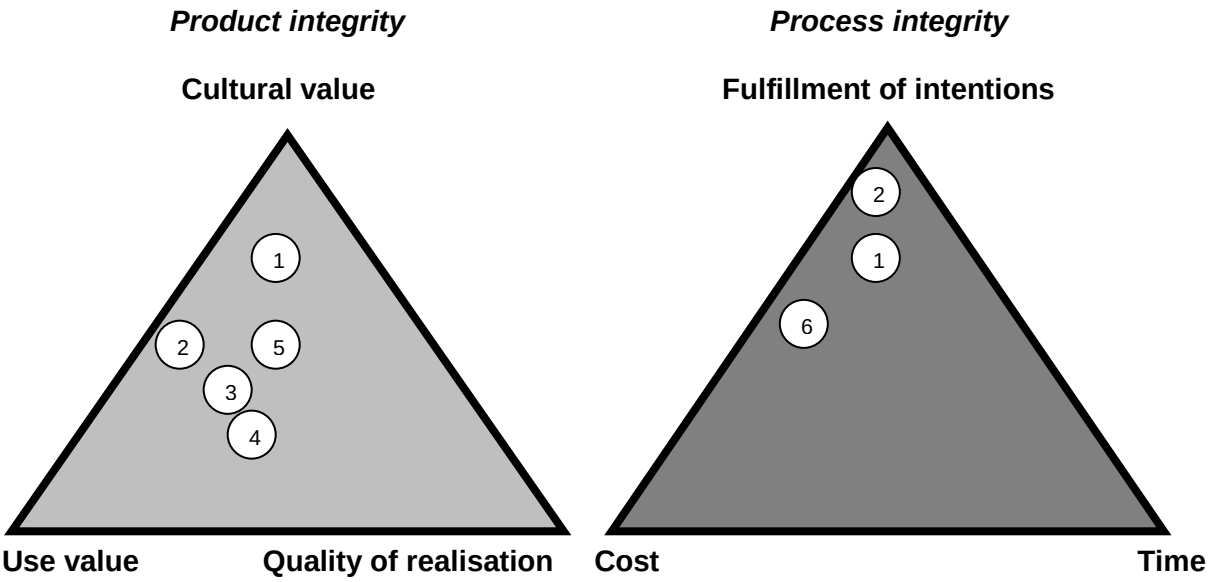
The six building projects that have been investigated and evaluated are presented in Table 2. They constitute the most important building projects undertaken by DR since its start in 1925 and differ very much in size and the time they were built.

Table 2: The buildings included in the case study

Estate/building	Locality	Period of DR's occupation	Area
Stærekassen (Nickname: Birds nest)	Copenhagen (with the Royal Theatre)	1931-1941	6.000 m^2
Radiohuset (Radio House)	Frederiksberg (near Copenhagen city)	1941-2007	30.000 m^2
TV-byen (TV town)	Gladsaxe (North of Copenhagen	1964-2006	100.000 m^2
R/TV-huset (Province radio/TV-centre)	Århus (in Jutland)	1973-	28.000 m^2
Distriktshuse (Regional radio centers)	Odense, Vejle, Ålborg (3 province towns)	1983-	Each 2.600 m^2
DR Byen (DR town)	Copenhagen (new development - Ørestad)	2006-	130.000 m^2

The result of the evaluation of the six building projects in relation to the models for product and process integrity is shown in Figure 9. The oldest building – Stærekassen – is the most extreme with a very dominating focus on cultural value. The reason for this was, that the building was adjacent to the Royal Theatre and mainly built to provide an extra theatre hall

with the remaining space meant to be used by DR. However, the building was not suitable for radio production – for instance due to bad sound insulation between the theatre hall and the radio studios. The project was a big scandal at the time and the planning of Radiohuset started only a few years after Stærekassen was occupied.



1. Stærekassen
2. Radiohuset
3. TV-byen
4. R/TV-huset and Distiktshuse
5. DR Byen
6. TV-byen, R/TV-huset, Distiktshuse and DR Byen

Figure 9: Evaluation of DR's buildings in relation to product and process integrity

Radiohuset from around World War II had a very strong focus on both cultural and use value and had the most dominant focus in the fulfilment of intentions. It has for 65 years served as DR's main radio centre and concert hall and is now a preserved building as one of prominent examples of modernist architecture in Denmark and it is occupied by the Danish Music Academy. TV-byen from the 1960's and 1970's had stronger focus on use value and the quality of realisation – particularly in relation to cost.

The buildings R/TV-huset and Distriktshuse from the 1970's and 1980's had the least focus on cultural value and most focus on the quality of realisation. Among the reasons are that they were built after DR had for the first time established an internal building client function and the buildings were not headquarters. The new headquarters DR Byen is seen as having the most equal balance between the factors in relation to product integrity, while the process integrity is evaluated to be the same for all the buildings except the two oldest with a stronger focus on the fulfilment of intentions.

5. Conclusion

The conventional value triangle of project management should not be regarded as an expression of some kind of absolute law, but only as a general illustration of principles for the relationships and priorities between the three factors of value, cost and time. Winch (2010) provides a more differentiated picture by substituting the conventional value triangle

by a model with a triangle for product integrity and a triangle for process integrity. With this model the possibilities to discuss the value of a project is improved by introducing the distinction between the quality of conception and quality of specification - or cultural value and use value. Thereby it provides a more realistic view on the tasks and challenges of project management.

Project management involves the two interrelated tasks of value management and resource management. Value management aims at effectiveness in maximizing the value output of the project within the resource constraints by defining appropriate intentions and maintaining product integrity with the right balance between cultural value, use value and the quality of realisation throughout the project. Resource management aims at efficiency by minimizing the resource input into the project by developing a predictable realisation and maintaining process integrity with the right balance between fulfilments of intentions, cost and time throughout the project. All together project management aims at reaching the project goals and optimizing performance by developing and maintaining project integrity with the right balance between value management and resource management throughout the project.

The framework with models of product and process integrity has been implemented in an evaluation of six of DR's buildings. The general picture is that DR's buildings have a strong focus on value and fulfilment of intentions. This is not surprising as DR is a public service broadcasting corporation. This means that the buildings on one side have to be high-tech production facilities and on the other side shall represent a cultural institution of national importance. The high priority of value and fulfilment of intentions was particular significant in the two oldest buildings which included a theatre hall and a concert hall, respectively. The recent development, DR Byen, also includes a concert hall and even though DR Byen is evaluated as having fairly well balanced product integrity, the development of the project has shown that the ambitions of DR's building committee in relation to the architectural expression of the concert hall increased over time.

The study indicates that the value triangles provide a useful framework to evaluate the project management and discuss the characteristics of building projects. It is a tool that can help to give a better understanding of the differences between different projects and can be used to identify the particular challenges for the project management in a specific project.

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Accessibility and heritage in the tourism perspective: some 'minor' case studies from Italy.

Luigi Biocca[1], Nicolò Paraciani[2]

Abstract

Tourism is gaining importance for the older population, due to the fact that elderly people have more-than-average available free time and show an increasing desire to engage in travel to tourist/cultural destinations. Some European funded programs are sponsoring tourism packages for new potential users as a policy to foster the economic growth of this sector.

Moreover, in the Italian scenario of major and well-known heritage sites there is a trend of exploiting "minor" tourist destinations that can disclose undiscovered sceneries and areas of historical and artistic value.

This paper aims to highlight "minor" case studies presenting potential values both for tourism and culture and to check whether newer requirements are met. The selection of such cases was made based on:

- compliance with the most important accessibility requirements (as stated by law);
- design suggestions;
- checking MIBAC guidelines.

Keywords: accessibility, usability, heritage.

1. Introduction

In the current age of worldwide financial crisis, tourism and culture represent a crucial resource for attracting tourists and create a friendly and enjoyable environment, along with revitalizing cultural heritage. In this perspective, the needs of potential visitors are to be considered using a more inclusive approach. To this purpose, the *"Act for promoting accessibility in cultural and heritage areas/buildings/properties"* (MIBAC, 2008), by the Italian Ministry of Cultural Heritage,

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introduces new accessibility guidelines in heritage and cultural areas for the benefit of visitors of all ages and abilities (including those with sensorial difficulties), also addressing design solutions, mobility facilitations and aid systems. Unlike the previous legislation, which addressed only motor difficulties (Biocca, 2008), the focus is now on a wider range of considerations, as summarized in the following (Picchione, 2008):

1. differences in level affect also people with walking difficulties, not only those using wheelchairs;

2. long walking distances represent a problem for people with walking difficulties as well;

3. good accessibility and usability of indoor spaces are necessary for larger user groups;

4. different specific codes (fire safety, health, etc.) of the construction sector need a common view for integrating solutions through design and construction processes;

5. low vision should be given more consideration in design guidelines and solutions;

6. orientation and sensorial difficulties need a more detailed approach in defining guidelines and solutions for identification points, signage systems and mapping.

The general founding principle is that making heritage areas more accessible and usable is a priority with respect to historical preservation, nevertheless design solutions must meet heritage quality and value without altering the image that visitors/tourists perceive of these sites (Biocca, 2010).

1.1 Heritage and tourism

Heritage plays a key role in the EU as a catalyzer of entertainment and tourism among various user groups. However, the lack of suitable infrastructures in terms of accessibility is clearly in contrast with a growing demand of usable facilities. Social tourism is a rapidly developing policy for tourism promotion and empowerment among seniors and people with less travelling opportunities, both in terms of affordability and easy access to facilities. Relevant issues that should be solved in order to achieve this goal are the following:

- insufficient communication and awareness of choices;

- need for easier access to information;

- insufficient information sharing among tourist stakeholders;

- difficult enjoyment of heritage sites due to lacking tourist facilities and services;

- insufficient dissemination of tourist resources nationwide.

A higher number of travellers implies a potentially enhanced development of cultural and landscape areas. Actions improving quality and usability of such areas include:

- a wider extension of *Design for All* principles to open spaces;

- usability of all spaces, also by means of new technologies and systems, and creation of widespread tourist information networks;

- exploitation of accessible local heritage sites, e.g. natural and archaelogical paths, through specific tourism policies;

- optimization of tourism reception and accommodation facilities for the benefit of various user groups, especially those including people with lower incomes and elderly people.

1.2 Mobility and design guidelines

Paths and walkways are essential mobility elements in natural areas, parks and open spaces in general. Planning paths and walkways affects mobility and amenity of viewpoints. Walking a long distance can be a considerable physical discomfort for many people, even to the point of tiring out seriously. Long horizontal walkways are common in many areas of cultural interest, e.g. large museums, historical city centres, archaelogical sites, parks and historical gardens, and natural reserves (Biocca, 2009).

Covering long distances can be a barrier for people with limited mobility like elderly and cardiopathic people, who can experience problems even along a smooth way longer than 50 m, while, on the contrary, people on wheelchair can cover much longer distances. Such situation can be even worse in walkways with many level differences due to the ground layout and the orographical land features. Walking problems can also arise with an irregular or uneven floor/ground or cobbled pavings, and these situations are quite usual in archaelogical areas and obsolete parks.

In order to cope with such inconveniences, *"arranging walkways with flat, smooth and slippery-proof pavings and equipped with rest and service areas every 50-100 m, possibly roofed and with benches or ischial supports"* is required by law, *"also for preventing the possibility of a tedious experience which could produce a feeling of tiredness and discomfort"* (D.P.R. 503, 1996). Moreover, *"focus must be on removing obstacles along walkways/paths. In particular, those with low and severe vision problems need to check and clearly recognize walking areas"* (D.P.R. 503, 1996).

Another key group of design recommendations includes orientation: some solutions can be easily and economically installed and, at the same time, allow users with vision and cognitive problems to use comfortably the built environment. Providing natural guidance systems as well as signals or furniture to identify ways is advisable. In particular, natural and well recognizable

plantar-touch elements are preferable to artificial guidance which can result more intrusive. Wayfinding also plays a key role in orienting visitors. It is a clear identification system of places and spaces as related to one or more designated destinations, where each signal shows how to reach them. These signals can often be maps located in strategic points or can be “mobile”, i.e. installed on devices a user can wear.

In places of cultural interest, maps located in strategic points (entrances, main crossings, vertical connections, direction changes, etc.) are required to be clear, accessible and readable to the largest possible number of users (Biocca, Morini, 2010). In the case of tactile visual maps, additional recommendations for blind people are: objects and lines in relief, Braille texts or in black relief, touchable textures, etc. In open spaces like parks, historical gardens and archaelogical areas, blind people and other visitors can experience 3-D mockups of the locations.

An architectural barrier is also defined as *“lack of suggestions and signals for a better orientation and recognizability of places and dangers for everybody and in particular for visually impaired and deaf people”* (D.P.R. 503, 1996).

Additional recommendations for a better usability of the built environment are related to implementation of services and facilities for reception and hospitality by:

- refurbishing rest areas, eating spots and toilets for all user groups;
- designing houses or rooms for resting and sheltering from adverse weather conditions;
- implementing alarm points for prompting the presence of any person experiencing health problems or safety risks.

Moreover, a network of info-points is relevant to disseminate knowledge about the site’s resources and providing information on how to reach locations easily, which transportation means to use and which time schedules. Potential users shall share such information both on the spot and from remotely, by means of different technology tools: web pages with search engines, interactive maps on desktops and mobile systems etc. In order to facilitate users, especially older, in visiting a venue, solutions for a remote preview are recommendable, delivered through virtual tours with information content so that everybody can evaluate in advance any difficulty in walking as related to their abilities. Finally, the placement of ICT devices (e.g. webcams) in strategic points can supplement safety and security.

2. Examples of recent case studies.

A short collection of recent case studies is here highlighted, with an emphasis on solutions that empower access and use of cultural properties, both heritage sites and open spaces.

2.1 Jazz concert hall and park - Rome, Italy

This case study is part of the final publication of the BAS (*Building Accessible Services*) EU project (CNR ITC, 2006). This project developed a methodology for assessing accessibility of different building types (Sakkas et al., 2004). It is a collection of best practices across Europe in terms of alternative solutions for enhancing access and usability of different building categories and infrastructures (services, facilities, transportation systems, leisure and education facilities, etc.).

The Jazz House is the result of a large redevelopment plan of a former mansion house. The whole complex has been designated to accommodate facilities for fruition of jazz music (both live and studio), a popular genre in the cultural environment of Rome (ZETEMA, 2005). The plan was to keep the original facades and encumbrances of the existing buildings, while remodelling layouts with different usage rooms. The three buildings now accommodate a concert hall with an information centre, a restaurant and a music-recording studio with visiting musicians' rooms.
several transport lines. A landscape planning requalified this heritage area, while new car parking lots nearby improved the general accessibility for visitors. The existing mansion house (Villa Osio) was designed in 1936. Recently, the Italian government entrusted the City Council of Rome with the confiscated property. The core of the redevelopment area is the main *A* building, whose ground floor is now accommodating the concert hall (auditorium) for 146 people, an entrance hall, and an information centre with CD music listening facility (see Fig. 1).

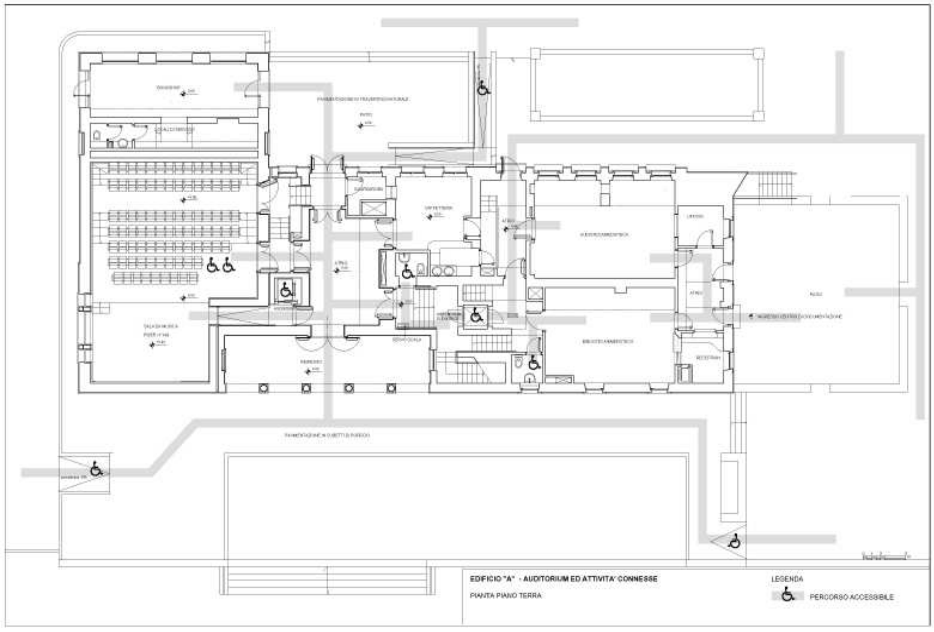

Figure 1: 'A' Building, ground floor (Zetema, 2005)

The first floor hosts the offices, a music direction room, and rooms and facilities for musicians, connected by a lift to the stage. The facades were modified only in order to restore the purity of the original style (see Fig. 2). There are two other buildings: *B*, next to the main entrance, with a restaurant-cafeteria and *C*, which is dedicated to music production and includes a recording studio, three music rooms, an office, a radio room, a direction room and small living units hosting visiting musicians. Inside the park, archaeological spots, lights, viewpoints and accessible pathways have been highlighted for the benefit of all citizens, regardless of concert scheduling.



Figure 2: Main entrance to the concert hall ('A' building) (Biocca, 2006)

The main building of the complex is a 'L'-shaped former mansion house, with a walking surface of 1200 m^2 on three storeys. The redevelopment design for accommodating the new rooms has its core in the concert hall, which required a relevant layout transformation in the smaller wing. The concert hall's layout plan is formed by two terraced seating areas serviced by corridors. The lower area has three seating rows at the same floor level as the entrance and an additional free space to allow a better access. Musicians, producers and presenters can access the stage through a smooth slippery-proof and colour-contrasted slope. The general facilities (dressing rooms and toilets) are on the first floor and are connected to the stage through an accessible elevator for musicians only. The entrance hall is equipped with an accessible toilet and a cafeteria.

Smoothly sloped ramps overcome differences in level outside as to walkways, patios and courtyard (see Fig. 3). Outdoor pavings are assembled with natural materials and the main indoor passages, as well as the way from the entrance hall to the concert hall, have no differences in level. The additional rooms of the main wing on the ground floor are refurbished as a music information centre with an audio and video room, a library and a reception. Access is from the west patio through smooth ramps. Accessible toilets for visitors are located nearby and in the basement, and can be reached through an accessible lift. The main staircase in the middle is equipped with an accessible lift and connects all the rooms. The smaller *C* building accommodates a music production centre, a hall, a secretary's room, recording rooms, direction room, and toilets on the ground floor. Every room is easily accessible.



Figure 3: Ramp access from the park side (Biocca, 2006)

Living units for the musicians are constituted by three double rooms with toilets on ground floor, accessible from the patio outside, one double and one single room, a small flat and a common living room on the first floor, all with toilets and balconies accessible through a staircase with lift.

Walking across the park is very easy thanks to no-step walkways made of ecological materials, well-lit and signalled with orienting information systems. The park is also furnished with several wooden benches along walkways and around buildings (see Fig. 4).



Figure 4: View of the park (Biocca, 2006)

2.2 University "La Sapienza", Botanical Garden – Rome, Italy

The Botanical Garden originally was part of the Vatican gardens under the kingdom of pope Nicolò III (1277-1280). Then in 1660, pope Alessandro VII decided that the University of Rome (now University "La Sapienza") should have its own Botanical Garden, separated from that of the Vatican. After other location changes during the XIX century, in 1883 it received its present collocation, within the garden of the Corsini Palace, rich of archaeological ruins belonging to the Thermal Baths of Settimio Severo (source: website of the Botanical Garden). The entrance to the Garden is free of charge for disabled people and there are explanation leaflets both in Italian and English. There also is the possibility of taking guided tours, with no additional payment, granted that a reservation is made in advancement by email. It is open from Monday to Saturday, during the whole year, with opening hours varying according to the period (spring to summer - from March to October, and fall to winter – from November to February). On the website there are news, info, contacts, a map of the garden with the different areas reserved to specific plants or built as specific gardens. Unfortunately, the only language available is Italian. For blind people there is a specific part, "The Aromatic Garden", with a tactile map and plants that can be smelled or touched. The parking area is free of charge for disabled people, and toilets are accessible, as well as pathways, at least the majority of them, both for wheelchair users, mobility impaired people and blind people. Furthermore, there are two electric transport means for reaching slope areas which are worthwhile visiting. On the website there are no information about accessibility, except regarding the free entrance for disabled people, but on the website devoted to accessibility and tourism in Rome (www.handyturismo.it) it is possible to know more about accessible paths.

2.3 Redevelopment plan of the “Josef Ressel” path in the natural reserve Igouza - Basovizza, Italy/Slovenia

The “Josef Ressel” path is a naturalistic trail developing for about 4 km amidst the woods of Igouza and Lipizza, crossing the border between Italy and Slovenia and thus connecting Basovizza (Trieste) to Lipizza (Nasti, 2008). The path was planned and developed to be accessible for people with visual impairments. In order to do this, the trail has been equipped with technological aids which can be found in correspondence with the stops located along the first 1.9 km of the path, which at present constitute the only walkable section. There are four stops along the path with a total of eight information boards in three languages: Italian, English and Slovenian, in addition to tactile tools and automated vocal messages allowing blind people to access the information about the local flora and fuana, as well as the geological and naturalistic features of the wooded area. It is also possible to freely request an audioguide that makes use of 65 electronic sensors receiving input from the presence of the user and transmitting the message related to the location that the user is passing through in that moment.



Figure 5: A view of the “Josef Ressel” Path (Nasti, 2008)

At a distance of about 1500 m from its starting point, the “Josef Ressel” path turns to the right, along the portion of the trail known as CAI 3, where the vocal signal can no longer be received for about 330 m before it becomes operative again, and the ground on which the path develops is uneven and hence poorly accessible. Therefore, an alternative path has been recognized in

order to let people with motor disabilities cross that particular area of the woods, although this solution is not entirely accessible itself because of the presence of calcareous rocky soil.

In order to solve this problem and make the entire path easily usable also by people with motor disabilities, an adjustment plan was proposed in 2005 (Nasti, 2008). This plan involved three main intervention areas:

1. Adjustment of the CAI 3 path: projection of a wooden walkway with a width of 100 cm to be joined to the existing one, in order to allow weelchair users to avoid the harsh terrain and safely cross the path;

2. Adjustment of the alternative path: leveling the calcareous rocks protruding from the surface of the soil by using a large hammer and a mill to reduce their size, so that the path would become less difficult for people using weelchairs;

3. Improvement of stop areas and parkings: replacement of the existing terrain with small rubble, 15 x 30 mm in size, in the stop areas and construction of a parking space nearby the path entry, with an accessible connection to this latter, placed on a plain area with max. 1% inclination and measuring 320 x 500 cm.

The adjustment plan also contemplates the setting up of a bird watching station that can be used by people on weelchair as well. The station should be built in an easily accessible and recognizable glade, which implies the presence of an accessible way to reach it coming from the path. The station should have the following technical features:

- threshold height less than 2 cm;

- open entrance (no door) at least 90 cm wide;

- indoor area measuring 150 x 150 cm, with no furniture;

- two sets of slits (openings), one at 75-140 cm from the ground and the other at 125-190 cm;

- console under the slits placed at 70 cm from the ground and measuring 50 cm in depth.

Other improvements being considered are: the introduction of mobility aids, such as electric scooters for people with fatigue problems and universal all-terrain weelchairs to ease the crossing of the more difficult sections of the path; the setting up of two public restroom facilities, having high-tech features, one placed at the starting point of the path and the other by the borderline, in an area accessible both from the CAI 3 and the alternative path.

3. Conclusions

The illustrated case studies were assessed using different methodologies (metrics, performance-based and guidelines) applied only basing on research and professionals' direct experience. There is no available survey at the moment on the response from end users, even though most conditions of these case studies regarding accessibility were found generally satisfactory among associations of users with disabilities. However, future efforts must address a unique assessment methodology which integrates the different approaches used so far and become an implemented assessment tool.

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Real Estate Performance Assessment for Sustainable Refurbishment

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Abstract

The European construction sector is characterized by a great amount of low performances building assets, researchers proved that simply improving the insulation of existing buildings with interventions of refurbishment does not give assurance on actual improvement of buildings sustainability. The aim of the research is to give the interested stakeholder a method that can be used as a certification procedure of buildings condition and in order to choose among different project alternatives to get the most sustainable solution in terms of economy, environment and society. This method investigates mainly two aspects of existing buildings: the building residual performance and the refurbishment potential in terms of sustainability gains. Consequently, the output of this method consists of two indexes: one related to the actual performance and the other to the refurbishment prospective. The first one is assessed considering all the aspects of the existent building, for instance: components service life, degradation, availability of mandatory documents, operational consumptions, etc.. On the other hand, the second index starts from the discovered criticalities and rises with project alternatives able to solve them. These two indexes are developed, starting from existing protocols and software, to obtain a system able to assess the sustainability performance since the early design stage. The connection between the two indexes allows assessing the real estate, characterizing each building with a performance level and evaluating the feasible sustainability improvements.

Keywords: Real Estate, Efficiency, Sustainability, Multicriteria, Anomalies

1. Introduction

In these last years the importance of the refurbishment of the real estate rapidly increased due to the economic crysis and the necessity to reuse existing buildings (due to the impossibility of building new constructions). Making the correct choices could lead to appreciable savings and doing this at its best requires a good knowledge of the building. A large numbers of methods were identified: Facility Performance Evaluation Zimring (2010), Building Condition Assessment Abbot, Mc Duling, Parsons, Schoeman (2007), The Stonewell Group Inc. (2006), Standard & Poor's (1995), Foltz, MCkay (2008), Ahluwalia

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(2008), Queensland Government (2011), Ezovski (2009), Straub (2002), ASCE 30-00 (2000). All these methods are mainly supposed to be instruments (tools) able to lead the users to the best choices for maintenance, in both short and long terms. This work, instead, is aimed at proposing a method able to both assess the current state of a building and evaluate the possible refurbishment strategies in terms of sustainability. The main objectives are: the creation of so called *efficiency indexes* of existing buildings and the identification of a method able to evaluate project alternatives and choose the best one. An application of the method to a building of the Politecnico di Milano Campus is shown as a case study. In this example, criticalities and strengths of the method have been evaluated using an iterative process.

2. Building efficiency indexes

The idea of creating *efficiency indexes* for the condition assessment of buildings was born together with the necessity to create and manage a well-organized building logbook, that allows stakeholders (owners, users and technicians) to get a better and faster analysis of the building itself. This work highlighted the necessity of mainly two types of indexes: one (documental) to describe the quality and quantity of available building documents taking into account legal requirements; the other (technical) to assess the building condition in terms of aging and anomalies of its components.

2.1. Documental efficiency index

The first index is organized as a weighted ratio between the number of available documents and the number of documents that should be available for the specific building. This ratio involves weights able to consider the different importance of all documents related building design, construction and operation. A list of required documents is the starting point for the documental index evaluation: in this study 9 documents families have been created to classify each document, needed either by law or by standard practice. These nine families do not list documents strictly related to industrial activities done inside the building (i. e. operation and maintenance documentation for industrial plants). The nine families of documents have been weighted with a pair comparison system to get their relative importance; the results are shown in the **Error! Reference source not found.**.

Table 1 – Weights of the 9 documents families

FAMILY	WEIGHT [%]
Construction	8.41%
Fire safety	19.86%
Structures	26.09%
Plants	17.60%
Safety and maintenance	7.16%
Urban planning	3.64%
Land registry	2.30%
As-built	12.80%
Provenance and easement	2.14%
TOTAL	***100.00%***

Some categories may be not necessary for a specific building (i. e. not every building needs fire safety documentation in Italy), so depending on the actual number of families the weight

is recalibrated. In addition to these weights, the documents inside each family are organized in four categories according to their importance, with an associated weight: a) Level 1: compulsory documents, which absence implies the illegal or unsafe use of the building; b) Level 2: compulsory documents, which absence does not imply the illegal use of the building; c) Level 3: important documents, not required by the law; and d) Level 4: (non exhaustive) list of documents just with explanatory purpose. The calculation of the documental efficiency index starts with the evaluation of the score of each document, obtained multipling the importance weight and the presence, which is 1 if the document is available and 0 if not.

$$P_{doc} = presence * importance$$

The score of a family of documents is the sum of all the available documents multiplied by their importance weight, as seen in the following equation:

$$P_{eff} = \sum_{i=1}^{n} P_{doc}$$

To obtain the final index for each family, this value is divided by the sum of all the necessary documents multiplied by their importance, as seen in the two following equation:

$$P_{max} = \sum_{i=1}^{n} P_{doc,i}^{necessary}$$

$$P_{family} = \frac{P_{eff}}{P_{max}} * 100\ [\%]$$

The families weight shown in **Error! Reference source not found.** are used in the definition of the documental efficiency index, as shown in the next equation:

$$I_{family} = P_{family} * Weight_{family}\ [\%]$$

So the calculation of the efficiency index for all the families is done by simply summing the weighted indexes of each family, as shown in the following equation:

$$I_{EffDoc} = \sum_{i=1}^{N} I_{family,i}\ [\%]$$

The efficiency index is a number between 0 and 1, where 1 is the best case, all needed documents are available and 0 the worst, no document is available.

2.2. Technical efficiency indexes

The technical efficiency index is used to assess building condition, by measuring building components degradation and their service life. This index is made by three sub-indexes: the first two comparing the actual service life of each component with its reference one (called

service life index) and the third one evaluating anomalies found on each building component (called *degradation index*). Since the technical efficiency index of a building is a function of the indexes of its components, a standard WBS (Work Breakdown Structure) has been created. This WBS, following UNI 8290 standard, has been organized through 5 levels, from the more general to the more detailed: 1. class of technological units; 2. technological units; 3. class of technological elements; 4. technological elements typology; 5. elements material. The index is calculated for both technological elements (i.e. components; level 3) and technological units (level 2); the other three levels are just useful for organization and comprehension of the WBS. The different importance of each component of the WBS has been taken into account calculating two different series of weights: the first related to the economic value and the second related to the criticality of each component. Both weights have been calculated and applied at the technological units level (level 2). The economic weight is proportional to the percentage contribution of each technological unit to the total construction cost. In the following Table 2, for example, the weights used for a residential building are reported. The pair comparison method has been used to assess the relative importance of each technological unit then converted into criticality weight. All the 18 technological units have been compared to get the results shown in the following Table 2. The two lists of weights are used to build the technological efficiency indexes.

Table 2 – Economic and criticality weights used

#	TECH. UNIT	ECONOMIC WEIGHT [%]	CRITICALITY WEIGHT [%]
1	Foundation structures	2.75%	13,32%
2	Retaining structures	2.75%	9,80%
3	Elevation structures	19.50%	12,88%
4	Vertical Opaque Shell	9.85%	5,55%
5	Vertical Transparent Shell	5.85%	5,20%
6	Slab on ground	1.85%	0,79%
7	Slab on external spaces	0.75%	1,60%
8	Roof	5.05%	9,25%
9	Vertical Internal Partitions	10.85%	1,43%

#	TECH. UNIT	ECONOMIC WEIGHT [%]	CRITICALITY WEIGHT [%]
10	Horizontal Internal Partitions	8.15%	1,76%
11	Vertical External Partitions	1.05%	0,67%
12	Horizontal External Partitions	2.30%	0,67%
13	HVAC	12.70%	3,92%
14	Water and sanitary plant	6.65%	6,28%
15	Electrics and special plants	6.55%	6,01%
16	Sewage disposal	1.35%	3,81%
17	Lift plant	1.80%	3,36%
18	Fire system	0.25%	13,72%

Another instrument needed for the computation of the efficiency indexes is a RSL (Reference Service Life) database that has been built starting from a literary review of major existing databases and from experts' interviews. A list (and a classification) of all possible anomalies for each component is another important necessary element for the calculation of the efficiency indexes. First of all, building components anomalies have been classified,

according to the magnitude of their damages on the component itself, in: a) minors; b) medium; c) serious. Anomalies are also classified according to the typology: bistable (on/off - 0%-100%) and non-bistable, with evaluation of the extension (low 25%, medium-low 50%, medium-high 75%, high 100%). Each anomaly has a univocal code, a name, a description and a measuring parameter. The complete list is made by totally 431 anomalies and each component has meanly 12 anomalies, for a total of 5100 possible cases.

It is trivial that in a building there is not the contemporaneous presence of all the components of the database. Each building component can be evaluated using a diagnostic form, which consists of four parts: a) form data (code, name, number); b) component data (code, name, notes, ASL Actual Service Life); c) anomalies check list (with the possibility to select the anomalies for the component and, if necessary, to put the extension); d) indexes output (automatically calculated as soon as the data are entered). Totally 438 forms, one per each possible component of a building, have been created. These forms are collected in 18 folders, which correspond to the 18 technological units of the WBS. The building technological efficiency index is made by three sub-indexes, the first two are the *service life indexes*. They are alternative, D^+ for components with ASL≤RSL and D^- for components with ASL>RSL:

$$D_C^+ = \frac{RSL-ASL}{RSL}\ [-]\ D_C^- = 1 - \frac{ASL-RSL}{ASL}\ [-]$$

Once the service life indexes for each component are known the same indexes can be computed for the upper level of the WBS. The indexes for each technological unit of the building are obtained with the following two equations:

$$D_{UT}^+ = \frac{\sum_{i=1}^{n} D_{C,i}^+}{i}\ [-]\quad D_{UT}^- = \frac{\sum_{j=1}^{m} D_{C,j}^-}{j}\ [-]$$

These formulas are simply the average of the previously calculated index. The last step consists in the evaluation of the service life indexes for the entire building by performing a weighted average of the indexes of the 18 technological units using weights described in Table 2:

$$D_B^+ = \frac{\sum_{k=1}^{o} D_{UT,k}^+ * \left(P_k^E + P_k^C\right)}{\sum_{k=1}^{o} P_k^E + P_k^T}\ [-]\quad D_B^- = \frac{\sum_{x=1}^{p} D_{UT,x}^+ * \left(P_x^E + P_x^C\right)}{\sum_{x=1}^{o} P_x^E + P_x^T}\ [-]$$

In this work these two outputs are supposed not to be aggregated because they describe two different categories of components and an average could bring to a loss of important information. On the other hand, the degradation index consists of three equations at the component level:

$$A_M = \frac{\sum_{i=1}^{M} P_{M,i} * E_i}{M}\ [-] A_S = \frac{\sum_{j=1}^{S} P_{S,j} * E_j}{S}\ [-] A_G = \frac{\sum_{k=1}^{G} P_{G,k} * E_k}{G}\ [-]$$

These three partial indexes have to be aggregated in one, describing the component situation, through a weighted average:

$$A_C = \frac{A_M * G_M + A_S * G_S + A_G * G_G}{(G_M + G_S + G_G) = 1} = A_M * G_M + A_S * G_S + A_G * G_G [-]$$

The next step, as in the duration indexes, is the calculation of the index at the technological unit level:

$$A_{UT} = \frac{\sum_{i=1}^{n} A_{C,i}}{i} [-]$$

The evaluation of the efficiency index at the building level uses the same weights and the same equations of the duration indexes:

$$A_B = \frac{\sum_{k=1}^{n} A_{UT,k} * \left(P_k^E + P_k^C\right)}{\sum_{k=1}^{n} P_k^E + P_k^C} [-]$$

2.3. Aggregation of the indexes

The last problem concerning the condition assessment of a building is the aggregation of the four indexes. The question is: is one index better than two or three or four ones? Many options could be evaluated: a) 4 different efficiency indexes (documental, 2 duration, 1 degradation), b) 3 different efficiency indexes (documental, duration, degradation), c) 2 different efficiency indexes (documental and technical) and d) 1 efficiency index (collecting all the previous). The main problem is the information lost during the calculation and not the aggregation (which is only an analytical problem): for an inexperienced user one index can be simpler than four but the information given by a single index could be misunderstood without an appropriate explanation (such as a detailed report). Therefore, in this work it has been decided to keep four separated indexes to better understand the possible criticalities. This aggregation process does not influence the calculation process explained before. The power of the presented method lies in the possibility to evaluate either some components alone or the whole building, without affecting the results.

3. Sustainability multi-criteria analysis method

A Multi-Criteria Method was chosen to collect existing instruments for (Environmental, Economic and Social) Sustainability assessment and for performance assessment of project alternatives. To the Sustainability of a project alternative means to evaluate some benchmarks such as: the whole life-cycle costs for the Economic Sustainability, the embodied energy, the CO_2, the thermal and electric energy demand for the Environmental one, and the thermal comfort, the air speed and air quality, the acoustic comfort and the illumination level for the Social Sustainability. The number of parameters should be established in connection with the analysed interventions. The output of the presented method is a ranking of the most sustainable project alternatives, with the aim to help the designer in the selection of the most suitable one. The method, called SMCAM (Sustainability Multi-Criteria Analysis Method) is created in such a way that it allows evaluating interventions of different categories, so one alternative does not have to exclude the other: it is possible to evaluate combination of different alternatives to get the best solution in terms of Sustainability. A large amount of parameters has been evaluated,

starting from International Standards and other research projects with the same theme Open House (2011), Akadiri (2011). These parameters are divided into three major categories, as written in the EN 15643 (2010). In this study the social sustainability has been converted into the internal performance, measured in terms of internal comfort perceived by the occupants. For the environmental assessment of sustainability six parameters have been chosen, starting from the analysis of the requirements of a building, both compulsory and voluntary. They have been divided in two subcategories: environmental impact and energy and resources consumption. The parameters used for the economical assessment are those that, assembled together, give the entire cost on the life cycle of an asset. The disposal cost has not been considered in this research because of two main reasons: the great uncertainty in its calculation (the disposal cost will occur at the end of the life cycle of a building, in our case study 60 years) and its low influence, as showed by the results of a sensitivity analysis; so the effort to add the evaluation of the disposal cost could not give better and more accurate results. The internal performance has been evaluated through the assessment of five main parameters related with the internal comfort. All the parameters can be seen in the Table 3. The method is built according to the AHP selection process Kaklauskas, Zavadskas, Raslanas (2005) and Sonmez, Ontepeli (2009). The first phase consists in the creation of the hierarchic scale, made by three levels and reported in Figure 1.

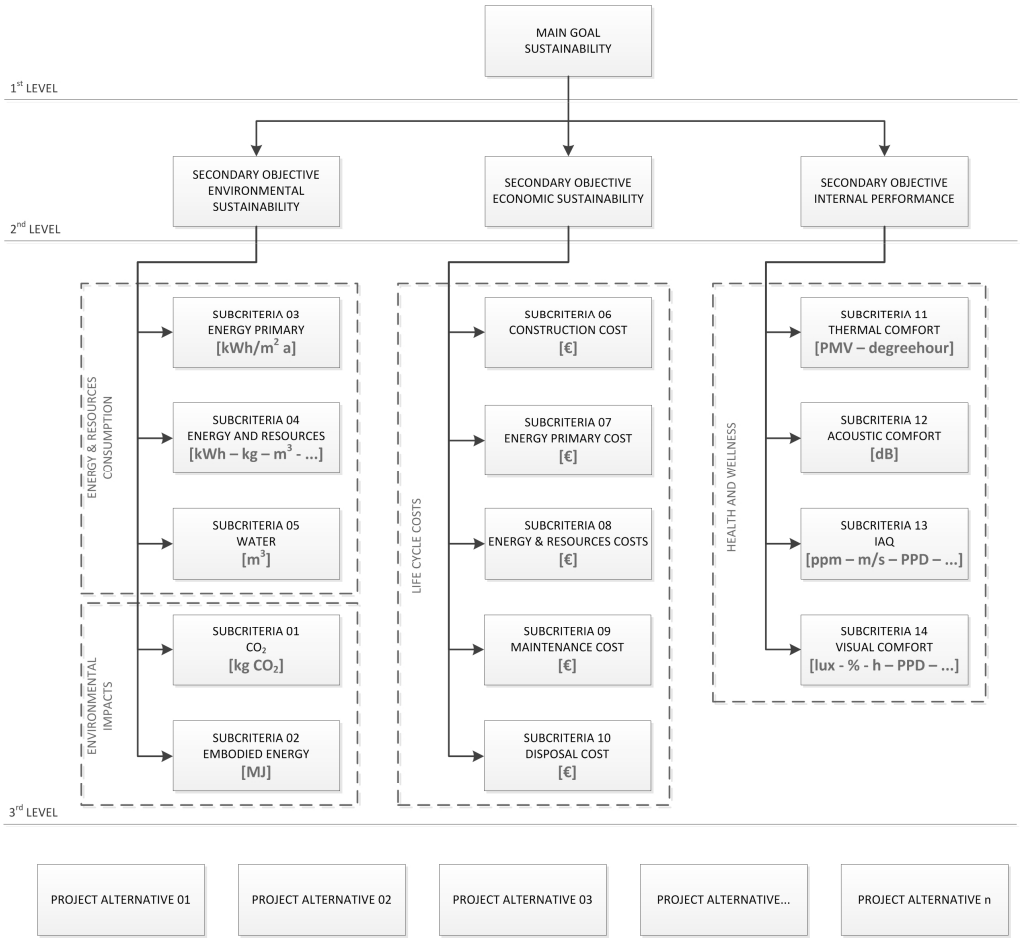

Figure 1 – Hierarchic scale of the SMCAM method

The project alternatives are in the bottom of the hierarchic scale, out of the three levels. The evaluation of different parameters by different units of measure and magnitude requires a

normalization process, which can be obviously made in many different ways. In this study the normalization method with equally distributed scale has been used, both for parameters that need to be maximized or minimized. This process is really useful because it normalizes the parameters giving as result 1 for the best solution and 0 for the worst one; this simplifies the entire process of selection, avoiding misunderstanding and errors. In this method a weighting system able to consider the relative importance between parameters seemed to be convenient, so a pair comparison among the elements of the second and third level of the hierarchic scale was conducted; the comparison was performed among elements of the same category (the three fields of sustainability) to get three series of weights. First of all, the relative importance of the fields of sustainability has been calculated, with the following results: a) environmental sustainability 55%, b) economical sustainability 21% and c) internal performance 24%. Then the relative importance of the parameters listed above has been calculated with the same method. The results are shown in the Table 3.

Table 3 – Relative importance of the parameters

PARAMETERS	WEIGHT [%]
ENV_Consumption of energy primary	37%
ENV_Consumption of energy and resources	23%
ENV_Water consumption	17%
ENV_CO_2 emissions	13%
ENV_Embodied energy	11%
ECO_Construction cost	33%
ECO_Cost of energy primary	27%

PARAMETERS	WEIGHT [%]
ECO_Cost of energy and resources	19%
ECO_Maintenance cost	13%
ECO_Disposal cost	7%
PERF_Thermal comfort	46%
PERF_Acoustic comfort	24%
PERF_Internal Air Quality	19%
PERF_Internal visual comfort	12%

The evaluation of the parameters was carried on by an online survey sent to a great amount of people, consisting mainly of professionals, professors, students of Architecture and Engineering. After the comparison, the alternatives could be analysed by collecting the data and calculating the related parameters. This last phase is the easiest from the mathematical point of view but it requires a strong reasoning. The method really helps in the decision phase because it allows the comparison at the third and the second level of the hierarchic scale; so the user can compare both the final and the partial ranking (environment, economy and internal performances) to better understand which solution fits best the objectives.

4. Case study

The first case study expressly selected to test the efficiency indexes and the SMCAM method consists of a building of the Leonardo Campus of the Politecnico di Milano, in Milan – Italy. The building is composed of classrooms distributed on 5 floors and offices and labs of various departments distributed on 8 floors. It has been built in the sixties so the main (the most interesting for this work) technologies are:

- slabs in concrete;
- pillars and beams both in concrete and steel;

- opaque envelope composed by a double layer of bricks with a gap in the middle, without insulation;
- windows with one glazing and steel frame without thermal cut;
- plane roof without thermal insulation;
- heating system with radiators in the classrooms;
- heating and cooling system with fan-coils in the offices.

4.1. Analysis of the current situation

Eight technological units have been analysed through the assessment of their components with the diagnostic forms. Totally 31 elements have been evaluated. Some criticalities came out from this work: there are many anomalies in the windows and in the external finishing of the envelope and the analysed plants (heating and electric), despite the lack of serious anomalies, the components seemed to be really obsolete and not responding to the current requirements, because their RSL has been exceeded. For each component (which means for each form) 3 indexes have been calculated: D^+, D^- and A; the documental situation of the building has not been evaluated. Then, the indexes have been evaluated at the technological unit level using a simple average within the components of each technological unit. The last phase gave the indexes at the building level using a weighted average. In the following *Table 4* the results are shown.

Table 4 – Efficiency Indexes at the building level

TECHNOLOGICAL UNIT DATA		WEIGHTS [%]	WEIGHTED EFFICIENCY INDEXES		
NAME	N. FORMS	TOTAL	D^+	D^-	A
Vertical Opaque Shell	5	15.40%	6.93%	13.11%	11.40%
Vertical Transparent Shell	3	11.05%	-	8.09%	4.83%
Roof	2	14.30%	-	7.15%	13.68%
Vertical Internal Partitions	4	12.28%	5.82%	-	11.10%
Horizontal Internal Partitions	4	9.91%	6.06%	7.57%	9.18%
HVAC	7	16.62%	10.55%	7.39%	16.20%
Electrics and special plants	4	12.56%	5.23%	-	11.78%
Lift plant	2	5.16%	3.87%	-	4.78%
BUILDING EFFICIENCY INDEXES			***39.54%***	***44.52%***	***85.27%***

The symbol - means that in the technological unit considered all the components are under or below their RSL. The results show that most of the components are reaching the RSL limit (D^+ is really low) and a lot of them have also exceeded this limit (D^- is near 50%). The level of anomalies seems to be good (85% is pretty high) but the values of the single technological units show that there are few problems in the envelope: the performances of the windows are really low and the external finishing is detaching. The plants are working but they do not really satisfy the current requirements since they are quite old and they need a strong refurbishment.

4.2. Project alternatives selection

Following the complete evaluation of the current state of the building, some project alternatives have been evaluated to get the best refurbishment solution in terms of sustainability. These possible solutions have been designed to solve the above-mentioned major criticalities. These alternatives have been studied because this building is part of a refurbishment program inside the bigger project “Campus Sostenibile – Città studi” and there is the possibility to concretely implement these solutions. The alternatives studied concern the technological units listed above: envelope, both opaque and transparent, roof, heating, cooling and electric plants. Many alternatives for each category have been studied, up to 44 totally. For each alternative all the fourteen parameters described above have been calculated with different techniques, depending on the degree of precision required and the data available. A BIM model of the entire building has been created to easily manage the alternatives and their related data. The phase after the calculation of the various parameters is represented by the correct application of the SMCAM method, as described in §3. So, the alternatives have been normalized and weighted using the weights of the Table 3 to get the rankings, that can be seen as sustainability indexes of the alternatives. These indexes could be partial (connected to just one branch of sustainability) or comprehensive of all the three major fields. Five alternatives have been selected according these criteria: the most sustainable alternatives overall and the necessary alternatives (which means alternatives connected to components with really low performances, not depending on the improvement of sustainability). The selected alternatives are listed in the *Table 5*.

Table 5 – Sustainability indexes for the selected alternatives

#	COMPONENT	CODE	ENVIRONMENTAL S.	ECONOMIC S.	INTERNAL PERFORMANCE	GLOBAL S.
1	Windows	A.01	0.3647	0.1251	0.0838	0.5737
2	Illumination	A.02	0.3728	0.1481	0.0471	0.5681
3	Heating system	A.03	0.2515	0.1430	0.0192	0.4138
4	Concrete panels	A.04	0.1844	0.1285	0.0192	0.3322
5	Concrete-framed glass panel	A.05	0.1788	0.1269	0.0192	0.3250

The first three alternatives bring serious improvements to the building; on the other hand, the last two are necessary because the concrete panels and the concrete-framed glass panel show really low performances and they require prompt replacement. The five alternatives have been aggregated to make a final comparison with the current situation of the building. The 14 parameters have been calculated without using the SMCAM method, because this phase is aimed at checking the solution. The *Table* shows a large performance increase in terms of environment and economy, and also a good upgrade in the internal performance level. The initial cost is obviously high but the 5 selected interventions should be distributed during years.

Table 6 – Comparison with the actual situation

PARAMETER	CURRENT STATE	SELECTED ALTERNATIVES	Δ [%]
EP_H [kWh_{term}/m^2 a]	141.59	33.55	-76.31%
EP_C [kWh_{term}/m^2 a]	36.15	33.6	-7.06%
ELECTRICITY [kWh_{elet}/m^2 a]	63.94	52.43	-18.00%
CO_2 [kg CO_2/m^2 a]	45.15	27.04	-40.11%
EE [MJ/m^2]	1,137	1,399	23.07%
INITIAL COST [€]	0	604,882	-
MAINTENANCE COST [€]	2,774,435	2,492,588	-10.16%
EP_H COST [€]	2,433,234	576,534	-76.31%
EP_C COST [€]	299,687	278,535	-7.06%
ELECTRICITY COST [€]	2,955,131	2,423,208	-18.00%
LCC [€]	8,690,734	6,375,746	-24.66%
THERMAL COMFORT [degreehour hot]	97,147	103,869	6.47%
THERMAL COMFORT [degreehour cold]	404,564	385,182	-5.03%
ACOUSTIC COMFORT [dB]	39.33	45.21	-13.01%
IAQ [PPD]	54.90%	54.90%	0.00%
VISUAL COMFORT [PPD]	30%	10%	-66.67%

This case study is part of the bigger project “Campus Sostenibile – Città Studi” that is aimed at refurbishing the campus and making it more sustainable. The good piece of news is that two of the previously analysed alternatives (windows replacement and implementation of the illumination system) are now in the construction phase. The other alternatives will be evaluated in the next months.

5. Conclusions

The efficiency indexes and the sustainability index obtained using the SMCAM method, combined together, resulted very useful for the comparison of different feasible solutions in a building refurbishment project. The efficiency indexes are powerful tools for designers, technicians and building users; the indexes are able to give a score to buildings, and a quick report with the explanation of the assessment. Furthermore, the SMCAM method helps the designers during the selection process of the project alternatives and it is also a useful tool for the dialogue with the customer.

Acknowledgments

The authors greatly acknowledge Fondazione Opificium and the Italian Associaton CNPI (Consiglio Nazionale dei Periti Industriali), for funding this research.

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Twenty-three years on in Lean manufacturing: Is there still anything for practitioners to learn?

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Abstract

Twenty-three years have elapsed since Lean techniques originated from the Automotive sector. From then on, Lean techniques have been adopted and fitted to several purposes and their application now ranges to several industry sectors. Meanwhile, the industry has been evolving so quickly that the ability to demonstrate Lean capabilities has turned into a mere order-qualifier in order for some manufacturers to be able to compete, forcing them to find new ways of facing the increased pace of change. An appealing solution for any firm would be to be able to increase their Lean maturity in the short-term. This research suggests that, as an alternative to a painful and costly internal development of Lean, the desired improvement can be achieved in a fast, efficient and cost-effective way by the direct transfer of existing Lean best practices currently implemented in different fields. This paper combines data gathered from a cross-industry interview-based research, conducted with some Australian Lean practitioners, with a comprehensive case study-based literature review of Lean best practices, in order to understand which combinations of best practices and industrial sectors would be able to guarantee the highest mutual benefits by a cross-industry transfer of Lean knowledge. The analysis (1) reviews current Lean best practice applications in (a) Aerospace; (b) Software development; (c) Fast Moving Consumer Goods; (d) Construction; (e) Mining; (f) Food supply chain; (g) Military; (h) Services; together with guidelines on how firms can perform an optimal transition to Lean, (2) benchmarks gathered data with Automotive and (3) clarifies the concept of maximum achievable Lean maturity accordingly. The outcomes have been plotted on a series of qualitative maps. Findings include that an optimal best practice knowledge transfer can be performed within four knowledge transfer “circles”, whose implementation is, therefore, highly recommended in order for each of the involved sectors to quickly achieve a fast and effective improvement in Lean maturity.

Keywords

Lean Manufacturing, Implementation, Best Practice, Cross-Industry, Knowledge Transfer

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1. Introduction to Lean Best Practice Applications Across Industry

More than 20 years have elapsed since Lean techniques originated from the Automotive sector in order to solve its intrinsic production inefficiencies and face the increased challenges of the global market. From then on, Lean techniques have been adopted and fitted to several purposes. Their application now ranges to several industry sectors from Aerospace, to Construction, to Consumer Goods. The current practice of these companies has started and evolved from the Lean principles described by Taiichi Ohno (1988) up to taking diverse and particular shapes. This research project starts from the idea of investigating the different patterns and characteristics Lean practices have followed in different industries and benchmark them to the latest developments of the 23-year-experienced Automotive mainstream. Nonetheless, there still appear to be several, fast-changing barriers to an effective implementation of Lean no matter how it is finally applied. In the recent past, researchers have been suggesting that obstacles to Lean thinking might hide within the company's own culture and the fierce competition it undergoes on the market, limiting its potential and resources to change and the availability of the latest information on how to do it (Mann 2010). As being confronted or challenged by an outsider's perspective can trigger new insights and pathways for collaboration (Clegg, Kornberger and Pitsis 2005), an effective strategy to overcome the barriers to Lean could be the evolution of current communities of Lean practice towards a cross-industry perspective. Indeed, as knowledge transfer has a proven link to organisational effectiveness (Tsai-Lung 2007), a short-term improvement via knowledge transfer of Lean best practices across several industrial sectors could represent a less costly and painful alternative to a long-term research and implementation. Each industry, then, could look at borrowing best practices from other fields, as these might have experienced similar problems in the past and have the right solutions available. This practice could turn out to be the fastest and even only solution for firms to be able to effectively acquire new Lean capabilities and increase their Lean maturity in the short-term. For what concerns geographical boundaries, this research has been carried out in the Australian environment. This constitutes both an advantage and a disadvantage. On the downside, as a continent with a small population and relatively low concentration of large businesses, there is a risk that Australia does not represent the overall latest development in terms of Lean applications. On the other hand, considering the advanced, multi-cultural and mostly unbiased economy, the Australian environment can be seen as the optimal scenario for an independent implementation of original, creative and successful Lean best practices that have been relieved from the pressure of the North American, European and Japanese Lean mainstreams.

2. Research Aims & Methods

This research aims at outlining a common pattern of evolution of Lean techniques from Automotive to other industries. To accomplish this task, the research analyses different sources and identifies common patterns in Lean techniques that have been exchanged across industries. By comparing them with case studies and integrating the analysis with the judgement of consultants and experts active in the field, the research achieves the definition of a unique framework able to facilitate the transfer of Lean knowledge across distinct environments and increase the effectiveness of the system. The research approach consists

of (1) a literature review of case studies of successful Lean implementations and (2) of targeted interviews tailored to the leading concepts found in the literature. This process is iterated for each analysed sector according to the information flow shown in Figure 1 (in Appendix). First, the literature and case studies are gathered and analysed (1), then a general set of questions is created (2) in order to obtain an overall plot for the interview. Therefore, the interview is performed (3) and data are collected (4). The next steps consist in the post-analysis of the results (5) and the formulation of preliminary hypotheses (6). Once all scheduled interviews have been conducted, the general framework to classify and assess Lean best practices is developed (7) and hypotheses on possible knowledge transfer flows are turned into conclusions (8). Steps from one to six have been iterated for every industrial sector to be analysed. Step seven has included a cross-reference analysis of all sectors in order to understand common aspects and develop the main hypotheses on the findings. In order to attain a global view of the different Lean practices which have been applied over the years, the selection of case-studies to be reviewed has focused on all sectors, in addition to Automotive, where Lean has found intensive implementation and use. These include:

- Aerospace
- Software Development
- Fast Moving Consumer Goods (FMCG)
- Construction
- Mining
- Food Supply Chain (SC)
- Military
- Services
- The Overall Transition to Lean

The last sector, i.e. the generalised transition of a business into Lean, has been used as a "virtual" yardstick to evaluate single sectors. In total, seven interviews have been conducted with the assortment reported in Table 1. The other relevant areas have been covered by literature case studies alone.

Table 1: Interviewee List

N.	***Interviewee***	***Position***	***Relevant Sector***
1	L.S.	Project Coordinator, Aerospace Projects	*Aerospace*
2	Dr R.T.	Senior Lecturer, Faculty of Science and Technology Owner, Technological Consulting	*Software Development*
3	S.S.	Managing Director, Management Consulting	*FMCG*
4	T.R.	Area Manager, Construction	*Construction*
5	P.G.	Project Manager, Mining EPCM Contractor	*Mining Projects*
6	R.S.	Former Director of Acquisition and Logistics, Air Force	*Military*
7	Dr E.F.	Associate Professor, Faculty of Business	*Transition to Lean*

Interviews have been “conducted by both researchers, one adopted the lead interview role, posing questions, whilst the other adopted a data collection role” (Perez et al. 2010, 62). Roles have been assigned in each interview in such a way that the leading interviewer would be the one who supervised the relevant literature review. The fact that a great amount of effort has to be put in the preparation and contact with the interviewee can cause the total amount of interviews performed to be far from representing a relevant sample. This is the reason why data collection has been aimed at exploiting a high-quality exchange of information in order to compensate for the low quantity of the tested sample. Indeed, the iterated one-to-one approach and subsequent discussion between the authors have still allowed to critically analyse the collected information with an unbiased approach, which constitutes the key to any critically-led research (Facione 2010). This process has yet promoted a two-way continuous flow of information between the interviewer and the interviewee, challenging the traditional and rigid one-way flow towards the interviewer and creating a positive, proactive environment for the interviewee to feel both engaged and comfortable at all times. The detailed case study literature review, related sources and the specific interview questions have not been reported in this paper in order to comply with length limitations. Due to the large dimension, graphs and figures generated by the research have been included as a separate appendix.

3. Identified Lean Best Practice Scenarios

A Lean best practice is intended to be a specific characteristic of the Lean system under analysis, i.e. a tool, a procedure or a set of actions aimed at productivity improvement and/or cost reduction. Therefore, the higher the number of Lean best practices, the more mature the Lean system is. The review of Lean case studies from the literature and the information collected in the interviews have allowed the identification and categorisation of Lean best practices within the different environments.

3.1 Current Lean Best Practice Scenario

The research has led to the identification and categorisation of the current Lean best practices per industrial sector under analysis. The confrontation with practitioners has shown the strong correlation of the number of best practices with the Lean effectiveness in different environments, proving the validity of the approach. It has been possible to observe that different best practices are currently widespread among different sectors. The results are reported in the Lean Best Practice Table attached as **Error! Reference source not found.** (in Appendix). The Lean Best Practice Table illustrates the current state of knowledge and implementation of Lean best practices across the analysed sectors in light grey. The character “✓★” means the Lean practice represents a world-class best practice of the related industrial sector. The character “✓” indicates that the Lean practice is well implemented in the related industrial sector and close to matching the performance of the leading sector. An empty box entails no known correlation between the analysed sector and the related Lean practice. This observation does not imply that future applications in the field are not feasible, whereas it merely conveys the present state-of-the-art. The field “Mining Operations” has been marked differently, as not enough research data were available. Therefore, listed items require further research in order to be confirmed as actual best practices.

3.2 Recommended Lean Best Practice Scenario and Comparison

The dark layer in Table 3 (in Appendix) relates to a possible future state of Lean best practices across different sectors, i.e. Lean implementations that can be raised to the level of best practices in each sector. The previous Lean best practice scenario in light grey has been used as a yardstick against which the analysis of possible knowledge expansion has been conducted. The symbol "↗" is employed to denote these Lean applications and recommend them as potential best practices for a future development of Lean in each particular sector. The analysis can be further extended to compare the current state of Lean practice against the recommended one on graphs. Therefore, a histogram and a bar graph can be plotted: the former regarding the sector analysis (Table 4: Lean Best Practice Chart

Figure 2 in Appendix) and the latter concerning the diffusion of Lean best practices (Figure 3 in Appendix). As shown in Table 4: Lean Best Practice Chart

Figure 2, Automotive is the sector which possesses the widest application of Lean best practices. Construction ranks sixth, behind, besides Automotive, Aerospace, Software Development FMCG and Services, but ahead of Military, Food SC and Mining Projects. According to

Figure 3, some practices such as the use of “visual supporting tools” or the adoption of “introductory workshops to Lean” are well spread across all sectors, as the nature of these practices is very straightforward and versatile. In contraposition, practices such as “predisposition towards the Lean culture” and the “focus on performance outputs” are not extensively implemented at a world-class level, although a future implementation through knowledge transfer is feasible.

3.3 Definition of Lean Maturity

Besides the visual approach, it is also possible to compare the values that have been used in order to generate the graphs. Table 4 (in Appendix) shows a rank (from best to worst) of sectors where Lean techniques have been implemented and the most widespread practices at current and recommended states of knowledge transfer (left and right columns). It also illustrates the rank of the necessary transfer of best practices and the sectors that would most benefit from a cross-industry knowledge transfer (central column). The numerical analysis of the Current and Recommended Lean Scenarios presented in the left and central columns by an even subdivision of the values into five categories enables to determine the current and recommended Lean maturity of a determined sector. The results are presented in Table 2. The number of times a specific Lean best practice has been used, as presented in the right column of Table 4 (in Appendix), can be, instead, used to determine the easiness of implementation of the practice itself, yielding the ranking of recommended improvements (not presented in table format). Despite ranking as “high”, Automotive still exhibits the potential for a considerable leap forward up to reaching the maximum achievable maturity. Nonetheless, each sector has the potential to make a leap forward in Lean maturity. In the case of Construction, Military and Food Supply Chain, this leap can lead up to an increase of two rankings in term of Lean maturity. These outcomes implies that, notwithstanding the fact that it originated in the Automotive field, Lean has been further developed by other sectors and has a tremendous potential for improvement in some of the currently lower ranked sectors, such as Construction, ranking first in recommended improvement differential.

Table 2: Current and Recommended Lean Maturity by Sector

Lean Maturity / Sector	Very High (25-21)	High (20-16)	Fair (15-11)	Low (10-6)	Very Low (5-0)
Automotive	***R***	*C*			
Aerospace	***R***		*C*		
Software Development		***R***	*C*		
FMCG			***R***	*C*	
Services			***R***	*C*	
Construction		***R***		*C*	
Military			***R***		*C*
Food Supply Chain			***R***		*C*
Mining Projects				***R***	*C*

C – Current; ***R*** – Recommended

3.4 Lean Best Practice Map

In order to allow not only the ranking of best practice knowledge, but also the visualisation of the distribution of this knowledge across the analysed industrial sectors, the outcomes of the above analysis have been plotted on a qualitative bi-dimensional map, the Lean Best Practice Map (Figure 4: Lean Best Practice Map / Knowledge Transfer Map in Appendix). In the Lean Best Practice Map, the two axes represent a continuum of Process/Project and Product/Service orientation of each sector. This choice allows to make some considerations on the achievability of an optimal knowledge transfer of Lean best practices among confining sectors. Process/Project represents the level of operational versus project work typically performed in the sector, the former being of ongoing and repetitive nature, whereas the latter being temporary and unique (Project Management Institute 2008, 22). Service/Product represents the mix of tangible and intangible goods a business sector is involved with and has been developed by Kotler et al. (1999, 646-647). The Lean Best Practice Map contains three indicators; extension, distortion and orientation of the oval shapes representing the analysed sectors. The extension of the oval shapes on the Lean best practice map is directly proportional to the score each analysed sector has obtained in the best practice count (see

Figure 2 in Appendix) and, consequently, the current and recommended Lean maturity. The distortion of the oval shapes along a specific dimension has been determined by a qualitative review of the spread of the sector practices along that dimension. For example, the Automotive sector has been held as characterised by a higher dispersion and variety of process and project-applications than on the Service/Product dimension. Perfectly round shapes represent sectors showing a balanced spread of practices along both dimensions. The orientation of the oval shapes has been defined by qualitative reasoning on the level of correlation shown by the two Process/Project and Service/Product dimensions in each sector. For example, it has been held that a more complex product would require an Aerospace company a more project-orientated approach. On the other hand, a more complex service effort, i.e. on maintenance, would require a higher process-orientated approach to the very same company. Perfectly horizontally or vertically aligned shapes represent sectors showing no sign of correlation between the two Process/Project and Service/Product dimensions. Both measures of distortion and orientation have been achieved without altering the overall extension value, i.e. the area of the shape corresponding to the Lean maturity.

4. Achievement of the Future Recommended Lean Scenario via Knowledge Transfer

4.1 Required Knowledge Transfer

Knowledge transfer across industry has been held in this study as the key to allow the Lean approach to progress to both a higher level of maturity in current applications and the development of new applications. The term knowledge transfer (KT) refers, in this research,

to the implementation of Lean tools and techniques from one sector to another characterised by a lower quality of such practices. Therefore, a KT analysis has been performed on the outcomes of the Lean best practice tables, with the support of the Lean Best Practice Map. The KT analysis has been based upon the hypothesis that an effective cross-industry knowledge transfer of Lean best practices would be facilitated by map proximity, i.e. confining sectors could more-easily achieve an effective transfer. This hypothesis is backed by English and Baker's (2006) framework for Rapid Knowledge Transfer (RKT), Tsai-Lung's (2007) review of the most common barriers to knowledge transfer and Holoyak and Thagard's (1995) view of analogical thinking as a source of highly novel innovations. Indeed, the first step in English and Baker's (2006) studies on how to achieve RKT is to search and import best practices, intended as any process input, step or output showing outstanding capability, reliability and adaptability by others. On the other hand, two of the top three barriers preventing an effective knowledge transfer, according to Tsai-Lung (2007), are environmental and technological characteristics. This standpoint, together with the lack of specific cross-field studies (Tsai-Lung 2007), does not preclude the idea that cross-industry knowledge transfer can be facilitated by sector affinity, i.e. confining sectors on the Lean Best Practice Map can be eligible for a highly effective transfer of Lean best practices. Eventually, Holoyak and Thagard (1995) state that cross-industry innovation often originates from analogical thinking, i.e. the process of adapting somebody else's idea to one's own setting and application (Gentner, Rattermann and Forbus 1993). This idea will work better if structural similarities that are most valuable for problem solving are recalled in the process.

4.2 Knowledge Transfer Map

The results of this analysis have been superimposed to the Lean Best Practice Map, generating the Knowledge Transfer Map reported in Figure 4 (in Appendix). This map shows the optimal knowledge transfer patterns of best practices among neighbouring sectors by white arrows and allows drawing some conclusions on the feasibility of the short-term increase of Lean maturity via knowledge transfer. In some cases, however, recommended Lean maturity cannot be achieved by optimal KT only. Non-optimal transfers have been added and categorised in the Knowledge Transfer Map by grey-scale arrows. Observations on both maps are reported in the concluding section.

5. Final Considerations

5.1 Knowledge Transfer Circles – Where to Gain Lean Maturity from

The presented Lean Best Practice chart (Table 4 in Appendix) has shown that each of the analysed sectors, including Automotive, has the potential to quickly improve the current level of Lean maturity in the short-term via knowledge transfer. The shift should happen by each sector transferring some of its current Lean best practices to other sectors prone to accept it. According to this analysis, sectors currently scoring the highest Lean maturity (Table 4 in Appendix) are, not-unexpectedly, Automotive, Aerospace and Software Development. Nonetheless, the fact that Aerospace and Automotive also score, respectively, second and fifth in gap to maximum achievable Lean maturity proves that there is indeed, even for these sectors, still something to learn. The lower ranking of some sectors such as Construction,

though, does not hinder the potential of improving considerably in the short-term. In particular, Construction, ranking sixth in current Lean maturity, leads the chart of recommended improvement.

A possible interpretation of the above findings is:

1. Effectively, there is still something for practitioners, even in Automotive, to learn (this is the definitive answer to the question posed in the research title);
2. Some Lean best practices currently implemented in different sectors have the potential to bring the Automotive (and Aerospace) leadership in Lean to a whole new level in the short-term.
3. The Construction business has the highest potential to increase its Lean maturity in the short-term, suggesting that even a project-centred environment can reach a "High" Lean maturity by improving in process capabilities

Doubts on the above findings, though, can concern whether the required knowledge transfer to reach maximum Lean maturity can always be achieved at an optimal level for every case. Thanks to their proximity on the map, an optimal and bi-directional best practice knowledge transfer can be achieved only within neighbouring sector areas. Examples include:

1. FMCG, Automotive and Aerospace;
2. Aerospace, Military and Software Development;
3. Construction and Mining Projects;
4. Services and Food Supply Chain.

In particular, an ongoing reciprocal transfer of information between Automotive and Aerospace is facilitated by the high levels of Lean maturity already scored by both in the current scenario. Such transfer shows the potential of not only achieving a reciprocal increase in Lean maturity, but of developing a whole new generation of Lean best practices and techniques. In addition, the cooperation among commercial Aerospace, Military and Software Development, and between Construction and Mining Projects also fits the common idea of ongoing similarities among these sectors and confirms the applicability of an optimal knowledge transfer of Lean best practices. Furthermore, the map positioning of Construction seems also to justify the current difficulties in developing a consistent Lean Construction theory directly from the Automotive basics. Nonetheless, the Construction sector unveils a large potential to improve once a higher focus towards the process, i.e. an expansion towards the left area of the map, is achieved. Further research will need to focus on finding ways of transforming what would be a complex Lean best practice knowledge transfer, due to the distance on the map, into an effective one. In this matter, the high degree of similarity noticeable between Construction and Mining Projects could help these two sectors, once reached a uniform knowledge level to move together in order to increase the speed and effectiveness of the process. As for the Lean maturity leader, Automotive, no matter the accessibility of the outgoing knowledge transfer flows, the inbound knowledge transfer (directed towards Automotive) would be characterised by a high degree of complexity, resulting in a considerable difficulty to achieve improvements. Nonetheless, quite unexpectedly, Services and Software Development seem to hold the right qualities to help

Automotive to improve, confirming Automotive-specific shortcomings in term of service, team pacing and requirement-related Lean practices. Whether a complex knowledge transfer from Services or Software Development into the Automotive sector could possibly be achieved by higher investments or the use of intermediaries (Gassmann, Daiber and Enkel 2011), its real value should be benchmarked by further studies against other possible alternatives to allow the achievement of a short-term improvement in Lean maturity. This reasoning applies to any transfer outside of the “optimal” ones expressed by the circles. The process required in order for any individual sector to benefit from complex knowledge transfer of Lean best practices in the near future would call for further considerable economic and research-related efforts.

5.2 Further Studies

The study has confirmed the need for further research on:

1. Validation of the proposed model for cross-industry knowledge transfer of Lean best practices with firms. A survey approach would guarantee the sufficient statistical sample (Lavrakas 2008; Wiedenfels 2009) to be able to draw some quantitative considerations on the achieved level of refinement and potential acceptance;
2. Implementation of proposed optimal cross-industry knowledge transfer of Lean best practices;
3. Investigation on feasibility of complex knowledge transfer outside of the circles and study of possible alternatives to allow the reaching of maximum Lean maturity;
4. Reweighting of proposed model and implementation strategy from a global perspective;
5. Reweighting of proposed model and implementation strategy from a different local perspective presenting systemic cultural and political differences from Australia;
6. Definition and evaluation of Lean-culture and productivity-related KPIs, such as effectiveness of knowledge transfer (Zhao 2011) and attained productivity increase versus Lean maturity, to allow evaluation of actual achieved results.

All of the listed points listed strongly support the idea that cross-industry transfer of Lean knowledge is a topic in great evolution with wide opportunities of research.

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Appendix

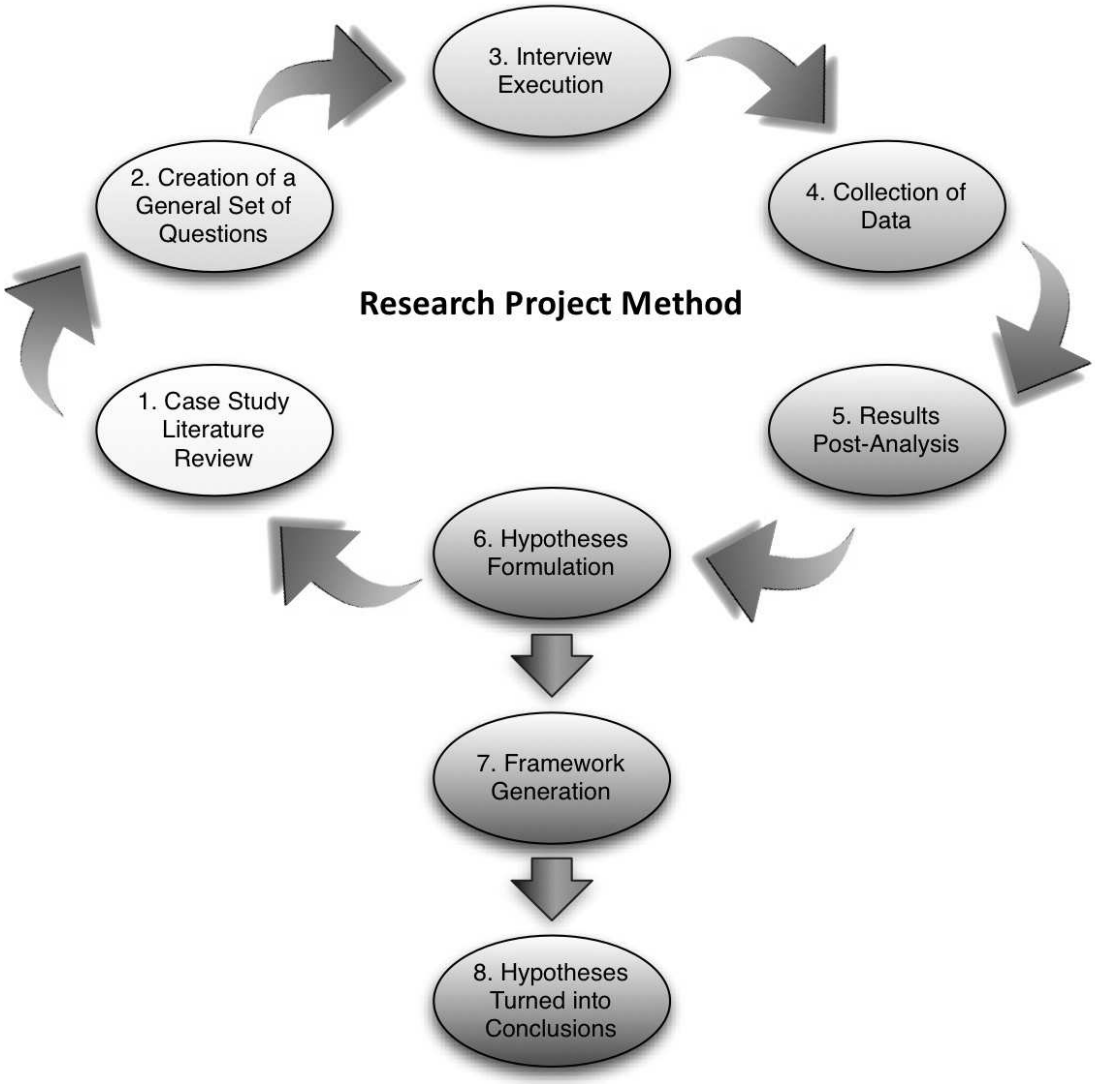

Figure 1: Research Method Framework

Recommended Lean Best Practice Scenario

Analysed Sectors		Reviewed Lean Best Practices: 1 Lean as a "Core Strategy"	2 Direct Knowledge Transfer from Automotive	3 "Ideal" One-Piece Flow	4 Lean Enterprise Approach	5 Pacing/Synchronisation of Development Teams	6 Customer Involvement	7 Optimised Flow of Information	8 Focus on Performance Outputs	9 Maintenance as Key to Functionality	10 Holistic Approach Towards Change	11 Lean Design/Engineering	12 Lean Project Delivery System	13 Projects as "Temporary Production Systems"	14 Visual Tools Support	15 Introductory Workshops to Lean	16 Use of the Client's Lean Tools	17 Lessons Learnt/Embedment of Lean	18 Simple Lean in SMEs	19 Value Chain Analysis	20 Standardization of the Supply Chain	21 Kaizen in Product Quality/Reliability/Mantainability	22 Lean Requirements Management	23 Lean Service	24 Cross-Functional Improvement Teams	25 Confort/Confidence in Self-Managed Teams	26 Predisposition Towards Lean Culture
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Automotive		✓		↗	✓	↗	↗	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	↗	✓	✓	✓	↗	↗	✓	✓	✓
Aerospace		✓★	✓★	✓★	✓★	↗		↗	↗		✓	↗		✓	✓	✓	✓	✓		✓	↗	✓	↗		✓	↗	✓
Software Development					✓	✓★	✓★	✓★	✓			✓	✓	✓	✓	↗		↗				✓	✓	↗	✓	✓	↗
FMCG		↗	✓	✓	↗			↗	✓★	✓★	✓★				✓	✓		↗		✓	↗	↗					✓
Construction						↗	↗	↗	↗		↗	✓★	✓★	✓★	✓★	✓	✓	↗	↗						↗	↗	↗
Mining	Projects							↗	↗				↗	↗	✓	✓★	✓★	✓★								↗	↗
	Operations			ⓘ	ⓘ			ⓘ	ⓘ	ⓘ	ⓘ				ⓘ	ⓘ		ⓘ		ⓘ	ⓘ				ⓘ	ⓘ	ⓘ
Food Supply Chain					↗		↗		↗		↗				✓	✓			✓★	✓★	↗	↗					↗
Military								↗**	↗	✓		↗			✓	↗					✓★	✓★	✓★		↗	↗	↗
Services		↗*		↗			✓	✓	✓						✓	✓			↗	✓	✓	✓		✓★			↗
Transition to Lean																									✓★	✓★	✓★

✓★	Best practice examined in the relevant section of the research
✓	Best practice confirmed by the research
ⓘ	Needs further investigation (see shortcomings)
↗	Recommended implementation via best practice knowledge transfer
*	Excluding applications with specific constraints (e.g. Emergency Rooms in Healthcare - see Lean Service section)
**	Excluding classified data
	Not implemented / Not applicable
	According to the authors' experience in the field
	Transversal section used as a benchmark to evaluate lean transition (see "The Overall Transition to Lean" section)
	To be reviewed in further studies

Table 3: Lean Best Practice Table

Table 4: Lean Best Practice Chart

Current Scenario		
Sectors		
1	Automotive	19
2	Aerospace	14
3	Software Development	13
4	FMCG	9
4	Services	9
6	Construction	6
7	Military	5
8	Food Supply Chain	4
8	Mining Projects	4
Best Practices		
1	Visual Tools Support	9
2	Introductory Workshops to Lean	7
3	Kaizen in Product Quality/Reliability/Mantainability	5
2	Value Chain Analysis	5
5	Focus on Performance Outputs	4
5	Projects as "Temporary Production Systems"	4
5	Use of the Client's Lean Tools	4
8	Cross-Functional Improvement Teams	3
8	Holistic Approach Towards Change	3
10	Lean Design/Engineering	3
10	Lean Enterprise Approach	3
10	Lean Project Delivery System	3
10	Lessons Learnt/Embedment of Lean	3
10	Maintenance as Key to Functionality	3
10	Optimised Flow of Information	3
10	Predispostion Towards Lean Culture	3
10	Standardization of the Supply Chain	3
18	"Ideal" One-Piece Flow	2
18	Confort/Confidence in Self-Managed Teams	2
18	Customer Involvement	2
18	Direct Knowledge Transfer from Automotive	2
18	Lean as a "Core Strategy"	2
18	Lean Requirements Management	2
24	Lean Service	1
24	Pacing/Synchronisation of Development Teams	1
24	Simple Lean in SMEs	1

Recommended Improvements		
Sectors		
1	Construction	10
2	Aerospace	7
2	Food Supply Chain	7
2	Military	7
5	Automotive	6
5	FMCG	6
5	Mining Projects	6
8	Services	4
8	Software Development	4
Best Practices		
1	Predispostion Towards Lean Culture	6
2	Focus on Performance Outputs	5
2	Optimised Flow of Information	5
4	Confort/Confidence in Self-Managed Teams	4
5	Customer Involvement	3
5	Lessons Learnt/Embedment of Lean	3
5	Pacing/Synchronisation of Development Teams	3
5	Simple Lean in SMEs	3
5	Standardization of the Supply Chain	3
10	"Ideal" One-Piece Flow	2
10	Cross-Functional Improvement Teams	2
10	Holistic Approach Towards Change	2
10	Introductory Workshops to Lean	2
10	Kaizen in Product Quality/Reliability/Mantainability	2
10	Lean as a "Core Strategy"	2
10	Lean Design/Engineering	2
10	Lean Enterprise Approach	2
10	Lean Requirements Management	2
10	Lean Service	2
20	Lean Project Delivery System	1
21	Projects as "Temporary Production Systems"	1
22	Direct Knowledge Transfer from Automotive	0
22	Maintenance as Key to Functionality	0
22	Use of the Client's Lean Tools	0
22	Value Chain Analysis	0
22	Visual Tools Support	0

Recommended Scenario		
Sectors		
1	Automotive	25
2	Aerospace	21
3	Software Development	17
4	Construction	16
5	FMCG	15
6	Services	13
7	Military	12
8	Food Supply Chain	11
9	Mining Projects	10
Best Practices		
1	Focus on Performance Outputs	9
1	Introductory Workshops to Lean	9
1	Predispostion Towards Lean Culture	9
1	Visual Tools Support	9
5	Optimised Flow of Information	8
6	Kaizen in Product Quality/Reliability/Mantainability	7
7	Confort/Confidence in Self-Managed Teams	6
7	Lessons Learnt/Embedment of Lean	6
7	Standardization of the Supply Chain	6
10	Cross-Functional Improvement Teams	5
10	Customer Involvement	5
10	Holistic Approach Towards Change	5
10	Lean Design/Engineering	5
10	Lean Enterprise Approach	5
10	Projects as "Temporary Production Systems"	5
10	Value Chain Analysis	5
17	"Ideal" One-Piece Flow	4
17	Lean as a "Core Strategy"	4
17	Lean Project Delivery System	4
17	Lean Requirements Management	4
17	Pacing/Synchronisation of Development Teams	4
17	Simple Lean in SMEs	4
17	Use of the Client's Lean Tools	4
24	Lean Service	3
24	Maintenance as Key to Functionality	3
26	Direct Knowledge Transfer from Automotive	2



Figure 2: Current vs. Recommended Lean Best Practice Scenario – By Sector

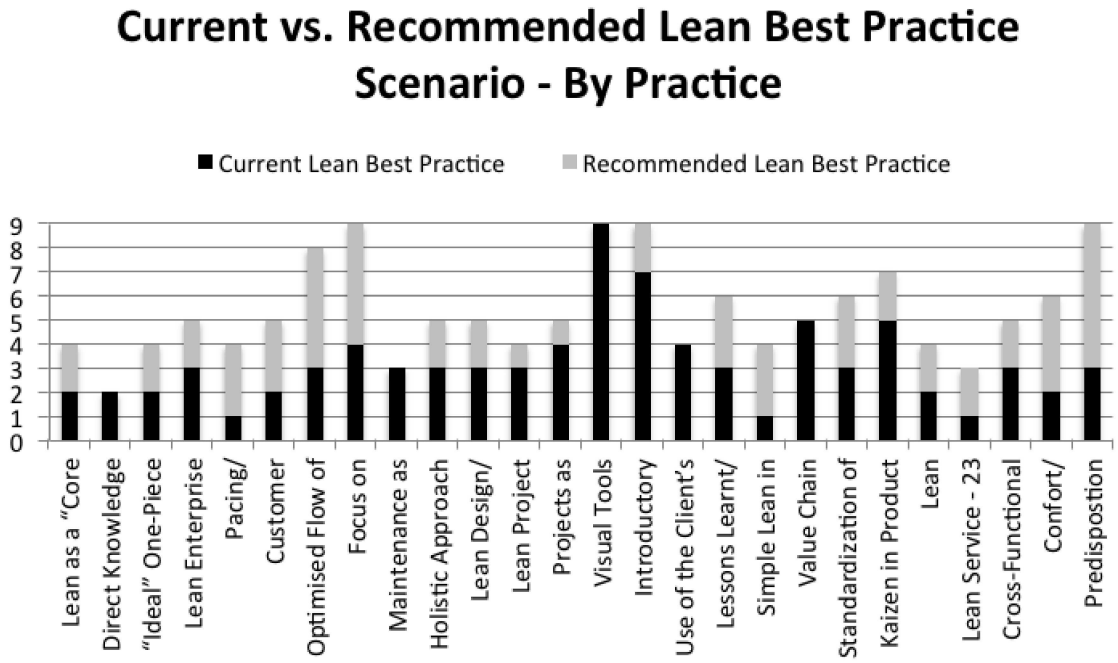

Figure 3: Current vs. Recommended Lean Best Practice Scenario – By Practice

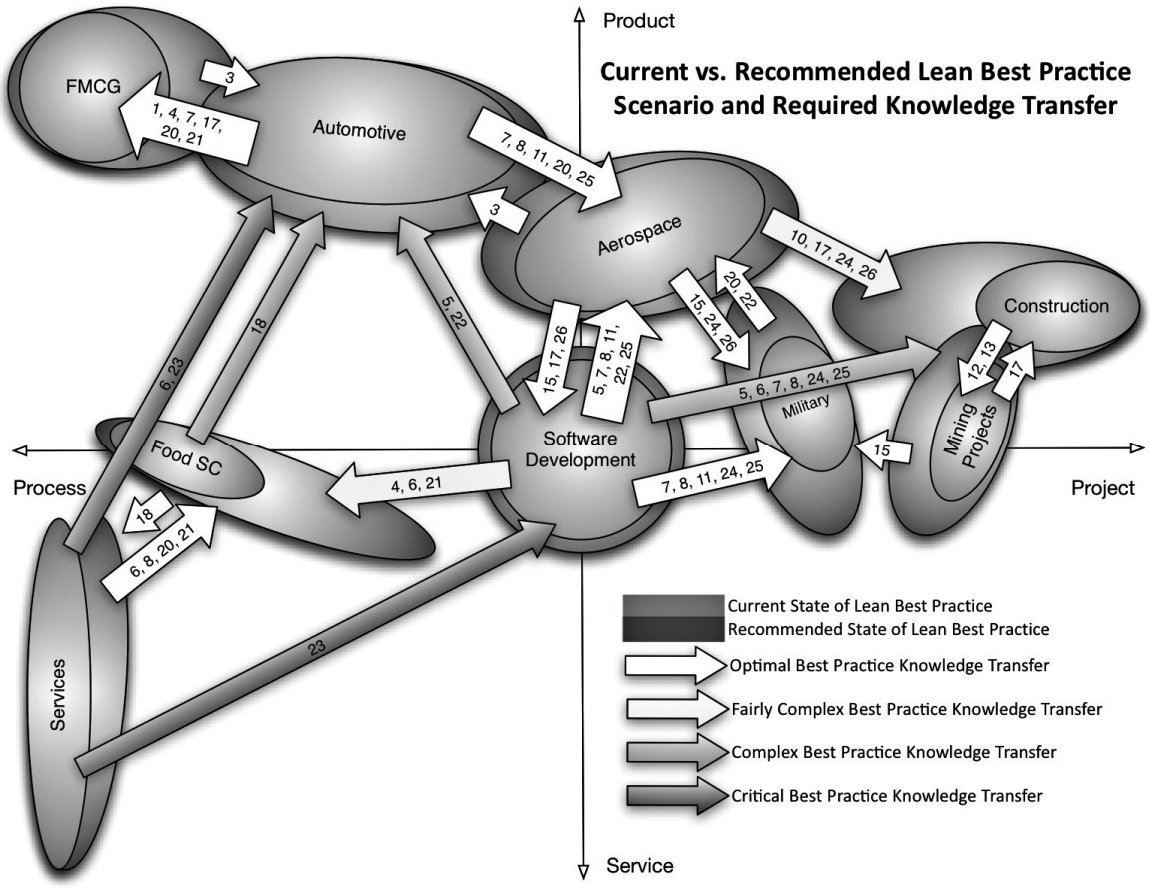

Figure 4: Lean Best Practice Map / Knowledge Transfer Map

Towards User-Oriented Suburb Renovation

Anu Soikkeli[1], Jouni Koiso-Kanttila[2]

Suburb renovation concept

A Finnish national research project, *User- and Business-oriented Suburb Renovation Concept*, was started in 2012. Energy efficiency is emphasised in the project, but it also addresses what improving the energy efficiency of suburban apartment buildings means from the standpoint of architecturally valuable and conservable buildings. Thus, the project will also test the impact that stricter energy efficiency requirements—effective in Finland in 2013—will have on renovation.

The primary goal is to develop a user-oriented, industrial, overall-economical renovation concept for suburban apartment building renovation as well as construction of additional storeys. The concept will make it possible to change from cost-based operation to a new type of service- and user-oriented business where renovation solutions can be site-specifically and all-inclusively tailored within the framework of a novel operating model that integrates suppliers and implement solutions by means of networked business operation.

The project's user-orientation refers to both interactive planning that includes the residents in the planning process and construction that allow the residents to live in their apartments during the renovation. Repairs to the shells of buildings are done with large prefab elements which are fastened to the frame of the building from the outside. In like manner, balconies, new lift shafts and additional storeys made of box like module elements are prefabricated and installed quickly and with as little disturbance as possible. A model book will be created together with partner companies in connection with the first realised pilot projects. The book will help housing companies start renovation projects by providing them with tools for ideating and planning participative, user-oriented renovations.

To make it possible to realise suburban renovations more comprehensively than house by house, the project will also collaborate with the Ministry of the Environment and participating cities in developing a new type of less complex town planning model for suburban renovations and in-fill construction.

Keywords: user-oriented, renovation concept, prefabrication, town planning

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1. Background

Construction in the near future will focus on suburb renovation and in-fill construction, which will face a demanding challenge due to the objective of improving energy efficiency. The concrete-frame apartment buildings constructed in Finland in the 1960s and 1970s are approaching the age when they require renovation. These buildings contain altogether about 570,000 apartments. (Lukkarinen et al. 2011, 42) Approximately 13,500 apartment buildings and 288,000 apartments will be in need of repair in 2016–2025. The cost of renovating these apartment buildings over this 10-year period is estimated to be €7.8 billion. (Lehtinen et al. 2005)

These suburban apartment buildings require exhaustive technical repairs both inside and out. For example, problems related to the quality of the concrete and the reinforcements of the sandwich elements used and the durability of the elements' trusses and fasteners, moisture damage and poor thermal economy are the most common reasons behind façade renovations. These suburban buildings also need roof, window and balcony repairs or renewal. Possible addition of balconies would also increase living comfort and pleasantness.

Research has been made about this kind of renovations. Research project Rebo in Norway dealt with comprehensive upgrading of 1960-70´s suburb apartment buildings. The aim of the project was to show how post war residential environments can be improved in general, with focus on energy efficiency, design for all and accessibility and residents´ participation in the planning process. Two typical multi-story concrete blocks of flats were renovated. It was demonstrated that economically profitable upgrades according Passive House concept are possible, when the building is in poor condition and a major renovation must be undertaken. Additionally, indoor climate and comfort of the residents were improved. (Buvik et al. 2011)

In Finland these types of renovation projects are excessively laborious and difficult for building managers, housing associations and residents alike. It is hard to find operators who are capable of or willing to take on suburban apartment building renovations, and it is often necessary to search for and hire several contractors for a project. It is very difficult to integrate their work. In practice, renovations are slow, expensive, dirty and disruptive.





Figures 1 and 2: A significant number of suburbs were constructed in Finland in the 1960s and 1970s in which multi-storey apartment buildings constructed of prefabricated concrete elements are the dominant building type.

Early inclusion of all parties involved in the renovation project and the feeling of actually being able to have an influence is the best starting point for getting renovation decisions passed in housing companies' decision-making bodies. Factors of choice and motivation related to buildings and renovation have been studied as they apply to both private and professional owners. (Brohmann et al. 2009, 4) Important in professional operation are management of economic processes and long-term owner policy, i.e. technical and economic rationality. Private individuals are motivated in matters centrally related to their own well-being, such as experienced comfort.

1.1 Social, economic and cultural durability

Reinforcement of social, economic and cultural durability and renovations that support sustainable development are the main cornerstones of suburb development. The principles of sustainable development are naturally connected to environmental challenges, such as slowing down climate change, but also to safeguarding the vitality of each living area. This way, e.g. new and in-fill construction can be used in suburbs to boost area populations, thereby ensuring that services remain and improving the prerequisites for public transport. (Lindgren 2008, 12)

New construction's impact on improving the energy efficiency of the building stock is a slow process. Therefore, it is very important to improve the energy efficiency of existing buildings. Suburbs are currently the least energy-efficient segment of Finland's building stock. The residential apartment buildings built in the 1960s and 1970s are most problematic—they are poorly insulated and they are the most numerous. The most effective measures for improving the energy economy of a residential building are adding insulation to the exterior of the ceiling and outer walls and making them more airtight, renewing the windows, balcony doors and exterior doors to meet the requirements of the near future, renewing heat production systems and constructing an intake and exhaust air ventilation system with heat recovery units in each apartment. (Uotila & Lahdensivu 2012, 85-88)

Most older people live and want to live in their own home. The need for services and an accessible residential environment are decisive factors associated with older people's coping at home. Buildings without lifts are a major problem in Finland's building stock. In 2005 there were 370,000 apartments in three-storey buildings without a lift. Near half a million people lived in these buildings—71,000 of them were at least 65 years old and needed a lift. (Pekka, Pelvas & Peltonen 2008, 74-78)

1.2 Wood material in renovation

The market outlook for renovating suburban apartment buildings changed significantly in Finland in April 2011 when a new fire code became effective. The new regulations allow construction of additional lightweight timber-framed storeys atop residential apartment buildings and renovation and additional insulation of the outer walls of buildings using lightweight timber-framed elements. (E1, RakMK) The reasons for the change are the desire to slow down urban sprawl and the need to preserve suburban populations in order to safeguard their services and thereby their attractiveness.

2. Objectives of the project

The EU's construction directive requires new buildings and renovations of existing buildings to be energy-efficient. Accordingly, in its national climate strategy the Finnish government has set a goal of decreasing the amount of greenhouse emissions produced by buildings. The Ministry of the Environment has prepared new construction regulations according to which also the energy efficiency of buildings must be improved in connection with their basic renovation.

The objective of this project—launched in 2012—is to develop a user-oriented, industrial, overall-economical and efficient renovation concept for suburban apartment building renovation and expansion. All renovation measures must improve not only living comfort, but also the energy efficiency of buildings. The parties to the project are the University of Oulu's Departments of Architecture and Industrial Engineering and Management, Aalto University's Department of Architecture, Tampere University of Technology's Department of Construction Engineering and the Technical Research Centre of Finland. Participating companies in the construction sector include StoraEnso, Isover Saint Gobain and construction companies. Other partners include cities like Joensuu, Kouvola, Porvoo and Turku, real estate representatives, the Ministry of the Environment and the Finnish Real Estate Federation.

Residential apartment buildings are renovated in Finland using the methods of new construction; industrial service concepts for renovation have not been developed yet in this sector. It is not possible to face the growing renovation debt of Finland's suburbs or the near-future requirement to improve the energy efficiency of the existing building stock without enhanced construction methods brought about by industrial construction. However, the individual needs of suburban buildings are so varied in terms of technical solutions and architectural and environmental constraints that it is not possible to develop a universally applicable renovation solution for suburban buildings.

The concept will make it possible to change from cost-based operation to a new type of service- and user-oriented business where renovation solutions can be site-specifically and all-inclusively tailored within the framework of a novel operating model that integrates suppliers and implement solutions by means of networked business operation.

Important from the standpoint of housing companies is the cost structure of the renovation project, as not many housing companies have reserved funds for renovation purposes. For this reason constructing an additional storey(s) may be a decisive opportunity for funding necessary façade and balcony renovation or building a lift, for example.

2.1 All-inclusive

Because no one in the construction field in Finland has the capability to naturally operate all-inclusively—in the same turnkey manner as single-family home deliveries are made—the goal of the project is to build a business-oriented operator network. Since the goal is overall development, attention should be paid to both customer satisfaction and the delivery chains of organisations and their management. With standardised operating methods manageability

will reduce costs, improve quality and decrease dispersion. The operating model will require companies to adopt new kinds of operating processes; the prerequisites for this will be created in the project by modelling value chains and developing networked business models. (Malvalehto et.al 2011)

The project's user-orientation refers to both interactive planning that includes the residents in the planning process and construction that allow the residents to live in their apartments during the renovation. That means speedy, non-disruptive construction work, which is not possible with the renovation methods that are currently employed.

2.2 Users in focus and a model book

For building managers and housing companies, user-orientation in the project means that the project's implementation planning, cost estimation and realisation are reliably available from one source and they are based on a project description compiled and agreed on together in advance. The concept will benefit residents and housing companies by allowing users to participate in renovation ideation and planning from the beginning of the process.




Figure 3 and 4: In Riihimäki the possibility of raising the four-storey buildings to cover the renovation cost and to improve the milieu has been examined. Present situation at the left. (Tomi Tulamo's master thesis, Aalto University 2010)

The objective in this research project is to compile a model book in collaboration with partner companies which will help housing companies start renovation projects by providing them with tools for user-oriented ideating and planning. The purpose of the model book is to present different types of all-inclusive solutions for block in-fill construction and construction of additional storeys atop suburban apartment building using box like module elements; energy-efficient renovation of the outer shell of buildings—particularly exterior walls—and façade renewal using various materials; construction of balcony systems and installation of lifts. The goal of the all-inclusive concept is, if necessary, install also apartment-specific ventilation systems as part of the new façade. To this can be added tools that serve energy and real estate management as well as apartments' indoor environments and methods for verifying performance (instrumentation, monitoring). The current state of buildings and the success of renovations should be verified with *in-situ* measurements.

2.3 Suburb in-fill construction

Suburb in-fill construction is justified from the standpoint of integrating and compacting the urban structure. This has a favourable effect on the environmental impact of communities and promotes preservation of suburbs' dwindling services, which is in the interests of area residents. From the perspective of housing companies, supplementary construction may be one way to finance necessary renovations, although this operating model requires revision of current town planning practices to make supplementary and in-fill construction flexible in practice.

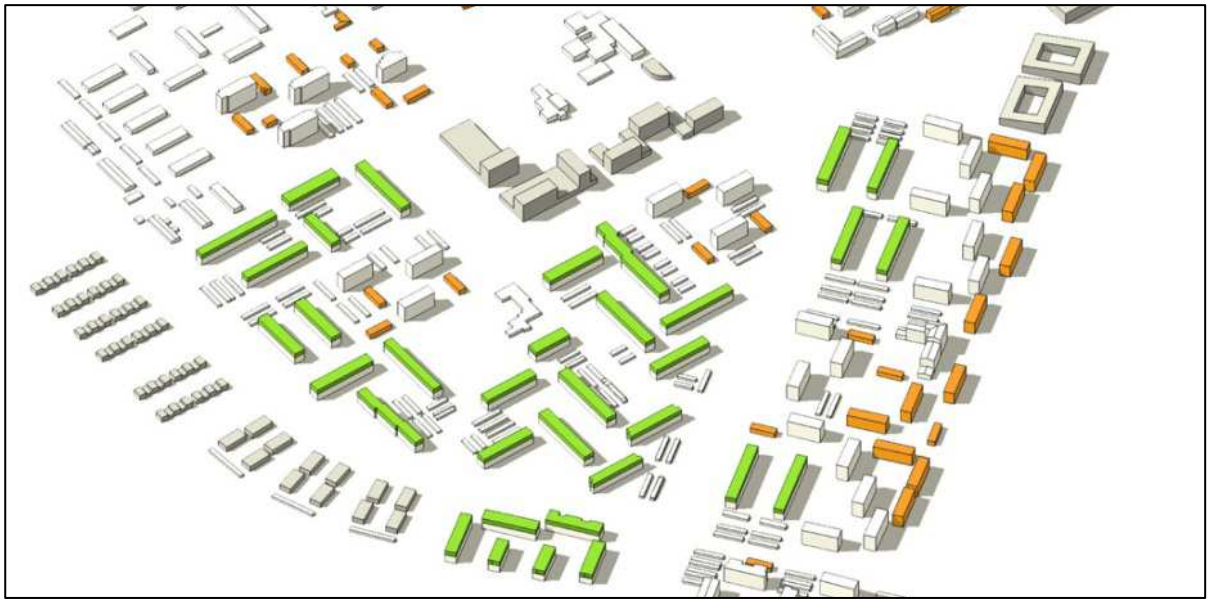


Figure 5: New buildings, in-fill construction within the block structure and additional stories to existing buildings in Kaukovainio suburb, Oulu. (Jaana Keränen's master thesis, University of Oulu 2011)

To make it possible to realise suburban renovations more comprehensively than house by house, the project will collaborate with the Ministry of the Environment and participating cities. An objective of the project is to develop a less complex town planning model for suburb renovation and in-fill construction in collaboration with cities, and simultaneously develop practices for environmental impact assessment tools to support and justify suburb in-fill and supplementary construction. It is also necessary to review parking place requirements from the viewpoint of areal services offered.

3. Content and the results of the study

3.1 Renovation of the facades

Energy efficiency is emphasised in the project, but it also addresses what improving the energy efficiency of suburban apartment buildings means from the standpoint of architecturally valuable and conservable buildings. Thus, the project will also test the impact that Finland's new and stricter energy efficiency requirements will have on renovation.

It is customary to improve the thermal insulation of the facades in connection with apartment building renovations in Finland. Ordinarily this is done by applying a coat of plaster on top of an additional layer of insulation or alternatively by removing the existing facade material, and usually also the most often damaged layer of insulation, and constructing new, better-insulated facades. (Heljo & Vilhola 2012, 33-34; Peuhkuri et al. 2012, 54, 65, 86)

Done in this manner, the work is expensive and slow and it disturbs the residents. For this reason new facade element systems have been designed for renovations in Finland and other European countries. A TES system based on large, lightweight stick-frame elements has been designed for facade renovations. The elements are fastened to the inner shell of a building's concrete exterior wall elements, and due to their lightness they may be several storeys high. (Heikkinen et al. 2009, 101) This type of system has already been used in two apartment building renovations in Finland—the INNOVA project in Riihimäki (Lahti et.al 2011) and Kummatti in Raahe (Hagan 2010).

Large, lightweight stick-frame elements offer a promising renovation solution, so in this study we have concentrated on developing this solution to make it widely usable in renovations. The challenge with exterior wall elements is the airtightness and load-bearing capacity of the exterior wall, especially in cases where the existing building lacks a load-bearing inner shell or the façades consist of horizontal band elements. The frames of elements also require special strength analysis if the façade facing is very heavy, e.g. brick slabs or planks.

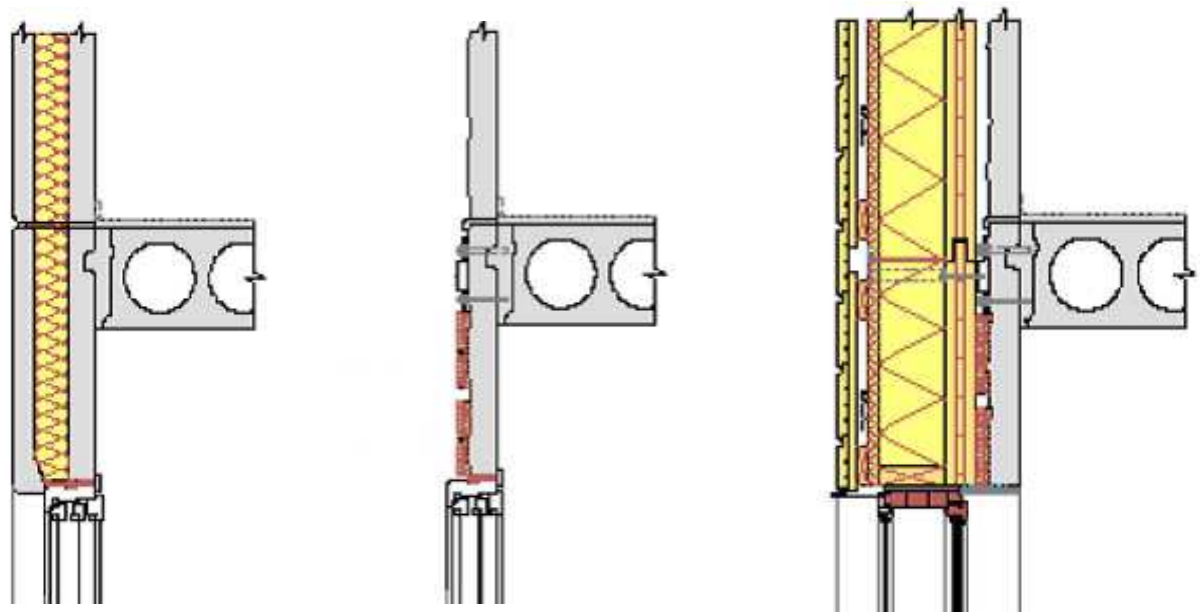


Figure 6: Energy efficient renovation of a typical apartment building made in 1970's. Left the original sandwich façade, external layers removed and on the right the new prefabricated CLT supported timber panels are fitted.

In this study we have designed renovation elements whose inner shell is made of self-supporting cross-laminated timber (CLT) panels. The CLT panels function as a load-bearing, stiffening layer in the element, but they also make the element airtight. And because of the

excellent load-bearing capacity of the CLT panel, the facade facing can be made from practically any material. This is important because the renovation concept for suburb renovations must be such that building renovations completed within its framework can be done using various façade facing materials so that the architecture of the building is preserved in the renovation, but also so that alternatively the architecture and appearance of the building can be changed completely, if so desired.

3.2 Module elements

Constructing additional storeys is an attractive alternative in connection with apartment building renovations, and this is often done in Finland, especially in areas close to city centres. In practice, though, construction has been difficult and costly, and for this reason in this study we are developing ways to utilise industrial prefabrication in construction.

The frames of suburban apartment buildings built in the 1960s to 1980s will easily carry the construction of lightweight additional storeys allowed by the new fire code of Finland. To minimise disturbance inflicted on the residents, it is sensible to construct them from box like module elements. However, designing and constructing module elements is challenging because the top ceiling slab usually cannot be loaded, whereupon loading has to be aligned with load-bearing walls below the slab, which may be few in number. On the other hand, to increase floor area it may be desirable to make the top storey larger than those below it. Special attention also needs to be paid to existing ducts and ventilation pipes that pass through the roof.

In this study we have examined the designs and dimensions of the load-bearing frames of typical suburban apartment buildings constructed in the second half of the 1900s and we have tested how additional storeys made of module elements can be constructed atop the frames. To avoid having the layout of the rooms in the additional storeys dictated by the layout of the rooms in the storeys below, we decided it is practical to make the module elements self-supporting. A modular element system with a load-bearing frame (walls, ceiling and floor) made of CLT panels has been designed in collaboration with StoraEnso.



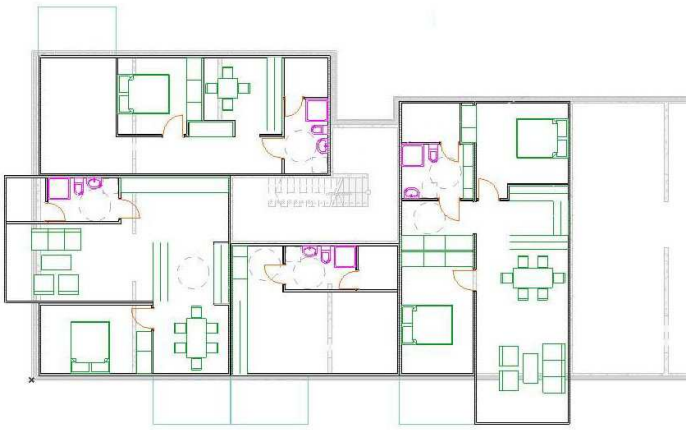


Figure 7 and 8: Left, fabrication of CLT module elements. Right, a plan for an additional storey made of prefabricated module elements.

Since the module elements are self-supporting, they can be installed so that the load-bearing walls of the elements either coincide with the load-bearing walls below or are perpendicular to them. This solution provides much freedom in designing additional storeys. The self-supporting structure also makes it possible to extend the new, additional storey far beyond the outer walls of the storeys below if so dictated by the room layout or contemporary architecture. Module elements can be quite large, but due to Finland's road transport regulations, it is recommendable to limit element width to 4.5 metres and length to 13 metres.

As the concept calls for speedy construction, also lift shafts need to be installable as large self-supporting elements, for example using Kone Oy´s lift technology which doesn´t require a separate machine room. The designs have been developed in collaboration with StoraEnso in such a way that the load-bearing frames of lift shafts also utilise CLT elements.

3.3 Pilot projects

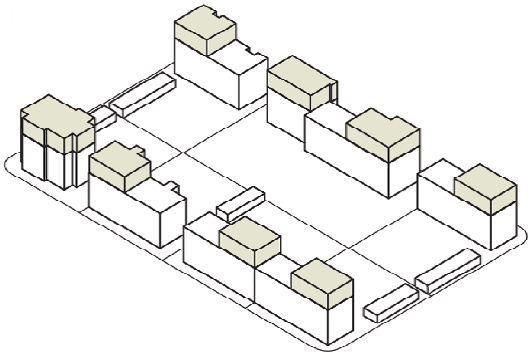
The results of the study will be tested in actual suburban apartment building renovations. The first pilot project is a block at Kirkkokatu 18 in Joensuu. The facades of two existing four-storey buildings on the block will be renewed using prefab brick-tile-faced self-supporting elements whose energy efficiency meets the requirements for new construction. At the same time new prefab balconies will be installed. As part of the renovation plan, we devised a way to construct the additional floors of the building being renovated and a new building in the courtyard by utilising module elements.

The project aims to demonstrate differences in the situations before and after renovations in building energy consumption, thermal conditions, ventilation and indoor air quality, performance of building structures as well as to collect feedback of the residents.

3.4 In-fill and additional constructing in suburbs

The building stock of Finnish cities is for the most part located in suburbs, and in international comparison Finnish suburbs are very sparsely and inefficiently built. Indeed, the Ministry of the Environment has set a goal of densifying the structure of Finnish cities, and at the same time make suburban land use more efficient. The target sites for town plan analysis have been chosen together with the cities: two suburbs in Turku, two in Porvoo, two in Kouvola and one in Joensuu. The areas differ greatly in size and nature, so they form an excellent series in which they complement each other. Assessment of the environmental impact of the sites has begun and the re-planning work of each area is on-going.

In these suburbs there is a need to both densify the sparse structure of these areas by erecting new residential buildings to fill in existing blocks and construct additional stories atop existing residential apartment buildings in connection with their renovation. In many cases it is practical to apply both solutions on the same block, as indicated by an assessment of areas near the centre of city of Joensuu.



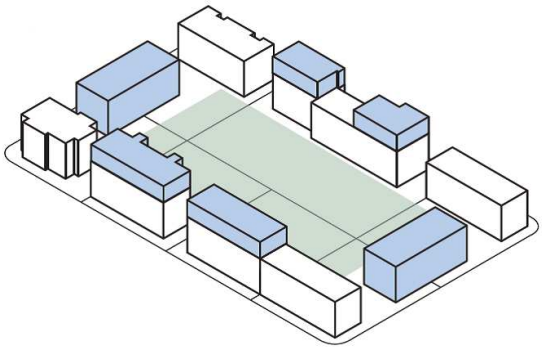


Figure 9 and 10: Additional stories and in-fill construction studied in Joensuu by the architects Anttila and Rusanen.

In this study we will examine whether the town planning procedure currently used in Finland is suitable for steering this type of supplementary and in-fill construction. The town planning procedure is laborious, and on the other hand supplementary and in-fill construction in existing suburbs will take place over quite a long time. So, the project will develop—in collaboration with the participating cities—less complex town planning models for suburb renovation and in-fill construction. At the same time it will develop practices for environmental impact assessment tools. These less complex town planning models could be e.g. an areal exceptional permit process with construction method guidelines or a general area plan with loose specification of permitted building volumes, in which case exact construction methods and building volumes would be specified for each block in the building permit phase. Cities will benefit from the results of the development by getting better methods for compacting the urban structure.

4. Final comments and conclusion

Suburb renovation in Finland is becoming an increasingly large and difficult problem to resolve. Suburbs are deteriorating, new energy efficiency requirements also require energy efficiency from renovated buildings and the largely manual work involved in renovation is slow and costly.

Because suburban apartment buildings require exhaustive technical renovation both inside and out, the motivation and needs of apartment owners are an essential part of the renovation process and the development of a new renovation concept. Residents' choices are limited by their financial capacity, but improvement of their own comfort is most important. Even in energy renovations—which in principle are within the sphere of technical and economic rationality—the primary criterion for making a decision is comfort (e.g. a draught-free apartment is more important than energy or monetary savings). This requires various all-inclusive solutions that are correctly focused also from the end user's (resident's) perspective, where not only are the need for technical repairs resolved and the level of

technology updated, but the residents are offered noticeably better comfort which can be seen and experienced as more pleasant apartments and environment.

The project is developing a user-oriented, industrial renovation concept for energy-efficient renovation and expansion of suburban apartment buildings as well as construction of additional storeys and lift shafts using self-supporting module elements. These solutions will not be developed specifically for certain companies; the development work will be done with government research funding and the solutions are meant to be widely utilised in suburb renovation and development. This will directly benefit residents, housing companies and real estate owners by enabling speedier, neater and cheaper renovations. The concept will also offer housing companies the possibility to upgrade buildings and thereby increase their value and attractiveness.

To manage renovation costs, the development work will concentrate especially on wintertime construction, which would allow house factories to use their underutilised autumn and winter capacity. However, this places challenges on job site conditions, especially moisture control, which needs to be addressed in the study.

The project will promote suburb supplementary and in-fill construction which will help reinforce the areas' population base, thereby ensuring that services are preserved, which is in the interests of the residents and the suburbs. That will also be an effective tool to retard the sprawl of cities.

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Ensuring the New Zealand Building Stock is Moisture Tolerant

Greg Overton[1], Mark Bassett, Steve McNeil

Abstract

BRANZ's Weathertightness, Air quality and Ventilation Engineering (WAVE) programme aims to develop solutions to moisture related problems that currently plague New Zealand homes such as leaky buildings and indoor mould.

WAVE comprises four work streams: weathertightness; ventilation; interstitial moisture; and indoor air quality technology. The research aims to pull these four areas together to develop a unified model of moisture and other contaminants in buildings.

This paper provides an overview of the programme and describes some selected highlights:

- **Airtightness and Ventilation of NZ homes**

  A survey of airtightness of NZ homes showed that new buildings are built more airtight than ever before, despite no code requirement to do so. Although this is likely to reduce homeowner's energy bills, it may inadvertently cause an indoor moisture problem unless supplemental ventilation is provided.

- **WALLDRY-NZ – An educational tool for cavity design**

  Water leakage rates through various claddings were measured and incorporated into an educational tool, WALLDRY-NZ. This tool was used to educate building professionals about the impact on wetting and drying potentials arising from design choices in the range of NZ climates.

A successful WAVE programme will provide a performance basis for weathertight design - removing some of the guesswork from current practice and ensuring a dry and safe future for the New Zealand building stock.

Keywords: Weathertightness, Ventilation, Education

1. Introduction

The WAVE (Weathertightness, Air Quality and Ventilation Engineering) programme is a 6-year programme that began in October 2009. The work is jointly funded by the Building Research Levy and the Ministry of Business and Innovation

WAVE is developing practical solutions to problems that currently plague New Zealand homes such as leaky buildings and indoor mould. The programme also aims to help avoid future issues resulting from changes to materials, designs and construction methods.

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Ultimately, the long term goal is for New Zealand to have homes that manage moisture properly and provide safe indoor environments.

In short, this programme recognises that the performance of the building envelope is linked to the environment within the building and aims to form a complete model of how buildings manage contaminants (including moisture). This would allow designers and builders to assess the impact of any features they want to implement.

The WAVE programme is split into four complementary work streams:

- Weathertightness
- Ventilation
- Interstitial moisture
- Indoor air quality

This paper focuses on highlights from the weathertightness and ventilation work streams: a survey of ventilation in NZ homes; and the development of an educational tool for building surveyors.

2. Airtightness and Ventilation of NZ homes

2.1 Introduction

Previous work, for houses built up until 1994 [1, 2, 3], shows the airtightness of new homes has increased over time even though there is no requirement for airtightness in the NZ building code. This study aimed to see if that trend was continuing and to investigate the relationship between airtightness and in-service levels of ventilation.

The airtightness of 36 houses built since 1995 and across four cities in New Zealand (NZ) was measured using a standard blower door test. In a subset of 31 of these homes, the average ventilation rate was measured over several weeks in the winter using a perfluorocarbon tracer technique (PFT) [4, 5]. The results provide a baseline for discussions about adequate ventilation provisions in NZ homes and will be used in an experimental facility at BRANZ to determine alternative cost-effective ventilation techniques.

2.1.1 Airtightness of NZ homes

The average airtightness result (at 50 Pa) from houses built before WWII was around 19 ach (air changes per hour) but this reduced dramatically to 8.5 ach for houses built between 1960 and 1980. A significant contributor to envelope air-tightening around 1960 was the shift from suspended tongue and groove flooring to sheet floor construction and slab-on-ground floors. Another change at a similar time was the shift from timber joinery to aluminium framed doors and windows, as well as a reduction of open fireplaces.

Newer construction practices are likely to have continued to influence the airtightness of houses. Recent examples of changes are the widespread use of bonded plaster cornices or a square stopped interior plaster finish, and the adoption of air seals around window and door assemblies to control rain penetration. [6]

2.1.2 Ventilation in NZ homes

In New Zealand, occupants are expected to open windows for ventilation and the NZ Building Code offers an acceptable solution 'G4 Ventilation' [7] requiring window and door openings to be at least 5% of the floor area. It is clear from the airtightness measurements of older houses that window opening may have been unnecessary to meet ventilation needs because the background infiltration was high. In newer houses, the changes in construction discussed above have closed down many infiltration paths and it may be necessary to actually open the windows to provide adequate fresh air.

2.2 Experimental Method

The airtightness and ventilation survey was split across 4 different cities in New Zealand: Wellington; Palmerston North; Dunedin; and Auckland. A database of building consents was used to obtain a random sample of consents for houses built after 1994 and these homeowners were contacted via a letter, resulting in a final total of 36 houses.

Of these 36 houses, 8 had supply-only positive pressure ventilation systems installed in the roof space. These systems distribute filtered roofspace air throughout the home depending on temperature measurements in the living space and roofspace.

2.2.1 Airtightness measurements

A blower door test to EN13829[8]was completed on each of the 36 houses .

The airtightness measurements were also used to give an estimate of the infiltration through the envelope using Equation 1.

$$Estimated\ Infiltration\ Rate = \frac{ach@50Pa}{20} \qquad \text{(Equation 1)}$$

2.2.2 Ventilation Measurements

Ventilation measurements were performed in 31 of the 36 houses during winter. Winter was chosen because it was assumed that ventilation would be at its lowest i.e. windows are open less often.

A Perfluorocarbon Tracer (PFT) technique [4, 5] was used and the equipment and analysis were supplied by the UK's Building Research Establishment (BRE). The technique involved deploying passive tracer gas sources and activated carbon sampling tubes in a building for several weeks. The resultant concentration of tracer in the sampling tubes was then used to calculate an average ventilation rate.

The tracer sources were distributed around the home in a volume weighted manner, with the bathroom being chosen as a reference volume in all cases.

Sampling tubes were placed in 4 rooms in each house, typically the lounge, bathroom, kitchen, and master bedroom. There were several important considerations when it came to the location of the source and sampling tubes:

- Source and sampling tubes needed a good degree of separation to ensure the sampler collects tracer that has been well mixed in the zone.
- Both sources and sampling tubes needed to be located as far as practicable from windows/doors to allow incoming air to mix within the zone.
- Temperature has a direct influence on the emission rate; the sources were not placed in direct sunlight or within 1.5 metres of heat sources. The temperature was also measured at each source location using Dallas DS1923 iButtons.

2.3 Results

A summary of the results from the work is shown in Figures 2 and 3.

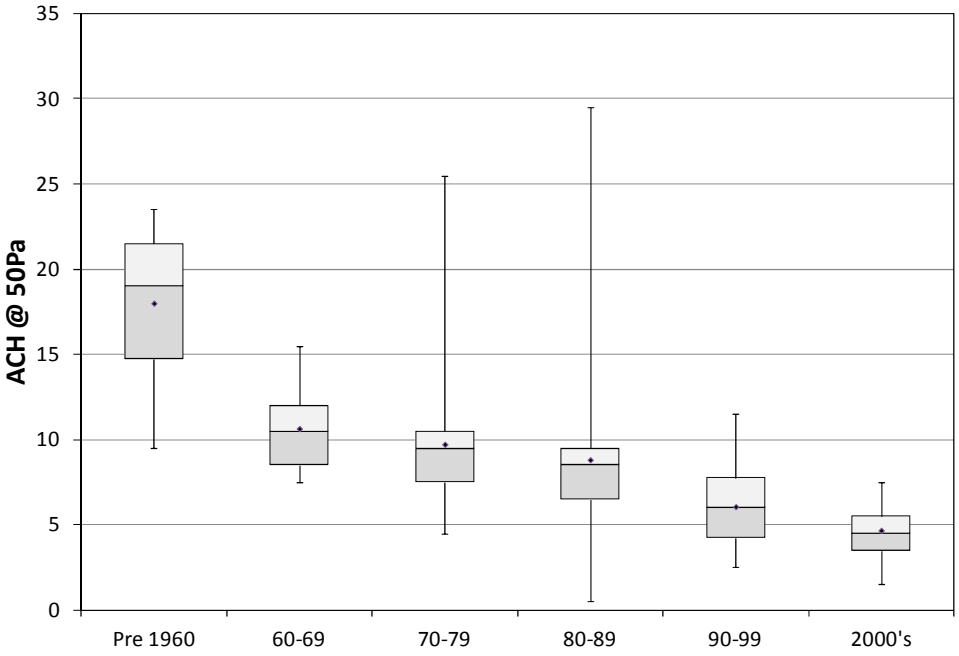

Figure 2: Airtightness Measurements of NZ Homes

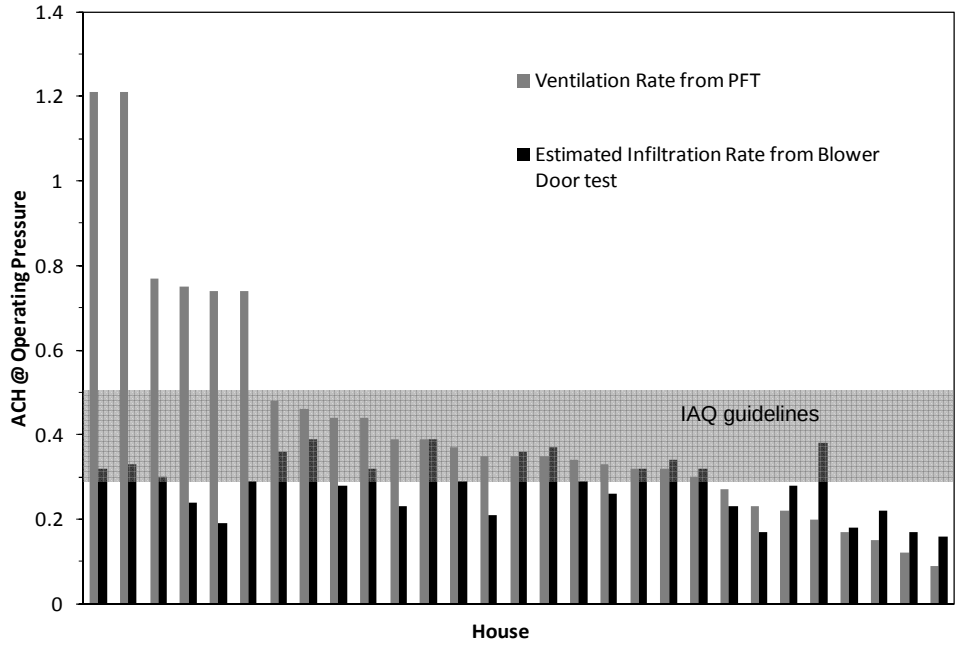

Figure 3: Measured Ventilation Rates and Estimated Infiltration Rates

Figure 2 shows how the airtightness measurements from this study compare with those from previous airtightness surveys in NZ.

Figure 3 shows how the average ventilation rate compares with the estimated infiltration rate for each house. Results are sorted so the measured ventilation rate decreases from left to right.

Also in Figure 3 is a shaded area representing 0.3 to 0.5 ach, the amount of ventilation deemed necessary to provide adequate indoor air quality [9]

2.4 Discussion and Future Work

It is clear that the trend to more airtight construction is continuing despite the lack of any building code requirements to so do. Compared to the previous survey (80's and early 90's homes) there was a reduction in the mean airtightness result from 8.5 ach to 6.7 ach. Incidentally, the floor area of the newer houses was also bigger than those in the last survey, increasing from 115m^2 to 155m^2. The recent airtightness results also fell in a tighter range suggesting more consistency in construction.

Figure 3 suggests about two-thirds of all new homes are likely to need ventilation on top of the background infiltration to achieve acceptable levels of indoor air quality. The results show that this doesn't always happen.

There is a wide variation in terms of the average ventilation rate achieved in modern NZ homes. Six of the surveyed homes had ventilation levels far in excess of international guidelines, potentially wasting energy and compromising thermal comfort. Three of these over-ventilated homes had supply-only ventilation systems installed, suggesting that the control of these systems could be improved somewhat.

At the other end of the spectrum, eight homes had ventilation levels below international guidelines. In these cases, the occupants are not providing the extra ventilation they need by opening windows or using fans etc. Evidence of indoor moisture problems e.g,.mould and condensation were observed in several of these houses.

Overall, NZ newer homes are on the border of becoming too airtight, if infiltration is to be relied on to supply fresh air. It would also appear that a ventilation scheme that relies on open windows is too unreliable. Modern lifestyles, security and energy costs are some of the reasons why occupants may not open windows as much as is needed.

The remainder of the ventilation work in the WAVE programme aims to improve the control algorithms for supply-only ventilation systems and develop possible alternatives that account for the wide range of airtightness in the existing NZ housing stock and adapt to occupant behaviour.

3. WALLDRY-NZ – An educational tool for cavity design

3.1 Introduction

WALLDRY-NZ is currently a Microsoft Excel-based computer program that encapsulates much of BRANZ's previous weathertightness research in one model [10].

WALLDRY-NZ was developed to bring flexibility to cavity wall design. The model is used in an interactive teaching environment, showing how alternative design choices influence water entry loads and ventilation drying rates in a wide range of climate zones within New Zealand. The tool allows students to develop practical intuition about the importance of cavity vent dimensions. This is useful basic knowledge for surveyors and building inspectors.

Walls designs with ventilated and drained cavities were widely adopted in New Zealand [6] after a systemic moisture failure in buildings of risky design and with direct-fixed barrier claddings. For the new cavities, sizes and vent areas from brick veneer and cavity stucco walls were simply copied for use with different claddings. An understanding of how cavity dimensions and vent sizes influenced ventilation drying and drainage was unavailable at the time but this has since been assembled by earlier studies [10]

In New Zealand, industry training has played an important part in remediating leaking buildings and bringing designers and builders up-to-speed with the new risk-based building code requirements for weathertightness. The New Zealand Institute of Building Surveyors (NZIBS) runs a training course for building surveyors who work for the NZ Government initiated Weathertight Homes Resolution Service. This week-long course covers diagnosis and remediation along with more fundamental material on timber decay and the physics of moisture. WALLDRY-NZ has a role in this course.

A comprehensive model of all the water entry and escape routes in buildings is still some way off, but several models have been developed to account for the influence of climate on water leakage and wall drying. Among the most prominent of these are the Canadian MEWS methodology [11] and ASHRAE 1091 research project [12]. This ASHRAE project provided much of the scientific underpinnings of cavity ventilation and ventilation drying on which WALLDRY is based.

3.2 Method

The details of all the research that contributed to WALLDRY is beyond the scope of this paper. However, the challenge for WALLDRY was to encapsulate the following into a single tool.

- Driving Rain Data for NZ
- Water Entry through weatherboards and brick veneers
- Ventilation Drying Rates – and how this is altered by wall design

3.2.1 Driving Rain Data

WALLDRY-NZ can provide the average daily rain load in $l/m^2.day$ on each of 8 wall orientations. Alternatively, the average rain intensity can be selected for periods when it is

raining. Rain and wind loads for 10 and 20 year return periods are also provided as a function of site exposure, orientation and building height. This latter data is provided to help select rain loads and wind pressures for testing.

Rain loads on facades were calculated using seven years of hourly climate data (1995-2002) for 40 sites using the procedure outlined by Sahal and Lacasse [13]. Wind speeds at the meteorological sites were adjusted to represent wind speeds at building height using the common power-law profile and terrain coefficients from Grimsrud et al [14].

Seasonal and annual average values of wind speeds are provided in WALLDRY-NZ to show that there are significant differences between coastal cities and those located inland. Figure 4 gives the average wind speed (at a building height of 4m) for a semi-sheltered building in Auckland.

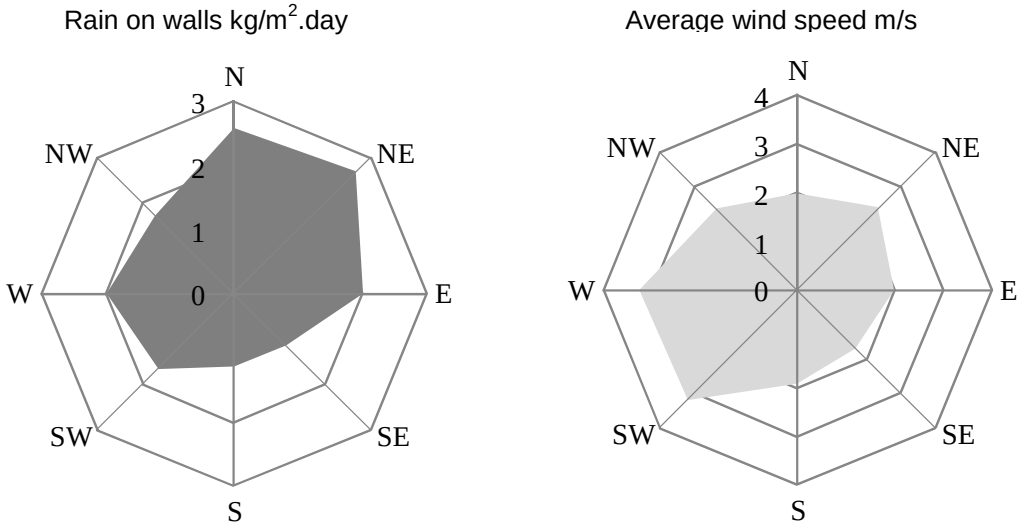

Figure 4: Yearly average rain and wind data for a 4m high brick veneer house with no eaves in a semi-sheltered area of Auckland.

As with much of New Zealand, there is a strong tendency for westerly airflows over the building although this is often not the prevailing direction for rain loads on walls. In Figure 2 the building receives its highest average rain load from the NE direction. Overall, the data in WALLDRY-NZ gives designers and building surveyors an appreciation of how wind and rain on a building vary with location and building geometry.

3.2.2 Water Entry Through Claddings

Weatherboard and brick veneer claddings are particularly common in New Zealand and the water entry rates calculated in WALLDRY-NZ are derived from leakage rate measurements for these claddings reported by Bassett et al [15]. This data gives leakage rates for a range of incident rain loads and the air pressure difference across the cladding in 12 weatherboard walls (painted and unpainted) and three brick veneer walls.

3.2.2.1 Weatherboards

The measurements showed that leaks in weatherboard walls depended more on build quality than on the fundamental geometry of weatherboards. Leakage sites were often at

cracks, fixings and at lap joints which had opened up between weatherboards that had cupped in the sun. The fundamental geometry of the overlap joint was found to be only a secondary factor although there was no doubt that bevel backed board designs drained out water at lap joints more effectively than rusticated designs. This dependency on condition and build quality means that accurate water leakage rates will be difficult to predict in practice. In order to move forward, three leakage classifications have been selected to capture the range of leakage for weatherboard claddings in WALLDRY-NZ:

Leaky. Representing timber weatherboards that have weathered and cupped or been installed with significant gaps in the horizontal overlaps (2-3 mm).

Average. Represents well maintained painted timber or reconstituted timber weatherboard wall with few obvious defects (cracks at fixings knot holes etc).

Low. Represents plastic and metal weatherboards with tight fitting (clip together) overlaps and effective butt jointers.

The water leakage rate, L ($g/m^{2.}.h$), for each of these classifications is calculated in WALLDRY as follows:

$$L = A + B\Delta P^2 \qquad \text{(Equation 2)}$$

Where A and B are constants (see Table 1) and *ΔP (Pa)* is the air pressure difference across cladding.

Table 1:. Water leakage characteristics representing weatherboard claddings

Water Leakage classification	*A* $g/m^2.h$	*B* $g/m^2.h.Pa^{0.5}$
Leaky	100	0.1
Average	1	0.05
Tight	0.1	0.0001

3.2.2.2 Water Entry through Brick Veneer

Water leakage characteristics of brick veneer walls have been studied [15] and were again found to vary with build quality. Leakage rates in three walls were measured in the range (100 – 300 $g/m^2.h$) at high rain loads (3 $l/m^2.min$) and zero air pressure difference. These leakage rates were similar to those measured by Drysdale and Wilson [16] (100 – 300 g/m2.h) but other authors report leakage rates over a wider range eg Newman and Whiteside [17] measured leakage rates (300 – 2000 $g/m^2.h$). Both Newman & Whiteside and Drysdale & Wilson, relate higher leakage rates to cracked mortar joints. They report that water leakage through brick veneer walls occurs primarily at leakage paths between mortar and brick which in turn relate to build quality and in-service loads.

Instead of a detailed physical model, the leakage rates calculated in WALLDRY-NZ are based on the measured leakage characteristics of three brick veneer walls and a simplified model (see Figure 5).

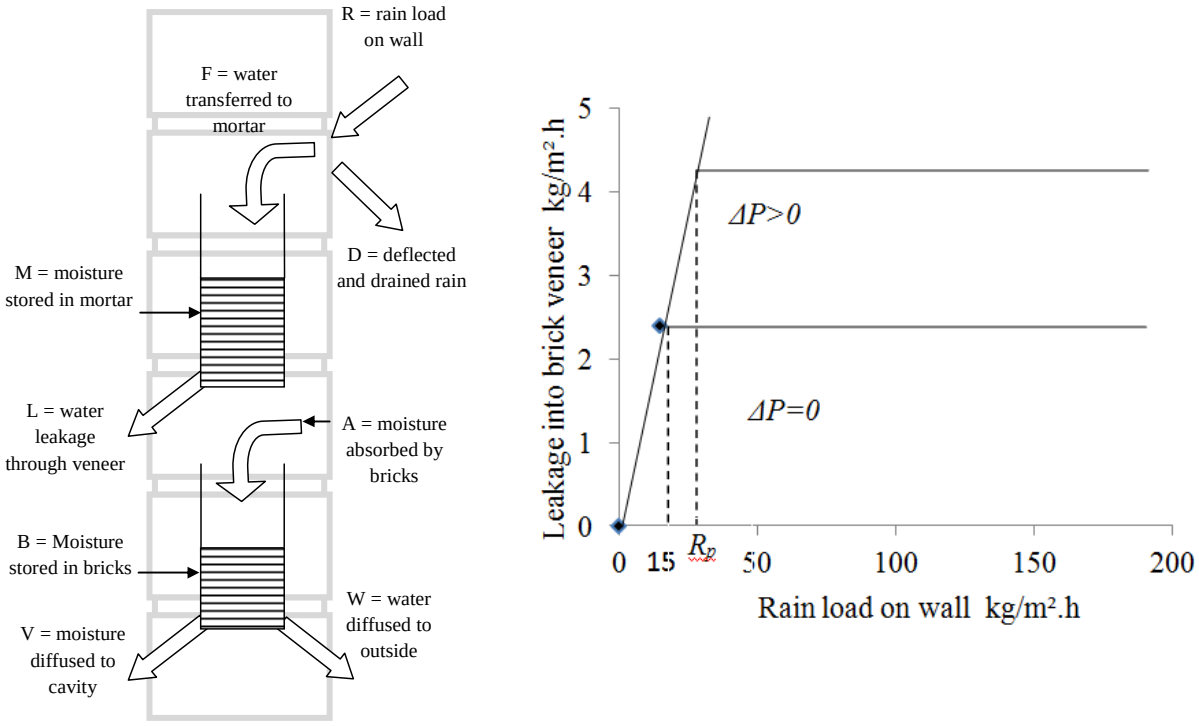

Figure 5: Simplified Model of Leakage and variation of leakage with pressure

The experiments showed that equilibrium value of *L* was independent of the rain load within the range of *R* = 15–200 kg/m^2.h [15] and depended on the air pressure difference as in equation 7:

$$L(\Delta P, R) = 2.4 + 0.416\Delta P \text{ (kg/m}^2\text{.h)} \qquad \text{(Equation 3)}$$

L(ΔP,R) must eventually fall to zero as *R* approaches zero and WALLDRY assumes this happens linearly (see Figure 2)

The measured water leakage rate (L) through the three brick veneer walls was found to increase steadily from dry, to an equilibrium value once the reservoir in mortar joints and bricks was saturated. The water leakage rate for one of the experimental walls increased to a steady value of 2.4 kg/m^2.h after 180 minutes. The water stored in the mortar joints and in the bricks in this particular wall is taken as the maximum value of moisture stored, *M, in WALLDRY*.

Water vapour diffusion from the brick and mortar *V* into the water managed cavity has been considered because it potentially adds to the moisture load to be dealt with by drainage and ventilation drying. Wetting and drying rates to inside *V* and outside *W* have been calculated using the two dimensional heat and mass transfer model WUFI [18]. Starting from a saturated wall, *V* and *W* were calculated in four seasons and for walls facing north, south, east and west in three climate zones. Drying rates were found to depend primarily on wall orientation while the fraction of drying to the wall cavity depended primarily on the cavity ventilation rate. With a fresh air cavity ventilation rate set at 12 ach (2 l/s.m) following Bassett et al [10], an average 8% of water absorbed in the bricks dried into the cavity and the remainder to the exterior. When this diffused moisture V was added to the leakage rate L, it contributed an average 15% to the total moisture load in the brick veneer cavity.

3.2.2.3 Summary of Leakage

Average water leakage rates are presented in Figure 6 as a percentage of rain loads for the three weatherboard wall categories and a brick veneer wall. These have been averaged over 7 years of weather data for 33 population centres in New Zealand and four wall orientations. The data has been presented on a logarithmic scale because the average percentage of rain load leaking through the wall varies over a range of three orders of magnitude. Figure 6 also presents the leaking percentage of rain loads as a function of wind exposure, indicating that the leakage category is by far the dominant factor.

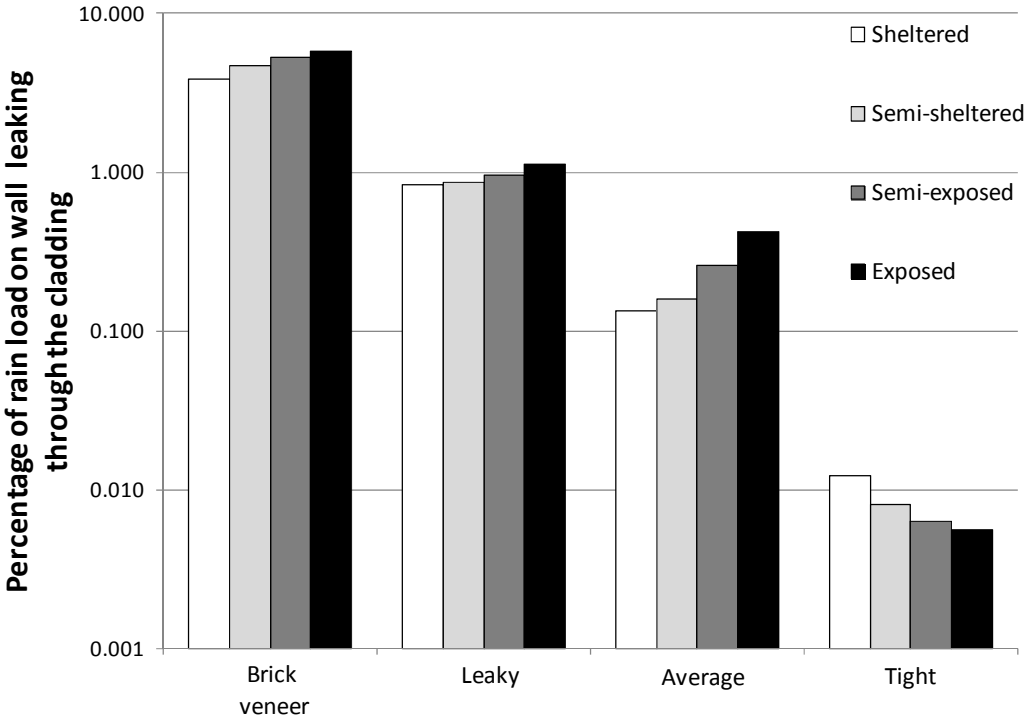

Figure 6: The average percentage rain loads penetrating four cladding classifications as a function of wind exposure.

3.3 Ventilation Drying

The ventilation drying rate calculations in WALLDRY-NZ are described in earlier papers [10]. These calculations have simply been applied to a wider range of climate and vent and cavity dimensions. Earlier studies showed that air infiltration paths play an important part in ventilation drying and this has to be accounted for as well specific opening at vents. This is particularly important where cavities are vented only at the base of the wall, and where ventilation might otherwise be considered to be “single sided”. In practical terms this meant all of the water managed cavities around a house had to be modelled to ensure that all of the infiltration paths are accounted for.

A single rectangular building shape has been used to model ventilation into and between wall cavities [10] Fresh air ventilation rates into each cavity were calculated along with re-circulated ventilation from adjacent cavities. The total ventilation made up of air from adjacent cavities and fresh air can be much higher (20 times) the fresh air ventilation rate in cavities with no internal partitioning (brick veneer) and twice the ventilation rate in

conventional open rainscreen cavities with non-vented battens. However, for the purposes of WALLDRY, moisture removal rates have been conservatively calculated from fresh air ventilation rates.

Several additional assumptions have been made in calculating ventilation drying rates. The first is that the whole wall is assumed to be uniformly wet. The earlier study [10] showed that non-uniform wetting could be accounted for in ventilation drying rate calculations but in practice the pattern of wetting is unknown and variable. WALLDRY-NZ also ignores water trapped in capillary joints e.g., junctions between wall battens and the cladding, so consequently the drying rates should be viewed as a drying potential rather than an actual drying rate.

3.4 WALLDRY-NZ USED EDUCATIONALLY

WALLDRY-NZ has been used to train building designers, regulators and surveyors in the physics of moisture in buildings. A screenshot from the current version of WALLDRY is shown in Figure 7

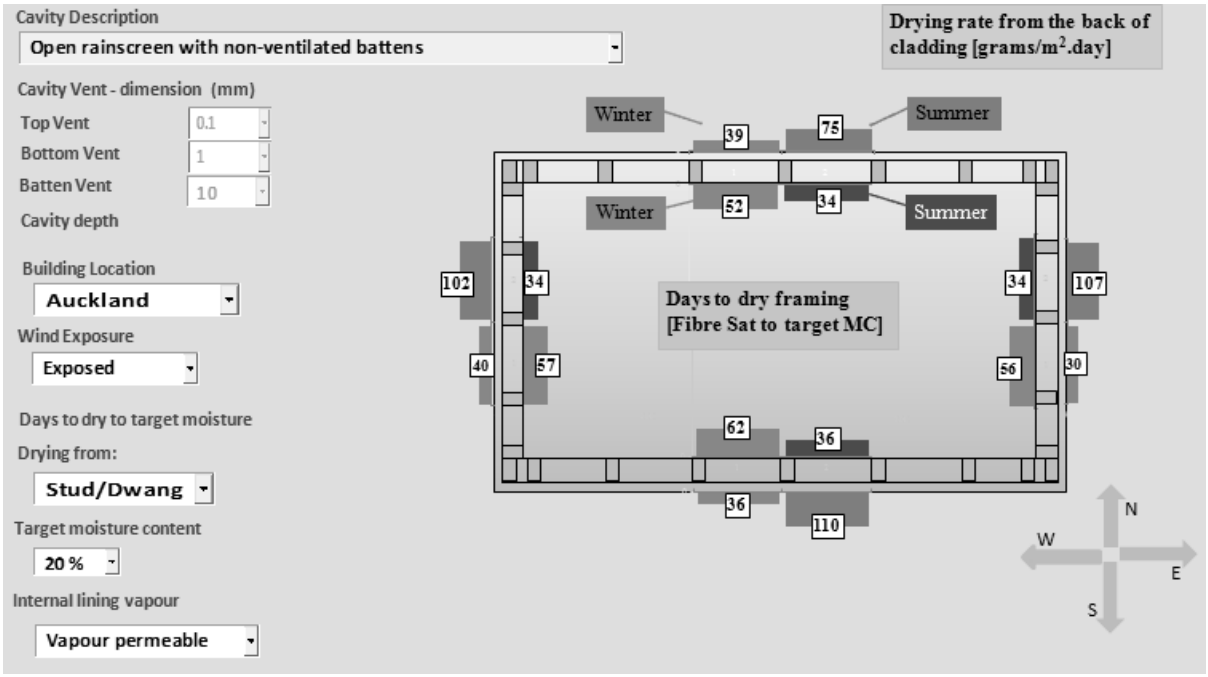

Figure 7: A screenshot of WALLDRY. The main outputs are on the right – a potential drying rate and the time needed for saturated framing to dry.

The model has been applied to study ventilation drying in relation to water leakage rates through common claddings, with the following educational outcomes:

- A prevailing westerly airflow can be clearly seen in wind roses for coastal cities in New Zealand. The highest rain loads are often from quite different directions, and depend on the building wind exposure and the presence of eaves. This data has a role in building design.
- WALLDRY-NZ shows that cavity ventilation drying rates depend more on the size and location of vents in walls than on where the building is located in New Zealand. Also illustrated is the significant role that infiltration plays in walls with only bottom

vents, and the role that vented battens can play in engineering alternative ventilation paths in these walls.

- The potential for ventilation drying in most cavity walls exceeds the estimated water entry loads. Although instantaneous water leaks may drain out along a non-absorbent drainage path, ventilation drying will almost always have the capacity to deal with water absorbed in absorbent claddings over time.

4. The future of the WAVE programme

BRANZ's Weathertightness, Air quality and Ventilation Engineering (WAVE) programme is scheduled to finish in October 2015.

By that time the following needs to be achieved:

Weathertightness:

- Quantify the water leakage at joints, particularly at windows, to allow upstands and other geometry to be determined using experimental data.
- Further understand the behaviour of different types of weatherboard to provide alternative solutions to designers.

Ventilation:

- Measure the moisture removal effectiveness of different ventilation systems using a experimental test house at BRANZ. Model this so that the results can be extended across NZ.
- Work with industry to improve the control functions of existing ventilation systems.

Interstitial Moisture:

- Provide guidance to industry on the role ventilation can play in managing moisture in roof spaces. Currently there is no provision for this in the building code with all water management dependent on the roof underlay.

Indoor Air Quality:

- Measure the effectiveness of photo-catalytic oxidisers at reducing fungal contaminant concentrations
- Develop a technique that integrates the findings from across the programme e.g. combine a model of moisture transport in the roof space with a model of ventilation in the living space.

A successful WAVE programme will provide a performance basis for weathertight design - removing some of the guesswork from current practice and ensuring a dry and safe future for the New Zealand building stock.

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Why do costs of civil engineering grow faster than prices in general?

Terttu Vainio[1], Eero Nippala[2]

Abstract

In recent years infrastructure ownership has been privatised. New public infrastructure is being built according to different public-private cooperation models. Despite the privatisation, the public sector – local and central government – finances a major share of new infrastructure. The international financial crisis and its impacts on the public economy make infrastructure maintenance considerably more difficult and cut investment in civil engineering. Along with scarce financial resources, the problem is exacerbated by the rising costs of civil engineering. Several input prices of civil engineering have increased clearly more than prices in general.

The issue is examined on two levels: the international and national levels. The used material consists of statistics compiled by Eurostat and the national statistical office as well as material acquired from clients. The aim of the two-level examination is to first determine whether the increased cost level of civil engineering is a global, a national or a cyclical phenomenon. Another aim is to discover the reasons for the runaway costs of civil engineering and whether their rise can be brought under control. The study will use primarily statistical methods.

The main reasons for the rise in the cost level are the increase in the prices of fuels and taxation. Changes in the content of infrastructure projects also tend to raise the cost level. Whatever the reasons, the situation forces the public sector to try and choose the most beneficial projects. The rapid rise of costs increases the pressure to improve productivity.

Keywords: cost, price, civil engineering, time series

1. Background

Civil engineering projects typically have a long lead time from planning to completion. The majority are financed by the public sector. Decisions are made at several stages in all civil engineering projects, especially in public ones. The costs of a project must be estimated at

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the same time. The first cost estimates are prepared already at a very early stage based on rough plans by comparing alternative solutions.

As planning proceeds, the content of projects becomes more precise and their scope tends to widen. In projects of long duration, even amendments to laws, e.g. on safety requirements or tax solutions, manage to increase costs. It has been noted that used cost calculation methods do not work on pricing of risks, pricing of projects implemented in difficult conditions (e.g. in a dense urban structure), or pricing of demanding types of work like tunnels. (Haapamäki, 2007)

Cost overruns are also caused by the failure to take a rise in cost level into account. That is more pronounced when the input costs of civil engineering increase significantly more than costs in general. If allowance for an increase in cost level is not made in comprehensive contracts, the profitability of contractors suffers. Clients, on the other hand, must know how to prepare for higher input costs both in traditional procurement models with an index clause and new procurements based on an alliance contract. (Hurskainen, 2009)

There are deficiencies in the cost management of civil engineering projects. It has been suggested that better understanding of the operating environment and monitoring of business cycles and markets can also improve cost management. Scheduling of projects so that unintended over-demand is not created by projects involving the same types of work or selection of the appropriate procurement model and contract form for each economic situation are suggested as means of managing costs. (Hurskainen, 2009)

This paper delves into the cost formation and cost level changes of civil engineering. The goal is to determine the factors influencing the sector's cost level, which would allow looking for ways to forecast cost developments. The target is member states of the European Union, one of which is examined in more detail.

2. Material and methods

The study consists of two parts. The first part identifies the factors influencing the cost developments in one country (Finland) and compares the results with changes in the levels of civil engineering costs in other European countries.

The second phase of the project involved searching for variables that would allow forecasting cost changes. For that, the correlations between variables describing civil engineering and its operating environment and cost developments were analysed.

Used research material consisted of public official statistics on civil engineering and its operating environment. The source of national data is Statistics Finland and that of European data Eurostat.

3. Civil engineering cost development in Finland

In Finland, the development of civil engineering costs is measured by an input cost-type cost index of civil engineering works as in most European and OECD countries. The input price index or input factor price index measures the weighted, combined price development of factors of production consumed in construction (labour, construction materials and components, services, machine work, etc.). The impact of each factor of production on the index corresponds to its share of the construction budget. The input price index describes the change in the construction costs of a construction lot, unchanged in terms of production technology and input cost breakdown, from the base year to the period under review. A construction lot or input structure is a combination of 40 different type contracts. Input price developments are based on market prices compiled either specifically for the cost index of civil engineering works or its parallel indices. (Official Statistics of Finland, 2005)

Based on this cost index of civil engineering works, sector costs have increased twice as much as the general price level since 2000 (figure 1). The inputs in civil engineering with the biggest impact on the development indicated by the index are fossil (fuel point figure 195 and bitumen point figure 385). The general price level increase is based on the cost-of-living index (2000=100). Costs of civil engineering works have also developed differently from those of building construction.

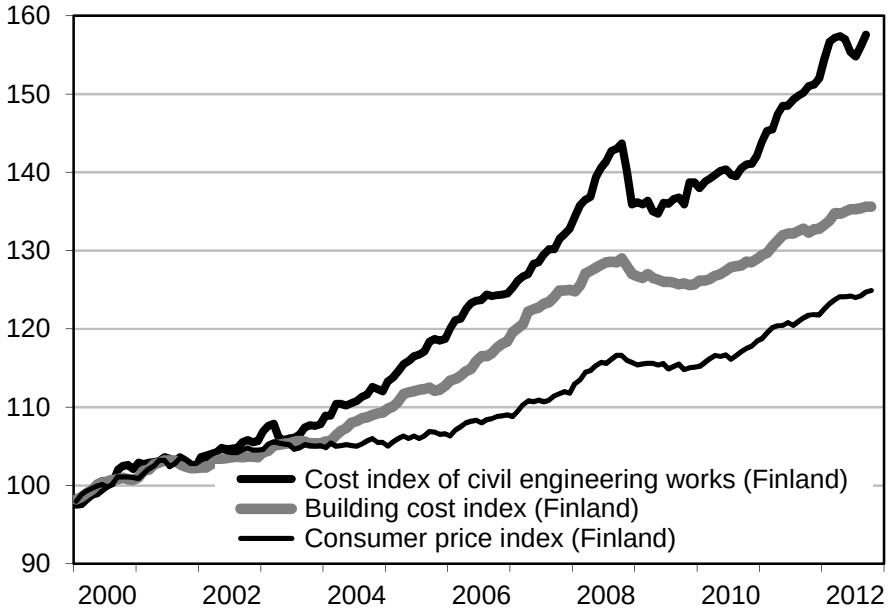

Figure 1: Costs of civil engineering works have increased twice as much as consumer prices in Finland. Index 2000=100. Source: Statistic Finland.

The cost level of Finnish civil engineering works measured by the national index and adjusted to the European cost level (EU=27) rose at the same rate from 2002 to 2005. In 2006−2007 the Finnish cost level rose at an accelerated rate compared to the general European cost level. National statistics indicate that the Finnish cost level has continued to rise at an alarming rate since 2007. Yet, the Finnish price level has fallen compared to the

European price level (figure 2). This allows drawing the conclusion that European costs have increased even more.

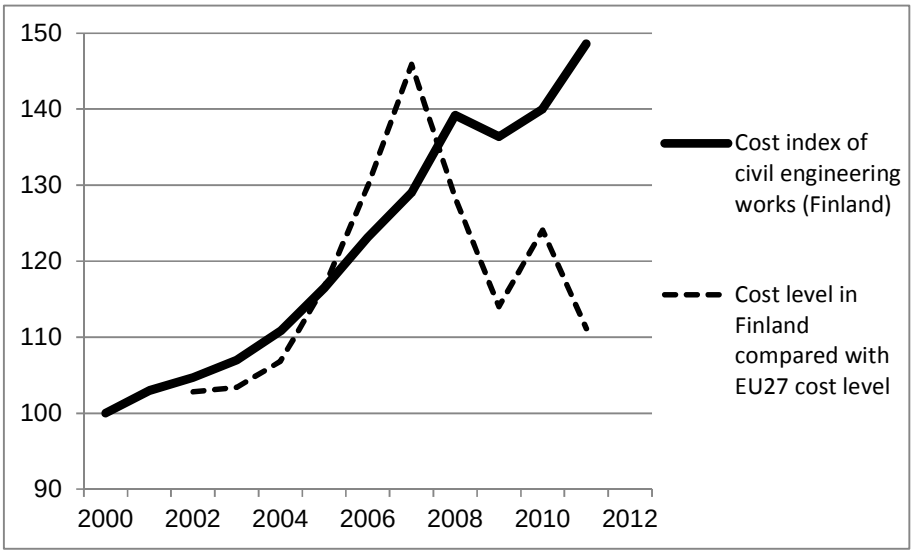

Figure 2: Costs of civil engineering works (Finland) have increased but price level has depreciated against EU27 price level. Sources: Statistic Finland and Eurostat.

Since 1993 construction clients have been asked to give their views on the level of civil engineering tender prices. According to them (figure 3), the tender prices of contractors, which had been considered high, collapsed back to normal in 2008. Clients find that tender prices have remained normal until autumn 2012.

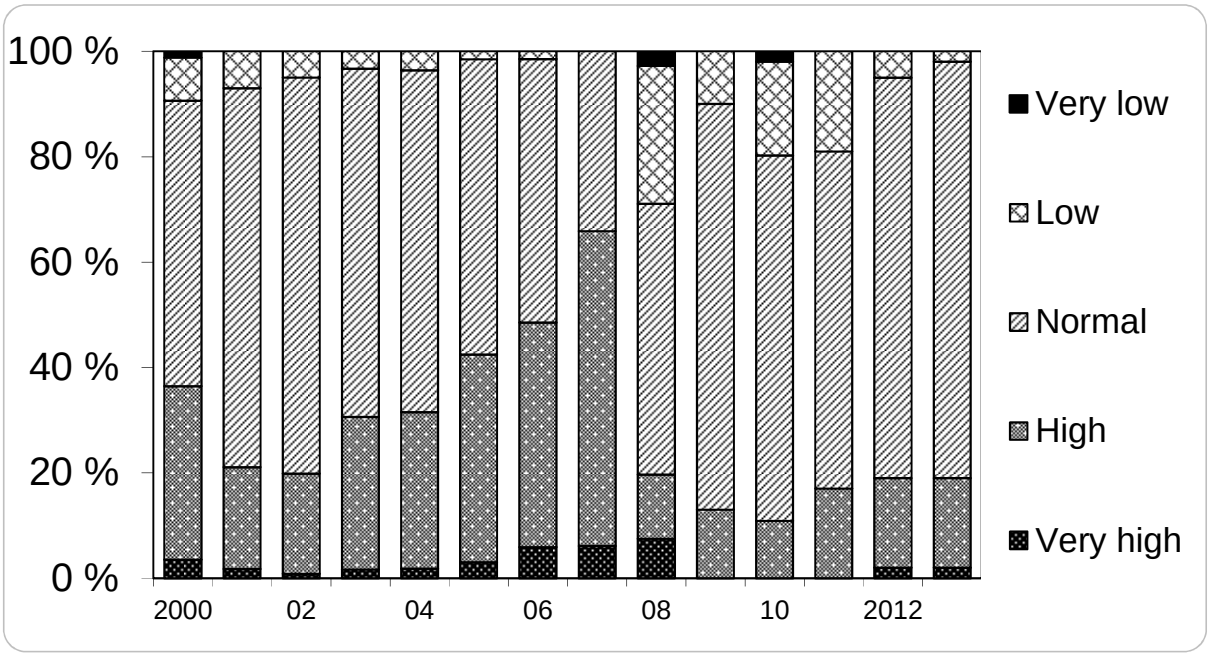

Figure 3: According clients quoted prices for civil engineering works collapsed 2008 and have stayed normal until 2012. The normal contractor's bidding price: the same level than client's own cost estimate. Source: Nippala, 2012.

The cost index of civil engineering works reflects the development of input prices. Tender prices consist of items such as risk provisions and a margin in addition to them. Analysis of the financial statements of civil engineering companies explains the steep increase in input prices while tender prices have remained normal (figure 4). Companies have compromised their margins. The traditional theory of supply and demand assumes that prices should fall when demand decreases, but that did not happen.

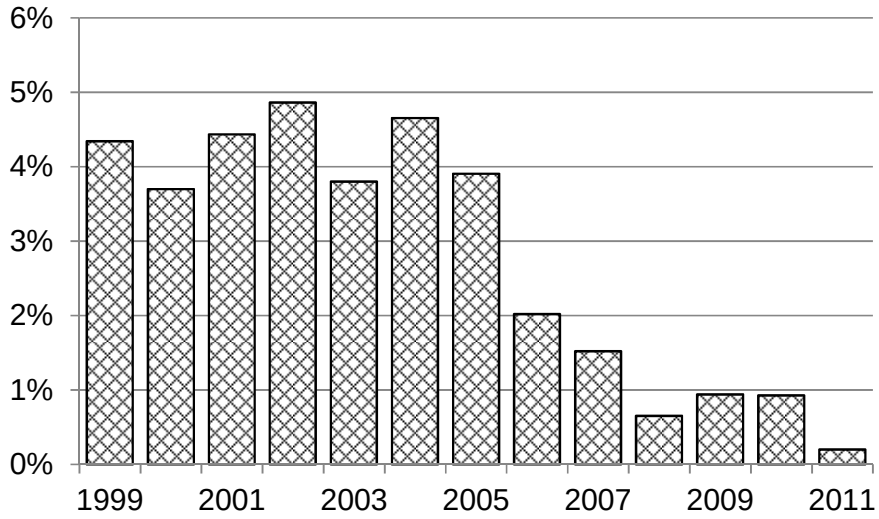

Figure 4: Net profit of civil engineering companies. Source: Statistic Finland.

3. Development of civil engineering cost level in European Union member states

Statistics on EU member states' civil engineering cost levels have been compiled since 2002. A common reference level (EU27=100) is calculated annually for the EU area as well as an index adjusted to the reference level for the member states and three other EU countries (Eurostat database, referred 29.10.2012). This analysis sought out those among the 27 countries when this index had been the highest or the lowest. These values were compared to the countries' civil engineering volume, economic development and fluctuations in the world market price of oil.

In 2007 the relative cost level of civil engineering works rose in 18 of the 27 monitored European countries. At the time, the economic situation in Europe was good. It was also good in all major economic regions on different continents (World Bank database, referred 29.10.2012). The U.S. economy was growing at 2 per cent, and though there were indications of losses suffered by banks there, the Federal Reserve was expected to be able to manage the situation. Economic growth was about the same in Europe and Japan. Russian growth (7%) was accelerated by oil. In the developing Asian markets economic

growth was many-fold compared to the old economies. China was growing at 11 per cent and India at 8−9 per cent.

In 2007 the world market price of oil shot up as production could not keep up with demand. Problems with production in Nigeria (The New York Times 17.9.2008) and a reduction in Russian production occurred at a time when China's demand for oil surged (OPEC press release 24.10.2008). At the time, it was assumed that the economic downturn would cut consumption of energy and lower the price of oil.

Economic growth generated tax revenue for the public sector. Its solid financial situation allowed increasing investment in civil engineering works in many EU countries. Typically, investments exceeding the normal level for civil engineering lag behind economic growth (Graf, 2000). Statistics show that the volume of civil engineering works remained high until 2009. In 2010 it collapsed. Despite the collapse, the cost level of European (EU27=100) civil engineering has increased.

4. Anticipation of cost changes − results of correlation analysis

Based on earlier analyses, the variables chosen for more in-depth study against the cost of civil engineering works were gross national product (GDP), inflation, wage development, oil price, bitumen price, metal price, soil and rock material prices, transport service price, , building construction volume and civil engineering volume,

The reviewed material consists monthly observations from 2000-2011 (144 observations). The relations of the variables were examined by methods typically used with time series. Because the material consists of annual data, trend removal, proportioning (logarithmic conversion) or differentiation are used to filter the material, as necessary.

Time-series which have constant mean and variance over time are said to be stationary. Stationarity is assumed for achieving reliable conclusions: non-stationary time-series may yield random results. As most of used variables are not stationary but time-dependent they are dealt with trend-removal. (Kendall, Ord 1990)

For yearly data the existence of a trend is dealt with filtering the observed trend. The direction of change may also be other than linear, for example, quadratic and time-dependent, which is why filtering is performed case by case. The quarterly data is processed with differencing to remove seasonal trend and thereby introduce stationarity. (Kendall, Ord 1990) In the analysis of civil engineering or the economy, trend removal refers, for example, to converting current prices to flat rates. The purpose of trend removal is to eliminate the change that takes place in the series in any case, such as recurrent economic fluctuations, to be able to examine their deeper nuances.

Logarithmic conversion is used to normalise the variables, that is, to observe relative changes in the variables. Logarithmic values were used in the comparisons when possible. Because a logarithm can only be taken of a positive number, some variables were defined

as a percentage of GDP if they contained also negative values and had originally given in that form in the material. The percentages also indicate relative values.

The variables are compared one at a time against civil engineering. The relation is first examined using graphic descriptors to assess their joint integration. Graphs are also made for trend-filtered variables to get a more accurate result for the dependencies of the directions of variables.

Change balances, i.e., sums of the numbers of changes in the same direction, are calculated for the pairs. This figure may support the correlation, which makes it possible to conclude whether the variables affect directly or inversely each other's changes. If the balance figure were close to half of the number of common events, it could be interpreted to imply that changes between the variables are not closely interconnected. By contrast, if the balance figure is close to the extreme ends (0 or maximum number of observations), it can be assumed that the variables are interrelated directly or through a third variable. For example, if 80% of the changes in variables *a* and *b* are in the same direction, they can be considered to be strongly directly proportional. Should the variables have only 20% changes in the same direction, they would have 80% changes in a different direction, indicating strong inverse proportionality.

Correlations indicate linear dependencies. In the case of time series variables, the correlations calculated for the initial values are rather high for unlimited variables, since time series often have a trend, a direction of development. Thus variables that increase or decrease over time may have significant correlations, as the scatter plots generated from them follow a trend. Filtered variables, again, have had their trend removed, so it is possible to observe similarities previously masked by apparent dependencies. Significant correlations between stationary series are a more reliable indicator of dependence than correlations between the original values.

Time-dimension is important feature in this study. Since correlations are calculated with time-series compared each other, they are placed in comparison with time too. Normally correlations are taken from values that occur simultaneously. This will yield only the dependency of concurrent events. By moving the compared value pairs we are able to observe the correlations between lagging and delaying variables. The method is called cross-correlation and it is instrumental in estimating the degree to which two series are correlated. From these correlations it is possible to gain findings from the causality between two series. Are changes taking place at the same time? (Kendall, Ord 1990)

While moving the series in time dimension the amount of compared pairs reduces. This is particular fall for those variables with small observation amount. This is particularly the case for those variables with a small number of observations.

The examined variables were divided in four groups based on the correlation analysis: leading, lagging, coincident and acyclical variables. Leading variables are those that in the light of the results of this analysis forecast changes in civil engineering costs. They included

GDP, building construction volume and oil price. These three test results for the cross-correlations are explained and visualised as 3D graphs (figures 5–7).

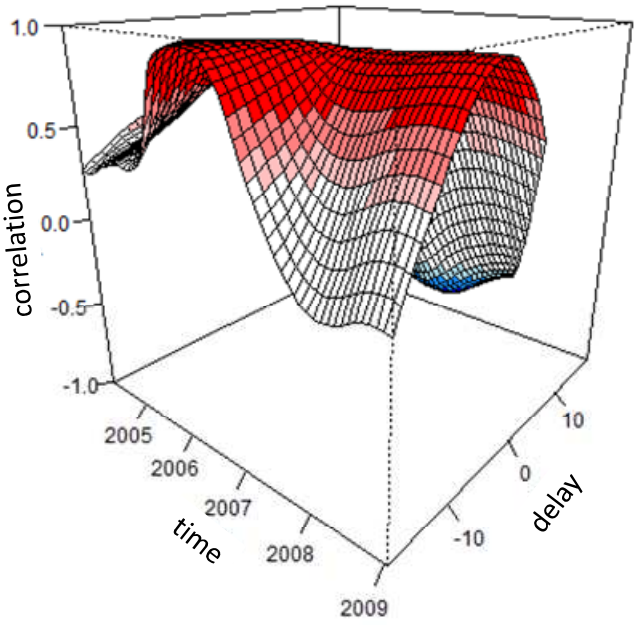

Figure 5: GDP reflects changes in the cost level of civil engineering works throughout the time series. The lead time has been halved in a short while (NB delay in months). Earlier, GDP development could forecast changes in costs of civil engineering works up to 18 months in advance. Presently, the lead time has shrunk to five months.

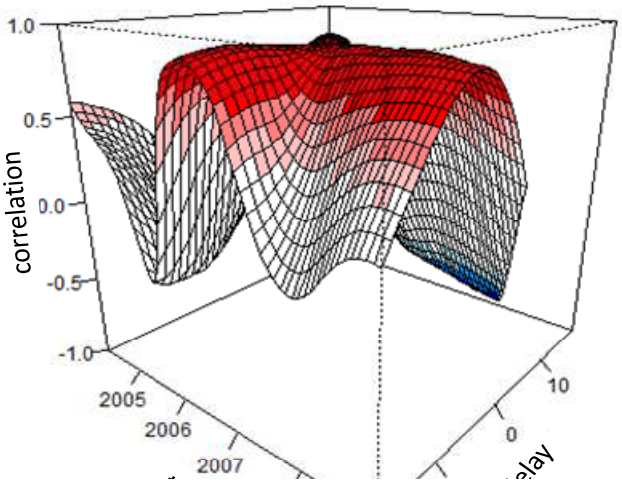

Figure 6: Changes in building construction volumes forecast cost changes. The delay between the changes has become shorter and stabilised at 5−6 months.

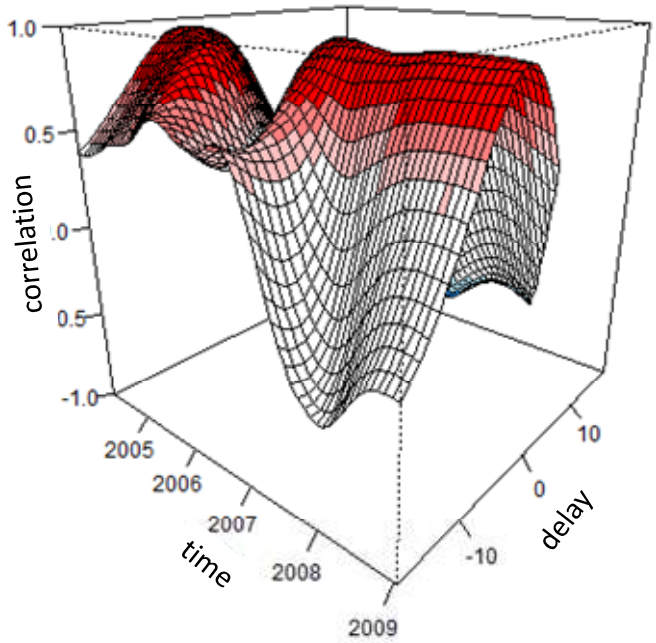

Figure 7: Changes in the price of oil unavoidably mean changes in costs of civil engineering. Earlier, the delay between an oil price change and cost changes was 6–12 months. Presently, it is only 2−4 months.

Correlating factors also affect the index either directly or through a common so-called third factor that affects both simultaneously. Changes in the prices of transport services and the volume of civil engineering works also occur concurrently with cost changes. Coincident reaction of transport services became established only in the 2000's. Earlier, transport service prices forecast changes in costs of civil engineering works.

Changes in the volume of civil engineering works also used to precede changes in the cost level, but today they change simultaneously (see figure 8). Thus change in civil engineering work volume is not significant from the viewpoint of cost forecasting.

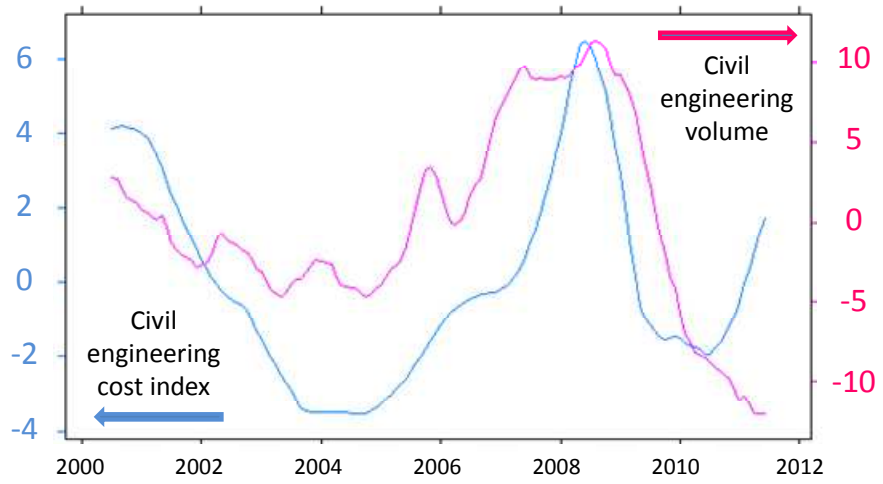

Figure 8: The demand does not come before but simultaneously with increase in prices.

Analysis of the lagging variables showed that their role can change. The results indicate that part of them have had a coincident or even leading relationship to the index. Yet, over time, the nature of the relationship has regressed and they have become lagging variables. An interesting fact is that sector wage development has lagged behind cost development, initially by 10 months, and now by as much as two years. Changes in the price of an important input of civil engineering works, soil and rock materials, are no longer a coincident variable, but lag behind changes in the cost index by 6 months.

The prices of fabricated metal products used to move quite inconsistently in relation to costs of civil engineering works, but have started to behave more consistently over time. The delay is about 9 months. The price of bitumen reacts similarly with a delay of 10 months.

The impact of inflation has varied during the review period. For long, it followed the costs of civil engineering works, but in the last few years the delay has shrunk so that changes occur almost simultaneously. It is no longer possible to determine whether inflation is a lagging or coincident variable to civil engineering costs (figure 9). Inflation is on the way of becoming a leading variable.

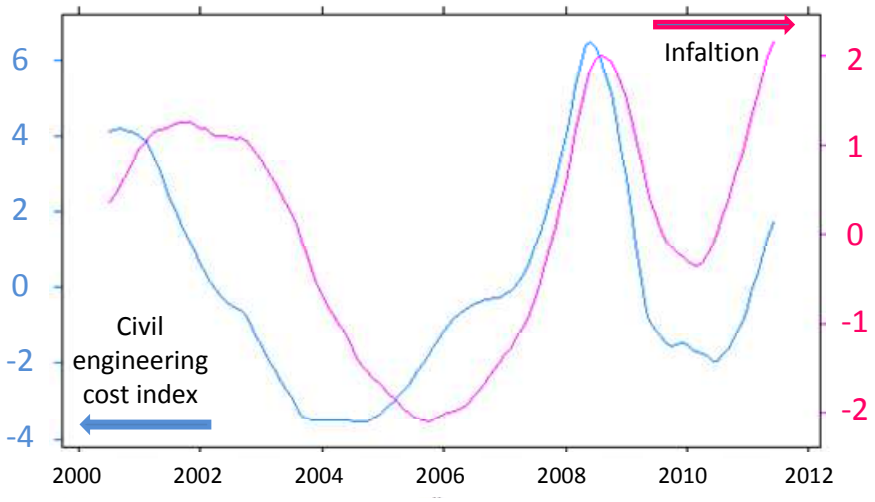

Figure 9: An interrelationship between civil engineering costs and inflation has been turbulent.

5. Summary

Civil engineering involves many types of work that require petroleum products. These products are needed to transport soil materials, to operate earthmoving machinery and to pave roads and streets. The aim of EU climate policy is to reduce the use of petroleum products. The means to achieve that goal include emission fees and taxes on fossil fuels. The increase in the world market price of oil and taxes together have increased petroleum products' share of the cost of civil engineering works to 20 per cent.

Globalisation and data communication have integrated the world's economies. This is evidenced e.g. by the fact that the delay between an increase in the price of oil and one in the input costs of civil engineering works has shrunk to a few months.

World market prices of raw materials also influence domestic inputs. According to the traditional theory of supply and demand, only growing demand increases prices until equilibrium is produced by increasing supply. The theory posits that a cost increase should follow from an increase in the volume of civil engineering works. Yet, according to the analysis of this study, that is not the case. Instead, volume and cost level increase simultaneously with each other and economic growth.

Civil engineering is local activity, but yet highly susceptible to changes in global economy. One indication of that is that the costs of civil engineering works have continued to grow even though demand has collapsed. Cost development is governed by international economic development instead of local supply and demand.

Thus, not only development of the national economy, but also development of the global economy and the world market price of oil must be considered in forecasting costs of civil engineering works. In the case of special work types, local supply may become the key factor in determining the cost level.

Acknowledgement

This article is a part of project Civil engineering in turning point financed by Tekes – the Finnish Funding Agency for Technology and Innovation and national civil engineering branch organisations.

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Concept for a Planning and Decision Model for Logistics in Tunnelling using Supply Chain Management and Outranking

Sebastian Etter[1], Gerhard Girmscheid[2]

Abstract

It is necessary to guarantee an optimal supply of all kinds of resources in construction production processes during the construction phase, including information in order to fulfil the requirements of optimal tunnelling logistics. This requires a systematic and holistic planning and decision model for logistics in tunnelling.

In this paper, a basic planning and decision model is introduced with the aim of a systematic development of an overall logistics system (OLS) in tunnelling. This OLS will be developed on the basis of Supply Chain Management (SCM) and is comprised of different partial logistics systems (PLS). These PLS (e.g. conveyor belt, trucks etc.) have to be defined for all different steps in the Supply Chain (SC) of all necessary resources (e.g. disposal of concrete, removal of construction waste etc.). After the definition of different PLS for each step, their merging to different OLS follows. Afterwards, a systematic decision making process (Outranking) identifies the optimal OLS out of all different OLS.

At the end of the paper, a short summary is provided as well as an outlook of how the presented model can be improved with additional parts.

Keywords: Tunnelling, Logistics, Supply Chain Management, Decision Making

1. Introduction

The idea of supply chain management (SCM) is based on efficiently dealing of limited resources as well as on holistic and network oriented logistics, structured by several demand and supply chains. The approach of logistics utilizing SCM achieved an immense reduction of costs and an increased efficiency in the stationary industry and the production process industry (cf. Graf 2004, Sennheiser 2008). Meanwhile, an enormous lack of efficiency exists in the construction industry. This lack of efficiency is caused mainly by inadequately planned construction production processes and/or logistics processes. A systematic and holistic logistics planning is essential especially in tunnelling, because narrow logistics paths in the tunnel and high uncertainty (e.g. geology, hydrology etc.) in different construction phases

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can result in inefficiencies. For example, inefficiencies may be caused by searching for construction materials, forced working breaks because of blocked working areas (by logistics or construction tasks), insufficiently dimensioned logistics processes, insufficient maintenance of construction machines, accidents and many other situations. These situations can often be avoided with an adequate planning of all logistics-logistics, logistics-construction and construction-construction interfaces. A similar lack of efficiency in logistics has also been identified also by several authors in the last few years (Vrijhoef and Koskela 1999, Krauss 2005, AbouRizk et al. 2011).

The aim of optimized logistics is to optimally secure the supply and waste disposal for the tunnel driving, the shell construction and the lining works in the tunnel. Therefore, an integrated logistics approach has to influence the construction production processes directly. For example: the use of mechanized formworks and pumped concrete instead of truck-transported concrete with manual formwork panels has a profound effect on these construction processes. Another point to consider is lean construction: Lean construction implies a holistic waste management for all logistics and construction processes so to reach optimized recycling and disposal tasks as well as to avoid unnecessary construction waste.

Hence, the research project “Operational Tunnelling Logistics” was initiated at the ETH Zurich with the aim of developing a planning and decision model for holistically optimized and integrated tunnelling logistics. In the field of construction process management several research papers and books have been published which give direction to the following model (Girmscheid 2010, Kersting and Girmscheid 2011a, Kersting and Girmscheid 2011b). The following project is structured in three different levels: On a **first level,** a general model for the logistics processes in tunnelling is modelled; on a **second level** a superior logistics concept for the general contractor is presented, while on the **third level**, specific logistics concepts for the single contractor are identified. A planning and decision model for an overall logistics system (OLS) is introduced in this paper, as a part of the first level. An OLS can be developed with this model. The model generates a flexible, with multiple criteria optimized tunnelling logistics on the principal’s level. Similar to the configuration, evaluation and selection tool for tunnel construction methods (developed by Schaiter and Girmscheid 2007) the whole model should also adhere to the economical minimal principle.

2. Methodologies and Theories

2.1 Research Methodology

The scientific framework of the presented work is embedded in the hermeneutic science program to understand, interpret and construct new socio-technical realities. Within the hermeneutic science program, Glasersfeld (1998) developed the constructivist research paradigm. Girmscheid (2004) introduced the research methodology of construction management science in accordance with these paradigms. The presented work is directly based on this logic based, deductive methodology.

2.2 Resource-Flow in Supply Chain Management

A key point of Supply Chain Management (SCM) is to organize and control the resource-flow using a holistic approach. All resources, which are required for construction processes, have to be managed. These resources are summarized according to Krauss (2005) in Figure 1. The resource-flow (see Figure 2) in tunnelling consists of procurement, distribution and delivery of resources to the production. After the production, the resource-flow continues with removal, processing and disposal of either the resource itself or its related construction waste. In the example of shotcrete (construction material), the **procurement** includes providing gravel, cement, water and chemicals; **distribution** entails distributing and storing on the installation site, next to **delivery** by pumping processes to the working face; *production* is the spraying process itself including the scaling of the rebound; **removal** involves the transportation of the rebound out of the tunnel; **processing** stands for the storage and treatment of the waste material; **disposal** represents the transport to the according disposal site. All processes, excluding production, belong to the logistics processes and build up the SC of a specific resource. Additionally, a forward and backward-looking information flow has to be guaranteed in the SC between every single process. Missed information or incomplete information leads to misunderstandings and cause additional, non-value-adding process time in construction production processes or logistics processes. Therefore, the information flow has to be standardized in the SC-Network.

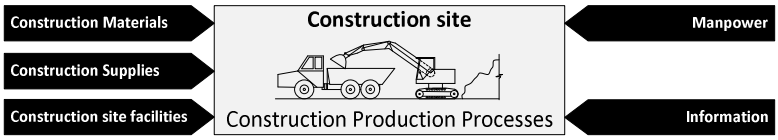


Figure 1: Necessary resources on a construction site

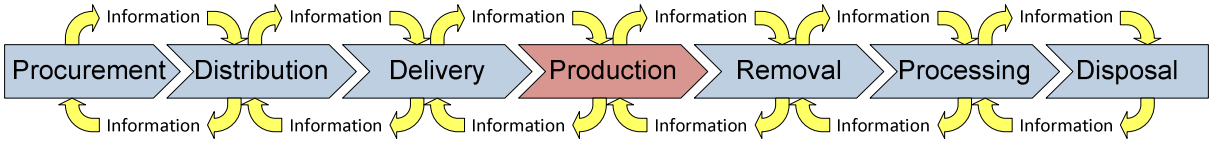


Figure 2: Supply Chain in tunnelling

The management of all SC merged to a supply chain network (SC-Network) is called Supply Chain Management (SCM) and is aligned with a specific strategy. The strategy of the SCM in tunnelling can be deducted in the following way: The main requirement for the logistics in tunnelling (or any other construction project) is to secure the support of the construction production processes. The construction production processes are the actual construction tasks such as excavation, shotcrete spraying, anchor setting as well as shell and lining construction processes. All these construction production processes are leading processes and logistics processes have to support them in any case. An interruption of a construction production process, caused by inaccurate logistics, leads to decreasing productivity of these processes, or in the worst case to an interruption of the construction works.

Therefore, the strategy of SCM in tunnelling should encourage innovative **holistic** logistics systems enabling a **lean** and **flexible** construction operation. **Lean**, because unnecessary transports, processes and waste have to be avoided; **flexible**, because unforeseen events can happen anytime; **holistic**, because between all processes interaction occurs and the

overall goal can consequently only be reached with a holistic approach. Missing optimisation of one or several interfaces (and therefore the interactions) can lead to suboptimal process sequences and cause a decreasing efficiency.

2.3 Outranking

Outranking was introduced by Roy (1968) and is a specific field of Operations Research (OR). OR is a scientific discipline which deals with systematic decision making. Multiple Criteria Decision Analysis (MCDA) is a part of OR and Outranking Methods are a specific field of MCDA. Outranking Methods support the decision making process similar to cost-utility-analysis (CUA) or the Analytic Hierarchy Process (AHP). Additionally (compared with CUA or AHP) Outranking Methods can deal with data inaccuracies in the decision making process. Furthermore, a pairwise comparison is calculated including for each pair the specific degree of preference for each pair. Outranking does not generate a single solution of decision problems, rather a ranking of the different alternatives. The ranking can be in one case strict (complete ranking) and in another case show the preferences and the indifferences between alternatives (partial ranking). This means less loss of data during the decision process and therefore a more transparent decision making process.

Basically, two different widespread outranking methods exist: ELECTRE and PROMETHEE. ELECTRE was introduced by Roy (1968). Further, Brans et al. (1986) developed PROMETHEE I (partial ranking) and PROMETHEE II (complete ranking), PROMETHEE allows more stable results than ELECTRE. The stepwise procedure of PROMETHEE is shown in Figure 3. Macharis et al. (2004) integrated AHP in PROMETHEE to calculate the weights in step 3.

Step 1 — **Determination of deviation based on pair-wise comparison**

$$d_j(a,b) = g_j(a) - g_j(b)$$

a,b ≡ Alternatives of the discreet solution set A ($a, b \in A$)
d_j(a,b) ≡ Difference between the evaluation values of *a* and *b* on criterion j of $\vec{T}(A)$
g_j(a) ≡ Achievement of objectives function of the criterion j of alternative *a*
$\vec{T}(A)$ ≡ Target vector with optimization criteria of A

Step 2 — **Application of the preference function**

$$P_j(a,b) = F_j\left[d_j(a,b)\right]$$

P_j(a,b) ≡ Preference function of criterion j of the alternatives *a* and *b* as a function of d_j(a,b)

Step 3 — **Calculation of a global preference index**

$$\pi(a,b) = \sum_{j=1}^{k} P_j(a,b) \cdot w_j$$

π(a,b) ≡ Weighted sum of all preference values of alternative *a* over alternative *b*
w_j ≡ Weight of criterion j with *j = 1,...,k*

Step 4 — **Calculation of outranking flows (The PROMETHEE I partial ranking)**

$$\Phi^+(a) = \frac{1}{n-1}\sum_{x \in A}\pi(a,x) \quad \text{und} \quad \Phi^-(a) = \frac{1}{n-1}\sum_{x \in A}\pi(x,a)$$

Φ⁺(a) ≡ Positive outranking flow of alternative *a*
Φ⁻(a) ≡ Negative outranking flow of alternative *a*
n ≡ Amount of alternatives
x ≡ Alternative of the discreet solution set A ($a, x \in A$)

Step 5 — **Calculation of net outranking flow (The PROMETHEE II complete ranking)**

$$\Phi(a) = \Phi^+(a) - \Phi^-(a)$$

Φ(a) ≡ Net outranking flow of alternative *a*

Figure 3: Stepwise procedure for PROMETHEE II [Behzadian et al. (2010)]

3. Developing logistics systems alternatives

3.1 Concept

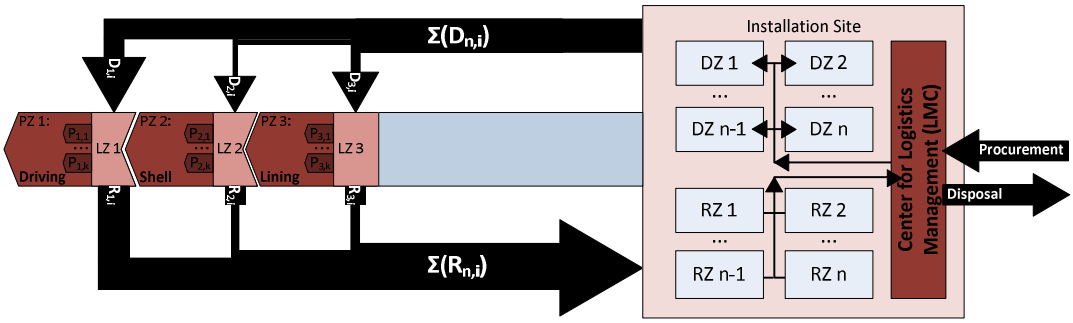
To guarantee a lean and flexible construction operation with a holistic logistics system, every single resource in the construction production processes needs to be planned based on the following procedure, in accordance with the SC introduced in Figure 2:

In a **first step,** the procurement of the resources has to be organized. This includes the raw material production and pre-manufacturing. To allow a fast and high quality construction process: prefabricated components, ready for installation should be preferred. This step must define, if the resource will be delivered by train or by truck and for sensitive resources a back-up system has to be determined as well. This is necessary to secure the SC, even if the regular system fails. The procurement ends with delivery to the Centre for Logistics Management (LMC). In a **second step**, the LMC distributes the resources to the different Delivery Zones (DZ) on the installation site. For this purpose, it is again necessary to define logistics systems alternatives for every resource. This includes mainly storage, but necessary processing processes in DZ, too.

In a **third step**, the LMC defines delivery systems to the Logistics Zones (LZ) nearby the Productions Zones (PZ) and the storing management (amount of stored resources) in the LZ. Deliveries to LZ are initiated by orders of the production zones; order and delivery can be executed either automatically or manually. The logistics zones have to be positioned as close as possible to the PZ, such to avoid any further resource transportation. Directly after the delivery the construction production processes starts. These processes end as soon as the fourth step starts. The **fourth step** of any SC is comprised of removal. Every construction production process generates waste: This waste then, has to be removed and transported to the installation site. The construction waste will be processed on the installation site. Construction waste is for example package material, excess material or excavated material from the heading face. Logistics systems have to be defined for every resource so that the transportation of its construction waste out of the PZ to the LZ in the tunnel and further to the Removal Zone (RZ) on the construction site is guaranteed.

As a **fifth step**, the LMC organizes the collection and processing (e.g. direct recycling on the installation site or separating in component parts) of the various resources. To avoid unnecessary disposal and to choose optimal logistics systems, the focus should remain on local recycling of the construction waste and excavated material. This allows a minimum of transportation after processing and more sustainable construction operations. As a **sixth step,** the unused material and construction waste has to be disposed. For every resource an optimal transportation and waste management system needs to be defined.

By defining possible PLS for every step, various OLS can be assembled by combination of the PLS. Not every combination is realizable, so that as a final step, the realizable systems have to be filtered out in a pre-selection. Only these realizable OLS fulfilling the system requirements of the whole construction project will be analysed in the decision process. The schema, which the realizable OLS have to fit, is shown in Figure 4.



PZ i: Production zone **i**
$P_{i,k}$: Production process **k** in PZ **i**
LZ i: Logistics zone **i** for PZ i

$D_{n,i}$: Delivery of ressource **n** for PZ **i**
$R_{n,i}$: Removal of ressource **n** for PZ **i**

DZ n: Delivery Zone of ressource **n**
RZ n: Removal Zone of ressource **n**

Figure 4: Production and Material Flow in Tunnelling

A construction process chain needs an increasing capacity with every single process to guarantee the overall functionality. Therefore every PLS following a previous PLS must possess a higher capacity to guarantee the functionality of the OLS. Furthermore, a system handling various different resources should be preferred. Another important aspect is that the OLS is dynamic. It changes during the construction phase, depending on the various construction lots. These dependencies between the phases have to be considered in logistics planning as well.

3.2 Example

A hypothetical highway-tunnel project is considered utilizing an open shield machine and a segmental lining in heavily rugged sandstone. Length of the tunnel is 4000 m, diameter is 11 m and the project lasts approximately 4 years. To keep the example simple, only the resources such as excavation material, concrete segments, mortar and personal are treated. **First**, the different possible PLS have to be identified for each step in the SC and for all resources (Table 1). Mainly, the alternatives are transportation by road or train as well as onsite or offsite production/recycling. To avoid any misunderstandings, it is recommended to develop plans and prepare further descriptions of the different PLS. **Second**, the combination of the different PLS to the OLS follows (Table 2). Here, it is inevitable to develop plans and further descriptions of the different OLS for the evaluation.

Table 1: Survey of different PLS along the SC of different resources

	Excavation material	**Concrete Segments**	**Mortar**	**Personnel**
Procurement	-	Onsite production	Company A (local)	Own personnel
		Offsite production with train transport	Company B (non local)	Contractor's personnel
		Offsite production with truck transport		
Distribution	-	JIT distribution	Storage for 1 week	Accomodation on construction site
		Storage for 1 week	Storage for 1 month	No accomodations
		Storage for 1 month		
Delivery	-	Train	Pumping	Walking
		Truck	Train	Buses
			Truck	Train
Production				
Removal	Conveyor belt	Train	Train	Walking
	Train	Truck	Truck	Buses
	Truck			Train
	Dumper			
Processing	Onsite recycling and storing	Onsite recycling and storing	Onsite recycling and storing	-
	Offsite recycling	Offsite recycling	Offsite recycling	
	Onsite storing	Onsite storing	Onsite storing	
Disposal	Truck transport to a local dumping site	Truck transport to a local dumping site	Truck transport to a local dumping site	Dismiss
	Train transport to a non local dumping site	Train transport to a non local dumping site	Train transport to a non local dumping site	Send to another construction site
	Using as filling material in the tunnel			

Table 2: Survey of three different OLS

		Alternatives		
		a	b	c
Excavtion material	Procurement	-		
	Distribution			
	Delivery			
	Production			
	Removal	Conveyor Belt	Train	Truck
	Processing	Local recycling	Local recycling	Local storing
	Disposal	Truck to local dumping site	Train to non local dumping site	Truck to local dumping site
Concrete Segments	Procurement	Onsite production	Offsite production (train)	Onsite production
	Distribution	Storage for 1 month	Storage for 1 month	Storage for 1 month
	Delivery	Truck	Train	Train
	Production			
	Removal	Truck	Train	Train
	Processing	Onsite recycling	Offsite recycling	Onsite recycling
	Disposal	Truck to local dumping site	Train to non local dumping site	Train to local dumping site

		Alternatives		
		a	b	c
Mortar	Procurement	Company A (local)	Company B (non local)	Company B (non local)
	Distribution	Storage for 1 week	Storage for 1 month	Storage for 1 week
	Delivery	Truck	Pumping	Pumping
	Production			
	Removal	Truck	Train	Train
	Processing	Onsite recycling	Offsite recycling	Onsite recycling
	Disposal	Truck to local dumping site	Train to non local dumping site	Train to local dumping site
Personnel	Procurement	Own personnel	Contractor's personnel	Own personnel
	Distribution	Accomodation on construction site	No accomodations	Accomodation on construction site
	Delivery	Buses	Train	Train
	Production			
	Removal	Buses	Train	Train
	Processing	-		
	Disposal	Send to another construction site	Dismiss	Send to another construction site

4. Selection of the optimal overall logistics system

4.1 Concept

4.1.1 Decision process

Especially in long term tunnelling projects with complex boundary conditions concerning technical feasibility, environment, economic situation and politics it is difficult to set up a realistic decision model. Therefore, it is necessary to provide a flexible and transparent decision model, to guarantee the consideration of the decision maker's experience as well as to ensure a systematic decision making process. These requirements are fulfilled by the outranking method PROMETHEE. It is possible to consider experience and unclear boundary conditions when making the final decision with PROMETHEE I, the partial outranking. An objective and systematically made decision can be still generated with PROMETHEE II, the complete outranking. Furthermore, it is proposed to use the techniques of AHP to systematize the criteria's weighing process.

4.1.2 Optimization Criteria

To reach a comparable and transparent decision finding process, it is inevitable to use standardized optimization criteria. Additionally, these criteria should be used to measure the performance of each process on the construction site. Measuring of performance permits to managing the SC according to Behrouzi and Wong (2011).

This leads to the conclusion that on one hand, the decision process for optimal logistics systems in tunnelling has to be a multi-criteria decision process and, on another hand these criteria have to be assessable during the planning phase and measureable during the construction phase. To control the SC-Network implies, controlling the degree of achievement with the different criteria as indicators. These indicators have to be calculated from the optimization criteria, so to guarantee a consistent SCM. The optimization criteria are also used to analyse the OLS and to calculate the partial and complete outranking with PROMETHEE. A catalogue of criteria was developed based on these requirements with the results in Table 3. The criteria are separated in main-criteria (costs, flexibility and

environment) and sub-criteria. The proposed unit to be considered is defined in Table 3 as well as the maximization or minimization conditions.

Table 3: Evaluated Optimization Criteria with preference functions

					Alternatives						Preference function		Parameters		
					a		b		c				s	q	σ
Costs	f_1	Purchase of resources	C_{res}^{fix}	min	65	[Mio. $]	70	[Mio. $]	62	[Mio. $]	d_1	Gaussian criterion			4.04
	f_2	Acquistion of land	C_{land}^{fix}	min	5	[Mio. $]	5	[Mio. $]	5	[Mio. $]	d_2	Gaussian criterion			1.00
	f_3	Rental of resources	C_{res}^{var}	min	11	[Mio. $]	8	[Mio. $]	12	[Mio. $]	d_3	Gaussian criterion			2.08
	f_4	Rental of land	C_{land}^{var}	min	2	[Mio. $]	1	[Mio. $]	2	[Mio. $]	d_4	Gaussian criterion			0.58
	f_5	Costs of personnel	C_{pers}^{var}	min	44	[Mio. $]	55	[Mio. $]	46	[Mio. $]	d_5	Gaussian criterion			5.86
Flexibility	f_6	Maximal capacity: driving	F_{driv}^{per}	max	30	[m/d]	45	[m/d]	30	[m/d]	d_6	Crit. with lin. preference & indiff.	20	5	
	f_7	Maximal capacity: shell construction	F_{shell}^{per}	max	30	[m/d]	45	[m/d]	30	[m/d]	d_7	Crit. with lin. preference & indiff.	20	5	
	f_8	Maximal capacity: lining	F_{lin}^{per}	max	30	[m/d]	-	[m/d]	30	[m/d]	d_8	Crit. with lin. preference & indiff.	20	5	
	f_9	Revision induced interruption	$F_{inter,r}^{per}$	min	20	[%]	25	[%]	21	[%]	d_9	Gaussian criterion			2.65
	f_{10}	Failure induced interruption	$F_{inter,f}^{per}$	min	0.3	[%]	0.9	[%]	0.1	[%]	d_{10}	Gaussian criterion			0.42
	f_{11}	System redundancy	F_{red}^{res}	max	80	[%]	10	[%]	90	[%]	d_{11}	Gaussian criterion			43.59
	f_{12}	Overcapacity of weakest link	F_{over}^{res}	max	30	[%]	60	[%]	30	[%]	d_{12}	Gaussian criterion			17.32
Environment	f_{13}	Average noise emissions	E_{noise}^{soc}	min	66	[dB]	72	[dB]	68	[dB]	d_{13}	Gaussian criterion			3.06
	f_{14}	Average vibration emissions	E_{vib}^{soc}	min	-	[a]	-	[a]	-	[a]	d_{14}	Gaussian criterion			1.00
	f_{15}	Average dust emissions	E_{dust}^{soc}	min	1	[mg/m^3]	1	[mg/m^3]	1	[mg/m^3]	d_{15}	Gaussian criterion			0.25
	f_{16}	Suplementary traffic	E_{traf}^{soc}	min	50	[Veh/d]	10	[Veh/d]	150	[Veh/d]	d_{16}	Gaussian criterion			72.11
	f_{17}	New infrastructure induced economic growth	E_{econ}^{soc}	max	1.5	[%]	2.0	[%]	1.5	[%]	d_{17}	Gaussian criterion			0.29
	f_{18}	CO_2 output	E_{CO2}^{eco}	min	unknown	[t]	unknown	[t]	unknown	[t]	d_{18}	Gaussian criterion			1.00
	f_{19}	Recycled excavated material	E_{recyc}^{eco}	max	90	[%]	80	[%]	85	[%]	d_{19}	Gaussian criterion			5.00
	f_{20}	Normal construction waste	$E_{waste,n}^{eco}$	min	120'000	[t]	220'000	[t]	170'000	[t]	d_{20}	Gaussian criterion			50000
	f_{21}	Polluted construction waste	$E_{waste,p}^{eco}$	min	20'000	[t]	4'000	[t]	20'000	[t]	d_{21}	Gaussian criterion			9238
	f_{22}	Water consumption	E_{water}^{eco}	min	10'000	[m^3/a]	8'000	[m^3/a]	11'000	[m^3/a]	d_{22}	Gaussian criterion			1528
	f_{23}	Acquistion of land	E_{land}^{eco}	min	-	[m^2]	-	[m^2]	-	[m^2]	d_{23}	Gaussian criterion			1

The **costs** (C_j^{fix}, C_j^{var}) in Table 3 have to be minimized and are separated in fix and variable costs of resources, land and personnel. The **flexibility** (F_j^{per}, F_j^{res}) is separated in the sub-criteria performance and flexibility. The maximal capacities of the logistics system and the assessed percentage of revision and failure induced interruptions determine the criterion's performance. Responsiveness can be measured based on the percentage of system redundancy and the overcapacity of the weakest link in the SC-Network. The main criteria **environment** (E_j^{soc}, E_j^{eco}) is composed by various social and ecological aspects, such as noise, dust and vibrations emissions, supplementary traffic and induced economic growth as well as CO_2 output, construction waste, water consumption or acquisition of land. Together, all these criteria constitute the target vector T (1).

Target vector: (1)

$$\vec{T}(A)=\left[C_{res}^{fix};C_{land}^{fix};C_{res}^{var};C_{land}^{var};C_{pers}^{var};F_{driv}^{per};F_{shell}^{per};F_{lin}^{per};F_{inter,r}^{per};F_{inter,f}^{per};F_{red}^{res};F_{over}^{res};E_{noise}^{soc};E_{vib}^{soc};E_{dust}^{soc};E_{traf}^{soc};E_{econ}^{soc};E_{CO2}^{soc};E_{recyc}^{soc};E_{waste,n}^{eco};E_{waste,p}^{eco};E_{water}^{eco};E_{land}^{eco}\right]^T$$

$$with \quad \left[C_{res}^{fix};C_{land}^{fix};C_{res}^{var};C_{land}^{var};C_{pers}^{var};F_{inter,r}^{per};F_{inter,f}^{per};E_{noise}^{soc};E_{vib}^{soc};E_{dust}^{soc};E_{traf}^{soc};E_{CO2}^{soc};E_{waste,n}^{eco};E_{waste,p}^{eco};E_{water}^{eco};E_{land}^{eco}\right]^T \rightarrow min$$

$$with \quad \left[F_{driv}^{per};F_{shell}^{per};F_{lin}^{per};F_{red}^{res};F_{over}^{res};E_{econ}^{soc};E_{recyc}^{soc}\right]^T \rightarrow max$$

4.2 Example

The three OLS of chapter 3.2 were evaluated in accordance with the defined criteria of Table 3. During the estimation, preference functions were defined for the different criteria as well. The Gaussian function (2) was chosen as preference function for all criteria, except for the maximal capacity. In this specific function with linear preference and indifference area (3) provides the best fit. In total six different preference functions exist and they are defined in Brans et al. (1986).

Gaussian function: (2)

$$P_j(a,b) = P_j(d) = 1 - e^{-\frac{d^2}{2\sigma^2}}$$

Function with linear preference and indifference area: (3)

$$P_j(a,b) = P_j(d) = \begin{cases} 0 & if \quad d \le 0 \\ \dfrac{d-q}{s-q} & if \quad q \le d \le s \\ 1 & if \quad s \le d \end{cases}$$

d ≡ *Differences* *s* ≡ *Threshold value*

σ ≡ *Standard deviation of the estimated values* *q* ≡ *Indifference-threshold value*

According to Figure 3, in a **first step** the differences in the criteria values are calculated in the first six columns of Table 4. If a criterion has to be minimized according to the target vector (1), then the difference is multiplied with -1. In the **second step** all preferences are calculated with the preference functions (2) and (3). A value of 0 means, that both alternatives are equal (indifference) when considering this specific criterion, while a value of 1 expresses strict preference. In the **third step,** the weights of the different criteria are defined next to the calculation of the global preference indexes as the sum of the weighted preferences (Table 4 and Figure 5). The positive and negative outranking flow is calculated in the **fourth step**. Furthermore, the partial outranking is defined (PROMETHEE I in Figure 5). An evaluation using PROMETHEE generated the following results: alternative *a* and alternative *c* are preferred compared to alternative *b*, since π(*a*,*b*) and π(*c*,*b*) are significant higher than π(*b*,*a*) and π(*b*,*c*). Furthermore, alternatives *a* and *c* are indifferent (no significant difference between π(*a*,c) and π(*c*,*a*)). In the **fifth step** the Netto-Outranking-Flow is calculated and the complete outranking is generated (PROMETHEE II in Figure 5) with alternative *a* as the optimal OLS, since Φ(*a*) > Φ(*c*) > Φ(*b*).

Table 4: PROMETHEE-calculation of the example

		Differences						Preferences						Weight	Weight Preferences					
		$d_j(a,b)$	$d_j(a,c)$	$d_j(b,a)$	$d_j(b,c)$	$d_j(c,a)$	$d_j(c,b)$	$P_j(a,b)$	$P_j(a,c)$	$P_j(b,a)$	$P_j(b,c)$	$P_j(c,a)$	$P_j(c,b)$	w_j	$w_j*P_j(a,b)$	$w_j*P_j(a,c)$	$w_j*P_j(b,a)$	$w_j*P_j(b,c)$	$w_j*P_j(c,a)$	$w_j*P_j(c,b)$
Costs	f_1	5	-3	-5	-8	3	8	0.75	0.00	0.00	0.00	0.39	0.97	11.1%	0.08	0.00	0.00	0.00	0.04	0.11
	f_2	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	2.8%	0.00	0.00	0.00	0.00	0.00	0.00
	f_3	-3	1	3	4	-1	-4	0.00	0.12	0.68	0.86	0.00	0.00	5.6%	0.00	0.01	0.04	0.05	0.00	0.00
	f_4	-1	0	1	1	0	-1	0.00	0.00	0.59	0.59	0.00	0.00	2.8%	0.00	0.00	0.02	0.02	0.00	0.00
	f_5	11	0	-11	-11	0	11	0.66	0.00	0.00	0.00	0.00	0.66	11.1%	0.07	0.00	0.00	0.00	0.00	0.07
Flexibility	f_6	-15	0	15	15	0	-15	0.00	0.00	0.67	0.67	0.00	0.00	4.8%	0.00	0.00	0.03	0.03	0.00	0.00
	f_7	-15	0	15	15	0	-15	0.00	0.00	0.67	0.67	0.00	0.00	4.8%	0.00	0.00	0.03	0.03	0.00	0.00
	f_8	30	0	-30	-30	0	30	1.00	0.00	0.00	0.00	0.00	1.00	4.8%	0.05	0.00	0.00	0.00	0.00	0.05
	f_9	5	1	-5	-4	-1	4	0.39	0.02	0.00	0.00	0.00	0.27	4.8%	0.02	0.00	0.00	0.00	0.00	0.01
	f_{10}	0.6	-0.2	-0.6	-0.8	0.2	0.8	0.86	0.00	0.00	0.00	0.20	0.97	4.8%	0.04	0.00	0.00	0.00	0.01	0.05
	f_{11}	70	-10	-70	-80	10	80	0.93	0.00	0.00	0.00	0.05	0.97	4.8%	0.04	0.00	0.00	0.00	0.00	0.05
	f_{12}	-30	0	30	30	0	-30	0.00	0.00	0.39	0.39	0.00	0.00	4.8%	0.00	0.00	0.02	0.02	0.00	0.00
Environment	f_{13}	6	2	-6	-4	-2	4	0.99	0.39	0.00	0.00	0.00	0.86	3.0%	0.03	0.01	0.00	0.00	0.00	0.03
	f_{14}	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	3.0%	0.00	0.00	0.00	0.00	0.00	0.00
	f_{15}	-0.5	-0.25	0.5	0.25	0.25	-0.25	0.00	0.00	0.12	0.03	0.03	0.00	3.0%	0.00	0.00	0.00	0.00	0.00	0.00
	f_{16}	-40	100	40	140	-100	-140	0.00	1.00	0.86	1.00	0.00	0.00	3.0%	0.00	0.03	0.03	0.03	0.00	0.00
	f_{17}	-0.5	0	0.5	0.5	0	-0.5	0.00	0.00	0.12	0.12	0.00	0.00	3.0%	0.00	0.00	0.00	0.00	0.00	0.00
	f_{18}	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	3.0%	0.00	0.00	0.00	0.00	0.00	0.00
	f_{19}	10	5	-10	-5	-5	5	0.86	0.39	0.00	0.00	0.00	0.39	3.0%	0.03	0.01	0.00	0.00	0.00	0.01
	f_{20}	100000	50000	-100000	-50000	-50000	50000	0.86	0.39	0.00	0.00	0.00	0.39	3.0%	0.03	0.01	0.00	0.00	0.00	0.01
	f_{21}	-16000	0	16000	16000	0	-16000	0.00	0.00	0.99	0.99	0.00	0.00	3.0%	0.00	0.00	0.03	0.03	0.00	0.00
	f_{22}	-2000	1000	2000	3000	-1000	-3000	0.00	0.20	0.59	0.86	0.00	0.00	3.0%	0.00	0.01	0.02	0.03	0.00	0.00
	f_{23}	0	0	0	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	3.0%	0.00	0.00	0.00	0.00	0.00	0.00

Global Preference Index					
π(a,b)	π(a,c)	π(b,a)	π(b,c)	π(c,a)	π(c,b)
0.39	0.08	0.22	0.24	0.06	0.38
Outranking Flow					
Positive			Negative		
$\Phi^+(a)$	$\Phi^+(b)$	$\Phi^+(c)$	$\Phi^-(a)$	$\Phi^-(b)$	$\Phi^-(c)$
0.24	0.23	0.22	0.14	0.39	0.16
Netto Outranking Flow					
$\Phi(a)$		$\Phi(b)$		$\Phi(c)$	
0.10		-0.16		0.06	

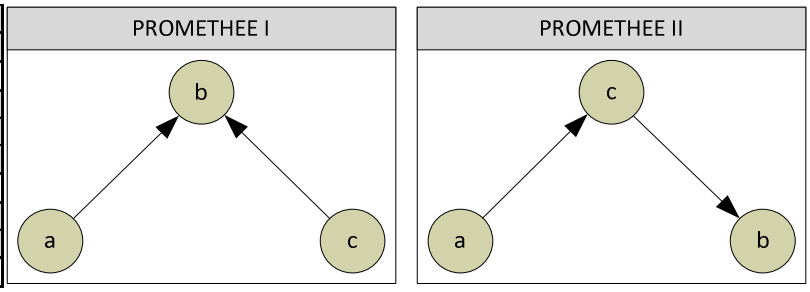


Figure 5: Results of PROMETHEE I & II

5. Results

The whole model is summarized in Figure 6. In a **first phase** (identification of different PLS), different handling systems have to be planned for each of the five different types of resource (Figure 1). This includes the procurement, distribution and delivery of the resources as well as the removal, processing and disposal of the construction waste (Figure 2). The sub-processes and single activities have to be considered for the identifications of the PLS as well. In a **second phase** (identification of OLS) the various PLS will be assembled to different OLS (system combination). After the combination a pre-selection follows, because some PLS-combinations do not work as an OLS. Also, some other OLS may not be realizable because of political or other boundary conditions. These not realizable systems have to be sorted out to optimize the effort in the decision process. The realizable OLS are analysed with PROMETHEE and the target vector (1). These criteria in the target vector should also be used to control the optimal OLS as the effective solution during the construction works. Additionally, the decision maker's experience is considered in the final decision due to the partial outranking of PROMETHEE I. Consequently, an objective decision can be provided for the optimal OLS with the Netto Outranking Flow.

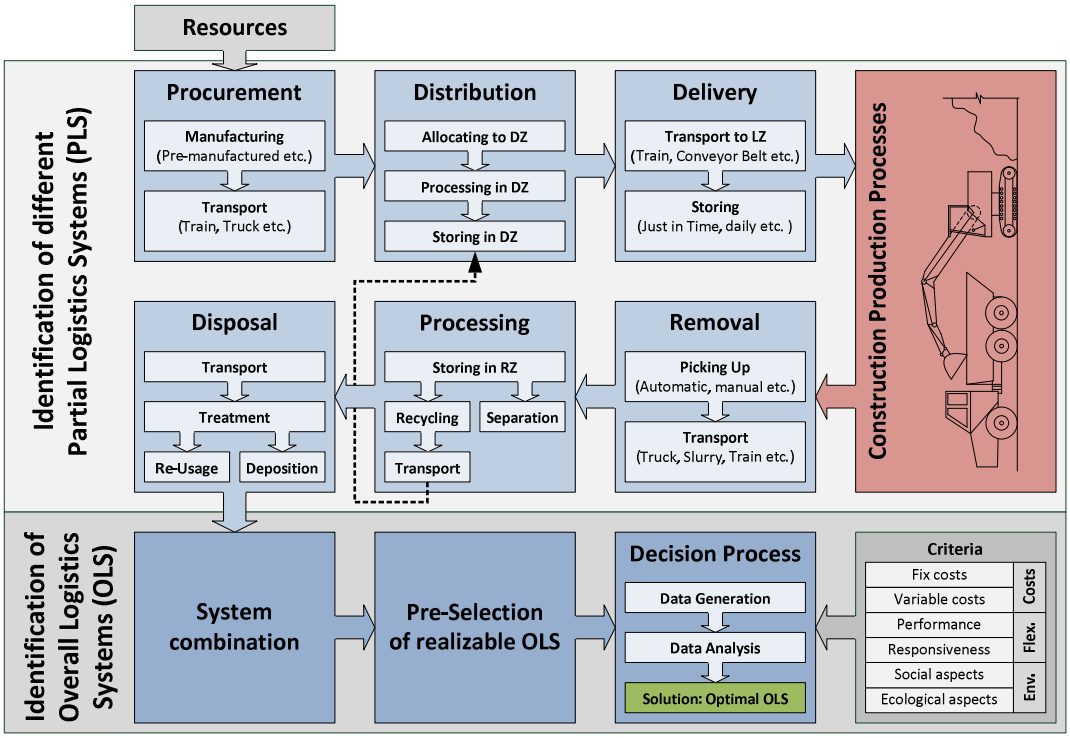


Figure 6: Planning model of an optimal OLS in tunnelling

6. Conclusion

SCM in the stationary industry is well investigated and is continuing improving. But the implementation of the ideas of SCM in the construction industry is a novel topic and not yet well investigated. Basic models exist, which describe, how SCM in construction production processes can be implemented. The present publication developed the existing models further to include implementation of SCM and OR in logistics planning in tunnelling. Therefore, the presented planning model can be used as a basis for a systematic and flexible development of OLS in tunnelling.

The advantage of this model is a holistic consideration of the material flow, with the construction production processes as the leading processes. The logistics processes can be optimally scheduled, to support the construction production processes with all necessary resources. Furthermore, all resources are considered including manpower and information.

Nevertheless, some parts of the proposed planning model can still be improved on. This concerns specifically the consideration of the different construction phases, the system combination, the data generation in the decision process and the information flow. The consideration of construction phases has to be implemented in the system combination, so to ensure an integrated approach of the total system. The data generation in the decision process of the existing model is based on an estimation of the values of the various criteria. The final aim of the model is to be integrated into a logistics simulation, which generates the values for the different OLS. To guarantee a stable information flow, a central information logistics should be developed, similar to the central logistic management introduced by Girmscheid and Etter (2012a) and Girmscheid and Etter (2012b). This centre manages all information generated by the whole project and ensures the support of all parties and processes with the necessary information. Additionally, the aspect and influence of long-term partnerships in tunnelling logistics should be investigated in greater detail.

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Infrastructure construction in change – what is the sensible path forward?

Eero Nippala[1], Terttu Vainio[2]

Abstract

Infrastructure construction is changing. The formerly closed domestic markets have opened up and become international in Finland like in many other countries. The transformation of a closed public sector into an open market has proven a challenge both to the public sector and enterprises. Infrastructures themselves are also changing. They can be made to include technology that gives extra value to clients. Infrastructure is never complete, but despite its static nature must be modified along with changes in regional structure, society and structural changes of industry.

The importance of competitive intelligence has increased in market-based operation. It is needed by the clients of infrastructure construction and the service providers, both in short-term planning of operations and long-term strategic planning.

This paper focusses on research delving into the long-term changes and challenges of infrastructure construction. The research assessed the future changes in infrastructure construction and their impacts on the basis of LoNGPESTEL analysis. The research was done in co-operation between the state, local government and the university and research organisations.

Asset management, financing of infrastructure maintenance, structural changes in the public sector, labour availability and competence, EU directives and environmental legislation, soil materials and recycling of materials, as well as urbanisation have been put forward as the greatest challenges to infrastructure construction.

Keywords: civil engineering, local impacts of trends, future challenges

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1. Introduction

Enterprises and organisations are operating in a global, changing environment. Changes form into global giga-trends and mega-trends. Internationally and nationally significant sectoral trends can be derived from them.

One aim of the 'Infrastructure sector in change' project is to derive such sectoral trends to allow concretising global changes for sector organisations and companies. Public sector organisations and enterprises, which react slowly to changes, need long-term forecast data.

Usually forecasting of future development is done by scenario techniques. For example Kast (1985) present relationship of general and task environments to the organisation. These relationships help our project to find changes and challenges of business environment and each company's activities to meet these changes (table 1).

Table 1: Relationship of general and task environments to the organisation (Kast, 1985)

1	General environment	Task environment
2	Economic	
3	Sociological	Customer
4	Demographic	
5	Natural resources	Technological
6	Legal	
7	Political	Sociopolitical
8	Educational	
9	Technological	Suppliers
10	Cultural	

Planning for uncertainty increasingly poses the question: "What is most likely to happen?" (Drucker, 1995) A generic approach to describing a comprehensive foresight project has been suggested by Peter Bishop et.al 2007 as in the following table (table 2).

Table 2: Approach to a foresight project (Bishop, 2007)

	Step	Description	Product
1	Framing	Scoping the project	Project plan
2	Scanning	Collection the information	Information
3	Forecasting	Describing alternative futures	Scenarios
4	Visioning	Choosing a preferred future	Prospective
5	Planning	Organising resources	Strategic plan
6	Acting	Implementing the plan	Action plan

Table 3: Scenario techniques have been categorized into eight basic types (Bishop et. Al., 2007)

1	Judgement	Including genius forecasting, visualisation and role playing
2	Baseline	Producing only one scenario, the expeted future, and conducted by trend extrapolation, system scenarios or trend impact analysis
3	Elaboration of fixed scenarios	In explicit consideration of multiple scenarios previous prepared using “incasting” or the popular SRI matrix method
4	Event sequences	Employing such approaches as probability trees, sociovision or divergence mapping
5	Backcasting	Adopting horizon mission methodology. Impact of Future Technologies or future mapping
6	Dimension of uncertainty	Using morphological analysis, field anomaly relaxation, GNB matrix or MORPHOL.
7	Cross-impact analyses	Calculating the relative probabilities of occurrence of future events and conditions in alternative scenarios employing a computer programme
8	Modelling	Having resource to trend impact analysis, sensitivity analysis or dynamic scenarios.

Even there are several scenario techniques (table 3) project group chose for the first step the PESTEL analysis. The reasons for that were quite short focus period, 5-7 years and also the need to tie future development to business environment analysis. If the forecast period become longer it is possible to carry out study with scenario techniques described at introduction.

2. Subject of research and theory

2.1 Operating environment of enterprises and organisations

Civil engineering produces all structures of the built environment except buildings. Its end products can be divided roughly in two groups: communities and communications between communities.

Communities are built to serve the needs of people. Water supply and sewerage is the community structure that serves an extreme basic need according to Maslow’s hierarchy of needs. Other community structures are streets, energy supply networks and green areas. Communities are linked to each other – as well as to areas beyond national borders – by roads, rail lines, harbours, airports, telecommunications networks and electric power transmission networks.

2.2 Research theory and methods

LoNGPESTEL analysis was the applied research theory which examines simultaneously broad global, national and local factors. Changes in the operating environment and factors affecting the infrastructure sector were culled from among them (Gillespie, 2011).

The factors considered in PESTEL analysis are:

1. Political factors (impact of the public sector on the economy): public subsidies, procurements, education, maintenance strategy and development strategy of infrastructure (road and rail network).

2. Economic factors: economic growth, inflation, availability and cost (interest on) financing, exchange rates, tax rate, etc.

3. Social factors: Ageing of population, unemployment, etc.

4. Technological factors: Economic regeneration with the help of new technologies (new products and processes). E.g. BIM-based design combined with GPS control of earthmoving machinery enables a technology jump in earth construction. Technology can lower costs and improve considerably the quality of the end product.

5. Environmental factors: Preparing for and mitigating the impacts of changes in weather and climate conditions. The increasing role of environmental protection will cause changes e.g. in taxation of transport and transport technology (hybrid cars). Environment-friendly products are capturing market share.

6. Legal factors: Laws and decrees governing the operations of enterprises, accessibility, minimum wage, recycling requirements. Changes in these affect the operations of enterprises.

The version of PESTEL analysis that takes into account local, national and global factors is called LoNGPESTEL.

1. Local factors include protection of highly endangered animal species near construction sites.

2. National factors like the Euribor rate in Europe or Russia’s joining of the World Trade Organisation.

3. Global factors like crude oil price changes.

Changes and challenges have been examined and produced in a workshop of the project steering group (12 participants) and a seminar (INFRAEXPO 12 in FINBUILD exhibition) for sector professionals (120 participants). The next phase involves scrutinising emergent trends by sub-sectors at workshops and concretising them into infrastructure sector changes.

3. Forces of change

Mega-trends are global change processes at work everywhere. Giga-trends are the drivers behind mega-trends that change very slowly. Mega-trends, for their part, create national, regional and local trends that may be different, even opposite, to each other. Trends may also be studied from a sectoral viewpoint (Ahvenainen, 2009).

Giga-trends, mega-trends and trends indicate the direction in which the operating environment and a sector are moving. Giga- and mega-trends also change. New opportunities announced by weak signals are called meta-trends. Meta-trends can develop into new mega- and giga-trends (Ahvenainen, 2009).

This article seeks to find infrastructure meta-trends, i.e. possible new trends.

3.1 Giga-trends – drivers of mega-trends

Population growth: stable in industrialised countries, but large differences between countries. Population growth in Europe is slow while the populations of Asia and Africa are growing fast. European population is ageing and the birth rate is low. This giga-trend is not in line with natural resources and under pressure for change (Ahvenainen, 2009).

Economic growth: Though the financial crisis has caused economic turbulence in recent years, the long-term growth of the world economy has been quite steady. The slowing of economic growth due to an increase in the price of oil and certain key metals may have an impact on this giga-trend. (Ahvenainen, 2009)

Technological development: Technological development is a significant factor contributing to globalisation. Changes in sustainable development and global economy require new techology and a new type of infrastructure. The probability of a technology jump is increasing. (Ahvenainen, 2009)

3.2 Global mega-trends

Giga-trends cause mega-trends. The latter include scarcity, environmental problems, internationalisation and an increase in the number of disturbances and conflicts. (Ahvenainen, 2009)

Scarcity is the result of consumption growth in our finite world. Scarcity drives up prices of raw materials creating shortages of energy, food, water and land. Related environmental risks consist e.g. of pollution, depletion of natural resources, loss of biodiversity, environmental accidents and uncontrollable effects of genetic manipulation.(Ahvenainen, 2009)

Internationalisation and globalisation will continue. The increasing number of crises and conflicts will require international co-operation. That has increased and complicated

interdependencies. International decision making is becoming harder, protectionism is arising.(Ahvenainen, 2009)

3.3 European trends

In the next few years Europe will focus on restoration of economic health and overcoming the cost crisis of public administration. The recession may lead to economic exile within the EU. At the same time, the EU is becoming bureaucratic and is functioning more slowly. It is difficult to agree on what is in the common interest due to complex economic interdependencies.(Stevens et.al, 2006)

The pace of change in Europe is picking up. Enterprises, even entire sectors, are born and die at an ever increasing rate. So-called butterfly economies are emerging whose competitiveness is based on ability to change. The challenge is to make the existing linear operating model non-linear. (Stevens et.al. 2006)

3.4 Meta-trends

Meta-trends are change factors and drivers that change giga-, mega- and trends, i.e. the direction of change. Meta-trends include increasing polarisation and inequality. Both poverty and wealth are increasing. More natural resources are being consumed. As a result, it is becoming more difficult to understand entity management and change. (Stevens et.al, 2006)

Economic and population growth are giga-trends that can cancel each other out. They are also in contradiction with sustainable development and can lead to scarcity and environmental problems.

The so-called ’slow life’ is raising its head. Remote work is increasing and populations are ageing. Slow and small systems are gaining ground also in the economy.

Values and feelings have become more marked in working life. Responsibilities are becoming a counterweight to profit responsibility, cost-effectiveness and the knowledge society. Value management has made inroads into working life. That has led companies to use hired labour and transfer ownership to tax havens.

4. Global and local impacts of trends

This paper concentrates on the future changes and challenges of this type of enterprises and organisations operating in the infrastructure sector. The most important working method has been joint seminars of the parties to civil engineering (two have been held by October 2012). The first seminar was attended by 12 project management team representatives from companies and the public sector. The seminar focussed on identifying changes and challenges of the sector. The results were presented for appraisal and completion at another seminar attended by 120 people (Table 4).

Table 4: PESTEL analysis of infrastructure sector, national and international factors (Nippala, Vainio, 2012)

	Local (Infrastructure sector)	National (Construction)	Global
Economic	Networking of companies Securing financing of companies Tax planning	Accrual of government debt Private financing of infrastructure projects Cost of money (Euribor) Credit rating	Globalisation Global financial crisis WTO Economic growth of export countries
Political	Public-service user fees Network user fees, e.g. lane rentals/construction-time incentives	Public financing of investments Asset management and service level	European Stability Fund Global trade agreements, WTO
Technological	Deployment of BIM Machine automation	BIM Smart grid	Standardisation Patenting Innovations within intelligent transportation and infrastructure, carbon free energy
Environmental	Extraction of soil materials Replacement materials Innovations in storm water treatment Hearing procedure Co-operation between town planning and traffic planning	Eco-efficient community Decentralised energy production Renewable energy sources Natural resource conservation Permission procedures	Climate change Energy availability Low-carbon economy
Legal	Environmental permission procedures Road, rail, street safety competencies	Waste Act Soil legislation CE marking building materials	Safety and health requirements EU directives
Social	Labour availability Know-how Work safety Interplay within stakeholders Social license	Training (amounts) Social media Demographic changes, dependency ratio Citizen participation system	Changes in user needs Increase in inequality Immigration

Economic

Global: Development of the global economy has a big impact on infrastructure construction. The economy of many countries is dependent on exports. Public sector tax revenue and its ability to invest are tied to the success of export companies. This foundation is shaken by the tax planning of companies and the financial crisis. Global trade agreements are made to facilitate trade between countries.

On the national level, accrual of government debt reduces construction and maintenance of infrastructure for which the government is responsible. An effort has been made to complement the low level of funding by launching joint ventures between the private sector and local government. Life cycle projects have gained ground.

The financial crisis make it difficult for infrastructure construction companies to get financing which raises costs. Networking is carried out to improve the situation and competitiveness.

<u>Political</u>

The membership of the World Trade Organisation has widened. Russia was finally accepted as a member in 2012. The membership is expected to lower Russian import duties and ease trade when the complicated customs duties are eliminated.

On the national level, state and local governments finance a significant portion of infrastructure construction. Large infrastructure projects are built based on political decisions. Politicians decide whether state and local governments borrow when municipal tax revenue is not sufficient to cover investments. Asset management and maintenance of the service level of the existing infrastructure stock also depend on political decision making. Local government determines network user fees. They may be increased by a maintenance fee. However, the accruing funds are not automatically funnelled into maintenance.

Insufficient maintenance and neglected necessary repairs are leading to restrictions in the use of infrastructure. Life cycle-related repair of structures financed by tax revenue can be postponed, a case in point being the roads in outlying areas. Wear and damage that are a risk to personal safety, on the other hand, is repaired, a case in point being railways. Repairs are also done where related costs can be offset by user fees as in the case of the runways of airports.

The decision whether to charge rent for a lane occupied during the construction period is also a political one. Rent is conducive to a short construction period which cuts costs and disturbances to the environment during construction.

Technological

New technologies related to infrastructure construction include BIM models and global positioning systems (GPS). Wireless data as a tool in transmission in ground improvement or vibration measurement are examples of new infrastructure construction applications.

Intelligent transportation also saddles construction of new transport networks with new requirements and may reduce investment needs. For instance, traffic jams can be eased by controlling traffic lights instead of building new lanes or roads, telematics improve road safety, and sensors can monitor the maintenance need of crucial structures in real time. New materials and recycling of old ones can replace valuable natural resources.

On the national level there is need to increase the productivity of infrastructure construction by a technology jump. The building process involves too many unproductive delays. There, a technology jump can be taken e.g. by using the BIM model in production management.

When 3D designs are available for production, diggers and other earthmoving machinery using satellite positioning can be used.

Building of an eco-efficient, low-carbon society requires co-operation between planning, design and implementation.

Environmental

The disputed global warming has an impact on infrastructure construction which depends on geographic location. Rising sea levels threaten both small island nations and many large cities. No preparations have been made for rising water levels. Heavy rains are enough to show the vulnerability of communities.

The depletion of oil and exploitation of difficult deposits increase the price of oil thereby promoting a low-carbon economy.

National environmental issues include the Waste Act, which categorises an increasing share of waste as requiring extra handling, and protection of the eskers shaped by the Ice Age.

New recommendations and instructions concerning storm water treatment will be made to prepare for rainfall growth.

The environmental theme also includes the obligation to hear citizens at various stages of all construction projects. In addition to virgin nature, animals and plants, landscapes will also be protected.

Legal

The legal aspects of global factors are related to the safety and health of people during construction and use of infrastructure.

On the national level, laws and decrees have been enacted to conserve biodiversity. For example, conservation of endangered animal and plant species is governed by legislation. The National Esker Protection Programme is geared to the same goal.

Competencies dependent on the demandingness of the project are required locally of designers and builders of the infrastructure sector and companies. Personal competencies must be renewed at certain intervals (e.g. a blaster).

Social:

People's needs also as infrastructure users are changing globally. For instance, fixed phone lines have been replaced by fibre optic and wireless connections that enable mobile life. Work and study are no longer tied to a certain place or even country. Mobility has increased.

Ageing of the European population affects the need to make all services, infrastructure included, suitable for the elderly.

On the national level population growth and the dependency ratio affect the development of society. Though education is the result of political decision making, it is also a social factor. What share of each age group is to be left completely uneducated, and how many are to receive a university education?

The construction sector is suffering from too few people being trained at all skill levels. The skills shortage among those already working in the sector is also increasing as new IT is being introduced.

5. Conclusion

This study deals with the mega-trends affecting infrastructure construction around the world and derives from them concrete future challenges for local enterprises and organisations. Such concretisation is necessary since changes are usually treated on a much too general level to be of use for sector actors.

The speed of change has accelerated and future meta-trends quickly become concrete local mega-trends to overcome. Forecasting is needed since many organisations and enterprises react slowly to changes.

In future, the depletion of natural resources, population growth, environmental protection and changes in people's needs will place strong pressure on infrastructure.

The supply of soil and rock materials is not unlimited and has to be replaced by something. Population growth creates pressure to develop transportation systems, energy supply and water services. Congestions in cities will increase, energy consumption will grow many-fold from the present level and availability of clean water is under threat.

Infrastructure construction trends are being derived from the mentioned trends. The work has been started but has not yet been finished. The greatest challenges indicated by the intermediate results are infrastructure asset management, infrastructure maintenance financing, structural changes in the sector, labour availability and competence, EU directives and environmental legislation, soil materials and their reuse, and urbanisation.

For the local companies technological challenges are for example use of machine automation and training of excavator drivers. Also staff must have all kinds of competence (rail, road, street) to do certain work. Environmental challenges are to get permission to use soil. Recycling of soil is also growing in the future because there are shortage of good quality soil or rock. Social point of view companies must devote to better breakrooms, safety equipments etc.

Acknowledgement

This article is one part of project financed by Tekes – the Finnish Funding Agency for Technology and Innovation and national civil engineering branch organisations.

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The Characteristics of Public Real Estate Asset Management and Maintenance Practice in New Zealand Council Community Buildings

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Abstract

Asset Management is an important element of the Council's policies and assists delivery of its service objectives. Asset management is a vital role to facilitate organizational performance, both in the public and private sector. Most of the asset management literature suggests that there is a relationship between asset management practice and organizational performance. New Zealand, Australia and the UK are perceived to have the most advanced asset management processes, driven by strong government direction. The New Zealand Government, via its 72 local councils, have used Asset Management Plans (AMP) as a tool for managing, operating and maintaining its property.

This research studies AMPs for community centres in New Zealand local councils, and shows that there is no standard approach in asset management practice. Non-standard approaches are likely to result in poorer asset management and limited improvement in public asset management practice, due to differences in management systems, quality, levels of service and KPIs. Furthermore, the mechanism of how maintenance management adds value and enhances council property performance via AMPs, and the link between maintenance practice for community centres and organizational performance as an outcome, is unclear. Thus, there is a need to understand how asset management, in general, and maintenance performance measurement, in particular, for community centres, can be successfully applied to improve the performance of council community assets. This paper presents an overview of the current characteristics of the property asset maintenance practice that is being implemented by New Zealand local councils related to community buildings in New Zealand.

Keywords: Property asset management, Maintenance management, Local government, Community buildings.

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1. Introduction

Property asset management has emerged as a distinct discipline as part of a broader worldwide trend, especially in the private sector. The public sector has mirrored the reforms through adoption of private sector practices. These practices have not developed uniformly across the world, but Australia, New Zealand and the UK are perceived to be the most advanced, driven by strong government direction (Phelps, 2011). The government owns or uses a substantial amount of property and provides real estate for public amenities, for example public halls, libraries, administration buildings and community housing. Governments emphasize the importance of considering real estate as a strategic portfolio whose composition, extension and employment plays a key role for local government performance (Vermiglio, 2011).

In the international literature, the New Zealand public sector is often considered a world leader in central government driven public asset management reform (Kaganova and Nayyar-Stone, 2000). In the context of any organization or business unit, the focus of asset management is to reconcile the demand for, and the supply of, a physical asset base and associated support services essential for the delivery of its core products or services. In this case, the principle role of asset management is to support the core business of the local councils, that is community services. Shardy *et al*. (2011) identified that the main characteristic of asset management practice is the focus on maintenance management. This study investigates the maintenance management of public assets, identifies problems associated with current practices, and focusses on identifying how the local council and management committee understand and maintain these assets. The findings will help local authorities to determine the advantages and disadvantages of its current practice, and could be used to evaluate the capabilities of asset and maintenance management processes.

2. Asset management in the government sector

McDonagh and Hayward (2000) defined real estate asset management as the management (planning, organizing, leading and controlling) of real estate assets and related personnel of those organizations whose primary area of business is other than real estate. Kaganova *et al.* (2006) added that real estate management should be referred to as the process of decision making and implementation related to the acquisition, use of and disposal of real estate. RICS (2012), in their public sector property asset management guideline refer to the definition given by The Institute of Asset Management UK as ‘the management of physical assets, their selection, maintenance, inspection and renewal which play a key role in determining the operational performance and profitability of industries that operate assets as part of their core business’.

The principle of asset management has developed over the last decade, and a number of approaches, standards and models are used. Asset management improvements have been driven by influences including maintenance legacies, rising services standards, socio-economic changes and scare public funds (Kaganova *et al.*, 2006). Good asset management involves optimising within any absolute constrains, including the mix of cost, risk and performance over the whole asset life (IAM New Zealand, 2012). IAM further

explained that the lessons learnt over the last 20 years from different sectors, for example; electrical, water utilities, transport systems, mining and manufacturing industries is realizing great opportunities in asset management. In local government, good asset management makes an essential contribution to the governance and management of a public entity's business and is an integral part of an organisations wider service and financial planning process (Audit New Zealand, 2010). The main purpose of asset management for public entities is to provide a desired level of service through the management of assets in the most cost-effective manner.

In New Zealand, councils are required to produce an Asset Management Plan (AMP) as a tool for managing public assets for short, medium or long term periods. The benefit and need of asset management planning continues to be promoted by central government, and its profile has been raised in local authorities. This has been reinforced through the guidelines and standards produced by central government and local government. Through the AMPs, the central government are looking for more local authorities to improve the quality of their asset management planning (Audit New Zealand, 2012).

In the asset management literature, it is assumed that there is a relationship between asset management, facilities management, maintenance practices and performance. Amaratunga and Baldry (2000) stressed there is a causal link between facilities management practices and performance. Vermiglio (2011) in discussing the definition of corporate real estate management by Krumm *et al.* (2000) stated that the management of an organization's real estate portfolio is achieved through aligning the portfolio and its related real estate services (facility management, property management and maintenance management) to the needs of the core business (processes), in order to obtain maximum added value for business (processes) and to contribute optimally to the overall performance of the organization. Vermiglio (2011) added that one important factor in performance measurement in order to enhance the planning and managerial control system of real estate property portfolio is maintenance activities.

Most services are provided through facilities (Brackertz and Kenley, 2002), including in the public sector. IAM New Zealand (2012) explained the backbone to a good management system for assets is the clear connectivity between the organisation's strategic plan and the on-the-ground daily activities of individual departments in planning, engineering, procurement, operations (facilities), maintenance and performance management. Shardy *et al.* (2011) in discussing their research findings stated the main characteristics found in the current practice of government real asset management needed more focus on maintenance management.

White (2011) in discussing the link between asset management and performance measurement in UK public sector estate asset management, cited the report outline prepared by Howarth (2006):

> *"Measuring the efficiency and effectiveness of property and facilities management is a critical component of better real estate asset management and provide the opportunity for increased productivity and delivery of saving".*

Based on the above review of the international literature, it is clear there are vital links between property asset management, facilities management, maintenance practice and performance measurement both in building and engineering maintenance.

3. Local Councils and Community Facilities

Local councils play an important role by providing physical spaces for activities that help to build strong communities. They provide resources and community facilities as a way of meeting their organizational outcomes to the community. Community facilities are a good example of the way in which councils and communities work together to provide for the needs of the local citizen. These facilities need to be managed to ensure most of the services provided are available and achieving organizational goals. Poor maintenance and ineffective maintenance programming of community buildings will lead to loss of building performance, organisational performance and reputation, decrease of level of services, increasing operational cost and maintenance. Therefore, maintenance management in local government is an important factor to maximise the performance of physical and community infrastructure.

4. Methodology, Data Collection and Case Studies

A constantly changing society has meant changing need for some district facilities. Greater mobility, changes in population and changing leisure need has had a significant impact on some communities (Whangarei District Council, 2007). These changes need to be identified, measured and translated into an asset management plan. Audit New Zealand (2010) has been successful in identifying a number of asset management problems which may be caused by poor maintenance approaches. The current practice of local authorities typically addresses only some specific aspects of asset management and maintenance strategies due to different asset requirements, complexity of the asset and the absence of a standardized whole life asset maintenance management process. In this study, AMPs from four diverse local councils in New Zealand were reviewed to define the characteristics of public real estate asset management and maintenance practice, particularly for community buildings. Through the literature review undertaken, there are five main characteristics that were found to show the differences in the practice of public asset maintenance management implemented by local councils for community buildings namely, asset management plan documentation and policy, maintenance organization, maintenance approach, procurement arrangements, and continuous improvement. This paper will focus only on two of these characteristics; maintenance organization and maintenance approaches. Their operation and maintenance (O&M) issues will be discussed to show significant differences in their asset maintenance management practice.

4.1 Local Authority A

In this case study, a *'Community Hall Strategy Plan'* sets out the planning, operation and maintenance plan for 36 community halls under the jurisdiction of Local Authority A. The strategy of this management plan is to provide clear information of facilities provided, clarify council roles and responsibilities, explain the funding framework and develop a

comprehensive database. Local volunteers largely drive the planning and construction of community halls with assistance from district fundraising and donations. These volunteers are a vital part of the district's social fabric, and management and maintenance of the community halls still relies heavily on volunteers. In New Zealand, the national trend within local authorities is towards community halls both owned and managed by local communities, with the councils primary contributions being to the maintenance of the facilities. It means all community facilities are supported by Councils, with no distinction based on ownership, but the maintenance approach is different among local councils. In this case study, all community halls are managed by the volunteer hall committees, generally legally constituted as Incorporated Societies or Trusts. The council contribution to maintenance is limited to external maintenance, ground maintenance, landscaping, external works and maintenance and operating costs, for only a few Council-owned buildings or Council-owned land. Council also assists the committees in terms of maintenance costs by making a provision for a Community Hall Maintenance Fund and Community Grants Fund, to which the hall management committee can apply for financial assistance.

In asset maintenance, the council assists the hall committee by providing advice, expertise and resources to assist community halls with their property maintenance requirements. A comprehensive periodical facility inspection is carried out on all community buildings by the Council, together with hall committee representatives, and this establishes an agreed baseline of information on maintenance needs and determines the maintenance requirements. A medium to long term maintenance work plan complete with a budget of maintenance works is then developed based on the inspection report. Consequently, a Building Assessment Record is prepared and used in order to develop a prioritization framework which will help the technical team assess requests for community hall maintenance in terms of support for usage, on-going viability and maintenance needs for safety and health requirements. At this time, the hall committees are able to apply for extra funding for any other specific projects or one-off renovation works. Normally, council's annual budget will be processed after a schedule of community hall maintenance projects have been submitted to them. The council continues to assist the committee in insurance matters, auditing of community hall committee accounts, fire safety provision and requirements, developing Community Response Plans and giving advice on administration especially on legal requirements. Some issues have been identified in this case study which result in difficulties in decision making in operation and maintenance due to confusion between the committee and council interest, usage, roles, responsibilities and authorities. The main issue is the difficulty attracting and retaining volunteers as the management committee members.

4.2 Local Authority B

Local Authority B has developed a *Community and Recreation Facilities Asset Management Plan (2009-2019)* as a guideline for managing their community assets on a long term basis. It includes 11 community halls, 2 public pools, 3 libraries, 57 public conveniences, 57 pensioner houses and 1 museum which total $45 million. The council uses asset management software, providing an integrated database system which helps the councils in financial and specialist local government application system solutions. The asset

management database is the asset register for all of the council's assets and stores information on the assets. It includes the value, condition, life and renewal date of an asset complete with details of the asset recorded such as its materials, construction and typical life determined from previous knowledge. An effective asset management tool is essential for effective decision making in asset and maintenance management. This case study shows the District Council has used an information asset management system since 2002, and it provides a greater understanding of the asset network and its conditions, which help the council in setting out asset policy and decision making processes.

The council is responsible for maintaining all community facilities under The Community and Recreation Division. The main policy and management of the asset are set-out by the council and used by policy and asset managers in strategic planning, asset management, policy planning, operation and maintenance. The Council has developed a Lifecycle Management Plan which includes a 10 years financial forecast, to illustrate a comprehensive framework consistent with asset management practices and analyses the construction, operation, maintenance and renewal of facilities. The purpose of this management plan is to help the property manager in planning, managing and operating the assets at the agreed level of service, and optimising lifecycle costs.

Asset maintenance management practice in this case study focusses on routine planned maintenance. Periodical asset inspection and condition assessment is carried out as part of a 3 year cycle building maintenance program to identify the structural condition and any defects to building components. Through these inspections, all components are ensured to meet safety standards and specification, and these data are recorded for information gathering which will aid in planning facility maintenance, upgrades, replacement and renewals. Data produced from these inspections are using in lifecycle based expenditure analysis, and are compared to the long term strategic plan where work plans are identified and produced. All operation and maintenance works are planned and conducted in accordance with industry best practice and maintenance contractors are appointed based on their experience with council procedures. Maintenance of community facilities are generally determined by public safety, national or local significance, location, specialist use and level of usage. The decisions in regards of maintenance works are made based on knowledge, experience and public input, such as public complaints and requests, and available funds.

The Council categorised maintenance management into 3 types; scheduled inspections, scheduled maintenance and unscheduled maintenance. Scheduled inspections are the routine inspections to monitor asset condition and identify the physical and structural soundness of an asset. Any identified maintenance needs are recorded and reported either under urgent or routine status. This type of inspection is conducted by visual and hands on approach, but all data is recorded in a computerised information database using asset management system software. Scheduled maintenance is the periodical or cyclic maintenance to ensure the assets continue functioning at the standard and level of service identified. This allows the assets to reach their maximum life expectancy. Under scheduled maintenance, routine maintenance is conducted by the community team which consists of the day to day operation and maintenance. Unscheduled maintenance, therefore is undertaken to repair an asset, to correct faults identified by routine inspections and

notification from the users. This is generally reactionary works that has not been foreseen such as repairing vandalised assets.

4.3 Local Authority C

Local Authority C has produced a comprehensive *Building and Property Asset Management Plan (BAMP)* to provide an overview of what the property team will be doing to contribute to the community outcomes and priorities identified in the 10-year Long Term Council Community Plan (LTCCP). As a major feeder plan for LTCCP, this document helps the council in improving their business and service processes and practices to become more efficient and effective. It contains information regarding changes and achievements in the asset portfolio, current and future demand as key drivers of growth and usage trends, level of services, risk management, lifecycle of the assets, financial forecast and their assets improvement plan. An interesting part of this plan is on the value management framework whereby strategic and operational asset management is being measured, monitored and reported, as part of performance management in assessing the effectiveness and efficiency in achieving the outcomes. Thus, effective asset management will reduce the long-term cost of ownership and servicing to the council.

Operation and maintenance (O&M) of community buildings has been managed by the council under a property asset team which is divided into two main departments; Property Management and Maintenance Management. The maintenance management department is responsible in all operation and maintenance of public real estate assets in line with statutory compliance, capital and contract management while the property team manages a diverse range of leases, licences and tenancies. This case study uses a lifecycle management approach to operation and maintenance management. It contains four lifecycle activities necessary in managing the facilities: 1) Operations; day-to-day work to keep assets operating, 2) Disposal; sale, demolition or relocation of assets, 3) Augmentation; creating a new asset or upgrade beyond asset capacity, and 4) Renewals; does not increase but restores original capacity.

Asset maintenance management covers planned maintenance and unplanned maintenance, and operation of the maintenance works are undertaken on the Council's behalf by approved contractors. Routine maintenance or day-to-day work is carried out to keep all community buildings and facilities operating, running smoothly and complying with statutory requirements and agreed levels of service. The property team responsible for managing the community buildings categorized maintenance into planned or proactive operation and maintenance and unplanned or reactive maintenance. Planned operation and maintenance is pre-arranged inspection and maintenance works undertaken to maintain the assets and prevent asset failure. This includes inspection works, monitoring and follow up maintenance and certificates for building mechanical and electrical components. Maintenance contractors are appointed to carry out a series of regular maintenance activities. In some instances, follow-up action and maintenance will also be undertaken to keep the current level of service and keep up statutory compliance. The council uses single supplier contracts for all operation and maintenance in order to ensure the effectiveness and performance of the assets.

Unplanned maintenance is an action to correct faults and failure as required, for example in repairing storm damage, leaking roof and windows, and rectifying vandalism damage. Incoming work requests are recorded in the team's Task Manager System, prior to the work being assessed, and then assigned to a pre-approved maintenance contractor. In terms of its service level agreements, the team is responsible for responding and resolving the problem to the customer's satisfaction within an agreed time period. Similar to planned maintenance, the council has plans to create single supplier contracts for such tasks as afterhours call outs and responsive maintenance.

4.4 Local Authority D

In this case study, the council has provided the most comprehensive asset management plan in managing public real estate property, from those assessed, especially for community buildings. The council has developed a *Community Facilities Asset Management Plan* for yearly usage in managing their 48 community facilities, which is in line with a 10-year Long-term Council Community Plan, previously established for the management needs and work programmes for community facilities owned by the council.

This plan explains the service provided by the council, how they manage growth, demand and asset lifecycle, sustainability approach, financial report and risk in asset management practices. Rapid population growth is the major factor causing increasing demand for community facilities. In order to ensure all community assets are in good condition, asset condition information is used to prepare work programmes to replace existing assets. Most assets are replaced before they reach failure to ensure they continue to provide a cost effective service. Different to other case studies, the council has used building condition survey assessments in order to analyse failure and determine which community building are in most need of renewal. The council also adopted a sustainable management approach to asset management practice and asset performance measures are utilised to determine the levels of service. Levels of service focus on what customers' value about community facilities and the service provided. Performance measures are linked to the council vision through identification of the management strategy and policy. Monitoring the performance of community centres is a council responsibility with key performance measures outlined in the management agreement.

Most community centre buildings have been managed by the council, with others managed by a management committee under a partnership agreement. This case study shows planned and unplanned maintenance is undertaken based on data collection from building condition surveys. Maintenance needs are identified through condition surveys using the National Asset Management Steering (NAMS) group property approach, undertaken on a 3-year cycle by contracted building surveyors. Such needs can also be identified by the contract cleaners which are required to notify the council of any maintenance issues they find. Monthly inspections are also carried out by council staff. Responsive maintenance is for urgent repairs that are required to keep an asset functioning. The facility maintenance contract is outsourced and deals with response maintenance and smaller maintenance repairs that are carried out for health and safety reasons, or to protect the asset. Technical contracts include items such as building warrants of fitness, lift maintenance, heating

ventilation and air conditioning maintenance. They are typically routine service contracts that include small value responsive maintenance repairs.

5. Discussion

In the field of maintenance management, the term maintenance approach refers to the maintenance techniques and strategies such as preventive maintenance (PM), condition-based maintenance, total productive maintenance (TPM), computerized maintenance management system (CMMS), reliability centred maintenance (RBM), predictive maintenance (PdM), maintenance outsourcing, effective centred maintenance, strategic maintenance management, and risk-based maintenance (Garg and Deshmukh, 2006). Through this study, it is found that all case studies are practicing a general approach to maintenance management, with their own strengths and weaknesses. The discussion of the practices and a comparison based on the characteristics mentioned in section 4.1 to 4.4 is presented in Table 1. The asset maintenance practice of each case study varies according to the management policy and organisation, and building management strategy the council adopts. The study shows there is no standardisation in asset maintenance management, in term of asset management plan documentation, maintenance organisation and maintenance approaches.

- The case studies show that each council uses different structures and forms of asset management plans in managing their community assets. For example, the AMP for Local Authority A explains the role of local authorities and community facilities, addresses the current conditions and issues of community assets, and their recommendations for managing community halls. Local Authority D used a more comprehensive AMP which clearly explains their community services, shows how they manage the community's growth and demand, describes their asset management risks, policy and asset lifecycle in asset management practices, includes a financial summary of community assets and proposes their plan for improvement, monitoring and review procedures in public asset management. This shows there is no standardization in the documentation of AMP by Local Authorities in New Zealand.

- Community buildings under Local Authority A are managed by volunteers (hall committee) and assistance from the council seems limited, but the case of Local Authority B, C & D, community buildings are managed by the councils. This situation affects the organization structure and level of services in asset and maintenance management. The discussion on operation and maintenance issues shows that asset management carried out by local authorities is more efficient and practical compared to community assets managed by volunteers.

- Local Authority A, B and C used periodic asset and facilities inspection for a justification of the need of maintenance management, but Local Authority D used standard building prioritisation methods from building condition survey data for decision making processes related to assets and maintenance management.

All local authorities used asset condition prioritisation methods in decision making processes, but the techniques are different and there is no standard approach. Local Authority A used a committee prioritisation method, Local Authority B used an integrated database system, knowledge tools, experience, public input and available funds, and Local Authority C & D based prioritisation on asset condition and condition survey analysis.

Table 1: Case studies summary

Characteristics	Local Authority A	Local Authority B	Local Authority C	Local Authority D
1. Maintenance Organisations	Volunteers: Hall Committee	The Council: The Community & Recreation Division	The Council: Property Management and Maintenance Management	The Council
2. Maintenance approach:				
a) Condition audit	Periodical facilities inspection	Periodical asset inspection	Monitoring	Condition survey & inspection
b) Maintenance technique	Routine & planned maintenance	Routine & planned maintenance (Scheduled inspection, scheduled & unscheduled maintenance)	Planned & unplanned maintenance	Long-term maintenance, routine maintenance & response maintenance
c) Data collection method	Inspection & building assessment	Condition assessment	Remote sensing, physical inspections assessment model & rating systems	Building condition survey & monthly inspection
d) Decision making	Committee based prioritising method	Based on integrated database system, knowledge tools, experience, public input & available fund	Based on asset condition	Based on condition survey analysis

6. Conclusion

This paper presented the result of a study on asset management plans (AMPs) of four local councils in New Zealand. The main objective of this study was to identify the characteristics of public real estate maintenance management practice on community centre buildings implemented by these government agencies. The findings of this study show that in relation to published literature, there is no standard approach in asset management and maintenance practice for community buildings. New Zealand Audit emphasizes in their report in 2010 that, there has been no improvement in public asset management practice by most of the councils for the period 2007 to 2009, and that the current practice of deferred maintenance will store up problems for the future. The AMPs show there is no standard

approach to measuring performance of their assets due to maintenance activities, within the management of their public real estate portfolio.

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Integrated approach for development of automatic building application systems

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Abstract

Building applications / permissions are mandatory passing points from design to implement building construction. One important benefit from use of automatic building permission system is the possibility to check design solutions in advance, which might give a higher degree of predictability and reduced production time. BIM-based design systems (software and process) exist, and it is therefore a paradox that the number of solutions for automatic checking of building applications, complete or partial, is very limited. Specification of computable rules is a challenge. This paper argues for the need of increased integration between legal building authority, informatics and construction can enable a shift in development of regulations adapted for model checking. There are no clear terms for identifying different types of automatic model checking systems. A framework for classification of degree of automatic processing of building application systems is presented. A new Norwegian public project called "ByggNett" is presented to illustrate ideas for an automatic building applications system.

Keywords: Model checking, regulations, building permission, ontology, BIM

1. Introduction to the missing links

Building permission is a mandatory point for all building and construction projects. Considerable amount of resources are put into this manually process, both by the applicant and by the building authority. A digital automatic, or semi-automatic, building permission systems should give a simplification with more predictable result for the applicant and less effort by the authority. The interest for automatic solutions should therefore be high. All "stakeholders" notes the need for improvements in this field, however the guts to take part is hard to discover. The regulations (law, act, code, directive, and standards) are written for human / professional interpretation. Converting regulations into computable rules is therefore not a straight forward job. Use of function based regulations is an extra challenge. According to previous study by Hjelseth (2012a, b) is a well-defined procedure for transforming regulations into computable rules needed for valid and reliable results. Can a multidisciplinary approach contribute to improved interpretation and prepare for implementation of rules into BIM based model checking software?

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The regulations are at national level (in Norway), but the processing of the applications is at local level. This has both to do with the legislation, and with the economy model. The application fee is going to the local building authority and calculated at full cost coverage. This reduces economic incitements for improvement of the application process, and development of joint national wide project for a joint solution. Maybe the outcome of increased degree of automatic processing of building applications must be valued as more predictable results, (and increased activity in the industry) and more targeted regulations (regulations can be tested on a variety of models / buildings).

2. Development of systems for automatic checking of building applications

2.1 Need for an integrated view

The arguments for an integrated approach is based on a perspective of development from the single domain view of the legal, informatics and construction domain, through the double domain view and ending up with a triple domain view which focus at the interface between legal, informatics and construction. The integrated approach is illustrated in figure 1.

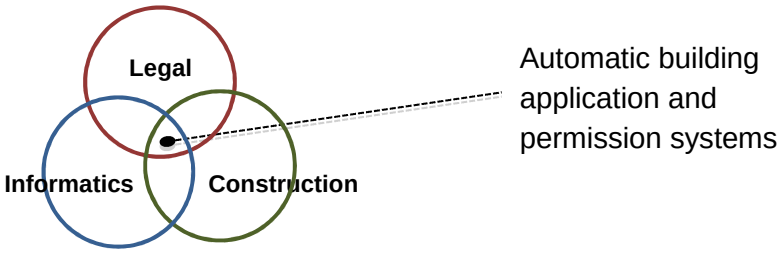


Figure 1: Model of integrated approach for automatic building permission systems

We start exploring these three domains by taking a single domain view and expand this to a double, and finally to the triple domain view of integration.

2.2 Single domain view

The three domains in the single model view model are:

- Legal specifications of regulations (regulations include: law, act, code, regulative, directives, standards etc.). Legal is a domain with long history and its own “language”. Legal have tradition for interpretations and references to other regulations for complete interpretation used in a single concrete case. Solving the discussion about “Performance based” versus “Prescriptive based” regulations is an important part of making regulations computable. Performance based specifications are known as “recipe” specifications, while prescriptive specifications are known as “end result” specifications (Gibson, 1982). BIM-based model checking software works with discrete metric. Prescriptive statements are therefore in principle prepared for implementation into BIM-based model checking software. Performance based specifications have quantitative goals or objectives. They are in principle much more interpretable, but might give better conditions for innovative new solutions

(Oleszkiewicz, 1994). Implementing this type of statements into model checking software is not a straight forward process.

- Informatics is a broad domain and often divided into two disciplines; the natural science based computer science and the organizational aspect from social science. The first domain is about “systems for how to exchange data” (syntactic / semantic interoperability). Use of standards from W3C such as Web Services, XML technology, and support for Sematic Web (W3C, 2012) and IFC and IFD (built on ISO standards) from buildingSMART (2012). The second domain is more focused on process and collaboration for “Systems for specification of information to exchange” (semantic / organisational interoperability). Use and IDM, Information Delivery Manuals (buildingSMART 2012) based ISO 29481-1 standard is an example of applicable specification of solution. Development of solutions can also be divided into three stages: 1) system design – 2) software programming 3) implementation. This paper focus on primary on system design.

- Construction includes architects, engineers, contractors, facility management (AEC/FM-industry). The industry is fragmented and the complexity and relations of work and information flow is hard to understand for outsiders. Process – and much of the information flow - is based on accumulated knowledge. Implementation rate of ICT is very low compared to heavy investment industries such as aerospace. The fragmented AEC/FMO industry is therefore very dependent on standards, both on legal issues like contracts and specifications system of product and works, as well as within ICT, where use of the ISO based IFC format is increasing.

2.3 Double domain view

As illustrated in figure 2 there are three well established research domains. But there is a lack of research projects, and research traditions, that covers the challenges regarding model checking of building applications. If we split the integrated figure 1 into double interactions, we find some established research approaches, illustrated in figure 2.

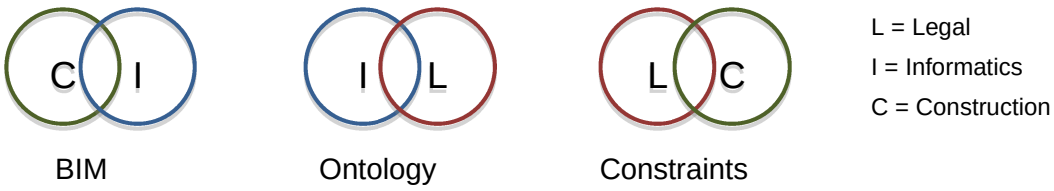


Figure 2: Combinations of interference between informatics, legal and construction

- BIM - building information modelling can be regarded as the crossover between informatics and construction. So far, the focus on “the I in the BIM” has been limited. Most focus is still on 3-D geometrical representation and visualisation. Agreement regarding delivery of information is not in practical use, despite that BuildingSMART has adopted the IDM standard (based on ISO 29481-1:2010) as one of its three “pillars” of BuildingSMART..

- Ontology: Regulations are based on text written in a way that often has to be interpreted. There is a challenge regarding function based and prescriptive regulations (IRCC, 2010).

Terms and definitions is not a part of the regulations (as with standards. Established practice makes interpretations more easy / predictable. Legal text is not structured for implementation into model checking software. The connection between regulations is also a challenge. Use and understanding of a term in one regulation is not necessary identical in another regulation, or can be identical under some conditions, but not all.

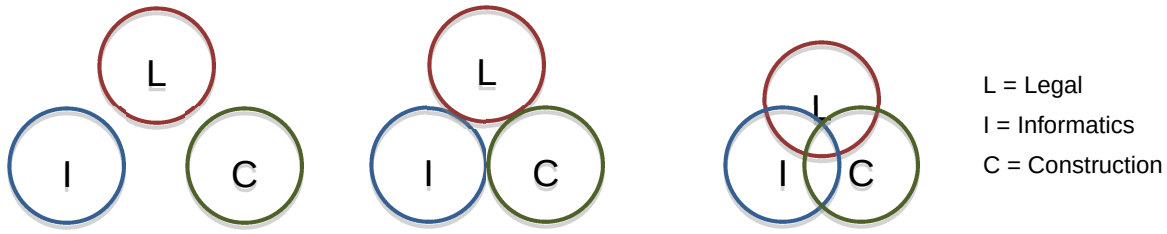
Understanding the impact support of tagging the text in regulations with RDF, (Resource Description Framework), (W3C, 2012) for strong semantics will be a large improvement for further system development. An example is the “Byggeregler på ett sted” (Regulations in one place) by the Norwegian Building Authority. This is a web-based archive with all relevant regulation, law, code, and guideline. This includes also previous versions, compared to paper based version, or finding the information by responsible authority, collecting and updated list of links is an improvement. However, compared with a RDF solution enabling search across all relevant documents, is the potential for further development very positive. Even if ISO offer standards in XML format, most standards are still only available in digital format as pdf-files. (ISO, 2012). ISO concept database is a collection of “Clause 3 - Terms and definitions” from all standards, but the concept database is not prepared or designed for advanced semantic search. However, when dealing with legal documents must the “doctrine of sources of law” perspective be included.

- Constraints: The legal regulations are determining what is mandatory to be included, or excluded, in a building project. This is done by defining requirement by putting up max or minimum values, including elements (such as elevators if the building is above a defined number of floors). This is defining constraints or framework for the design solution. Presumably it should be easy to understand, and implement, logical word by word, in a model checking system. However, this is not as easy as it looks like. The regulations are not clear about what information is needed. The definition of the metric in the regulations is often not clear enough – or open for definitions – or extremely detailed in millimetres. This can cause increased conflicts of interests between the political intentions of the regulations and what is realistic to conduct. Use of discretional assessment is a challenge – especially when the local authorities make their own assessments.

A classic situation is the inherited conflict between performance based and prescriptive based regulations. Identifying relevant metric is important when interpreting function based regulations into a model checking system which only process discrete metric. Studies by Hjelseth (2012a, b) and by Hjelseth & Nisbet (2010, 2011) indicate the defining metric from performance based regulations is solvable as “parametric” rules. The doctrine of sources of law must be taken into is relevant to give valid transformation of regulations into rules applicable for automatic BIM based model checking.

2.4 Triple view perspective; The integrated L+I+C model

The limitation with the double view can be reduced, or removed, by use of the triple view model which are focusing on the interactions between all three domains; Legal + Informatics + Construction. The L+I+C model are presented in figure 3. This model can be used to illustrate how large is the common domain for automatic checking of regulations.



Stage 1: No interaction
Stage 2: Some interaction, aware of each other's "situation", but no common domain
Stage 3: Further integration – common domain – Model / Rule checking is established

Figure 3: The L+I+C model for development of integrated triple domain view

The interaction between the three domains in practical / concrete situations does not have to be symmetrical, regarding number of "elements" between the domains. In many cases will the double view be the starting point, and supplement of the third domain does not result in a radical re-development of all domains. The new, third, domain will often works as a catalyst and trigger small changes with large impact.

An example of this is the previous example with function based regulations and defining of metrics. By use of informatics, it is practical to process an increased number of metric. Instead of using pre-accepted solution, it is possible to define a list of "characteristic properties" (the unique properties used when testing the pre-accepted solution). This does not imply a re-structure of the regulations itself, only a reference to the list of characteristic properties where they have used qualitative indicators. Processing would not be practical without an integrated view. List of characteristic properties would not be regarded as "simplification" in traditional human use of the regulations due to more text/specifications. The regulations have only to include a reference list of characteristic properties. Existing pre-accepted solutions can be used as a foundation for specification of characteristic properties. The informatics is just using its capacity to process large amount of discrete data. Model checking within this context can now be done with high degree of automatic processing with valid and reliable outcome.

3. Classification of degree of automatic processing of building application systems

Lack of harmonized terms for describing comparing solutions for automatic processing of building applications makes it hard to understand the content and purposes of different solutions, and to compare degree of automatic processing in different solutions. Table 1 presents a framework for classification. The taxonomy for classification is based on identifying degree of automatic collection of relevant information and degree of automatic assessment of the application.

Table 1: Framework for classification of degree of automatic processing in public building application systems

Level/ Term *)	Service: Automatic/ Manual	Applicant filling in	Input from other public registry	Submission system	Output to other public registry	Building authority Approval
0	Manual 100 % 0% / 100 %	Manual writing into paper forms	No input	Physical mail, hand-over	No output	Manual
1	20% / 80 %	All forms manual on computer	Registry managed by building authority	Transport by e-mail. Mail allowed	Information to other public authorities listed in application	Manual, but complete application checked automatic
2	40% / 60 %	Check that all forms are filled in	Business registry	Submission system with feedback of correct received Mail allowed	Digital transfer to some registry after manual control of quality	Pre-defined regulations done auto. Checklist on manual
3	60% / 40 %	Adapted forms, filling manually, some automatic transfer from other sources	Map / visualisation	Submission system with feedback of correct received Mail not allowed	Digital update of some registry. Manual /semi-automatic control of quality	Pre-defined regulations done auto. Report on regulation to be checked manual
4	80% / 20 %	Mostly automatic transfer from other sources / software systems	Geo related info like ownership of property. Regulations of site etc.	All information received digital by one system. High security. Mail not allowed	Geo reference of building. Ownership of property. Liability	Most regulations checked automatic. Manual overview and assessment of complicated reg.
5	100% / 0 % Automatic 100%	Automatic information from internal systems	Automatic from all registry	All digital received. Feedback on progress	Automatic to all registry	All computable regulation checked auto. Min. manual

***)** Terms related to each level:

0. Manual system
1. Form based submission system
2. Form validation system
3. Digital application system
4. Integrated digital application system
5. Integrated digital application and validation system

4. Development of technical solutions

4.1 Development of commercial solutions

Commercial software like Solibri Model Checker (use IFC-based, information rich) from Solibri Inc. in Finland (Solibri, 2012), and in some degree Navisworks (use several formats, but limited information) from Autodesk in USA (Navisworks, 2012) illustrate the potential in model checking. However, commercial solutions do not include rule-set of public regulations. This could be an option if the national building authorities developed and delivered detailed specifications (IDMs) for programming computable rule-sets. The commercial software developers could compete in offering customized services to their clients.

4.2 Overview of developed national public solutions

Digital solutions for processing building applications are not common service. Lack of common international terms makes it hard to discover potential solutions in other countries. The “CORENET” e-Submission System in Singapore is well known (CORENET, 2012). UK has developed the “Planning portal”; UK Government's online planning and building regulations resource for England and Wales (Planning Portal, 2012). Korea is developing the Seumter Code Checking System based on research at the Kyung-Hee University (Kim, 2012). This list is not comprehensive and the author appreciates feedback about other initiatives. Norwegian Building Authority has developed a “ByggSøk” (Building Application) opened in 2007. This is a web-based solution for verification of filled in forms related to specific types of applications. They plan to develop a more sophisticated solution called “ByggNett” (DIBK, 2012).

4.3 Development of public solutions for digital building applications in Norway

4.3.1 ByggSøk Norway

The internet based building submission system called “Byggsøk” was opened in July 1st 2003. The development lasted for three years and the cost was about 2 million Euro (2003 rate). With ByggSøk can the builder fill out the application and sent it via the internet. The level of service and complexity is illustrated in figure 4 (DiBK, 2012).

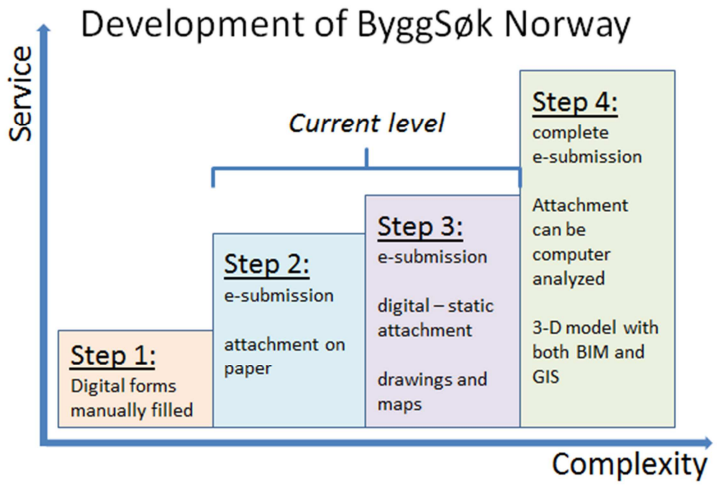


Figure 4: Development progress of the Norwegian ByggSøk solution (DIBK, 2012).

ByggSøk verifies that all required “fields” in the application forms are filled in before it can be submitted to the local building authority. Present version of ByggSøk cover step 3, but do also allow use on step 2. Step 2 in ByggSøk corresponds to Bew-Richards (2008) BIM Maturity Model (“the Wedge”) at level 1. Step 3 and 4 corresponds to level 2 on the Bew-Richards 0 to 3 scale.

In 2012 was approximately 110.000 applications submitted to the local building authority. Approx. 37% was submitted as paper-based forms (completed manually on paper, or as print-out of pdf-forms completed manually on the computer). ByggSøk was used as a tool for completing approx. 70.000 (63% of total) applications. The processing of all applications

submitted by ByggSøk is done at the local building authorities, in the same way as traditional applications based on paper forms. The application from ByggSøk can be submitted as:
1) printout on paper and sent by mail ordinary mail / delivered manually local building authority office. This enables supplement of paper drawings and other documents.
2) digital files by internet. The application forms as one single pdf-file, in addition to an XML structured file. Supplementary documents and drawings must be attachments as pdf-files. There is an option for submitting additional documents / drawing by mail. The processing does not start until the local building authority receives this.

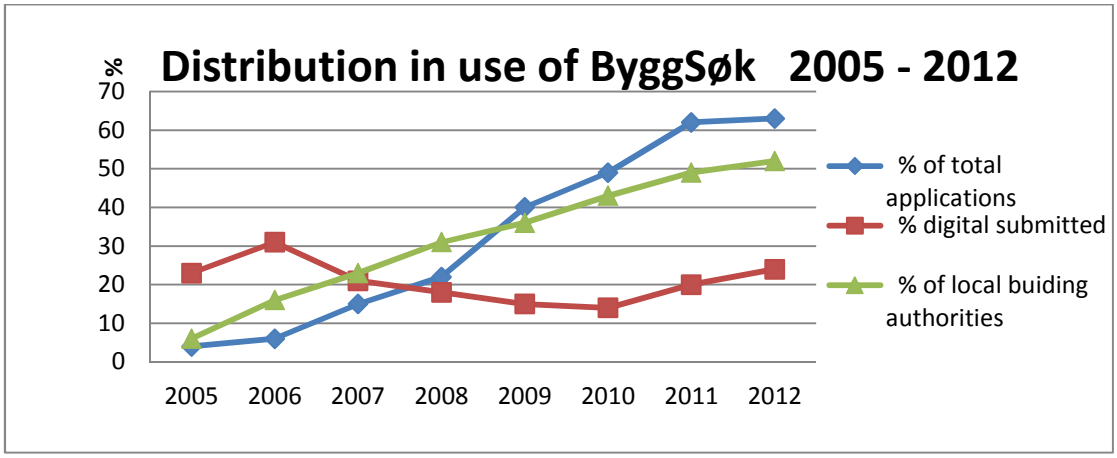


Figure 5: Distribution in use of ByggSøk 2005 - 2012 (DIBK, 2012).

Figure 5 illustrates an increase in use of ByggSøk as tool for preparing the application. However, the percentage of digital submission has not increased. The Norwegian Building Authority points out two perspectives as possible explanations:
- Applicant: Large number of documents from many sources has to be digitized. ByggSøk is only used to ensure that all relevant forms are filled in. No benefits (reduced fee, shorter processing time) for 100% digital applications. ByggSøk is used as an advanced "application writer" with input validation of fields in the form (but no validation of content).
- Local building authority: Lack of system to process the applications in a digitized way (XML-import and use of digital attachment). Received applications are printed out and processed manually.

4.3.2 ByggNett Norway

The Norwegian Government has in their white paper to the Parliament (St.meld. 28, 2012) given priority to the development of "ByggNett" (BuildNettwork) as a common platform for exchange of digital information in the AEC/FM-industry. The ambitions includes:
- further development ByggSøk into the new ByggNett framework for collaboration
- national registry for documentation of buildings
- integration of building information modelling (BIM)
- increased digitizing in general for all processes in the AEC/FM-industry
- integration of "Altinn" (extensive public Norwegian web-based solution for tax and business information)
- re-development of regulations (preparing for automatic model checking of projects)
- high focus on simplification (this is supported by a "Bygg enkelt" (Build simply) project.

Principles aligned with directives from the Norwegian Agency for Public Management and eGovernment (DIFI). They have proposed how joint national components should be managed, financed and developed. Common components or "building blocks" are defined as components in the IT solution that can be jointly used or reused in multiple IT solutions that allow the development of electronic services in the public sector. (DIFI, 2012).

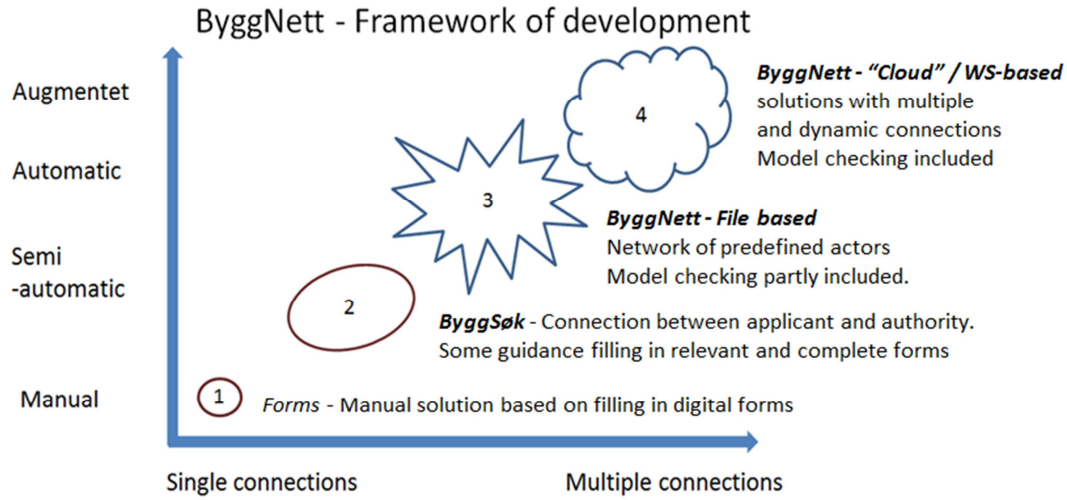


Figure 6: Possible development positions for future ByggNett solution

Figure 6 illustrates the dynamics in a possible development of the "ByggNett concept". Stage 3 represents a file-based approach where use of BIM models in IFC-format has a central role. Partly implemented model checking indicates that some parts of the regulations are not prepared for automatic (semi-automatic) checking. The information exchange is between predefined (known) actors. Stage 4 represent a "cloud" based solution based high degree of Web-Services. This requires well defined specifications of the information exchanged – so the receiver only get what's relevant. The following quote from the white paper to the Parliament (St.meld. 28, 2012) illustrates a pervasive approach for development of new and integrated solutions and services:

> ***"A scenario for the digital construction***
> *…..In the future, a builder could start with a digital model of the site with associated infrastructure that can be downloaded from the Internet. It automatically gathers information from many public and private registers (map data, property data, neighbour addresses, geological setting, the model of existing buildings etc.)*
> *…. With the aid of data from model, the builder considers alternative and environmental consequences, make live analyses and calculate costs. …*
> *….The digital model contains all the information needed for applying for a public permits and for a complete build process. The authorities have aligned building regulations so that the developer can check the model builder already from the sketch phase and throughout the modelling process.*
> *…. All relevant authorities interact on the same model.*
> *… When the building is finished, the public and private registry can be updated with relevant information from the model. In this way will the public have all necessary information about the building accessible for later needs….*"
>
> (St.meld. 28, 2012). Translation by author.

This states an ambition aiming complete digital information flow and pervasive use of digital solutions. The augmented perspective – to prepare for future needs – which will need more information about a large number of use cases. ByggNett will act as a role model of public government to take the leadership for digital collaborations processes in the AEC/FM industry – and public authorities involved the AEC/FM sector (DIBK, 2012).

4.4 Impact of model checking support

Use of model checking support can be regarded as a helpful tool and the catalyst for digitalization for the AEC/FM industry in general. The AEC/FM-industry is in most countries a highly regulated sector. In Norway a large number of public authorities can have an influence on the building application outcome. Examples of relevant authorities are: Labour Inspection Authority, Food Safety Authority, Directorate for Cultural Heritage and more. For the applicant is faster processing and lower fee of building application is of course relevant. But looking closer, this is most important in smaller projects were this has a higher ratios compared to design time and project cost. However, maybe the qualitative improvements resulting in more predictable outcome is the most important impact. The ability to use this as support during the design process can have significant impact on the design of buildings. Likewise can the national building authority use digitalization during development of new regulations and to explore consequences of new regulations and to identify interactions between different regulations. Internal survey at the Norwegian Building Authority (DIBK, 2012) regarding coordination about regulations for buildings in use pointed out that many regulations was overlapping, and could be collected in a single common regulation with just minor parts for each authority. The list of benefits of automatic assessment systems includes:

- Equal requirements for information for all local authorities
- Equal assessment for information for identical type of projects
- Digital information enables reuse for other purposes.
- Digital network of information
- Solutions for pre-check of application in advance of formal submission
- Support for design according to the regulations.

5. Discussion

The arguments in this paper for an integrated approach are based on principle and theoretical approach for an “ideal” solution. The empirical foundation in this paper is limited. A large number of legal and technical issues regarding development of digital solutions for automatic processing of building applications are not included in this study. This paper does therefore not give the full picture. The proposals in this study can therefore only be used as guidelines for development and further research.

6. Conclusion

The “L+I+C model” (legal + informatics + construction) explain the need of an integrated approach for development of automatic building permission systems. The L+I+C model clarify the interface between informatics, legal and building aspects and gives an overview of what can be applicable for automatic, semi-automatic or manual compliance checking. Support of automatic, or semi-automatic, building permission systems is assumed to give a simplification with more predictable result for the applicant and less effort by the authority.

Use of terms is often confusing, making it hard to understand content and functionality in application systems. To improve this situation a framework for classification of automatic / semi-automatic building permission systems been developed.

7. Further research

Further studies will focus on identifying countries and projects which develop and implement systems for processing of building applications. Analyses will include study of submission and validation / model checking systems and type and number for rules implemented. The author welcomes information about relevant projects and possibilities for collaboration.

8. Acknowledgement

Acknowledgement to Norwegian Building Authorities for sharing experiences, information about ByggSøk application and history and strategy for development of future ByggNett.
A special thanks to architect and elk hunter Lars Aasness for spending his spare time to comment this paper.

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The Mixed Use Residential Building: A building block for the cities declared saturated by air pollution in Chile's Mediterranean Climate.

Christopher Whitman[1], Gabriela Armijo[2], Leticia Roubelat[3]

Abstract

This paper presents an analysis of the problem faced by the cities of Chile's central valley and a study of the current international and Chilean situation of a specific building typology: the mixed use residential development. Chile's central valley has a Mediterranean climate characterized by cold winters and hot summers. Almost all of the cities located in this region have been declared saturated by airborne pollution PM10 directly resulting from thermally inadequate housing stock and the inefficient burning of poor quality wood for heating and cooking. Through their emphasis on single function zoning and mono-functional modernist planning, the Chilean planning instruments lead to increased journey times and a reliance on the private car for daily transport, adding to the airborne pollution. In 2007 the Chilean government introduced thermal building regulations for residential properties; however their low requirements have been criticized at both a national and international level. Some private and public residential projects have attempted to improve their energy efficiency but to date these projects have focused on the single family dwelling, a housing typology inherently inefficient due to its high surface to volume ratio and its implied land use. The sustainable mixed use residential building offers the opportunity to provide efficient housing, workplaces and basic services in the same built form thereby reducing unnecessary journeys and promoting community cohesion. The international case studies show that there exist the necessary technologies and theoretical knowledge, whilst the review of the national situation concludes that although there exists interest and political will, developers are unwilling to innovate and take a risk on an as yet unproved market. Time is therefore required to allow research and the testing of a business plan for a prototype of a building block for a sustainable future for Chile's contaminated cities.

Keywords: Housing, mixed-use, energy efficiency, airborne contamination

1. Introduction

According to the latest national census of 2012 (INE 2012) over 50% of Chile's population are concentrated in the Central Valley. The climate of this region is classified by Kottek et al.

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(2006) and Russo et al. (2008) as Mediterranean, a warm temperate climate with short cold winters of 4 to 5 months, dry summers with intense insolation and diurnal thermal oscillation averaging around 20ºC in summer and 10ºC in winter. The region runs north-south from latitude 32.8º South to latitude 37.2º South over a distance of 480km and is bounded to the west by the Andes and to the east Chile's coastal range. The topography formed by these mountain ranges and their lateral spurs creates a series of interconnected bowls with poor ventilation which, coupled with a thermal inversion layer approximately 500m above ground level in winter, traps the airborne pollution produced by the regions cities and industry. As a result many of the cities have been officially declared saturated by airborne contamination PM10 by the Ministry of the Environment (Table.1).

Table 1: Zones declared saturated PM10. Source: SINIA Sistema Nacional de Información Ambiental

Location	**Region**	**Year declared saturated (PM10)**	**Principal source of airborne contamination**	**Decontamination plan**
Chuquicamata	II Region, Altiplano	1991	Mining Industry (smelting)	Implemented 2001, zone declared latent 2005
María Elena y Pedro de Valdivia	II Region, Altiplano	1993	Mining Industry (smelting)	Implemented in 1997. Complied in 2010
Santiago	Metropolitan Region, **Central Valley**	1996	41% **I**ndustry, **38% transport**, **16% firewood** 5% agricultural fires.	In place since 2003 – Definitive Project currently being considered by the President of Chile
Temuco-Padre las Casas	IX Region, **Central Valley**	2005	**93% Firewood**, **7% Transport** and others	Definitive Project currently being considered by the President of Chile
Concepción	VIII Region, Coastal	2006	37% industrial **32% Firewood** **3% Transport** 34% Other	Feasibility study being developed
Tocopilla	II Region, Coastal	2006	2 Coal fired Power Stations	Definitive Project being developed
Rancagua y valle central de la IV Región	VI Region, **Central Valley**	2007	**28% Firewood** 32% dust 25% Mining Industry (smelting) 15% Other	Feasibility study being developed
Calama	II Region, Altiplano	2009	Mining Industry (smelting)	Feasibility study being developed
Talca	VII Region **Central Valley**	2010	**Mainly Firewood**	
Chillán	VIII Region, **Central Valley**	2012	**Mainly Firewood**	
Osorno	X Region Lake district	2012	**Mainly Firewood**	

In many of the cities declared saturated, emissions from firewood for heating and cooking play a major role. Given that all middle class and social houses are not provided with central heating, inhabitants must post-fit their own heating solutions, in many cases opting for the most economical solution rather than the most efficient. In the case of the cities of Temuco–Padre las Casas the Plan for Decontamination (CONAMA 2009) identified three major

contributing factors; poor quality firewood with a high relative humidity; inefficient stoves and fireplaces lacking double combustion; and the poor quality of the building stock with insufficient thermal insulation. The other common factor present in many of the cities is the airborne pollution produced by transport, a direct result of planning policies which create ever greater commuting distances and a reliance on private cars.

1.1 Official Plans for Decontamination

By law those cities and regions declared saturated by airborne pollution must develop an Atmospheric Decontamination Plan (Plan de Descontaminación Atmosférica PDA). In the case of the Metropolitan Region of Santiago this plan concentrates principally on improving the quality of fuels used by industry, transport and residential. It does however mention the need to promote the best use of the capacity of existing urban fabric, that is to say densification (Congreso Nacional de Chile 2010). The plan for the twin cities of Temuco-Padre Las Casas in Chile's 9th Region is more specific in its reference to the built environment. The thermal improvement of residential building envelopes forms one of the four key measures, alongside the improvement of firewood quality, replacement of inefficient wood burning stoves quality, and an education program to increase public awareness (Congreso Nacional de Chile 2010). The plan highlights the need for both the refurbishment of existing housing stock and the efficiency of new residential projects. Studies have shown that improvements to the building envelope above and beyond that required by Chilean thermal building regulations could reduce household heating energy consumption by between 54 & 68% (Ambiente Consultores 2007), with an estimated overall financial benefit of US$48.8 million when both savings in fuel and healthcare are included (Congreso Nacional de Chile 2010). Initiatives are currently in place for thermal reconditioning of existing dwellings, however as yet there is no requirement or incentives for raising the standard of the 15,000 new dwellings built every year in the region (INE 2012).

It therefore appears that an additional part of the solution to the problems faced by the cities of Chile's Central Valley should be the search for a new residential building form that is designed to be energy efficient and that incorporates a mix of uses with the intention of reducing unnecessary journeys and maximising the use of already urbanized land.

1.2 Housing in Chile

1.2.1 Thermal conditions

Of the 5.7 million dwellings in Chile (INE 2012) 63% were built prior to the introduction of the Chilean Thermal Building Regulations. These regulations were introduced in two phases. The first introduced in 2000 required only thermal insulation of the roof with thermal conductivity (U-values) defined according to 7 thermal zones calculated according to the heating degree days. U-values requirements for roofs in the Central Valley range from 0.47 W/m^{2}K in the north of the region to 0.38 W/m^{2}K in the south (Instituto de la Construcción 2006). In 2006 the second phase of the regulations was introduced covering the insulation of walls and ventilated floors. U-vales for walls range from 1.9 W/m^{2}K in the north of the Central Valley to 1.7 W/m^{2}K in the south. Although Chile was the first Latin American country

to introduce Thermal Building Regulations the required thermal conductivity has been criticized both at a national (Bustamante et al. 2009) and internationally (Caldera Sánchez 2012) for their leniency. Many believe that six years on from their introduction the requirements for walls require revision and updating.

A survey by the Instituto de la Construcción (2008) of 402 dwellings located in 29 housing complexes in 4 different Chilean cities showed an average indoor winter temperature of 15°C. These dwellings were constructed in 2002, that is to say after the first phase of the regulations but prior to the second and so therefore should have insulation in there roof build up. It also indicated problems of overheating in summer and 80% of the properties presenting problems related to condensation and mold growth.

1.2.2 Fuel Poverty

The concept of fuel poverty was defined by by Lewis (1982) in the National Right to Fuel Campaign in Bradford UK as "the inability to afford adequate warmth in the home". This definition was revised by Healy (2004) to one that related specifically to housing design as "The inability to heat ones home to an adequate (safe and comfortable) temperature owing to low income and poor (energy inefficient) housing." The term refers to households that must spend over 10% of their annual income on fuels in order to achieve satisfactory indoor heating. This calculation is based on the theoretical value that a household would need to spend and not their actual expenditure. In many cases the required cost escapes the financial means of the household and so satisfactory indoor heating is not achieved. Therefore a household suffering from fuel poverty either spends too much on heating fuel and/or suffers poor hygrothermal comfort. A study by Márquez et al. (2006) showed that all but the richest two fifths of the Chilean population suffer fuel poverty.

1.2.3 Urban Planning

Since the 1930s Chilean urban planning has been dominated by the North American modernist model of single use zoning which discourages or actively prohibits mixed use developments. Large areas of cities are developed as purely residential neighbourhoods with no requirement for the associated infrastructure such as schools, preschool nurseries, convenience stores and workplaces. This obliges the residents to use motorized transport even for simple everyday tasks. Despite government initiatives, such as Transantiago in Santiago which intended to improve public transport, both buses and metros continue to be overcrowded and run with no fixed timetable. Due to a shortage of new buses, many old, highly polluting buses were reintroduced to Santiago streets during the first year to meet the passenger demand. Outside of Santiago public transport remains based on small diesel buses that in general lack regular maintenance. At the same time the drive for meeting social housing targets has lead to the selection of sites based on their low economic value as apposed to the convenience of their location, almost always being located on the city limits far from work opportunities. This has lead to ever increasing commuting times and costs for those who have the least income. Even for the wealthy the desire to live in a detached house with individual garden has lead to urban sprawl and a reliance on the private car. Isolated attempts at regulations to promote mixed use developments have been unsuccessful due to

conservative developers who resist innovation. In addition mixed tenure has not been possible due to regulations related to social housing grants. The current government in its manifesto proposed changes to housing policy which would allow the purchase with government subsidies of existing or new-build dwellings not located within social housing blocks. This may pave the way for a market in mixed tenure residential projects, however to date the government has made no changes to the existing laws.

To summarise the study of the context of Chilean housing we can conclude that all Chilean dwellings, both rich and poor, do not provide good hygrothermal conditions; that the current thermal building regulations are insufficient; that all but the highest socioeconomic strata suffer fuel poverty; that heating systems are inefficient and that mono-functional planning policies augment dependence on motorized transport both public and private. As a result of all these factors airborne pollution is elevated to the point of saturation, impinging on the health of the cities inhabitants. Well designed, thermally insulated, mixed use residential buildings would suggest a possible component, which along with other measures such as upgrading of existing building stock and cleaner fuels, could provide the first steps towards resolving some of these problems. There follows a study of some international examples of mixed use residential buildings which aim to provide the building block for sustainable communities.

2. International Case Studies of Mixed Use Buildings

2.1 Stonebridge Hillside Hub, Harlesden, London, Southeast England UK

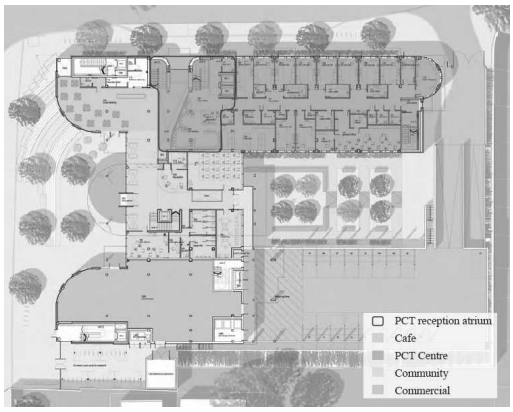
Stonebridge Hillside Hub designed by Edward Cullinan Architects (2009) is a mixed-use residential project which forms the civic focus of the reconstruction of the 1960s Stonebridge housing estate in northwest London. The project was originally envisaged as a series of distinct buildings. These included a health centre, a supermarket, a community centre and housing. The architects proposed that these functions be combined in one single building with the aim of forming the “social glue” of the community. The community functions of the building were in turn designed to pivot around a cafe space that was intended to tie these functions together. Unfortunately to date no tenant has been found for this cafe however different community groups use the space for annual events such as the Older people’s Forum’s “Time of your life” day which enables the local community to gather together for speeches, dinner, dancing and talking (Cullinan 2012). The project includes 25 apartments with government subsidies and 34 for the private market, in addition to: a community centre; computer centre; multi-purpose hall; offices; healthcare trust; café; supermarket; parking and bicycle parking; and a community garden. The housing has received Eco-Homes Very Good” certification and has won the What House Silver Award for Best Starter Home 2009. In addition the overall project was shortlisted for the Best Housing project in the Building Awards 2009 and in 2011 received a Special Civic Trust Award for Community Impact & Engagement.

The thermal insulation exceeds British building regulations by 20% with a calculated energy demand of 73kWh/m2/year. The social centre has rainwater harvest and solar panels for hot

water. Provision for separation at source for recycling is provided with individual waste bins below the kitchen sinks and centralized storage facilities for municipal collection.

The group that owns the community centre also owns the café space and adjoining supermarket. The rental received from these spaces allows them to provide a continuous and varied program of community activities.





Figures 1 and 2 Stonebridge Hillside Hub main elevation and ground floor plan.

2.2 Sonnenschiff, Vauban, Freiburg, Southwest Germany

Sonnenschiff which is German for “Solar Ship” was designed by the German architect Rolf Ditch (2004). The project located in the sustainable neighbourhood of Vauban comprises of 59 dwellings of which 9 are two story “penthouses” situated within roof gardens (fig.3); 3600m^2 of offices, studios and clinical practices on the second and third floors; 1200m^2 shops and cafes at street level; and 138 parking spaces in the basement. Public transport links Vauban to the centre of Freiburg 4km away, this combined with the car-sharing system significantly reduces private car use and associated emissions. The dwellings are designed to “Pasivhaus” and “Plusenergyhaus” standards with the PV arrays mounted on their roofs providing more energy than the dwelling requires. When operation and construction costs are included in the calculation, these house are cheaper than normal German market homes. The architect claims a primary annual energy saving of about 1 million kWh (Disch 2006).The innovative technical items included are: PV roofs, use of geothermic energy, rainwater reuse, high standards of external thermal insulation, vacuum insulation, and controlled ventilation with heat recovery.

Considering these factors one would expect that the Sonnenschiff has become a standard role model for German housing. However it has been argued that the project was only made possible by the architect Rolf Disch taking on the role as social entrepreneur as well as architect and with much perseverance over a long period of time (Wüstenhagen 2011).



Figure 3. Roof plan showing 9 "penthouse" dwellings.

2.3 One Brighton, Brighton, Southern England UK

Commissioned by BioRegional, the same developers behind the iconic Bedzed project in London, One Brighton was designed by Feilden Clegg Bradley Architects (2009). For the project BioRegional teamed up with one of the UK's largest housing developer Crest Nicholson to build a project that appeals to the general housing market rather than a specific "green clientele" whilst still embodying the 10 principals of One Planet Living; zero carbon; zero waste; sustainable transport; sustainable materials; local and sustainable food; sustainable water; land and wildlife; culture and community; equity and local economy; and health and happiness. In the two blocks the project provides 172 residential units with a mixture of private and social ownership. In addition it includes commercial units and 929m^2 of community spaces, including a community cafe. The tenant for the community spaces is The Ethical Property Company. The company buys properties and develops them as centres that bring charities, cooperatives, community and campaign groups together, where they can share skills and ideas. Groups in The Ethical Property Company's centres benefit from reasonable rents, flexible tenancy terms and office space and facilities designed to meet their needs.





Figures 4 and 5. One Brighton rear elevation and roof top allotments.

Just as with Bedzed, the project has centralized heating fuelled by a biomass boiler; a car club; PVs and solar thermal panels. The walls are clad with an external insulation of rigid cellulose fibre panels, which provide U-values 25% better than British thermal building regulations, the U-value of walls being 0.21W/m^{2}K. The windows achieve a thermal conductivity of 0.80W/m^{2}K with triple glazing and laminated pine internal frames and aluminium external frames with "warm-edge" technology by the company Swedish timber Products. On the roof terraces there are allotments in raised bed timber planters which allow residents to grow some of their own food and at the same time encourage interaction between neighbours.

3. National Context

3.1 Mixed Use Residential Buildings in Chile

In Chile the majority of new residential buildings of all scales are mono-functional. From houses to high-rise apartment blocks there is little attempt to integrate a mix of functions within one built form. Isolated cases of residential buildings above a 2 storey commercial podium are rare and are rarely encountered in projects within the last decade. Developers have become specialized in residential or commercial buildings and rarely cross from one typology to the other (Schlack 2012).

3.1.1 Plaza Lyon, Providencia, Santiago de Chile, Central Valley, Chile

The Plaza Lyon complex by Murtinho & Asociados Arquitectos (1980-82) was designed under the planning policy of "conjunto armónico" which permits a greater density provided that public space and communal functions are incorporated within the design. The design is influenced by post-modern thinking, reinterpreting historical typologies of Santiago such as the city block, the gateway, the continuous facade, the square and the patio (Fernández 1991). The building of 70.000m^2 incorporates residential apartments, offices, retail (department store, shops and supermarket), public spaces and underground car parking, in addition to being directly connected to an underground metro station. Interviews with the building's administration have reported problems arising due to the complicated mix of functions and related security issues (Schlack 2012).

With walls of 200mm uninsulated reinforce concrete with a typical u-value of 2.2W/m^{2}K and single glazing the building is far from being an energy efficient model. However it should be considered that the thermal conductivity of the walls is only slightly higher than the current Chilean thermal building regulations of 1.9 W/m^{2}K, a fact that reflects the low requirements of the regulations.





Figures 6 and 7 Plaza Lyon mixed use development, Providencia, Santiago de Chile

3.2 Energy Efficiency in the Chilean Residential Market

Whilst there do not exist many examples of Chilean mixed use residential buildings, energy efficiency is slowly beginning to play a role in the Chilean residential market. The concept "Full Electric" of Chilectra, the electricity distribution company of the metropolitan region, has been promoted in new residential projects promising dwellings free from intradomicilliary air pollution coupled with greater efficiency with the use of off peak electricity. According to information published by Chilectra in 2009 44% of the new residential apartments built in Santiago included this concept, an increase from 2008 when the same statistic was 30.5% (Prieto 2009). Whilst true that electric heating systems do not produce intradomicilliary air pollution and using off-peak electricity reduces peak demand and therefore the national energy demand, it should be considered that in 2009 59% of the electricity was generated with greenhouse gas emitting fossil fuels (Ministerio de Energía 2010). Therefore this concept still has a long way to go before it can really be considered sustainable.

Another novelty in the Chilean housing market is the installation of thermal solar panels for hot water. The first apartment building in Chile that included thermal solar panels was the Edificio Al Ras, located in Sucre 1900, Ñuñoa, Santiago. In this project of 96 apartments 21 evacuated tube collectors were installed on the roof, providing 10.800 litres per day of hot water or 112.5 litres per apartment. Many other apartment buildings soon followed suit labelling their buildings as "ecological" based solely on the inclusion of thermal solar energy. In the emblematic building Edificio GEN, Portugal 415, Santiago, the architect Felipe Assadi has attempted to integrate flat plate thermal solar panels with the architecture of the building. The panels are located in the north facade with one panel per flat forming part of the balcony balustrade. Despite the insurmountable problem of overshadowing from the pre-existing 20 storey building located directly to the north, it is interesting to see that solar panels have become a key selling point in the private Chilean residential market. In August 2009 the Chilean government passed the law N° 20.365 that established a range of tax rebates for developers for the installation of thermal solar panels for dwellings with a build cost of up to 4,500UF (approximately US$212.000). Although it took a year before the law was put in force, in the last two years the sale of thermal solar panels has increased 292% (Antunovic 2012). The law was only originally intended to last until December 2013 but in 2011, following criticism over the delays in its implementation, the Minister of Energy announced a possible extension of this time frame. As yet this extension has not been confirmed.

Another government program related to energy efficiency came into being as a specific response to problems faced by the cities declared saturated by airborne pollution arising from firewood. This program for thermal reconditioning of existing dwellings was annexed to the existing program knows as PPPF (Programa de Protección del Patrimonio Familiar) the Program for the Protection of Family Assets. The program consist of subsides for the installation of thermal insulation and double glazing. One example of the application of this subsidy is the case of Edificio Barros Arana located in Temuco one of the cities declared saturated. Built in 1959 the two social housing blocks have recently been renovated with the application of 50mm of expanded polystyrene External Insulated Façade system (EIFS) achieving a u-value of 0,56W/m^2K. Due to limited funds fenestration was only upgraded from steel framed single glazing to aluminium framed single glazing. However some residents, at

their own cost, have installed secondary glazing but only on bedroom windows. Even so, residents of the building interviewed by the authors reported greatly improved thermal comfort and one resident reported 50% reduction in their firewood consumption. In addition to these saving the authors noted how well informed and enthusiastic the residents were with regards to energy efficiency following the renovation process.

3.2.1 Chilean Energy Efficient dwellings

To date there yet to be built in Chile a sustainable mixed use residential project. The cutting edge projects that have aimed for energy efficiency have been limited to houses; either detached such as in the case of the gated community of Condominio Frankfurt Temuco (fig 8); or terraced in the case of Lo Espejo II in Santiago (fig 9); or in a few exceptional cases purely residential apartment blocks such as Edificios Rotterdam (fig 10), la Haya and Brandenburg also in the city of Temuco. In all of these projects the major aim is to improve the thermal properties of the building envelope but none of them innovate with the building form or mix of building program. All are purely residential projects which continue the reliance on motorized transport for even simple daily tasks.



Figures 8, 9 and 10 Condominium Frankfurt, Lo Espejo II and Edificio Rotterdam

4. Conclusion

The cities of Chile's Central Valley face a serious problem regarding airborne pollution with many already declared saturated in terms of PM10. This pollution in many cases is directly related to the poor quality housing stock that is thermally inadequate and the use of inefficient wood burning heating appliances. Transport is also cited as a major contributing factor, with a high dependency on private cars and an overcrowded, highly polluting, public transport system. It would therefore appear that an energy efficient mixed use residential project could provide a key building block for a sustainable future for these cities. This would reduce the emissions related to wood burning heating through lowering heating demands by improved thermal envelope, providing an efficient volume to surface area ratio and allowing low emission centralized heating systems to be implemented. The mixture of uses would also reduce the emissions related to transport by allowing walkable neighbourhoods where the majority of daily needs are met in neighbouring or even the same building. In Chile rare examples of mixed use residential developments have existed in the past. Energy efficiency is an emerging market in Chile but as yet is limited to a few key projects predominantly focused on the individual house rather than residential housing blocks. International examples show that it is possible to combine complex programs in visually pleasing

architecture and that sufficient technical knowledge exists to create energy efficient sustainable buildings. The review of the national situation concludes that although there exists an emerging energy efficiency market, developers are unwilling to innovate and take a risk on the as yet unproved market of the mixed use residential building. Time is therefore required to allow research and the development of a strong business plan for a prototype that can form a building block for a sustainable future for Chile's contaminated cities.

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The Enforceability of Termination for Convenience Clauses

Professor Phil Evans[1]

Abstract

Traditionally the right to terminate a contract has been based on the classification or importance of the term. Specifically, is the term a condition or is it so important that a party would not have entered into the contract unless assured of performance of the term. However termination for convenience clauses (TFC) are being increasing used in a wide range of construction contracts where the principal may wish to terminate a contract in situations which would not give rise to lawful termination at common law. This paper discusses the origin of TFC clauses, the legal issues arising from their use, common law principles relating to termination and suggestions for appropriate wording for TFC clauses based upon a consideration of the relevant principles developed from Australian case law.

Keywords: termination, AS 2124, rights, convenience, good faith

1. Introduction

The right to terminate a contract has been traditionally based on the classification of the term; specifically is the term a condition or a warranty, or is the term so important that a party would not have entered into the contract unless assured of performance of the term. Additionally a contract may provide express details of what may be determined "substantial" breaches which will give rise to the election to terminate as in the Australian Standard General Conditions of Contract, AS 2124-1992. However, we are now frequently seeing an increase in the use of express termination or termination for convenience clauses (TFC) or termination "at will" clauses, which give the Principal or Owner the right to unilaterally terminate a contract. These clauses were originally used in large infrastructure or defence contracts to ensure that government is able to act freely in order to vitiate contractual obligations where it is in the public interest, or where policy may change, even though this may interfere with the normal common law contractual rights of the other party. They are now being used in a range of construction agreements. [1]

Current case law appears to be undecided on the legal issues arising from a clause which provides unfettered right to terminate. This paper will discuss the basic legal principles applicable to termination for convenience clauses. The issues to be discussed include the implication of a term of good faith, the effect of capricious or arbitrary behaviour by a party and whether the right to terminate is unfettered. The paper will also discuss issues of

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compensation and the appropriate wording of enforceable termination for convenience clauses with particular reference to construction contracts.

2. The Origin of Termination for Convenience Clauses

Whilst at first sight the use of "without cause "or "termination for convenience clauses" (TFC) appears to be relatively recent, they appear to have their origins at the end of the American Civil War where these clauses were inserted into federal government contracts in order to allow the government to wind down military procurement and pay contractors for work already completed under the contract. [2]

In *Torncello v United States* [3] it was stated in relation to a TFC clause;

"It originated in the reasonable recognition that continuing with wartime contracts after the war was over was clearly against the public interest. Where the circumstances of the contract had changed so dramatically, the government had to have the power to halt the contractors performance and settle."

Since the end of the Second World War, TFC clauses have also been widely used in American private construction contracts and since 1997 the American Institute of Architects (AIA) standard form contracts have featured a TFC clause.[4] Locally these clauses are used in government contracts to allow for termination of projects where there have been policy changes or significant cost overruns but they are increasingly be applied in private sector contracts.

The clauses are also useful by providing a speedy resolution where the relationship between the parties has broken down or there are allegations of poor performance which at the same time may be difficult to prove to the level required for resolution or termination at common law. However there a number of legal issues which may arise with respect to the use of a TFC clause. Before these are considered the right to terminate generally at common law will be discussed.

3. Fundamental principles of construction contract law.

A construction contract is essentially no different to any other commercial contract with the exception of a clause permitting the principal to appoint a "superintendent" to administer the contract and generally the inclusion of a dispute resolution clause. In any dispute arising out of the performance of the contract or the interpretation of its terms, the issues for the court, adjudicator or arbitrator are; to determine the essential elements of formation (offer, acceptance, capacity, intention, legality and consideration) together with the terms of the contract (express and implied), then decide if the obligations of both parties been performed or breached and finally what remedy is available to the innocent party.

The application of this approach can be seen in *Pindan Pty Ltd v Uniseal Pty Ltd* [5], where McKechnie J set aside an interim award of the arbitrator and remitted the matter back to the

same arbitrator for determination in accordance with his Honour's directions. Specifically the directions were that the arbitrator should determine the terms and conditions which were incorporated into the contact, establish on the evidence of there was a breach and finally consider if the breach caused a loss to the other party.

This approach at first sight appears straight forward, however as Kirby P observed in *Coal Cliff Collieries Pty Ltd v Sijehama Pty Ltd* [6] courts and lawyers may expect the agreements of business people to be clear and complete but unfortunately, in the market place, agreements (especially when prepared by lay persons) often fall short of what a lawyer might desire. In particular when determining which actions constitute a breach which may give rise to the election by the innocent party to terminate, in order to avoid the consequences of unlawful breach [7] it is important to understand the common law right to terminate.

4. Termination at common law

At common law it is well established that the "innocent" party can only elect to terminate a contract where there has been a breach of a condition or what is described in the Australian General Conditions of Contract as a substantial term[8] or generally as a breach of a condition or a term which goes right to the heart of the contract rather than a minor term or warranty. [9] Unfortunately the classification of all terms as either conditions or warranties is a simplistic view of the various terms. The importance may not always be obvious and in some cases it may well be that some terms are capable of both substantial and minor breach. These terms which are generally described as intermediate or innominate, may create issues where a party seeks to terminate a contract for breach of a term which could in fact be minor and which consequently result in wrongful repudiation. [10]

Consequently, some terms may be viewed as critical to the operation of the contract such that without assurance of strict performance the parties would probably not have entered into the contract in the first place. For example in *Tramways Advertising Pty Ltd v Luna Park (NSW) Ltd* [11] where Chief Justice Jordan stated;

"The question whether a term in a contract is a condition or a warranty i.e. an essential or a non-essential promise, depends upon the intention of the parties as appearing in or from the contract. The test of essentiality is whether it appears from the general nature of the contract considered as a whole, or from some particular term or terms, that the promise is of such importance to the promisee that he would not have entered into the contract unless he had been assured of strict and substantial performance of the promise, as the case may be and this ought to have been apparent to the promisor."

At the same time, expressly providing that all terms in the contract are conditions, the breach of which will give rise to termination, will not be enforced. In the Court of Appeal decision in *L Schuler AG*, Edmund Davies LJ specifically referred to the non lawyer's practice of referring to all terms as conditions. [12] In a later decision, Lord Diplock stated that whilst

"condition" is used in a variety of senses it does not mean that a breach, however minor, by one party entitles the other party to elect to bring the contract to an end. [13]

5. Termination under AS Standard or industry based construction General Conditions of Contract

Standard general conditions of contract (GCOC) typically provide provisions relating to the lawful grounds for the termination of the contract. These are invariably described as "substantial" breaches which whilst not exclusive, provide a right to terminate which may still fall short of a breach which goes to the heart of the contract but would still provide the innocent party with a right to terminate.

In AS 2124-1992, Clause 44.2 refers to default by the Contractor and notes that substantial breaches include;

- Suspension of work in breach of clause 33.1
- Failing to proceed with due expedition (clause 33.1)
- Failing to lodge security (clause 5)
- Failing to use materials or standard workmanship required by the contract Clause 30.1
- Failing to comply with directions of the Superintendent (clauses 30.3, 23)
- Failing to provide evidence of insurance (clause 23.1)
- Providing n untruthful statutory declaration or documentary evidence in respect of clause 43

Similarly clause 44.7 of AS 2124-1992 lists the substantial breaches under which the Principal may be in default of its obligations. Clause 39 of AS 4000-1997 also stipulates the events which may constitute a substantial breach of the contract. Clause 39.2 refers to substantial breaches by the Contractor while clause 39.7 refers to substantial breaches by the Principal. These provisions essentially mirror those found in As 2124-1992.

PC-1 (1998) [14] lists the breaches which permit the other party to issue notice to the party in default.[15] ABIC MW-1 [16]provides that the failure of a party to meet its substantial obligations permits the other party to commence the termination procedures as set out in Section Q.

6. Case law decisions on the express right to terminate

Current case law appears to be undecided on the legal issues arising from a clause which provides an unfettered right to terminate as illustrated by the following cases.

In *Champtaloup v Thomas* [17]

The purchaser of a property had an express right, in accordance with the terms of the contract, to rescind a contract in the event of the occurrence of proscribed events. In evidence at trial, the purchaser stated that these events had nothing to do with his decision to rescind the contract. The NSW Court of Appeal held that where a party has a contractual right to terminate, even when that right is exercised capriciously, arbitrarily, unreasonably and not bona fide, the right is not restricted or lost. The Court held that the right was validly exercised and refused to limit the rights given by the contract. [18]

Renard Constructions (ME) Pty Ltd v Minister for Public Works[19]

In *Renard Constructions*, the decision of the NSW Court of Appeal was inconsistent with the decision in *Chantaloup.* In *Renard Constructions*, under clause 44.1 of the general conditions of contract (NPWC3) if the contractor breached the contract, the principal could call upon it to show cause as to why the contract should not be terminated. The principal was unhappy with the contractor's performance and required the superintendent to issue a show cause notice. The contractor accordingly responded to the show cause provision. Nevertheless principal proceeded to terminate the contract.

The majority of the court held that the powers conferred on the principal under the clause must be exercised reasonably and consequently by analogy, in good faith. While *Renard Constructions* is authoritative in the context of express termination clauses, the issues arose from a consideration of the show cause notice, which nevertheless is a feature of all construction contracts.

Gary Rogers Motors (Australia) Pty Ltd v Subaru (Australia) Pty Ltd [20]

This decision held that the use of a TFC can be challenged on the basis that it is inconsistent with an implied condition that the parties are to act in good faith. In *Gary Rogers Motors (Australia) Pty Ltd v Subaru (Australia) Pty Ltd* the agreement between the parties allowed that either party could terminate the agreement by giving the other party notice in writing. Subaru were discontented with the performance of Gary Rogers and issued a notice of termination. The court held that in this case there was an implied term requiring good faith and fair dealing in the relationship. This means that the exercise of a TFC (depending on the exact wording of the clause) could be subject to a challenge on good faith grounds if the election to terminate was exercised either capriciously, arbitrarily or for an improper purpose (thus reflecting the comments in *Abu Dhabi National Tanker Co v Product Star Shipping Line (N0 2)*[21]

Kellogg Brown Root Pty Ltd v Australian Aerospace Limited [22]

The issue of good faith in the exercise of a power under a termination for convenience clause was considered in the case of *Kellogg Brown Root Pty Ltd v Australian Aerospace Ltd*. Australian Aerospace were engaged by the Commonwealth to supply 12 helicopters

and Kellogg Brown Root (KBR) was engaged as a subcontractor to provide training services for the project. The agreement contained a dispute resolution process and also a TFC. When a dispute occurred, KBR gave notice commencing the dispute resolution process but Australian Aerospace responded by giving notice to terminate for convenience. KBR then sought an injunction restraining Australian Aerospace from terminating the agreement. KBR alleged that Australian Aerospace's right to terminate was subject to an implied term of good faith and fair dealing. They submitted that Australian Aerospace had breached this implied term by terminating the contract. KBR further submitted that the behaviour of Australian Aerospace was indicative of an opportunistic attempt to avoid any adverse determination arising for the dispute resolution process. The court noted that in Australian Aerospace giving the notice of termination before the dispute resolution process had been carried out they had acted to pre-empt the process.

Whilst the focus was on the issue of whether the terms of the subcontract permitted the implication of a good faith term under the *BP Refinery* [23] principles, and whether the implication of the term was as serious question to be tried under the *American Cyanamide* [24] principles, Hansen J noted that the case for an implied term and its breach was arguable.

Thiess Contractors v Placer (Granny Smith) Pty Ltd [25]

This case is definitive with respect to the application of good faith in applying a TFC and whether the right to terminate is unfettered. In 1989 Thiess entered into a schedule of rates mining contract with Placer to undertake open cut mining at Placer's gold mine at Laverton, Western Australia. In 1991 a number of unforeseen problems arose and as a consequence of variations under the contracts Placers costs per cubic meter of mined material significantly increased. Placer subsequently negotiated with Thiess for a new contract which was based on a risk sharing basis rather than schedule of rates basis. A term of the new agreement was that the parties "work in good faith on all matters relating to the contract." The new contract provided for a fixed profit to be earned by Thiess based on a agreed percentage on costs. A new contract on this basis was entered into on 13 July 1992.

In March 1995 Placer terminated the contract in reliance on a TFC which entitled it at any time and for any reason it might deem advisable to cancel and terminate the contract. Clause A 6.5.1 stated;

"[Placer] may at its option, at any time and for any reason it may deed advisable, cancel and terminate the Contract, in which event [Thiess] shall be entitled to receive compensation as follows;" [26]

Upon termination Thiess would receive compensation for unit price items and demobilization as well as certain other compensation.

Thiess commenced proceeding against Placer alleging that the termination had been unlawful and claiming substantial damages. Placer counterclaimed alleging that in breach of the express obligation of good faith, Thiess had falsely represented the costs of certain plant

costs it would incur in work under the contract. Thiess submitted that prior to entering the new contract Placer represented that it would only rely on the termination clause in the contract if the mine were closed or if the mine was uneconomical to work. On the evidence, the court rejected the submission and noted that Placer had insisted on the termination clause being inserted into the contract even though Thiess wished it to be removed. Further Thiess was well aware of the risks agreeing to the contract with the termination clause and accepted those risks. The trial judge noted that "This clause appears to be clear and unambiguous in providing Placer with an absolute and uncontrolled right to termination." [27]

With respect to the issue of good faith relative to the termination clause, Templeman J made the interesting comment that the good faith provisions were typical of many contained in sections dealing with good faith, but which at the same time, do not define the rights and obligations with any precision. [28] Templeman J further noted that their implementation clearly requires goodwill and cooperation on the part of both parties and that good faith must include these matters and additionally that the obligation of good faith requires the parties to deal honestly with each other.[29]

Templeman J considered that the good faith obligation applies to general matters relating to carrying out the works, derivation of rates and interpretation wherever they arise in the contract. In summary the obligation off good faith requires the parties to act honestly with each other and to take reasonable steps to cooperate in relation to matters where the contract does not define rights and obligations or provide any mechanism for the resolution of disputes.

However in relation to the interpretation of the contract, Templeman J noted the obligation of good faith was far more difficult to define. Templeman J held that the application of the good faith provision in clause B1.1.5 had not application to the TFC (6.5.1). Thiess had submitted that the obligation of good faith requires the termination clause on to be invoked when Placer had a reasonable reason for determining the contract. Templeman J however noted that the construction of the TFC was clear and unambiguous. It was an express provision which entitled Placer to terminate the contract "….at its option, at any time and for any reason it may deem advisable…." Thiess had relied on the English decision of *Abu Dhabi National Tanker Co v Product Star Shipping Line* [30] which noted that;

"Where A and B contract with each other to confer a discretion on A, that does not render B subject to A's uninhibited whim. In my judgment the authorities show that not only must the discretion be exercised honestly and in good faith, but, having regard to the provisions of the contract by which it is conferred, it must not be exercised arbitrarily, capriciously or unreasonably."

Templeman J noted that whilst " Placer had a discretion whether or not it would terminate the contract, the termination clause provided it with an absolute and uncontrolled discretion which it was entitled to exercise for any reason it might deem advisable. That is a contractual right which relieved Placer from any obligation to have regard to Thiess' interest." [31] In his "Summary of Conclusions", Templeman J noted (in part) [32]; that the termination

clauses gave Placer an unfettered right of termination and in any event, Placer exercised its rights of termination honestly and in good faith.

Subsequently Thiess appealed against the dismissal of its claim and the upholding of the counterclaim. [33] The court dismissed Thiess' appeal relating to Placers right to apply the TFC. The court noted that Placer had insisted on the termination clause being inserted into the contract even though Thiess wished it to be removed and Thiess was well aware of the risks of agreeing to the contract with the termination clause and accepted those risks.[34]

7. Express and implied conditions of good faith

It can be seen that the issue of an express right to terminate is inextricably linked to the issue of good faith. However the issue of good faith in the operation of commercial contracts and the interpretation of terms is far from settled. The term is controversial because we do not have a legal definition of what constitutes good faith in commercial agreements. [35] For example *in South Sydney District Rugby League Football Club Ltd v News Limited* (2000) 177 ALR 611 @ 695, Finlay J. said that Australian law has not yet committed itself unqualified to the proposition that every contract imposes on each party a duty of good faith and fair dealing in contract performance and enforcement.

The issue was considered by the High Court in *Royal Botanic Gardens & Domain Trust v South Sydney City Council (2002)* 186 ALR 289 @ 301. Kirby J indicated his view that the notion of reasonableness, fairness and good faith appeared to be in conflict with the doctrine of Caveat Emptor inherent in common law conceptions of economic freedom. [36] However there have been a number of cases where courts have determined that there are situations where an obligation of good faith (or fair dealing) will be imported into contractual relationships. These include *Amann Aviation v The Commonwealth (1990)* 192 ALR 601, *Renard Constructions (ME) Pty Ltd v Minister for Public Works (1992)* 26 NSW LR 234 *Hughes Bros. Pty Ltd v Trustees of the Roman Catholic Church and Archdiocese of Sydney (1993)* 31 NSW LR 91 *Hughes Aircraft Systems International v Air Services Australia (1997)* 146 ALR 1 *Alcatel Australia Ltd v Scarcella (1998)* 44 NSW LR 349 and as mentioned above *Garry Rodgers Motors (Australia) Pty Ltd v Subaru (Australia) Pty Ltd (1999)* FCA 903. However, there are a number of other decisions where the courts have declined to imply conditions of good faith in the operation of commercial agreements. These include *G S A Group Pty Ltd v Sieve Plc (1993)* 30 NSW LR 573, *Service Station Association Limited v Berg Bennett & Associates Pty Ltd (1993)* 117 ALR 393, *Esso Australia Resources Pty Limited v South Pacific Petroleum NL (Receivers and Managers Appointed) (Administrators Appointed)* [2005] VSCA 228) and *Kendells v Sweeney* [2005] QSC 64.

More recent decisions have also not assisted us with the issue. In *Vodafone Pacific Limited v Mobile Innovations Limited* [37] Justice Giles J declined to hold that commercial contracts generally, and specifically dealing with the right to termination, could not imply a term of good faith. Further, in *Solution 1 Pty Limited v Optus Networks Pty Limited* [38] whilst the court was willing to imply a term of good faith into a contract, in this case it was excluded because the term which permitted Optus to terminate on 120 days notice at its absolute

discretion was absolute and further there was an entire contract clause which expressly excluded any implied terms.

8. Good faith requirements under AS GCOC

The Australian Standard General Conditions of Contract (GCOC) expressly refer to the application of fair dealing or good faith on the part of the Superintendent. The duality of the role in acting as both agent for the Principal and independent certifier has been considered in a number of cases and will not be considered here suffice to say that there is no legal impediment to the Superintendent acting in both roles. [39]

AS 2124-1992 Clause 23 states;

"The Principal shall ensure that... in the exercise of the functions of the Superintendent under the contract, the Superintendent-

(a) Acts honestly and fairly

(b) Acts within the time prescribed under the contract or where no time is prescribed within a reasonable time; and

(c) Arrives at a reasonable measure or value of work, quantities or time"

AS 4000-1997 Clause 20 states;

"The Principal shall ensure that at all times there is a Superintendent, and that the Superintendent fulfils all the aspects of the role and functions reasonably and in good faith."

The issue of good faith has been considered above and as noted is far from settled. However judicial decisions have made it clear that in the context of certification and approval the contract administrator must make an assessment free for interference and only taking into account whether the work has been done in accordance with the requirements of the contract.

Similarly in the context of what is reasonable behaviour for the purpose of both AS 2124-1992 and AS 4000-1997 what is "reasonable" is a question of fact depending on the particular circumstances. [40]

Whilst not in the context of construction contracts, the decisions in *Burger King Corp v Hungry Jacks* [41]and *Alcatel Australia Ltd v Scarcella* [42]provide some assistance in determining the possible elements of good faith. These include an obligation on the parties to cooperate in achieving the contractual objectives; compliance with honest standards of conduct; and compliance with standards of conduct that are reasonable having regard to the interests of the parties.

9. Drafting an express right to terminate clause

In the absence of a High Court decision on the matter and in view of the divergent state court decisions, the law is still unsettled. However the early decision in *Renard Construction* and the more recent decision in *Thiess* provide some assistance with respect to construction and infrastructure contracts but it is acknowledged that the case law generally indicates that courts will be reluctant to imply a term of good faith in all commercial contracts. In drafting an operative TFC the following factors will be relevant.

- The obligation off good faith requires the parties to act honestly with each other and to take reasonable steps to cooperate in relation to matters where the contract does not define rights and obligations or provide any mechanism for the resolution of disputes.

- Where the principal has discretion, whether or not to terminate the contract, if the termination clause provides it with an absolute and uncontrolled discretion which it is entitled to exercise for any reason it might deem advisable, that right will be unfettered. Particularly if it has been brought to the contractor's attention, or was subject to discussion at the time of entering into the contract.

- When drafting a termination clause in a commercial contract, consider including a clause which expressly excludes the application of good faith with respect to the provisions of the TFC.

- In the absence of an express term excluding the application of good faith, where a duty of good faith is implied it will not prevent a party from taking steps which are designed to protect its legitimate interests. [43]

- When a party is acting in a manner that is consistent with its contractual rights to promote its legitimate interests, there should be no breach of any implied duty to act in good faith. [44]

- In the TFC make provision to ensure that the Contractor is to be compensated for its losses including loss of profit and an overheads contribution on the balance of the work. If this is absent then there is the possibility that that clause may be considered as penal or in some circumstances as unconscionable

10. Termination for Convenience clause example

The following clause is representative of a TFC clause which is considered to provide an unfettered right to terminate at will.

TERMINATION BY THE PRINCIPAL FOR CONVENIENCE

Without prejudice to any of the Principal's other rights and powers under this contract, the Principal may at any time for any reason within its sole discretion upon 10 Business Days

Notice to the Contractor terminate the Contract. Upon receipt of such notice the Contractor shall remove its Constructional Plant from the Site, shall otherwise cease the performance of its obligations under the Contract and shall endeavor to mitigate any expense or losses that it or the Subcontractor may incur or has incurred in relation to its obligations under the Contract.

If the Principal terminates the Contract under this clause then the Principal shall be liable to pay the Contractor the total of:

(a) For work executed prior to the date of termination, the amount which would have been payable if the Contract had not been terminated and the Contractor had made a progress claim on the date of termination;

(b) Subject to the obligation of the Contractor to mitigate its costs and expenses, the cost of materials reasonably ordered by the Contractor for the Work under the Contract, which the Contractor is liable to accept, but only if the materials become the property of the Principal upon payment;

(c) All retention monies and security; and

(d) The reasonable cost of demolition

up to a maximum amount of the balance of the contract sum (as it is adjusted pursuant to the Contract) unpaid at the date of termination and other amounts payable pursuant to the Contract at the date of termination. The amounts to which the Contractor is entitled under this clause shall be in full satisfaction and compensation of the Contractor in relation to the termination and the Contractor shall have no other entitlement as a consequence of the termination under this Clause or in relation to carrying out the work under the Contract to the date of termination.

There appears to be little in the literature or authorities, relating to the form and content of the compensatory provisions; however it was noted in the English case of *Abbey Developments Limited v PP Brickwork Ltd* [45]

"Termination for convenience clauses frequently provide that the Contractor is to be compensated for its losses including loss of profit and overheads contribution on the balance of the work. If they do not then they risk being treated as leonine and unenforceable as unconscionable."

11. Conclusion

Traditionally the right to terminate at common law has been dependent on the classification of the term. That is, is it a condition or a warranty? Where a contract is terminated for breach of a minor term or mere warranty then the termination will be unlawful and provide the right of the innocent party to the damages which flow from the breach. A term containing

an express right to terminate for convenience is inextricably linked to the requirement of the parties to undertake obligations in good faith but without clear High Court authority on the issue of good faith, the law remains unsettled. However guidance can be obtained from a number of decisions which have held that where the principal has the discretion, whether or not to terminate the contract, if the termination clause provides it with an absolute and uncontrolled discretion which it is entitled to exercise for any reason it might deem advisable, that right will be unfettered. In the absence of an express term excluding the application of good faith, where a duty of good faith is implied it will not prevent a party from taking steps which are designed to protect its legitimate interests. When a party is acting in a manner that is consistent with its contractual rights to promote its legitimate interests, there should be no breach of any implied duty to act in good faith. Finally the TFC should provide that the Contractor is to be compensated for its losses including loss of profit and an overheads contribution on the balance of the work. If this is absent then there is the possibility that that clause may be considered as penal or in some circumstances as unconscionable

References

[1] See Gray, Anthony (2012) *Termination for convenience clauses and good faith.* Journal of International Commercial Law and Technology, 7 (3). pp. 260-275.

[2] See New York Law Journal, Volume 345-No 30, 15 February 2011

[3] 681 F.2d 756, 764 (Ct.C1.1982)

[4] See AIA A201-1997 General Conditions of Contract for Construction, Clauses 14.4

[5] [2003] WASC 168

[6] (1991) 24 NSW LR1 at 21

[7] *See Commonwealth of Australia v Amann Aviation Pty Ltd* (1991) 174 CLR 64

[8] See AS 2124-1992 (Clause 44) and AS 4000-1997 (Clause 39)

[9] See *Bettini v Gye* (1876) 1 QBD 183 and *Poussard v Spiers and Pond* (1876) 1 QBD 410

[10] See *Hong Kong Fir Shipping Co Ltd v Kawasaki Kisen Kaisha Ltd* [1962] 2 QB 26*; L Schuler AG v Wickman Machine Tool Sales Ltd* [1974] AC 235.

[11] (1938) 38 SR (NSW) 632 @ 641-642

[12] See *Schuler AG v Wickman Machine Tool Sales Ltd* [1972] 1 WLR 840 (The Court of Appeal decision)

[13] See *ANZ Banking Group Ltd v Beneficial Finance Corp* (1982) 44 ALR 241.

[14] Property Council of Australia Project Contract (PC-1 1998). PC-1 is produced by the Property Council of Australia and has been designed to represent the interests of the commercial property industry. It does not represent to balance the interests of the owner and the contractor but is premised on the view that those who pay for projects are entitled to allocate the risks.

[15] See clause 14.2 (Owner) and clause 14.3 (Contractor)

[16] Australian Building Industry Contract, ABIC MW-1 2003, Major Works Contract. The ABIC contracts are jointly published by the Master Builders Association and the Australian Institute of Architects. They are intended for use in architect administered building contracts.

[17] [1976] 2 NSWLR 264

[18] However in *Godfrey Constructions Pty Ltd v Kanangra Park Pty Ltd* (1972) 128 CLR 529 the High Court held that similar rights could not be exercised "unconscionably or unreasonably".

[19] (1992) 26 NSWLR 234

[20] (1999) FCA 903

[21] (1993) Lloyds Rep 397

[22] [2007]VSC 200

[23] *BP Refinery (Westernport) Pty Ltd v Shire of Hastings* (1977) 180 CLR 266

[24] *American Cyanamide v Ethicon* [1975] AC 396

[25] (2000) CIV 1970 of 1995 16 April 1999 Templeman J; Lib No; 990187

[26] Lib N0; 990187 at page 95

[27] Lib N0; 990187 at page 95

[28] A helpful discussion on the issues of good faith is the decision of Gummow J in *Service Station Association v Berg Bennettt & Associates* (1993) 45 FCR 84.

[29] Lib N0; 990187 at page 98

[30] [1993] 1 Lloyd's LR 397 at 404

[31] Lib N0; 990187 at page 101

[32] Lib N0; 990187 at page 246

[33] *Thiess Contractors Pty Ltd v Placer (Granny Smith)Pty Ltd* [2000] WASCA 102

[34] *Thiess Contractors Pty Ltd v Placer (Granny Smith)Pty Ltd* [2000] WASCA 102 at paragraphs 18,19

[35] For detailed information on the issue of good faith generally, see "Good Faith in the Performance of Contracts" Peden, E. (2003) LexisNexis

[36] See also *Coal Cliff Collieries Pty Ltd v Sijehama Pty Ltd (1991) 24 NSWLR 1; Australis Media Holdings v Telstra Corporation* (1998) 43 NSWLR 104.

[37] [2004] NSWCA 15.

[38] [2010] NSWSC 1060.

[39] See *South Australian Railways Commissioner v Egan* (1973) 130 CLR 506; *Renard Constructions (ME) Pty Ltd v Minister for Public Works* (1992) 26 NSWLR 234; *Peninsula Balmain Pty Ltd v Abigroup Contractors Pty Ltd* (2002) 18 BCL 322.

[40] See Note 33

[41] (2001) NSWCA 187

[42] (1988) 44 NSWLR 349

[43] *South Sydney District Rugby League Football Club Ltd v News Ltd* (2000) 177 ALR 611).

[44] *Thiess Contractors Pty Ltd v Placer (Granny Smith)Pty Ltd* [2000] WASCA 102

[45] (2003) EWHC 1987

The Performance of Houses in the Canterbury Earthquake Sequence

Graeme J Beattie[1]

Abstract

Over the period from 4 September 2010 until late in 2011 the Canterbury region of New Zealand was subjected to a sequence of more than 10,000 earthquakes, four of which were large enough to have significant effect on the buildings and infrastructure in the area. The most devastating event occurred on 22 February 2011, where the 6.3 Richter magnitude earthquake was centred at a very shallow depth and very close to the central business district of Christchurch at lunchtime, resulting in 185 deaths. Much of the housing stock was subjected to either the effects of liquefaction (differential ground settlements and lateral spreading) or severe shaking. There were two deaths in the 150,000 houses and these were the result of a cliff collapse on to the properties.

In the latter half of 2011, BRANZ conducted a comprehensive survey of more than 300 houses located in Christchurch city to determine the effects of the earthquake on the housing stock and its ability to resist the seismic actions. The surveyed properties were randomly selected throughout Christchurch and this provided a range of house construction types and ages and also a range of soil conditions. This paper describes the analysis of the data obtained in the survey, giving consideration to the types and weights of construction materials, the style of house construction (foundation type, shape, number of storeys, etc) and the subsoil conditions, and relates the observed damage to these influencing factors. Recommendations are made on the dwelling likely to provide the best performance under earthquake attack.

Keywords: earthquake, seismic, house performance, survey

1. Introduction

At 4:35am local time on 4 September 2010, a magnitude 7.1 earthquake struck the Canterbury region of New Zealand (NZ). The earthquake was centred near the township of Darfield, a small country community approximately 40km west of the city of Christchurch, and its epicentre was at a depth of 10km. The shaking intensities in Christchurch were in the range of 0.16g to 0.65g peak ground acceleration (PGA) in the horizontal direction and 0.05g to 0.3g PGA in the vertical direction [Cousins & McVerry 2010]. Spectral accelerations were in the order of 0.8 times the design spectral acceleration in the frequency range of typical house structures. While the effect on Christchurch houses was generally the loss of

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unreinforced masonry chimneys and some minor damage to interior linings, several areas were affected by ground liquefaction and associated lateral spreading.

Typically, a series of aftershocks occurred over the following months although none of these events caused further significant damage, until 12:51pm on 22 February 2011 when a 6.3 magnitude event struck beneath the urban area of the city. The epicentre was located 10km southeast of the central business district (CBD) and at a depth of 6km. The range of horizontal PGAs recorded in the urban area ranged from 0.2g to 1.41g and in the vertical direction, 0.06g to 2.21g [Bradley & Cubrinovski 2011].

Spectral accelerations relevant to typical New Zealand house structures in the February event were of the order of twice the design spectral accelerations in some parts of the city.

Further significant shallow events occurred on 13 June 2011 (magnitude 6.3) and 23 December 2011 (magnitude 6.0) with their epicentres located close to the 22 February epicentre. The events of 4 September 2010, 22 February 2011, 13 June 2011 and 23 December 2011 are referred to in this paper as the main events. Shaking activity has diminished significantly in the latter half of 2012 but 10,000 odd aftershocks have occurred over the period between 4 September 2010 and June 2012 and these have also served to rattle households.

This paper provides the results of a damage survey of a representative range of Christchurch houses that was undertaken over the period from July to September 2011. The survey therefore does not include the further damage sustained in some areas of the city during the 23 December 2011 event. The paper also draws on the experience of the four BRANZ structural engineers who were involved in the safety assessments of houses in the eastern and southern suburbs following the February 2011 event. It describes the response of typical NZ houses to the earthquake disaster and makes suggestions on improvements to house designs to provide greater resilience in such events.

2. Survey process

Following the 22 February 2011 event, BRANZ undertook a survey of 314 houses, randomly selected from within the boundaries of Christchurch city. The process involved randomly selecting a little more than 50 mesh blocks from the Statistics New Zealand census database [Statistics New Zealand]. Mesh blocks are roughly based on numbers of people residing within the block and generally represent an area a little larger than a residential block. Within each mesh block, six adjacent houses were selected for surveying at the southeast corner of each mesh block and the surveyors visited each property. Figure 1 shows the locations of the surveyed houses (yellow pins).

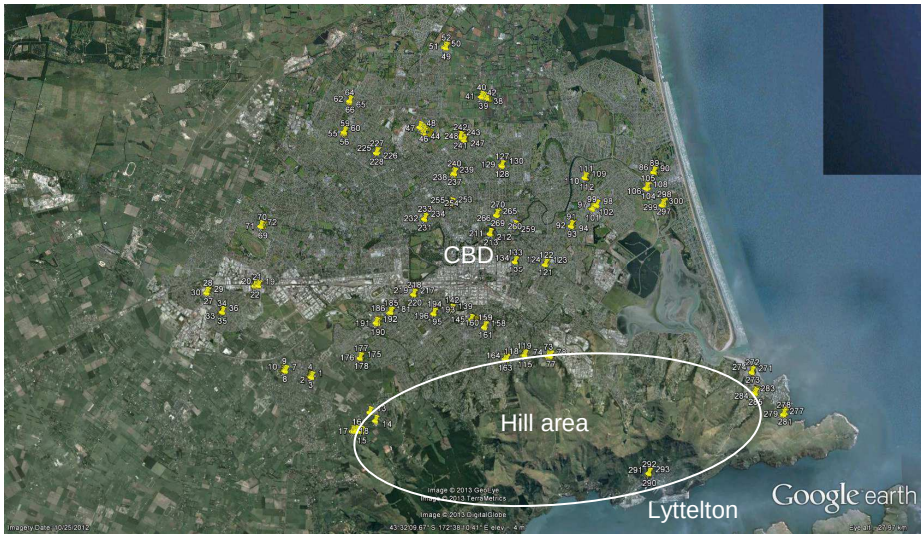

Figure 1: Locations of surveyed houses (CBD = central business district)

A team of two BRANZ representatives undertook the survey with a comprehensive survey form to gather observations about the site and its hazards (eg liquefied, rock-fall susceptible), house age, house style, construction materials and then estimates were made of the extent of damage sustained by the various elements of the structure. If the occupier of a property was not at home the surveyors moved to the next property adjacent and this was repeated until information was gathered from six houses in the block. The approximate total number of houses in Christchurch city is 150,000 and so approximately 0.2% of the total population was surveyed in this process. This paper presents the results of the survey.

3. SURVEY RESULTS

This section presents information gathered on the sites, the construction characteristics of the surveyed houses and recorded damage.

3.1 The site

The majority of Christchurch city is situated on the flat Canterbury plains, but there has also been urban development on the Port Hills to the south of the CBD over the entire life of the city, with the hillside development making up approximately 10% of the total housing stock. The survey proportions of flat land and hillside houses match this ratio relatively well (Table 1).

Table 1: Breakdown of ground slope at surveyed sites

Degree of ground slope	Percentage of surveyed houses
Flat	86
Gentle	5
Steep	8
Hilltop	1

3.1.1 Liquefaction occurrence

Of the 270 properties surveyed on the flat, 81 sites (30% of the flat land properties) had experienced ground liquefaction in either one or more of the first three main earthquakes. All of these properties were subject to ground liquefaction in February 2011, 31% of these had also experienced liquefaction in September 2010 and 42% in June 2011. The ground liquefied at seventeen of these properties in all three events.

3.2 House Age and Style

The Christchurch housing stock comprises dwellings constructed from the latter part of the 19th century through to the present day. Five age bands were selected into which each house was placed. The bands were pre-1930, 1930 to 1959, 1960 to 1979, 1980 to 1999 and 2000 onwards. These age bands were chosen to represent distinct periods of development of standards for house construction in New Zealand. Prior to 1930 there were no standards. In the early 1930s the first regulatory standards were produced. These were largely prescriptive and based on typical construction styles in the USA. They were not always adopted by the local jurisdictions either. In the 1960s the timber framing standards were developed further in a series of model building bylaws. These were in use until 1978 when the first engineering based light timber framing standard (SANZ 1978) was published. A significant review and republication of this standard occurred in 1999. The percentages of houses surveyed from each of these five bands are given in Table .

Table 2: Percentages of the surveyed houses in the five age bands and breakdown of foundation type for each age band

Age band	Percentage of surveyed houses	Percentage of slab on grade houses in the age band	Percentage of houses with perimeter foundations in the age band	Percentage of other foundation types in the age band
Pre-1930	14	2	65	33
1930-1959	24	5	87	8
1960-1979	33	21	79	0
1980-1999	15	63	33	4
2000 onwards	14	87	7	6
All ages	100	31	63	6

New Zealand houses are generally one or two storeys, but on hillsides it is common for there to be more than two storeys. Houses built to the NZ non-specific design standard, NZS 3604:2011 (SNZ 2011) and its predecessors are limited in height to a maximum of 10m and two and a half storeys, the half storey being in the roof space. Houses built outside of these (and other) requirements must be specifically designed.

In the survey population, 233 houses (74%) were single storey structures, 74 (24%) were two storey structures and 7 (2%) were three storey dwellings. Of the single storey dwellings, 58% were a simple rectangular shape, 31% were “L” shaped, 3% were “T” shaped and 8% were complex shapes. Of the 74 two storey dwellings surveyed, 55% were a simple

rectangular shape, 23% were “L” shaped, 5% were “T” shaped and 17% had a complex shape.

3.3 House Foundation Types

There are two major foundation types in use for house construction in Christchurch. Slab on grade floors have been the predominant construction style over the last 30 or so years for houses on the flat and also for some properties on the hills. This is confirmed from the survey of randomly chosen houses (Table 2). Over the early to mid 20th century, the preferred foundation style was a concrete perimeter foundation wall with concrete piles inside the perimeter. Such a style was typical on both the flat and the hills. In the hillside houses the floor was often supported on jack studs on short piles (Figure 1). Very occasionally houses were built entirely on timber piles in the early part of the 20th century.



Figure 1: Jack studs beneath a hillside dwelling (tilt due to superstructure lateral displacement)

3.4 House Superstructure

3.4.1 Structural frame

Of the 233 single storey dwellings surveyed, 228 were framed. It was not possible on most occasions to tell whether the framing was timber or light gauge steel, because the damage to the dwelling was insufficient to reveal the framing. However, light gauge steel framing is a relatively new construction type in NZ and therefore it is expected that the great majority of the surveyed houses had timber framing. The other five houses had either concrete, concrete masonry or unreinforced brick masonry walls. Of the 74 two storey dwellings surveyed, 80% had framed bottom storeys and 20% had either concrete or concrete masonry bottom storey walls. In all but one of these cases the top floor was framed.

3.4.2 Wall claddings

Several cladding systems are common in NZ. These include timber weatherboards, brick/block veneer and stucco, although the latter is much less common nowadays. Table shows the distributions of cladding on the surveyed houses. It can be seen that the totals for the lower and upper storeys of the two storey houses are greater than the 74 two storey houses surveyed. In both cases the reason is that on occasions there was more than one cladding type on a house.

Table 3: Distribution of wall cladding types on surveyed single and two storey houses

Cladding type	Single storey houses	Two storey houses	
		Lower storey	Upper storey
Weatherboards	70 (30%)	28 (29%)	36 (37%)
Brick/block veneer	128 (55%)	29 (31%)	14 (15%)
Stucco	34 (14%)	8 (8%)	7 (7%)
Ply or fibre cement sheets	10 (4%)	9 (9%)	17 (18%)
Exterior insulating finishing system (EIFS)	7 (3%)	8 (8%)	7 (7%)
Other	8 (3%)	13 (14%)	15 (16%)
Total	233	95	96

3.4.3 Roof claddings

The most common roof claddings in use in NZ in the first half of the 20th century were corrugated steel and concrete tiles. In the last 60 years there has been an increase in the use of pressed metal tiles and clay tiles, although the use of heavy tiles in general has decreased over the last 30 years. Other systems such as rubber membranes, asphaltic tiles and shingles have been rarely used in NZ. Table provides a distribution of roof cladding types versus the age band of the house for the surveyed houses.

Table 4: Numbers of houses with roof cladding type for each age band

Age band	Heavy tiles	Sheet cladding (eg corrugated steel	Metal tiles	Other
Pre-1930	2 (3%)	37 (20%)	6 (12%)	2 (22%)
1930-1959	29 (41%)	32 (17%)	11 (22%)	2 (22%)
1960-1979	32 (45%)	57 (31%)	12 (24%)	0 (0%)
1980-1999	5 (7%)	32 (17%)	8 (16%)	2 (22%)
2000 onwards	3 (4%)	27 (15%)	12 (24%)	3 (34%)
Total	71 (100%)	185 (100%)	49 (100%)	9 (100%)

3.4.4 Interior linings

In the early 20th century and before, lathe and plaster was a common lining system for houses. This system continued to be used through until the 1940s. Gypsum based plasterboard was introduced in the late 1920s and has gone on to be the most popular lining

material at the present time. Fibrous plaster was also popular from the 1950s until the 1980s because it had a very smooth face for accepting wallpapers. Of the surveyed houses, 79% were lined with plasterboard, 18% with lathe and plaster, 8% with fibrous plaster and 8% with other linings. These percentages total to greater than 100% because on occasions there was more than one lining type present in a single dwelling. Since the first publication of NZS 3604 in 1978, plasterboard linings have fulfilled a bracing role in timber framed houses. Prior to this bracing was provided by diagonal timber braces in the wall framing and the plasterboard had a non-structural function.

3.5 Recorded Damage

Along with gathering information on the characteristics of the properties, estimates were made of the levels of damage sustained by the various components of the dwellings. Analysis of the gathered damage data is still going on. It is notable that no timber framed houses collapsed in any of the earthquakes unless affected by ground movement such as cliff collapses above or adjacent to houses or rolling rock impacts. It is also important to remember that the performance expectation in the NZ Building Code (DBH 1992) is that buildings should not collapse when subjected to what is referred to in the NZ loading standards as the ultimate limit state loading condition. However, damage is expected to occur to buildings in an event of this size. This condition was exceeded in many areas of the city, particularly in the February 2011 event.

Of the 314 houses surveyed 167 were damaged in the September 2010 earthquake, 237 in February 2011 and 136 in June 2011. It is not known when 20 houses were damaged. Only 10% of the houses surveyed had sustained no damage, but in many of the damaged houses it was limited to joint cracks in plasterboard linings, and cracking in fibrous plaster or lathe and plaster linings.

Much of the damage to houses on the flat was due to differential ground settlement and lateral spreading associated with liquefaction and varied from quite minor to major (Figure 2). In houses not affected by ground liquefaction, the most obvious signs of house damage viewed from the outside were failed unreinforced masonry chimneys on older houses and the loss of portions of veneer.



Figure 2: Severely damaged house from differential ground settlement and lateral spreading

In the hill suburbs, the shaking was more severe, resulting in substantial damage to brick veneer claddings, heavy tile roofs and interior linings.

3.5.1 Foundations

Slab on grade foundations performed well under earthquake shaking. However, ground deformations beneath these slabs, caused either by liquefaction settlement or lateral ground spreading on the flat or ground slumping in the hill suburbs, resulted in sometimes severe distortions of the concrete slabs. Of the surveyed properties, 81 had some evidence of liquefaction. Eighteen of these were slab on grade foundations and 14 were undamaged. The common perimeter concrete foundation with internal piles also fared well under ground shaking but was affected by varying degrees by the ground movement. It was common for these perimeter foundations to be unreinforced in the early to mid 20th century houses but most foundations constructed after this contained at least one 12mm diameter bar, often plain. Whether reinforced in this way or not, these foundations were unable to resist the ground deformations and fractured (Figure 3). Fifty seven of the surveyed properties with perimeter foundations were located where the ground had liquefied and 24 of these were undamaged.



Figure 3. Example of reinforced concrete perimeter foundation pulled apart by spreading ground

3.5.2 Wall cladding systems

Seventy two percent of the brick/block veneer claddings on the surveyed houses sustained damage, 76% of houses with stucco claddings and 67% of houses with monolithic claddings (eg plastered sheet materials and EIFS) (Table). About a quarter of veneer clad houses had a significant proportion where cladding fell off or was detached or unstable. Almost all veneer clad buildings with more than 10% of cladding fallen, detached or unstable were in the hill suburbs, with the balance mostly being houses with separate unattached foundations for the brick veneer and the framing. Veneers constructed after the mid 1990's performed much better than earlier construction because of improvements in the tie fixing systems to the framing that were introduced at that time.

The majority of houses surveyed with monolithic cladding suffered from some sort of cracking, but only 21 houses of this type were surveyed. Most of the cracking was from the corners of windows and experimental studies conducted at BRANZ some years earlier (Beattie 2006) had indicated that such damage was relatively easy to repair. The damage to weatherboard claddings was not specifically recorded because it was generally observed to be very low. As expected because of the greater ground distortion, the proportion of houses that had jammed doors or windows was higher in the areas that were affected by liquefaction than those that were not.

3.5.3 Roof claddings

Damage to sheet roof claddings and metal tiles was confined mainly to damage sustained from falling chimneys and tended to be minor. Concrete and clay tile roofs also sustained damage from falling chimneys but those in the hill suburbs often suffered from dislodgement of the tiles from the supporting battens (Figure 4). It was common for such tiles not to be

tied to the framing or for the ties (if they were present) to have corroded. Very high vertical peak ground accelerations (>1g) were recorded in February 2011 in the hill suburbs and this is sure to have contributed to the tile dislodgement.

Table 5: Percentage of stucco, masonry and monolithically clad houses with different types of damage

	% cracked			% fallen, detached or unstable			% with cracks over substrate joints		
Area of wall affected	>50%	10-49%	<10%	>50%	10-49%	<10%	>50%	10-49%	<10%
Stucco	10	26	38	0	0	0	-	-	-
Veneer	12	18	41	11	6	8	-	-	-
Monolithic	0	5	10	0	0	0	5	24	38



Figure 4: Dislodged concrete roof tiles

3.5.4 Interior linings

Eighty five percent of the surveyed houses had damage to wall linings and 73% had damage in the ceiling linings. Joint cracks were the most common form of damage, with 72% of houses suffering from them. Wall linings rarely became detached. Diagonal cracks were rare in houses that only had plasterboard linings. Most of the diagonal cracking that did occur in plasterboard appeared to be at the corners of openings, and some was observed in houses that suffered from severe sagging and hogging in the foundations due to ground movement.

As with wall linings, joint cracks were the most common form of damage in ceiling linings, with 49% of houses suffering from them. Diagonal cracks were not common in plasterboard ceilings but far more common (27%) in fibrous plaster ceilings. It is believed that because the fixing of the fibrous plaster ceilings is often more rigid than the plasterboard products (eg wadded connection to the framing), distortion of the supporting framing causes the diagonal cracks to occur. It was rare for whole sheets to fall from the ceiling or the walls, but popping of fixings occurred in about 10% of the surveyed houses.

Diagonal cracks were more common in wall linings than in ceiling linings. This is likely to be due to there being openings causing stress concentrations. NZ plasterboard manufacturers recommend fitting sheets around the corners of openings to provide a better finish performance during normal seasonal changes in the timber framing, which does make the sheets more susceptible to diagonal cracking than linings with joints coincident with the edge of the opening, as the walls rack in an earthquake.

4. Recommendations for improved performance

The survey results and also the observations made by the author and colleagues during the house safety evaluations provided an opportunity to form a view on the recipe for better performing houses.

Timber framed houses are particularly resilient, as borne out by their performance in this sequence of earthquake events, where none collapsed unless affected by rockfall or ground collapse. However, damage should be expected in earthquakes of this severity because distortion of the structure occurs as the earthquake energy is absorbed. Most of this damage is repairable at low to moderate cost but there are certain design approaches that can lessen the amount of damage.

Houses that were affected by ground distortion from liquefaction were shown to be better protected when a stiff foundation system such as a reinforced waffle slab was used, which could bridge over ground distortions without having excessive curvatures. Houses with heavy claddings clearly distorted more than those with lightweight claddings when the ground beneath them liquefied. Under shaking action alone, heavy houses can be designed to have stronger bracing systems to resist the greater inertial forces.

Simply shaped houses such as rectangular forms performed better than more complex forms. When complex forms are present, different parts of the house can clash with other parts under shaking actions. This is particularly obvious at the intersections of wings in an “L” or “U” shaped house, where damage was observed to be more severe.

Houses constructed on steeply sloping sites were more badly damaged when the foundation systems were not designed to properly cater for the potential stiffness incompatibility between the short and tall foundations. Similarly, hillside houses built with large windows to make the most of a view often suffered from a stiffness incompatibility between the view facing walls and the walls on the opposite side of the house, resulting in breakage of the windows. The provision of stiffer bracing systems for the view facing walls will serve to lessen these effects.

5. CONCLUSIONS

This paper has provided a brief description of the earthquakes that occurred in the Canterbury region over the period from 4 September 2010 until December 2011. It also discusses the types and proportions of house construction present in the city of Christchurch

and then goes on to describe the results of a survey of 314 randomly selected houses over the period following the June 2011 earthquake.

The survey has shown that the performance of timber framed houses under the intense shaking has been good in terms of the performance expectations of the NZ Building Code. No collapses occurred directly from the shaking. However, damage was sustained by many of the houses, the majority of it reparable, but in some cases which were affected by significant liquefaction re-building will be necessary.

Several actions have been suggested to be taken in the design and construction of houses for improvement of their performance in earthquakes.

Acknowledgement

The survey project was undertaken with funding provided by the Building Research Levy and by the Ministry of Science and Innovation through the Natural Hazards Research Platform.

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Monetary value as a proxy for vulnerability in statutory adjudication and other construction regulation

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Abstract

By and large, statutory intervention into contracts for construction projects is limited to circumstances in which it is perceived by the legislature that one party is likely to be vulnerable to the other, and that this vulnerability is such that it is appropriate to constrain the parties' freedom to contract as they wish.

It is in the nature of such legislation that inevitably it will be a somewhat blunt instrument for reforming parties' commercial behaviour, applying as it must to firms and individuals which are *deemed* to be so vulnerable, regardless of whether they are *in fact* vulnerable.

This paper examines the use in statutes of monetary value – whether of the contract price, of claims or otherwise – as a means of determining such vulnerability. It focuses in particular upon whether any particular value has been – or should be – viewed as an appropriate proxy for such vulnerability.

The paper reviews the current situation in Australia in respect of two key areas of construction activity where the legislature has seen fit to intervene into parties' freedom to contract on the grounds of protection of the vulnerable: the residential building sector (protection of owners as consumers) and security of payment (protection of subcontractors and suppliers). The latter is investigated in the context of recent proposals towards harmonisation of the various state-based legislation in Australia and, in particular, Jeremy Coggins's suggestion that a dual system for regulation apply depending upon the monetary value of the claim.

It is concluded that, despite the inevitably somewhat arbitrary nature of nomination of a monetary value, it remains an essential element to any statutory test for vulnerability. This both supports the viability of a monetary trigger as an element within a harmonised model for Australian security of payment legislation (which of itself might be considered in other countries where similar legislation is in place) and invites further research into whether it is possible to nominate an optimal value for statutory intervention in respect of construction industry regulation.

Keywords: legislation, consumer protection, security of payment, statutory adjudication, construction industry.

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1. Introduction

Construction law has been described by Bruner (2007: 13-14) as "a primordial soup in the 'melting pot' of the law". Perhaps the primary reason that such a description is apt is because the law – at its heart, a system of regulation which seeks to offer predictability of outcomes to parties subject to it – is applied in the construction sphere to an industry and to practices which display almost infinite permutations throughout the world and over time.

Drafters of standard forms of building contract, or of statutes applying to the industry, need to anticipate those permutations when devising schemes which intervene into construction participants' freedom otherwise to behave as they think fit (provided, of course, that they comply with generally-applicable laws). These drafters seek to identify, in the abstract at the time of drafting, parties whose behaviour needs to be regulated or upon whom protections are to be conferred: that is, despite the drafter not having the *actual* party in their contemplation, the scheme they devise will *deem* parties displaying certain characteristics to fall within its bailiwick.

In turn, a statute which prescribes, for example, that parties are unable to include certain matters in their contract – or, on the other hand, that they *must* include certain things – will need to incorporate a mechanism which determines the types of arrangements will be subject to that scheme. A typical approach for these mechanisms is to identify the arrangements by reference to the type of work being undertaken and its monetary value. For example, under the *Domestic Building Contracts Act 1995* (Vic), a statute of the state of Victoria, Australia, contracting arrangements are captured by the legislative scheme if they are for "domestic building work" (essentially, that in relation to a home) and the greatest level of intervention is applied to arrangements where the contract price exceeds A$5,000.

This paper examines the nature and content of these mechanisms. It seeks, in particular, to identify whether it is possible to propose an optimal basis for intervention into the parties' contracting arrangements where one of the parties is identified as being "vulnerable" to the other in the sense that it is unable reasonably to protect its interests through negotiation of appropriate terms in the contract. It does so via the following structure:

- In section 2, undertaking a survey of mechanisms currently used for legislative intervention in construction contracts, focusing upon the approaches to residential building across the Australian states and territories; this reveals a lack of uniformity despite these statutes broadly seeking to "crack the same nut" in a policy sense – that is, protection of those who are deemed unable to protect themselves via the contract; it is noted, moreover, that there is little evidence to show that the drafters applied meaningful objective criteria to establishing the nexus between vulnerability and protection;

- In section 3, examining an area of legislative intervention where there was in fact detailed consideration given to the basis on which that nexus would be applied, with the result that the monetary value was retained as a limb of the test: the definition of "consumer" under the *Australian Consumer Law* (***ACL***); and

- In section 4, considering whether the approach applied in relation to the *ACL* may usefully be applied to construction industry regulation, especially in the context of recent proposals to harmonise the "security of payment"[2] legislation in place across the Australian states and territories and, especially, Jeremy Coggins's proposal (2011, 2012) that a dual system for regulation apply depending upon the monetary value of the claim.[3]

We conclude that, despite the inevitably somewhat arbitrary nature of nomination of a monetary value, it remains an essential element to any statutory test for vulnerability. This both supports the viability of a monetary trigger as an element within a harmonised model for Australian security of payment legislation (which might be considered in other countries where similar legislation is in place),[4] and invites further research into whether it is possible to nominate an optimal value for statutory intervention in construction industry regulation.

Whilst this investigation is limited in its scope and therefore its conclusions, it is undertaken in the context of little previous research having been done in the area and therefore seeking to prompt further research and debate amongst the international construction community.

2. Mechanisms for legislative intervention

The stated purposes of the *Domestic Building Contracts Act 2000* of the state of Queensland include achieving "a reasonable balance between the interests of building contractors and building owners" (s 3(a)). Legislation with similar aims is also in place across the seven other states and territories of Australia.[5] The legislation operates in varying ways across Australia, but features which apply across most jurisdictions include the prescription of matters which contracts for residential work must, or must not, include. These are explicitly designed to redress the disadvantage in relation to bargaining power, disparity of knowledge and lack of

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[2] This paper adopts "security of payment" as the prevailing generic term for legislation in Australia which seeks to regulate payment processes, and disputes, in order to facilitate cashflow within the contracting chain. This encompasses the "adjudication" element which represents the accepted terminology for similar legislation in the UK, New Zealand and elsewhere.

[3] Having said that, this paper does not seek to engage directly with whether it is monetary value or the types of claim which provides the most appropriate differentiator for the application of the dual scheme. Essentially, as is noted in section 4, Coggins's proposal rests upon monetary value as a proxy for vulnerability – hence, the attention paid to it in this paper. On the other hand, Brand and Davenport (2011 but see also the previous articles by the authors referred to in that paper) have cogently argued that the intent and policy objectives of the Australian security of payment legislation would more appropriately be promoted if the distinction was between "progress claims" – which would be processed under the "Defined Scheme" (currently reflected under what they term the "Australian model", which is referred to as the "East Coast model" in section 4 below) – and more generalized "money claims", which would be resolved under the West Coast model. See, further, n 26 below.

[4] See the list in Coggins and Donohoe (2012: 196-7) and the discussion by Brand and Davenport (2011: 256-8).

[5] See, primarily, *Building Act 2004* (ACT), *Home Building Act 1989* (NSW), *Building Act 2005* (NT), *Domestic Building Contracts Act* 2000 (Qld), *Building Work Contractors Act 1995* (SA), *Housing Indemnity Act 1992* (Tas), *Domestic Building Contracts Act 1995* (Vic), *Home Building Contracts Act 1991* (WA). For a recent consideration of the Australian (and New Zealand) residential building legislation see Britton (2013: 17-21).

understanding of contractual principles which home owners, as a class, are perceived to suffer vis à vis builders.[6] For example, warranties as to standards of workmanship and materials are implied into contracts on a basis that cannot be excluded by the parties,[7] and "cooling off" periods are provided for (within which the owner may end the contract after signing it in certain circumstances).[8]

Having said that, there is little uniformity of approach across the various states and territories. This is especially the case when it comes to the trigger for application of these prescriptive aspects of the Acts. Whilst these triggers are by way of a combination of the type of work being undertaken and the value of the contract under which it is undertaken, both elements vary significantly across the country. By way of example, Table 1 illustrates the variation in respect of the minimum contract value to which the provisions apply.

Table 1: Contract values as trigger for application of residential building legislation

State/ Territory	Relevant legislation	Contract value A$
Australian Capital Territory	*Building Act 2004* (ACT) (see rule 27 Building (General) Regulation 2008 (ACT))	12,000
New South Wales	*Home Building Act 1989* (NSW) s 7AAA	5,000
Northern Territory	*Building Act 2005* (NT) (see rules 41J and 41E Building Regulation (NT)	12,000
Queensland	*Domestic Building Contracts Act 2000* (Qld) s 9	3,300
South Australia	*Building Work Contracts Act 1995* (SA) s 27(2)	12,000
Tasmania	*Housing Indemnity Act 1992* (Tas) s 5	12,000
Victoria	*Domestic Building Contracts Act 1995* (Vic) ss 29-43 and definition of "major domestic building contract"	5,000
Western Australia	*Home Building Contracts Act 1991* (WA) s 3(1)	7,500

This type of disparity in legislative approach is to a certain extent an expected and inevitable result of a federal structure such as that in place in Australia where the former colonies (now States) retain legislative power over matters (in this case, residential building work) which have not been ceded to the central government. However, in a relatively small country like Australia (at least, in terms of population and the size of the construction industry), such

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[6] Explanatory memorandum, Queensland Domestic Building Contracts Bill 1999; Victoria, *Parliamentary Debates,* Legislative Assembly, 14 November 1995, 1140 (Mrs Wade).

[7] See, eg, *Domestic Building Contracts Act 1995* (Vic) ss 8, 20, 132.

[8] See, eg, *Domestic Building Contracts Act 1995* (Vic) s 31.

differences across state borders may be expected to hamper the efficiency of commerce or, at the very least, to cause confusion to builders and consumers alike.[9]

As was noted at the outset, this paper seeks to identify whether any particular monetary value might provide an optimal trigger for the imposition of provisions designed to protect vulnerable parties. As a first step, however, the figures cited above are of relatively little value to this task, not simply because of their level of disparity but also there is scant evidence available as to why these figures were chosen by the various legislatures. None of the supporting documentation produced by Australia's Parliaments – primarily, explanatory memoranda and second reading speeches – provides a clear explanation or methodology for adopting these values. In turn, it is difficult to resist the inference that the trigger points have been framed in a somewhat arbitrary fashion.

3. Approach taken in the *Australian Consumer Law*

Whilst little evidence exists as to the basis on which contract values have been prescribed under the Australian residential building legislation, there is greater guidance available in respect of the regulation of consumer protection generally under the *Australian Consumer Law* (***ACL***).[10] This is Commonwealth (federal) legislation which largely replaces, by dint of agreement with the states and territories, the patchwork which existed until 2011 comprising the *Trade Practices Act 1974* (Cth) and various state-level laws.

The following section examines the process by which an element of the *ACL* akin to the residential building legislation was drafted in 2010. This seeks to illustrate that, whilst stipulating a monetary value as a proxy for vulnerability inevitably tends towards arbitrariness, it is a fraught exercise to frame a proxy which does not include such a value. Similarly to the residential building legislation, the *ACL* prescribes certain implied conditions and warranties, in this case in arrangements for the supply of goods and services. The conditions imposed on suppliers include providing adequate descriptions of goods,[11] and ensuring that the goods are of merchantable quality[12] and reasonably fit for their purpose.[13]

The application of the relevant provisions rests upon a definition of "consumer" in s 3 of the ACL. This is a complicated definition with a number of applicable further provisions and qualifications, but in essence it provides that a person acquires goods or services "as a consumer" if and only if the price paid or payable for them does not exceed A$40,000 *or* they are of a kind "ordinarily acquired for personal, domestic or household use or consumption". The "or" is significant here: it effectively means that the "ordinarily acquired…" limb only has

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[9] For a discussion of the impact of such disparity in the context of security of payment legislation, see, eg, Coggins, Fenwick Elliott and Bell (2010: 19-20).

[10] The *ACL* is contained in Schedule 2 to the *Competition and Consumer Act 2010* (Cth).

[11] *ACL* s 70.

[12] *ACL* s 71(1).

[13] *ACL* s 71(2).

relevance to goods the value of which exceeds A$40,000. In turn, purchasers of goods with a value of less than A$40,000 are (subject to the applicable qualifications) *deemed* to be worthy of the provisions' protection regardless of the actual nature of the transaction.

This dual approach was and remains controversial. When the monetary trigger (then, A$15,000) was first enacted under the *Trade Practices Act 1974* (Cth) (***TPA***), the Parliamentary committee acknowledged the arbitrary nature of adopting such a threshold but felt that allowing the figure to be altered by regulation addressed the concern (Griggs et al (2011): 63). However, when the time came to draft the revised version of the *TPA* which was to become the *ACL*, the Senate Standing Committee on Economics strongly advocated for the removal of the monetary threshold, and the Bills as prepared did not include it. The Committee (2010: [3.42]) noted that "[i]t has long been recognised that the monetary threshold is arbitrary and contentious. It is anomalous that a business should have the same protection as an individual consumer if they buy goods for less than $40,000".

Despite this, the monetary threshold limb was reintroduced at the last minute. The Committee received submissions by various stakeholders proposing that the removal of the monetary ceiling would reduce consumer protection because, for example, goods that were purchased by small businesses for the use of employees (as "consumers") would not meet the "personal, domestic or household" criterion.

4. Use of a monetary proxy in legislation regulating construction

4.1 The challenge

The previous section sought to illustrate, by reference to the experience under the *ACL*, that attempting to define vulnerability within a statute in the absence of a monetary threshold is a fraught exercise. This is arguably even more acutely the case when it is the construction industry which is being regulated by the statute. The diverse range of multidisciplinary activities, the complex relationships that exist between parties and the commercial sophistication of participants in the industry makes the appropriate framing of a "purpose" or "nature" test of universal application an extremely difficult task.

In the context of the *ACL*, Griggs et al (2011: 77) have rightly called for further work to be done in pursuit of a unifying definition of "consumer", but have emphasised that such a quarry has thus far proved elusive. In the absence of such a definition, it is our view that a legislative scheme which combines the necessary element of defining the scope of the activity which is covered (for example, residential building work) with a monetary threshold as a proxy for vulnerability remains the most viable approach.

A monetary trigger has the key benefit of promoting certainty for parties – whether they be home owners, subcontractors or developers or the myriad other participants in the construction industry – albeit at the inevitable expense that the exact threshold chosen will be a somewhat "blunt instrument". Moreover, it arguably provides the most realistic reflection of the way in which consumers decide whether to enter into contracts: Paterson (2009: 953) has summarised a number of relevant studies by noting that, being unable to process large

amounts of information, consumers tend to focus on key items within the contract, price being prominent amongst these.

4.2 Australian "security of payment" legislation

If it is accepted that some sort of monetary threshold is a necessary element in the test for vulnerability which is worthy of legislative intervention, the next key question is what the appropriate amount should be for that trigger. This is very much a live question in the context of proposals to harmonise Australia's "security of payment" Acts – legislation which seeks, to varying degrees, to regulate project payment streams.

Over the past 14 years, security of payment legislation has been progressively passed in every Australian state and territory based upon the adjudication provisions of the UK *Housing Grants, Construction and Regeneration Act 1996* to a greater or lesser extent.[14] There are essentially two models in place in Australia: the so-called "West Coast" model incorporating the Western Australian and Northern Territory Acts and the "East Coast" model represented by the other states and territories' Acts.

As characterised by Speranza (2011: 172), the West Coast model is generally less prescriptive as to what can, and cannot, be included in the contract than the East Coast model and therefore intervenes less into parties' freedom to contract. Coggins and Donohoe (2012: 199) and Brand and Davenport (2011: 259) also note that, whereas the East Coast model is intended only to apply to matters arising directly out of the payment claim, adjudications under the West Coast model cover (like the original UK Act) disputes under the contract generally. However, as has been remarked upon by commentators including Brand and Davenport (2011: 259), "mission drift" has extended the ambit of claims under the East Coast model so that they routinely include substantial amounts generated by matters outside of the payment stream.[15]

As has been pointed out by Bell and Vella (2010: 567-8) and Coggins (2011: 36-7), whilst the specific aim of the legislation was to protect vulnerable participants in the supply chain by "stamp[ing] out the unAustralian practice of not paying contractors for work they

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[14] *Building and Construction Industry Security of Payment Act 2009* (ACT); *Building and Construction Industry Security of Payment Act 1999* (NSW); *Construction Contracts (Security of Payments) Act 2004* (NT); *Building and Construction Industry Payment Act 2004* (Qld); *Building and Construction Industry Security of Payment Act 2009* (SA); *Building and Construction Industry Security of Payment Act 2009* (Tas); *Building and Construction Industry Security of Payment Act 2002* (Vic); *Construction Contracts Act 2004* (WA). These Acts are referred to in this paper respectively as the "ACT Act", "NSW Act" and so forth, and collectively as the "SOP Acts". A comprehensive bibliography in relation to them is provided by Collins (2013: 374-430).

[15] For example, in *John Holland Pty Ltd v Walz Marine Services Pty Ltd* (2012) 28 BCL 62, the subcontractor submitted a claim under the Queensland Act for A$2.26 million in delay and disruption costs (albeit "styled [as] variations": [5]). Similar examples are cited by Coggins and Donohoe (2012: 216).

undertake on construction",[16] it was clearly the case that the legislation was also intended to reform behaviours across affected sectors of the industry.[17] This aim was sought to be achieved via provisions including prohibition of "paid when paid" clauses,[18] granting a default right to progress payment if no such agreement exists,[19] requiring prior notice for withholding payments,[20] establishing the right to suspend performance of contractual obligations for non-payment[21] and the right to refer disputes to fast-track adjudication.[22]

4.3 Further reform in 2013?

In early 2013, the Inquiry led by Bruce Collins QC into construction industry insolvency in New South Wales observed that, despite the legislative reforms, there has been little overall improvement in the cashflow outcomes for subcontractors. For example, he found (2013: 54) that more than A$1 billion was owed to subcontractors in NSW as a result of recent insolvencies during the 2011 financial year. The Report also confirms (2013: 61-64; 99-101) that inequality of bargaining power remains a root cause of the ongoing "subbie squeeze". In turn, Collins has recommended a "thorough review" of the NSW Act (2013: 74) with a suite of specific reforms proposed including expansion of the matters which an adjudicator can review (recommendation 39), the setting of maximum periods for payment after certification (recommendations 24, 29, 34 and 35) and removal of the requirement that parties "opt-in" to the operation of the Act via payment claims (recommendation 38).

Whilst these changes might well be expected to increase the likelihood that a subcontractor could take advantage of the Act's procedures, they do not directly address the issue that is the focus of this paper and discussed in detail in the next section: that the legislation does not allow for a qualitative assessment as to the vulnerability of the individual party before its potentially far-reaching interventions into the parties' freedom otherwise to contract as they see fit are triggered.

4.4 Lack of a specific vulnerability test

The apparent intent to reform the culture of the industry, enshrined most strongly in the East Coast model through its more prescriptive intervention into contracts, is reflected by the

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[16] Morris Iemma MP, Second Reading Speech for the Building and Construction Industry Security of Payment Bill, NSW Legislative Assembly, 29 June 1999 (*Hansard* p 11). Similarly, Collins (2013: 14) has more recently identified, as one of the two pillars on which his Report into construction insolvency rests, that '"it is against the good conscience of the community… to stand by and tolerate… a repeatedly demonstrated inability of the existing legal system to protect subcontractors against the default and the financial mismanagement of [head contractors]."

[17] Certain sectors and activities are excluded: see Coggins, Fenwick Elliott and Bell (2010: 16-19).

[18] See, eg, NSW Act s 12; WA Act s 9.

[19] See, eg, NSW Act s 8; WA Act s 15.

[20] NSW Act s 14; WA Act s 17.

[21] NSW Act ss 15, 24; WA Act s 42.

[22] NSW Act s 17; WA Act s 25.

legislation being deemed to apply to all arrangements within affected sectors without reference to the value of the arrangement (except in Victoria and potentially in Queensland, as discussed below).

Thus, there is no test for application which relates to the vulnerability of specific parties. Rather, the East Coast model essentially provides (see, eg, the description by Speranza (2011: 171-2)) that, where a supplier of work or services captured by the Act chooses to "opt-in" to the use of the Act, they endorse their payment claim as prescribed and the Act's provisions relating to the payment stream and adjudication then apply. As has been noted by Bell and Vella (2010: 570-2), the potential effect of this is to reverse the bargaining position which traditionally applied in the contracting chain: instead of those who do the work having to wait to get paid, those for whom the work is done must "pay now and argue later".

It has for many years been recognised in Australia, the UK and other places where no vulnerability-based element applies, that the legislation is being used by well-resourced and arguably non-vulnerable parties to make substantial claims by way of "ambush". The deliberately short time-frames[23] leave little opportunity for a respondent (the party from whom payment is claimed) to put forward a fully-considered case.

This limitation on respondents' rights, along with others embedded in the East Coast model, has led Coggins to propose (2011: 43) that the model tends inherently to the denial of procedural justice (this may, however, not be unintended given that the East Coast model is essentially a certification review process: Coggins and Donohoe (2012): 213) and therefore leads to the "disconcerting" result that "multi-million dollar progress claim disputes are being resolved, albeit on an interim basis, by means of a fast track adjudication scheme which limits the adjudicator's power to investigate and potentially bars a respondent from having its arguments heard by the adjudicator."[24]

4.5 Victorian approach: distinction based on contract value

In Victoria, however, elements of the scheme limit its application by reference to the type of claims and the value of the contracts. Provisions which currently are unique to the Victorian *Building and Construction Industry Security of Payment Act 2002* (Vic), introduced in 2006, seek to limit the use of the Act's provisions regulating payment (including expedited adjudication) to "pure" payment claims. Thus, "excluded amounts" such as in respect of latent conditions, claims for damages and delay-related claims, cannot be included in payment claims under the Act (see ss 10A-10B) and only certain types of non-agreed variations can be included.

The mechanism for deciding which variations can be included in payment claims under the Act depends upon the value of the contract, with the legislation essentially nominating three contract value-based thresholds. If it is below A$150,000, non-agreed variations of any

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[23] Generally, a matter of 5-8 weeks: see Bell and Vella (2010: 569) and Coggins (2011: 49).
[24] Coggins (2011: 43). See n 15 for examples of these claims.

amount may be included; if between A$150,000 and $5,000,000, 10% of the contract value can be claimed by way of non-agreed variations; and if it exceeds A$5,000,000 and the contract includes a dispute resolution clause, no non-agreed variations may be claimed.

The Second Reading speech for the amending Act gave little guidance as to the detailed policy underpinning this regime, but confirmed that the aim of placing a maximum cap was to ensure that the smaller value contracting sector and the subcontracting sector would be subject to the scheme, while larger contracts would be exempt from it.

The Victorian approach seems unnecessarily complex, especially through its incorporation of three categories rather than the single point of distinction (between parties which are vulnerable and those which are not) favoured by this paper. Nonetheless, it explicitly addresses the "mission drift" referred to above by limiting the types of claims which can be funnelled through the Act to those relating directly to the payment stream and, more generally, narrows the scope of application of the Act as the value of the contract increases. In turn, parties regarded as not being vulnerable in the relevant sense – and, therefore, falling outside the legislative scheme – retain the freedom to stipulate their own means of resolving payment-related disputes under the contract.

In December 2012, the *Discussion Paper* released by the Queensland Government outlined the Victorian approach (at pp 15-16) and sought submissions from stakeholders as to whether the types of payment claims under the Queensland Act's jurisdiction should be restricted in a similar manner or otherwise (including by reference to the contract price).

4.6 Dual scheme approach to harmonisation

The unique provisions in Victoria are but a more prominent example of a raft of differences which exist between the various Australian SOP Acts, and even within the two main models' Acts. Many commentaries on these differences have been written[25] but, generally speaking, the Acts vary significantly in relation to policy, procedure, terminology and physical layout. The potential impact on commerce having been recognised, attention has turned in recent years to models which could prove viable by way of a harmonised scheme across Australia.

Coggins (see, especially, 2010, 2011 and 2012) has proposed a "hybrid" adjudication scheme which utilises either the East Coast or West Coast models depending on the amount of the payment claim. In doing so, the proposal seeks to address both of the twin problems referred to above: lack of uniformity across jurisdictions and the expedited process being used inappropriately by those who arguably are not vulnerable.[26] Essentially, according to

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[25] See, eg, Bell and Vella (2010), Coggins, Fenwick Elliott and Bell (2010), Brand and Davenport (2011) and Coggins and Donohoe (2012).

[26] As is discussed above (see n 3), Brand and Davenport (2011) have proposed a dual scheme model the distinction for which rests upon the type, rather than monetary value, of the claim. The model is attractive as a potential cure to the lack of harmonization of Australian security of payment legislation, especially because it arguably offers a closer alignment with the key policy driver of the legislation – promoting cashflow – than is currently achieved in the various Acts. The proposal is not, however, considered in detail in this paper given the focus here upon monetary value as a proxy.

Coggins's proposal, the "regulatory" East Coast model would be used for small purely progress payments below the threshold value of $25,000 and any other claims – whether above this value or under it but incorporating matters outside payment for work undertaken – would be determined using the West Coast model's "evaluative" process.

Coggins chose the $25,000 figure as covering a substantial proportion of the subcontractors in the lower end of the hierarchical chain, based upon a study (see 2011: 360) comparing the adjudication claim values between Queensland and Western Australia during the period 2008-2009. According to the comparison, 52% of the claims in Queensland and 30% of the claims in WA were below the value of $25,000.

5. Where do we go from here?

Ultimately, any legislative scheme which seeks to intervene into contracting arrangements to protect parties seen as vulnerable needs to strike a balance between such protection and the maintenance of certainty within the contracting community. The Coggins "hybrid" proposal goes a significant distance towards achieving such a balance in respect of security of payment, thanks largely to its incorporation of a monetary trigger. This is, however, a feature which, as noted above, is currently absent from the various Australian Acts (with the exception, in relation to variations, of Victoria).

Having said that, the A$25,000 threshold for payment claims proposed as part of the scheme inevitably may be viewed as somewhat arbitrary. Thus, in the context of security of payment legislation and other areas of construction regulation, the challenge remains to find a principled basis on which an optimal – or, at least, defensible – mark can be framed. We think that this question ought be the focus of further, detailed research, both as to the appropriate principle and, ultimately, the monetary threshold chosen.

We also suggest that the following observation from John Akehurst, then Managing Director of Woodside Petroleum Ltd, might provide guidance in striking the right balance:

> "For truly successful companies, the traditional master-servant relationship of project owner and project contractor is becoming obsolete. We have learnt that by sharing the risks, we share the rewards." (Australian Constructors Association (1999: 3))

It reminds us to be wary of blanket legislative intervention across an industry – including in its highly sophisticated and experienced sectors – where the aim is to protect those who are vulnerable due to an imbalance in bargaining power or information asymmetry.

The exercise is, however, worth embarking upon. Figures cited by Brand and Davenport (2011: 254) indicate that nearly a million people – well over 5% of the country's adult population – are employed in construction businesses in Australia and that the vast majority of trade service businesses have relatively small turnover, with income of less than A$100,000. It is the contention of this paper that an appropriately-framed monetary threshold can provide an umbrella of protection to these thousands of businesses whilst addressing the concerns of the large and sophisticated, but relatively few, non-vulnerable entities in the industry that their freedom to contract with like entities not be unnecessarily curtailed.

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Alcohol and other drugs in the Australian construction industry: a pathway for safety focused cultural change

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Anecdotal evidence from the infrastructure and building sectors highlights issues of alcohol and other drugs (AODs) and its association with safety risk on construction sites. Currently, there is no clear evidence on the prevalence and risk of AOD use among Australian construction workers and there is limited evidential guidance regarding how to effectively address such an issue. The current research aims to scientifically evaluate the use of AODs within the Australian construction industry in order to reduce the potential resulting safety and performance impacts and engender a cultural change in the workforce. A nationally consistent and collaborative approach across the workforce will be adopted. A national assessment of the use of AODs was conducted in participating organisations across three states. The World Health Organisation's Alcohol Use Disorders Identification Test (AUDIT) was used to measure alcohol use. Illicit drug use, 'readiness to change', impediments to reducing impairment, feasibility of proposed interventions, and employee attitudes and knowledge regarding AOD was also measured through a combination of survey items and interviews. Through an educative approach and consultation with employers, employees, union groups and leaders in applied AOD research, this assessment was used to inform and support cultural change management of AOD use in the industry. Results (n=494) indicate that as in the general population, a proportion of those sampled in the construction sector may be at risk of hazardous alcohol consumption. A total of 286 respondents (58%) scored above the cut-off cumulative score for risky or hazardous alcohol use. Other drug use was also identified as a major issue. Interview responses and input from all project partners is presented within a guiding principle framework for cultural change. Results support the need for evidence-based, comprehensive and tailored responses in the workplace. This paper will discuss the final results in the context of facilitating cultural change in the construction industry.

Keywords: alcohol, drugs, construction, safety cultural change.

1. Introduction

Anecdotal evidence from the infrastructure and building sectors highlights issues of alcohol and other drugs (AOD) and its association with safety risk on construction sites. Currently, there is no clear evidence on the prevalence and risk of AOD use among Australian

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construction workers; despite AOD consumption being relatively prevalent within the Australian community (Holland, Pyman and Teicher 2005) and the clear link between such consumption and subsequent declines in cognitive and behavioural performance (Elliot and Shelley 2006). The collection of empirical data is needed to ascertain the level and nature of risk in order to design effective interventions and strategies that are tailored to the construction industry.

Almost universal across the Australian construction industry is the adoption of the theoretical construct of organisational safety culture (Glendon 2003; Guldenmund 2000; Reason 2000). A positive safety culture can result in improved occupational health and safety and organisational performance (Dingsdag, Biggs, Sheahan and Cipolla 2006; Biggs, Dingsdag and Roos 2008; Biggs, Dingsdag, Kirk and Cipolla 2010). When considering predominant pathways to create behavioural change in the workplace, there are two main pathways to ensure compliance: (1) the extrinsic pathway, governed by systems and rules with rewards and punishments; and (2) the intrinsic pathway, establishing voluntary compliance via individual commitment to safety (Glendon 2003). For example, in the mining industry the extrinsic pathway with a legislative framework governing mining operations and the implementation of AOD policy and programs has resulted in a heavy focus on testing. However, within the construction industry across Australia, there is generally not as extensive or explicit AOD workplace legislation and there is also wide variability between organisations, sites and practices. In general the construction industry relies heavily on an educative approach built around the intrinsic motivation of individuals to operate safely when it comes to AOD use (Guldenmund 2000; Sully 2001).

It is argued that developing a nationally consistent, contemporary and collaborative approach across the construction workforce is needed to engender a cultural change in the workforce. Such an approach may take a similar form to the on-going initiative in securing a cultural change to drink-driving in our society where peer intervention and support is encouraged and appears integral to maintaining such change (Ferguson, Schonfeld, Sheehan and Siskind 2001). The current research aims to scientifically evaluate the use of AOD within the Australian construction industry to engender a cultural change in the workforce - to render it unacceptable to arrive at a construction workplace with impaired judgement from AODs. A national approach across the Australian construction workforce - involving government representatives; employers and employees; unions; and other key industry stakeholders and experts will be adopted. An evaluation of the extent and nature of the problem, through an AOD consumption and behaviour assessment, will inform the necessary cultural change based on a non-punitive, rehabilitative and educational approach. Previous work by Biggs et al (2008) and Fleming, Lingard and Wakefield (2007) provide a significant starting point for framing cultural change in the construction industry.

2. Method

This project was approved by the QUT Human Research Ethics Committee and led by an Academic Project Leader in partnership with a senior Industry Project Leader from a major Australian construction company. The project team collaborated with academic leaders and experts in applied research in the area and was guided strategically by an Industry Steering

Committee with membership comprising representatives from key government, industry and union groups. The project involved two key phases:

2.1 National qualitative and quantitative assessment of the use of AOD

2.1.1 Participants

In order to access a widely dispersed and geographically challenged working environment, a survey method was adopted to gain a quantitative assessment of the use of AODs in the Australian construction workforce. It was expected that the survey would be distributed to approximately 500 employees at selected construction sites across Australia from four participating companies. Operational sites were selected by the Industry Project Leader in consultation with the respective regional and safety management team. Sites were selected both on current availability and cross-representation of construction activity. Eventual site selection included high density CBD contruction, major roadway development, tunnelling, railway extensions, and extensions to a current major casino complex. All employees at the selected sites were invited to participate. In addition to the survey, semi-structured interviews were conducted to gain some qualitative insights into the safety impacts of AOD in the workplace. Interview numbers were dependent on the availability of employees on the day of each site visit.

2.1.2 Measures

The World Health Organisation Alcohol Use Disorders Identification Test (AUDIT) was used. The AUDIT, while originally designed for use with clinical populations, has been widely used and validated in a variety of populations and contexts, including the workplace (Davey, Obst and Sheehan 2000; Donovan, Kivlahan, Doyle, Longabaugh and Greenfield 2006; Lennings, Feeney, Sheehan, Young, McPherson and Tucker 1997; Younga and Maysona 2010). There are 10 items on the AUDIT which are classified into three domains. The first domain (Q1-3) measures the quantity and frequency of alcohol consumption and screens for possible risk of hazardous consumption. The second domain (Q4-6) examines abnormal drinking behaviour, which may indicate early or established alcohol dependence. The third domain (Q7-10) probes for negative consequences related to alcohol consumption. Each question is scored from 0 to 4, with a cumulative range of 0-40. A total AUDIT score of 8-15 indicates a risk of harmful consumption and is most appropriate for simple advice focused on the reduction of hazardous drinking. A total AUDIT score of 16 or more indicates a high risk of alcohol problems and suggests the need for brief counselling and continued monitoring. A total AUDIT score of 20 or above warrants further diagnostic evaluation for alcohol dependence. Although these thresholds were established on the basis of a study on a clinical population, they have also been widely used and validated in non-clinical populations (Babor, Higgins-Biddle, Saunders and Monteiro 2001).

Four additional exploratory questions were developed by two expert professors in the research team for the purpose of this study and were included in the survey. These relate to readiness to change (e.g. “do you think that you presently have a problem with drinking” and “in the next 3 months, how difficult would you find it to cut down or stop drinking?” and ‘other

drug' consumption (e.g. "when have you most recently used marijuana/cannabis" and "when have you most recently used ecstasy or meth/amphetamine type substances". Demographic details were also included in the survey.

Semi-structured interviews were conducted across a number of roles within the participating companies to identify major issues and themes. Interview questions centred on perceptions towards AOD use in the workplace (including perceived prevalence in the industry, how it affects you, your safety, performance and productivity, as well as that of your co-workers) and attitudes and perceptions towards existing AOD workplace policies (including knowledge of, perceived effectiveness and attitudes towards them as well as what could be improved).

2.1.3 Procedure

Corporate headquarters and operational sites of the industry partner organisation were visited to distribute the survey and conduct semi-structured interviews with both management and employees. The research team worked closely with the relevant operational site and safety managers in order to access employees most effectively on each site. The survey was distributed in hard copy to employees during their breaks along with an information sheet and a plain envelope to seal the completed survey in before returning it to the researcher. All surveys were confidential and anonymous. The researchers clearly communicated this to employees and that participation was entirely voluntary, that no names are recorded and that the data remains with the researchers at the end of the project. The interviews took place at both corporate headquarters and operational sites in a private room. Detailed notes were recorded by hand during the interviews and later thematically analysed.

2.2 Development of a cultural change management program

Using previous work by Fleming et al (2007) and Biggs et al (2008) a set of cultural change management guidelines are presented; incorporating the information collected in the interviews. Suggestions for how to implement the guidelines are also provided using input from the interviews and all project partner organisations.

3. Results

This paper firstly reports the results of the survey. Key findings from the interviews are then presented within the cultural change framework.

3.1 Participants

Final survey results are based on the completion of 494 surveys. All employees who were provided with a survey, at the selected sites, completed and returned it to the researcher on-site. The majority of respondents (n=464) were male, with a mean age of 35.7 years (SD=11.4). Most respondents (398) were employees; with the remaining 85 respondents employed as a contractor. The survey was distributed across all roles within the company with the majority of respondents classifying themselves as a tradesperson (155), a labourer (117), a plant operator (68), in an administration or engineering role (53) or as a supervisor

(47). Surveys were collected across three states (Victoria, South Australia and Northern Territory). Interviews were conducted with ten employees across several roles in the company. Several less formal conversations were also had with employees on-site.

3.2 Survey

Of a possible maximum cumulative score of 40, the 494 respondents recorded a mean score of 9.98. Scores ranged from 0 to 40 with a median score of 9. A total of 286 respondents (58%) scored above the cut-off cumulative score for risky or hazardous alcohol use of ≥ 8, with 185 respondents (65%) falling into the 8-15 scoring group, 58 respondents (20%) falling into the 16-19 scoring group and 43 respondents (15%) scoring 20 and above. Subsequent analysis focused on the three individual AUDIT domains that look specifically at consumption, dependency and alcohol-related problems (see Table 1). The maximum score for Domain 1 is 12 (scores ≥ 6 indicating a risk of alcohol related harm. The maximum score for Domain 2 is also 12 (scores ≥ 4 indicating possible alcohol dependence. Any score in Domain 3 warrants further investigation.

Table 1: Mean AUDIT scores for each domain

AUDIT Domain	Mean (SD)	No. of respondents (and %) who scored at or above the cut of
Domain 1: Consumption	6.17 (3.1)	300 (61%)
Domain 2: Dependency	1.38 (2.1)	79 (16%)
Domain 3: Alcohol related problems	2.48 (3.1)	291 (59%)

Four additional questions were included in the survey regarding self-rated dependency and past other drug use:

Seven per cent of respondents reported that they either possibly or definitely had a problem with drinking. A further four per cent of respondents reported that they were unsure. Fourteen per cent of respondents reported that it would be either fairly difficult or very difficult to cut down or stop drinking. Of those who scored above the cumulative score for hazardous alcohol use (n=286), 212 respondents (74%) reported that they do not have a problem with drinking and 157 respondents (55%) reported that it would be either very easy or fairly easy to cut down or stop drinking. In terms of prevalence, a total of 292 respondents (59%) had used marijuana/cannabis in their lifetime, with 46 respondents having used it in the last year (15.8%). A total of 196 respondents (40%) had used ecstasy or meth/amphetamine type substances in their lifetime, with 62 respondents having used it in the last year (31.6%).

3.3 Cultural change management

Fleming et al (2007) identified the following 6 best-practise principles for creating a robust safety culture in the construction industry. They are intended to operate at an industry level as broad principles for adoption at both corporate and project levels:

1. Demonstrate safety leadership
2. Promote safety in design
3. Communicate safety information
4. Manage safety risks
5. Continuously improve safety performance
6. Entrench safety principles

These principles are presented in this section to assist with the facilitation of organisational cultural change around AOD use in the construction industry. Supporting evidence collected from the interviews is also presented in italics. The suggestions for implementation are based on findings from the interviews and also input from all project partner organisations who were invited to provide information about what they consider to be important for the effective dissemination of AOD education in the construction workplace.

3.3.1 Guiding principles

1. Demonstrate safety leadership

Strong safety leadership is critical and involves communicating the importance of safety in all interactions with subordinates, subcontractors, suppliers and other project stakeholders throughout all processes within the life of the construction project (Fleming et al 2007).

"The importance of management support, maintaining a strong supervisor relationship with a strong commitment to preventing harm caused by AOD".

"Need to avoid that breakdown [between employees and management]" and go through your supervisor...get to know each other especially with a small crew".

"Can be the perception that if you ask for help you might lose your job".

Biggs et al (2008) provide a more detailed framework that outlines the specific safety leadership behaviours that are considered essential to the development of a positive safety culture. These include: communicate company values, demonstrate leadership by motivating and inspiring others and developing a sense of 'ownership', clarify required and expected behaviours, personalise safety outcomes, develop positive safety attitudes, engage and own safety responsibilities and accountabilities, increase hazard/risk awareness and preventative behaviours, improve understanding and effective implementation of safety management systems and monitor, review and reflect on personal effectiveness.

2. Promote design for safety

Effective safety management at the design stage can minimise risks to the health and safety of people who subsequently construct, occupy and maintain a facility/structure (Fleming et al 2007). In terms of managing specific risk factors such as that of AOD, strong safety management and promotion from the outset of the project is critical for communicating commitment to safety at subsequent stages of the project and being consistent and transparent with all safety messages across all stakeholders and all stages of the project.

"Consistent communication of policies and expectations right from the start of the project."

"If everyone's on the same page it makes everything easier".

3. Communicate safety information

Communication and consultation are essential to the management of safety and it is important that this starts as early as possible in the project. Open and honest dialogue regarding safety issues should be maintained throughout the life of the project (Fleming et al 2007).

"While current policies and employer assistance programs were generally seen as effective, there was an overall support for the development of more comprehensive and tailored educational initiatives for employees and contractors within the construction workforce. In particular, the need for preventative programs – rather than focusing on the consequences of AOD use when it could be too late. Specifically identified was the need to educate younger employees about "how to cope" with the lifestyle that can accompany a high-salary, project-to-project, transient type work and "getting in early before we have to deal with the aftermath".

"Acknowledging the difference between 'career workers' and 'it's just a job workers' was identified as an important consideration in terms of how to communicate educational messages most effectively to employees".

"Consideration of the culture of specific occupational groups was also identified as being important in that the nature and pressures of a job, with specific skills and hazards, can have a major effect on employees' lives and relationships."

Messages can be communicated and embedded via company health and safety policy statements, safety posters, tool box talks, 'walk-arounds' by management and regular reinforcement by all 'non-safety' managers (Biggs et al 2008).

4. Manage the risks

The systematic management of safety risks through the elimination or reduction of risks is a requisite for improved safety performance within the construction industry (Fleming et al 2007). Ensuring that people possess the knowledge, skills and abilities they need to work safely is a critical aspect of good safety management (Fleming et al 2007).

"Managers come with different levels of experience and need to know how to handle AOD issues – it's important that they are enabled to manage properly. Also Important that everyone is treated the same and policies apply to all."

"Different supervisors care about different things...some aren't very comfortable with people who ask for help". "They have a lot of issues to deal with and responsibilities...they're not born with all the skills".

"Links to reduced safety and productivity levels were confirmed by a number of those in safety advisory positions. Overall, there was a general lack of understanding and knowledge surrounding the physical and psychological effects of AOD use and how these effects might impair performance...No idea about types of drugs, effects and how long it stays in the system". This was despite the overall attitude that the use of AOD is detrimental to workplace productivity and safety. In terms of prevalence, AOD use was perceived (by those in safety roles) as a major issue that is only getting worse, particularly drugs because they are harder to detect as well as the changes that are seen in drug type 'popularity' and the increasing use of synthetics forms of illicit drugs. Prescription medications and other legal stimulants such as energy drinks were also identified by safety staff as a major concern."

"Can't afford for people's perceptions to be inaccurate".

5. Continuously improve safety performance

Safety management should strive for continuous improvement by regularly reviewing safety performance, seeking feedback from project stakeholders, and using the lessons learned to improve performance and to share and promote best practices in the construction industry (Fleming et al 2007).

"Educating the therapists and counsellors that are made available to employees, about the construction industry was identified in the research as something that could be of great value."

"Can't use direct measures such as accident rates – fortunately these are not high enough. Need to use indirect measures such as near misses and testing work culture and safety in general. i.e. knowledge of safety, support for a policy."

6. Entrench safety principles

Throughout the application of these principles, best safety practices should be entrenched as an integral part of an industry-wide safety culture. It is important that larger construction organisations work to disseminate safety knowledge and best practice among the small to medium-sized enterprises (SME) with whom they do business (Fleming et al 2007). Construction organisations should require SME subcontractors to fully participate in project safety management programs, including safety planning, training, monitoring and reporting (Fleming et al 2007).

"Importance of ensuring that sub-contractors are subject to the same policies and practices that company employees are subject to in their regular practices."

"Negotiate safety at the start when joining with alliance partners – so that practices are consistent and to the same standard".

Biggs et al (2008) highlights the importance of personalising the impact of risks and why it is important to the individual and to the project that employees ensure their own safety and health and that of others – that a fatality is not just a statistic but a workmate who has a name, a partner, children, parents and siblings. Emphasising that the industry still has too many avoidable injuries and fatalities and that in some jurisdictions, individuals may be held accountable under reckless conduct (Biggs et al 2008).

3.3.2 Suggestions for implementation

The interviews provided various suggestions for how to communicate AOD education to employees at work. These included the need for clear and simple visual hard copy brochures, fact sheets or posters, as well as videos about the physical and psychological effects and impacts of AOD. *"[Resources] need to be simple and short to maintain attention, easily accessed, visual, to the point, easy language". "Information is only really given once they get to counselling – rather than earlier on – need more information on the front line about what effect it has".* Training sessions (separate from the tool box talks and daily pre-starts) were also identified as an opportunity to focus on a specific safety issue in a certain level of depth – "*that would work well, put some food on".* There was also a positive response to the proposed development of a web-based resource – which would assist those who may find it difficult to seek help or advice about AOD at work. *"The more information the better...then they can make their own decisions".* A mentoring initiative was also suggested as a way of communicating knowledge, experience and advice to those younger workers who may benefit from a more one-on-one approach with more experienced fellow workers. *"A lot of them do listen".*

In terms of communicating the results and outputs of this research to people in the construction industry, the following suggestions are made:

- Facilitation of a management/leadership workshop or information session to brief staff on the research, key findings and what the key safety messages or company values are. This can be an opportunity to encourage and motivate leaders to make a strong commitment to a cultural change around AOD in the industry.

- Leaders can also be encouraged to participate in the online AOD education module developed for this project (targeted at management and supervisory staff) and referred to "*A Practical Guide to Safety Leadership*" by Biggs et al (2008) for a more detailed framework for implementing a positive safety culture.

- Information about the research including the link to the online resource can be further disseminated to management and supervisory staff via company newsletters, intranet and presentations.

- Communicate the findings from this research to employees throughout the respective organisations via tool box talks, safety posters and other hard copy visual resources, emails, memos, informal conversations and any other communications process that might be available. A 'package' of practical information that is tailored to the industry would be useful.

- Advertise and promote in the workplace the use of confidential AOD help or advice contact numbers and/or service providers (both external and those provided internally by the employer) to reduce any existing stigma or fear of seeking extra information or support through the workplace. Communicate the internal assistance options such as the company EAP as well as external sources of assistance.

- Continue the use of current AOD educational resources, particularly the union supported programs such as the "Just Not at work Mate" educational policy and program.

Based on feedback provided by the project partners, the research team can provide the following training and educational resources to assist with the dissemination of key messages from this research:

- A 1-page summary document outlining key findings and 'take-home' messages

- A short set of power point presentation slides outlining key findings and messages

- A 4-page industry booklet that will outline the project's aims, methodology and findings as well as outlining the benefits to industry – available electronically at www.sbenrc.com.au

- The online educational module for managers and supervisory staff.

4. Conclusions

This has been the first known study to scientifically evaluate the use of AODs in the Australian construction industry – to better understand the issue and inform the best educational solutions for improving safety.

Results from the national assessment indicate that as in the general population, a proportion of those sampled in the construction industry may be at risk of hazardous alcohol consumption. As general AOD use does not necessarily translate into workplace AOD use and impairment, these results do not tell us about when those in the 'at risk' group are drinking. A proportion of those 'at risk' will consume alcohol outside of work whereby their behaviour has no relevance to their performance at work. For others, alcohol risk will translate into workplace risk. This evidence does not allow any accurate indication of what this risk might be. Hazardous AOD use is a health issue and the health and wellbeing of the

workforce is relevant to the workplace. This research has provided us with some important evidence about the level of risk that people in this industry are putting their health at. From a safety perspective, AOD education and leadership is a proactive approach to ensuring that the risk from AOD is minimised and potential resulting accidents are prevented.

While many in the current sample appear to be at risk of hazardous alcohol consumption, a large proportion of these respondents claimed not to have a drinking problem. Many of these respondents also indicated that it would be fairly easy to cut back or stop their drinking behaviour. These results suggest that those who may be at risk are unaware that a problem may exist, further highlighting the need for educational programs to increase knowledge and awareness of the effects of AOD. Other drug use (both illicit and licit) also remains a huge concern.

Findings from this research support the need for evidence-based, comprehensive and tailored responses in the construction workplace. Previous work by Biggs et al (2008) and Fleming et al (2007) provide a useful framework for creating a robust safety culture in the construction industry to ensure that AOD risk is eliminated from the workplace. Findings from the interviews and input from project partners over the course of the project have provided insightful and invaluable information for the industry to consider in their safety management processes. Further funding is required to extend and evaluate the outputs of this study, particularly the online educational tool and the development and evaluation of other on-site resources. This research was undertaken with the benefit of a grant from the Sustainable Built Environment National Research Centre.

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Liveability of Settlements by People

in the *Kampung* of Surabaya

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Abstract

The Australian Government has earmark about $ 20 million for 2011 to 2013 for cities to increase its livability. The livability of settlements becomes a serious issue in developed countries due to among others pressures of rapid population growth. The Cities Alliance working with ICLEI has identified critical urban problems. A successful city must offer investors security, infrastructure and efficiency, and put the needs of its citizens at the forefront of all its planning activities. Poorly managed urban settlements will be unable to keep pace with urban expansion, and un-serviced slums will proliferate, bringing with them poor health, poverty, social unrest and economic inefficiency.

A new understanding of livable settlement is needed, both on mix qualitative and quantitative indictors, to make appropriate changes in their own setting and in a dynamic rather a static instrument information on good policies/practices. Over time rather than just statistics a multi stakeholder approach should be encourage for data collection, analysis, dissemination and use. With two thirds of the world's population predicted to live in cities by 2050, keeping urban communities safe, secure and healthy is one of the most demanding challenges we face This paper aims to elaborate the potential and challange of the *kampungs* toward a Surabaya Liveable City. This paper is conducted through data documentation from various resources.

Surabaya has for long aimed its urban development to anticipate the need of all its citizens to meet the challenge of the XXI century in not just in the livability standard, but more so to build the resilience capacity of its low income citizens living in the indigenous urban settlements of *kampungs*. Much has been done by city government in support to build a smart, humane and ecological city where two third of its citizens live in tha *kampungs*. Livability should be seen from existing condition with clear view of the future dimension in urban development that can be reached by all citizens.

Keywords: livability, *kampung*, smart, humane, ecological

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1. Introduction

The Australian Government has earmark about $ 20 million for 2011 to 2013 for cities to increase its liveability through The Liveable City Program. The program objective is to improve the productivity, sustainability and liveability of the city by effective planning and design and efficient use of new and existing infrastructure. The Cities Alliance working with ICLEI has identified critical urban problems. A successful city must offer investors security, infrastructure and efficiency, and put the needs of its citizens at the forefront of all its planning activities. Poorly managed urban settlements will be unable to keep pace with urban expansion, and un-serviced slums will proliferate, bringing with them poor health, poverty, social unrest and economic inefficiency. All these objectives can only be ensured its sustainability if all the citizens enjoy the same opportunity to be what she or he wanted to be in a just and equitable way.

Urbanization processes experienced by developing countries during the last decades, have often been considered as the principal factors inhibiting a sustainable urban development and inevitably leading to an overall crisis in the cities. The liveability of settlements becomes a serious issue in developed as well as developing countries due to among others by pressures of rapid population growth that cause the urbanization. However, for the last decade, Surabaya through the development of urban *kampungs* managed to proof that liveability should be fused between the city and its *kampungs*.

2. Liveability as The Key Element of Sustainability

A new understanding of livable settlement is needed, both on mix qualitative and quantitative indictors, to make appropriate changes in their own setting and in a dynamic rather a static instrument information on good policies/practices. Over time rather than just statistics as multi stakeholders approach should be encourage for data collection, analysis, dissemination and use. The definition of liveability includes much issues such as participation, equity, resilience, inclusiveness, and accessibility. According to Ji (2006) liveability refers to the quality of life that is experienced by the people based on the ability to sustain the people. Concept and criteria of liveability should adapt to the contextual condition of each city or town.

Livability and sustainability has a contextual differences in time and place dimensions. Livability is a condition that will be reached at this time and in this space. While sustainability is an idealized conditions from now, until the foreseeable future and within the smallest space (settlement) on a broader dimension (Mansee, 2008). Thus, livability is a necessary condition to achieve sustainability (sustainability) ranging from the small scale (residential) to global scale.

2.1 Smart, Humane and Ecological; as Fundamental the Principal toward Liveable City in Surabaya

With two thirds of the world's population predicted to live in cities by 2050, keeping urban communities safe, secure and healthy is one of the most demanding challenges faced by all.

The other improtant issue is its ability to innovate at all time. The Philips Livable Cities think tank believes that livable cities are successful cities. They have identified three important and interlinked ingredients of a livable city: resilience, inclusiveness, and authenticity.

Liveable city has also a dimension of geographic, social, economic and cultural-specific, so that each region will develop an appropriate concept. Smart, Humane and Ecological (SHE) concept now adopted in the city of Surabaya is an approach that seeks to integrate the many development dimensions of physical and human elements in a balanced manner. *SHE* concept is aimed to improve the quality of life of the people in a sustainable manner. The following are the elaboration of the principles of *SHE* city concept.

Smart entails as an effort to solve problems of live in a smart way and to realize an intelligent human being with inner capacity as a potential resource. Implementation of the principles of smart will not only be limied to education, but to include the performance of government and urban development programs in promoting the aspects of effectiveness and efficiency. *Humane* principle stresses the importance of the development for and of inner quality of all community members rather than streessing the physical development aspects only. Urban development provide justice and equitable opportunity for all people to develop themselves according to the potential. *Ecological* principle this is implemented in urban development geared to promote the improvement of the environmental quality. Environmentally sustainable urban development not only be implemented in the physical development aspects but also in the development of a sound environmental consciousness of the society.

SHE principles implementation requires an integrated and consistent so that quality of life improved. Understanding the application of SHE priciples need to be reach by and for all stakeholders.

2.2 *Kampung* as the Agent of Change

Surabaya is the capital of Easy Jawa Province and the biggest metropolitan city in Indonesia, inhabited by approximately 3 million people. Surabaya was established as early as 1293 with the same name. Surabaya is the longest living metropolis which has many *kampungs*, and the inhabitant has strong feeling of high solidarity, with the spirit of heroism that never knew the idea of surrender. Initially around the estuary of the Brantas river, many small settlements exist. Over time these settlements agglomerated and consolidate to form a town and now to be come the City of Surbaya.

Kampung was the result of the transformation of the small village like settlements the remain in its unique quality and now become an integral part of town and city throughout Indonesia, still survives as the important development element of the city. The high-density with minimal infrastructure is the characteristics of the *kampung* that earlier gives the impression of a slum area. According to Silas (1983) kampung are not slum but initially lack urban services and consist mainly of low income housing. Since late sixties, the governments of Jakarta and Surabaya made innovative effort to improve the living environment in the *kampungs*. The objective of the program was to bring basic services and physical infrastructure to the very

front door of the houses in the *kampungs* and doing improvment work with community participation.

3. Framework and Methodology

This paper aims to elaborate the potential and challange of the kampung toward a Surabaya Liveable City. The improvment and transformation fenomena of the *kampung* will be the focus of the discription. The analiyze will conduct by discriptive qualitatif way. This paper is conducted through data documentation from various resources. The main data compiled from Surabaya City Development Board.

4. Toward Surabaya Liveable City: Potential and Challenges

Surabaya City is one city that is consistent in transforming slums into urban settlement. By 2006 the city of Surabaya has implemented KIP (developed later into Comprehensive KIP) despite no longer receiving funding support from the central government. The programs of central government (PNPM) is synergized with local programs in an effort to speed up the forming of community that can better look after their own need by and for themselves will ad-hoc assistance from local government. Humanity approach through innovation and creativity programs undertaken to create a sense of community belonging and ownership. Besides the physical and economic programs, human resource development is a key success factor of development in the kampungs that should not be ignored.

4.1 The Potential

The *kampung* of Surabaya is the place where most of the inhabitants live, nearly 70% of the inhabitants of the city live in kampung. So the initial *kampung* is an important element of the city and should be a prominent priority in development. Elaboration of the concept of SHE can be identified from the intelligence community to overcome any problems in their respective environments. *Kampung* inhabitants solve the water needs by processing waste into potable water used for watering plants, washing motor, etc. In addition to solving environmental problems, efforts are also able to reduce the cost of water consumption. Innovation communities in developing domestic sewage treatment plants with a variety of models indicate a potential opportunity in accordance creativity.



Figure 1: Different Kampung with Different Waste Water Treatment Model (Surabaya City Development Board, 2012)

In the economic field the municipality develop '*prominent kampung program'* to accommodate the economic potential of the community. With the *'one village one product'* approach every *kampung* develop home-based enterprise such as *'dynamo kampung'*, *'rice cake kampung'*, *'recycling kampung',* etc. Many private sectors support this scheme by giving training courses, promoting the products, to assisting the marketing to overseas countries.



Figure 2: Activity and Product of The Prominent Kampung (Field Survey, 2011)

Surabaya is well known for the success of the *Kampung* Improvement Programme (KIP). KIP has been implemented since the colonial time and have been transformed into other programs based on community needs and urban achievment. The success of KIP should be seen integral to the development of the city. *Kampung* which is part of the city should be empowered to be able to sustain the rapid development progress. Community are the main object of development that determine success or failure in the long term development of the city. Sense of belonging is key to the successful development of the village in the city of Surabaya. Public awareness not only on the city government's development program, but also seeks to improve the liveability independently. Increasing the number of environment cader is a real concern for the sustainability of village communities and urban development. Environment cader are the main drivers of environmental activities in the *kampung*. Through the environment cader communities in Surabaya able to improve the liveability of the settlements.



Figure 3: Number of The Environment Cader in Surabaya (Surabaya City Development Board, 2012)

4.2 The Challenges

Creative and innovative development program was implemented in accordance to the needs and aspirations of the respective inhabitants without compromising to local cultural characteristics. Regions in Indonesia with unique geographic characteristics, socio-economic and culturally diverse cannot be automatically generalized to be the standard pattern of development. Flexibility in accommodating various needs within the development program is a necessity that is not well taken in consideration by the government. Programs initiated such as *KIP*, *P3KT*, *P2KP*, *PNPM*, (various capacity development programmes) etc. in Indonesia should not be seen as a development project for a short time frame only. Sustainability of the program is a challenge due to the limited financial support from the central to the local government. Local governments must consistent in maintain the continuity of programs in order to achieve the goal of improving people's welfare. *Kampung* development approach proved to have a large impact on the stability of the city life, so that people have the means to form human actualization intelligent and civilized.

To ensure the sustainability of the achievements in making a city liveable with *kampungs* as the major part for human habitation, it is extremely important to further developed the economic and social potential of the great number of people living in the *kampungs*. The challenges in meeting this objective is the support given to the kampung community to bring their economic and social potential into the main stream of the city level. City government of Surabaya use the SHE principle to assist the *kampung* community by providing better education and health facilities accessible by all and making the economic acitivies growth by making the needed resource easily reached and provide urban scale marketing facilities available at low cost to sell their product to all level city consumers.

5. Conclusion

The experience of Surabaya in developing the eco-city based on the objective of Smart-Humane-Ecological principles has made Surabaya a city that were able to create a society that is active an making the city development beyond the prevailing standards of town and cities in Indonesia and simultaneously encouraging the citizens to act as the winner and creating a civilized living condition. It is also important to note that the achievements of Surabaya were reached through the continuous effort by the local government, involving as much as many stakeholders from local people, business entities, local university staff and students as well as various NGOs. Also financial resources needed to do the work depand mailny from and by local resources complemented by other resources, including from national government. Thus the experience of Surabaya in this respect in not unique and can easily be adopted and implemented in other cities and towns.

Surabaya city has many challenges, and an opportunity to realize an ecological city in accordance with local conditions. Through the concept of SHE Surabaya seeks to realize the ideals of a liveable city. Through the support of all stakeholders, especially the community as the owner of the city, Surabaya is expected to not only be a liveable city but able to even become a sustainable city for next generations.

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Exploring the conflicts between BIM and existing project processes in Hong Kong

Aoxiang Ren and Mohan M Kumaraswamy

Abstract

The Hong Kong construction industry has in general, developed a basic appreciation about Building Information Modeling (BIM), migrating from knowing 'what it is' and 'how to use it' to adopting it in a few projects. However, most industry participants are still hesitant to adopt it BIM more widely. This has been allegedly a typical attitude when our industry faces an innovative technology. Meanwhile, the perceived requirements to adjust existing operational processes to achieve further benefits from BIM development leads to many potential conflicts, hence increasing participants' concerns in proceeding further. Therefore, there is a need to identify and understand the main conflicts between BIM and current project processes, mainly referring to organizational structures and operational flows. Based on a series of semi-structured interviews with senior BIM practitioners and experts from different stakeholders in the Hong Kong industry, as well as a BIM questionnaire survey targeting the Hong Kong construction industry, this paper illustrates the main conflicts and apprehensions indicated above. These findings will lead to future research and then contribute to a proposal to develop measures to accelerate progress towards more collaborative processes for BIM implementation and consequential benefits realization in Hong Kong.

Keywords: BIM, conflicts, Hong Kong, project processes

1. Introduction

Taking the 'One Island East' Project (started in 2004 and finished in 2008) to be one of the first projects that substantially implemented BIM in Hong Kong, BIM has gone through at least 8 years' development in the Hong Kong industry. BIM functions have been gradually developed to generate more benefits for the projects, but the current limited benefits still can not persuade most stakeholders to adopt BIM in their projects in Hong Kong, given the cost related to BIM implementation in terms of training, software and hardware. The principal reasons for the perceived industry hesitation are the conflicts/barriers between BIM and the existing project processes.

The relationship between BIM and project processes, being interactive and potentially iterative, can deliver high synergies. BIM provides a much better platform to develop a more collaborative working environment for a project, while a more integrated project process can extract more and deeper benefits from BIM. This point was also illustrated in the guide of Integrated Project Delivery (IPD), a relatively new procurement approach being populaized in the USA (AIA, 2007) that aims to achieve higher level integration in the project processes. The relationship of IPD with BIM was summarized as: Integrated projects could be done

without BIM and BIM could be implemented in non-integrated processes; but only when they were combined together, both of their potential benefits could be maximized (AIA, 2007). Most construction project processes in Hong Kong can be categorized as 'non-integrated processes', which indicates that BIM implementation in Hong Kong may encounter a series of conflicts/barriers in the prevalent industry 'culture' and scenarios. Therefore, this paper is designed to explore the specific conflicts/barriers that limit BIM applications and potential benefits in the Hong Kong industry.

2. Literature review on conflicts/barriers encountered in current BIM implementation

BIM is not an innovative tool applied to only address a single independent issue, since its scope can and should cover the whole project, affect all participants and last over the project lifecycle. Therefore, the factors/barriers affecting the adoption of BIM span over a wide spectrum.

According to Lu and Li (2011), attention is generally drawn to two categories of BIM factors, namely the technical complexities of BIM adoption and the expected collaborative working environment. The two resulting research areas also reflect the tool and process properties of BIM. Gu and London (2010) provided similar categorisations of the two main factors, as: technical tool functional requirements and needs, and non-technical strategic issues.

To be specific, under technical issues, interoperability in BIM is one of the urgent needs from the participants. Research carried out by Grilo and Jardim-Goncalves (2010) concluded that the interoperability in BIM was significant for the interoperability among the participants. Bernstein and Pittman (2005, as cited in Azhar, 2011), also found that the data interoperability across different software was one of the three major technical issues retarding the BIM implementation, the other two issues being the computability of the design data and the information exchange among the BIM components. Besides the interoperability, a questionnaire survey carried out by Tse (2004) revealed other technical barriers, such as poor library, low running speed of the system and lack of table customization.

On the other hand, on the issues related to collaborative working environment and project processes, Lu and Li (2011) believed that BIM would change the traditional construction industry over a wide range of its typical characteristics, including those of people, processes, communication and work culture. Grilo and Jardim-Goncalves (2011) also claimed that BIM was changing the way that companies were working, as well as providing new processes for collaboration. Indeed, it is commonly accepted that BIM is both a new tool and a new process. A new process requires relevant changes in the existing project processes to generate a more collaborative working environment. However, changes will never be easy, especially for the 'traditional' construction industry. For example, one of the key factors to ensure a truly well-implemented BIM is the early involvement of the key participants, but the present procurement systems leave little room for this to happen. The architects or engineers still carry out the design work independently in most projects in Hong Kong,

without any input from the contractor, although there are positive moves towards 'Early Contractor Involvement' (ECI) in some countries (Rahman and Alhassan, 2012).

This paper will mainly focus on exploring the second issue mentioned above, namely the conflicts/barriers between BIM and existing project processes in the Hong Kong industry. This paper will present Hong Kong based findings from: 1) a series of semi-structured interviews with senior BIM practitioners and experts from different stakeholders, and 2) a BIM questionnaire survey targeted at the Hong Kong industry.

3. Research methods

As mentioned above, although case studies are also being conducted in the ongoing parent study, two main research methods were applied in the reported research to explore the conflicts/barriers when implementing BIM in current project processes in Hong Kong, namely semi-structured interviews and a BIM questionnaire survey. Since both the interviews and the questionnaire survey were carried out in Hong Kong, the research findings mainly reflect the Hong Kong industry's present landscape.

3.1 Semi-structured interviews

Totally 18 individual interviews were conducted to collect practitioners and researchers opinions about the conflicts and barriers mentioned above.The composition profile of the interviewees is shown in Figure 1.

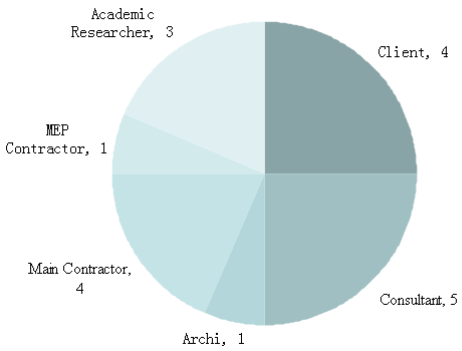

Figure 1: Profile of the interviewees

As in Figure 1, the interviewees are from various industry groupings in the Hong Kong industry and hence play different roles in their projects. This cross-section is believed to make the interview findings comprehensive enough to provide a reliable reflection of the current situation in the Hong Kong industry.

Each interview lasted from 45 minutes to 60 minutes and the interviewee was invited to provide his/her opinions on each of a series of BIM related questions, such as motivations

for BIM adoption, current BIM implementing processes in Hong Kong and conflicts/barriers in integrating BIM in the existing project processes. Findings related to conflicts/barriers were derived from the interviews and are presented in Section 4 of this paper.

3.2 BIM questionnaire survey

Compared with the individual interviews conducted in this research, this questionnaire survey presented a broader view about BIM development in the Hong Kong industry. One of the objectives of this questionnaire survey was to explore the gaps and constraints that retarded collaborative working in the BIM environment, being designed to help to probe the conflicts/barriers mentioned above.

To be specific, in the third section of the questionnaire survey, respondents were asked to express their opinions on the frequency and difficulty of the technical issues and non-technical issues resulting from BIM implementation in their projects, as well as their level of agreement on constraints that retard the collaborative working environment for BIM. A '1~5' Likert scoring scale was used to quantify their responses. For example, 1 indicates 'never' and 5 expresses 'always' on the frequency of a particular issue, as listed in the options.

This questionnaire survey involved of two rounds of delivery, since the number of responses was considered inadequate after the first round. Questionnaires were delivered to the following target groups through emails:

1) Members of the Hong Kong Institute of Building Information Modeling (HKIBIM) (142);
2) Interviewees of the individual interviews (31);
3) Committee members of Civil, Building Service and Structural Divisions of Hong Kong Institution of Engineers (HKIE) (77);
4) Randomly selected Honorary Fellows, Fellows and Members of HKIE from Civil, Building, Building Service and Structural Divisions of HKIE (645);

HKIE is the internationally recognized multi-disciplinary institution of engineers in Hong Kong and randomly picked members from its civil division, building division, building service division and structural division can represent the industry's common opinions on the iisues probed in the survey. Meanwhile, HKIBIM is an institution particularly for BIM practitioners, whose members have BIM related working or research experiences in Hong Kong. Therefore, the target groups are appropriate to provide opinions that can reflect the industry's attitudes and perceptions.

From 10th May 2012 to 17th September 2012, accounting for 8 overlapping persons and 65 undeliverable emails, 822 questionnaires were successfully delivered to the above groups. Of 68 responses received, only 32 were considered usable and hence analyzed as described in the next section.

4. Research findings: conflicts/barriers between BIM and the existing project processes in Hong Kong

4.1 Findings from interviews

The relevant conflicts/barriers as derived and distilled from the interviewees are as follows:

1) The existing project processes leave little space for the early involvement of the key participants.

2) Clients are not aware of BIM benefits，hence do not drive its implementation.

3) Architects generally follow the traditional processes, since BIM requires more efforts.

4) Contractors are generally hesitant, since not sure of the true benefits from BIM.

5) The Hong Kong industry provides limited time for the design phase in the project process, while the creation of a BIM model usually requires more efforts and more time.

6) Mechanical-Electrical-Plumbing (MEP) contractors are mobilised quite late in the project process.

4.2 Findings from the questionnaire survey

6 technical issues and 5 non-technical issues related to BIM were listed in the questionnaire and respondents could indicate their opinions both on the 'frequency level' and 'level of difficulty' for each issue through a '1~5' scoring system: (a) Level of Difficulty: 1-Quite Easy; 2-Easy; 3-Middle; 4-Hard; 5-Extremely Hard, (b) Level of Frequency: 1-Never; 2-Rare; 3-Sometimes; 4-Common; 5-Always.

For the analysis of difficulty and frequency of the technical and non-technical issues, this study adopted each issue's average scores on difficulty and frequency to conduct the follow-up analysis. The product of difficulty average score and frequency average score were also calculated. Issues with higher product values were considered as more critical conflicts/barriers in BIM implementation. Results are shown in Table 1 and Table 2.

Table 1 Technical issues

Answer Options	Average Score (Difficulty)	Average Score (Frequency)	Difficulty X Frequency
Interoperability	3.10	3.16	9.79
Poor library	2.77	2.97	8.23
Lack of standards/guides	3.00	3.13	9.39
Long learning curve	3.32	3.23	10.74
High cost of the software and hardware	2.97	3.06	9.09

Lack of BIM technician and Software are not mature	3.67	3.67	13.44

Table 2 Non-technical issues

Answer Options	Average Score (Difficulty)	Average Score (Frequency)	Difficulty X Frequency
Changes in the operation process	3.16	3.16	9.99
Changes in the organizational structure	2.97	2.84	8.42
Changes in the information flow, conflicts with the traditional project culture and employees being reluctant to use new technology	3.52	3.39	11.91
Not all the stakeholders are adopting BIM	3.29	3.58	11.78
Not sure about the benefits of BIM	3.00	3.20	9.60

Based on the above two tables, the first four critical conflicts/barriers encountered in BIM implementation in Hong Kong industry are:

1) Lack of BIM technician and Software are not mature (technical);

2) Changes in the information flow, conflicts with the traditional project culture and employees being reluctant to use new technology (non-technical);

3) Not all the stakeholders are adopting BIM (non-technical);

4) Long learning curve (technical).

5. Discussion

This section provides a general discussion of the results and possible reasons for the above conflicts/barriers as derived from the interviews and questionnaire survey from three perspectives: namely industry level, project level and organization level.

At the industry level, the Hong Kong construction industry has developed a fast track culture since the participants always want to complete their projects as quickly as possible. This point was consistent with the 5th and 6th barriers identified in section 4.1 and the 2nd issue identified in section 4.2. In order to achieve early operation so as to reap profits earlier, time spent on design is highly compressed in Hong Kong industry. This leads to numerous changes during the construction phase in many projects in Hong Kong. This scenario is unsuitable for BIM implementation. This compresses the time available for design in the project process to mostly inadequate levels. As an innovative technology that requires more efforts and time to implement, BIM will not be welcome within such kind of project processes and the prevalent fast track culture.

At the project level, most projects in Hong Kong are delivered by the Design-Bid-Build procurement route that indeed isolates key participants within different project phases, limiting the potential benefits from BIM. Early involvement of the key participants ensures early input from contractors, installers, fabricators and so on (AIA, 2007; Ralman and Alhassan, 2012), which is an important route to maximizing BIM benefits. However, this situation is hard to achieve in present project procurement processes in Hong Kong, such as Design-Bid-Build. This was the 1st barrier identified in section 4.1. As discussed previously, a delivery process that enables early involvement of key participants can maximize the benefits of BIM, while conversely, this type of delivery process will run smoother on a BIM based platform that facilitates information exchange across both project phases and project sub-teams.

For companies themselves, at the organization level, many clients are not fully aware of BIM's potential benefits, many architects are not willing to expend extra efforts on creating BIM model and contractors are apprehensive about the unknown net benefits of setting up their own BIM divisions, which reflect the 2nd, 3rd and 4th barriers identified in section 4.1 and 1st, 3rd and 4th issue identified at the end of section 4.2. Most interviewees have high expectations of clients' positive attitudes as well as facilitative actions for BIM implementations. BIM related costs need special upfront funding. It also needs more efforts to create and use the BIM model. These also require incentive mechanisms or measures from the clients to motivate the various teams, otherwise most stakeholders will not take the initiative to adopt BIM. Furthermore, since BIM is able to span the whole project lifecycle, clients have the greatest potential to benefit from BIM most. Meanwhile, considering the current major BIM applications such as clash detections, contractors also share the benefits of BIM implementation. However, except for a few projects in Hong Kong where 'pain-share and gain share' mechanisms (DTF, 2006) have been incorporated in Target Cost Contracts (Kumaraswamy and Rahman, 2006), architects share few BIM benefits but incur far more efforts to create and use BIM models. Thirdly, most contractors in Hong Kong hire BIM consultants to handle any BIM related work stipulated in the contracts. It is a reasonable choice when there are just a few projects that require BIM implementation, given the high cost of setting up permanent in-house BIM divisions to deliver on-off and ad hoc BIM requirements. Along with the development of BIM in Hong Kong, more and more contractors have to answer the question of whether it is better to set up in-house BIM divisions, or to hire a BIM consultant. The relatively high cost of setting up a BIM office is quantifiable, while the benefits are not so clear to many contractors, hence retarding BIM development at the firm level. Drawing on the experiences of other countries, such as UK and Singapore, clients, especially the government clients, should take the lead to integrate BIM in the current project processes (BIM industry working group, 2011; Cheng, 2011).

6. Conclusions

A set of relevant conflicts/barriers was identified through semi-structured interviews and two types of conflicts/barriers to BIM implementation were probed in the questionnaire survey, namely technical issues and non-technical issues. Generally, under the current Hong Kong

industry culture, the existing project processes have retarded the implementation of BIM. BIM's benefits are limited in such project processes, so the clients are less motivated to encourage or promote, leave alone proactively drive BIM adoption. Other participants are unlikely to take the initiative to adopt BIM if the client is passive. In order to advance BIM implementation in Hong Kong, the existing project processes need to be revised in some ways to provide opportunities for the early involvement of key participants such as contractors and operators so as to derive many more benefits from BIM to convince participants (Sing and Dunn, 2008). It is difficult, if not impossible, to immediately replace the existing project processes with some new processes that are capable of providing a better environment for BIM, such as IPD (AIA, 2007). What is reasonable is to revise the existing project processes step by step, gradually approaching more appropriate project environment for BIM, for example in moving from non-contractual partnering to contractual partnering, e.g using the New Engineering Contract (NEC) as has been successfully piloted in public work project in Hong Kong (Tsui, 2012) and is now being introduced to many ongoing and upcoming projects.

Limitations of the reported research are seen as: 1) 18 interviews and 32 questionnaire responses may not be enough to reflect a comprehensive scenario of the Hong Kong industry; and 2) Conflicts/barriers derived from the interviews and questionnaire survey have not been validated. It will also be useful to develop some suggested measures, even proposals, to address the finally identified conflicts/barriers. Therefore, ongoing and future works target more interviews and case studies in the Hong Kong industry, proposal development based on relevant guides or principles and a focus group meeting to validate the reported conflicts/barriers, as well as the suggested measures/ proposals to address these conflicts/barriers.

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